Final Report

Puerto Rico Coral Reef Monitoring Program: 2025 Survey

Coral Reef Conservation Program NA23NOS4820135 State and Territories Conservation Cooperative Agreement

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I. Definitions and Acronyms

Rugosity – measurement of the reef substrate relief resulting from the excess in chain links above the 704 links that correspond to a completely flat 10m long transect. 1 chain-link = 1.4 cm.

Reef overhang – reef space where the chain drops freely to the bottom without being in contact with any recognizable substrate category. Overhangs typically occur below a coral ledge, branch, or rock outcrop.

Gap – narrow open reef space between two other substrate categories. These gaps are typically narrow and deep enough such that the substrate below the chain is unrecognizable.

Sessile-benthic – permanently attached to the substrate without any locomotive ability (e. g. hard corals, soft corals, black corals, sponges)

Pelagic – organisms that live in the water column, not attached to the bottom

Demersal – associated with the bottom, living at the bottom or near the bottom

Motile megabenthic invertebrates – invertebrate animals (> 2 cm) with locomotion, capable of free movement over the reef substrate (e.g., lobsters, crabs, shrimps, conch)

Turf algae – mixed assemblage of short algae (< 2cm) growing as a rug over reef hard bottom.

Calcareous algae – green algae in the Phylum Chlorophyta that secrete calcium-carbonate skeletons

Fleshy algae – refers to soft, fleshy algae. Includes algae within several phylogenetic groups

CCA – refers to unidentifiable or mixed assemblage of crustose coralline algae. Red algae in the Order Corallinales that secrete Mg-calcite skeletons.

Cyanobacteria – microscopic free-living marine autotrophic (photosynthetic/oxygenic) bacteria in the Phylum Cyanophyta that grow together forming reddish mats or patches over reef surfaces. Also known as "blue-green algae.

Stony corals – sessile-benthic marine animals in the Phylum Cnidaria, Order Scleractinia that form a rigid calcium-carbonate skeleton. Also known as "stony corals".

Soft corals – sessile-benthic colonial animals in the Phylum Cnidaria, sub-class Octocorallia that form flexible skeletons attached by a holdfast to the bottom. Also known as "gorgonians".

Black corals – sessile-benthic marine animals in the Class Anthozoa, Order Antipatharia that grow as flexible vertically projected aposymbiotic colonies of a jet-black or dark brown color.

Hydrocorals – colonial marine animals in the Phylum Cnidaria, Class Hydrozoa that secrete hard calcareous skeletons resembling hard corals. Also known as "fire corals" and/or "lace corals"

Sponges – sessile-benthic primitive organisms that belong to the Phylum Porifera that form dense skeletons

SCTLD – Stony Coral Tissue Loss Disease

CI – Confidence Interval

Fish size classes:
C1 – 0 to 5cm fork length (FL); C2 – 6 to 10cm FL; C3 – 11 to 15cm FL; C4 – 16 to 20cm FL; etc.

ANOVA – Analysis of variance

NOAA – National Oceanic and Atmospheric Administration

CRCP – Coral Reef Conservation Program

PRDNER – Puerto Rico Natural and Environmental Resources

PRCRMP – Puerto Rico Coral Reef Monitoring Program

CARICOMP – Caribbean Coastal Marine Productivity

II. Clarifications and changes from previous PRCRMP surveys

Corals

- Since the beginning of the PRCRMP in 1999, data on percent reef substrate cover by boulder star coral, *Montastrea annularis* and its two-sibling species, *M. faveolata* and *M. franksi* (Weil & Knowlton 1994) were reported as *Montastrea annularis* complex. The taxonomic classification of these species has changed, and are now under genus *Orbicella* (Huang et al., 2014). A decision was made, (since 2018), to report the data on reef substrate cover by the three separate species. The three species are reported as *Orbicella annularis, O. faveolata* and *O. franksi* (Ellis & Solander, 1786).
- Nomenclature changes have been adopted for the symmetrical and knobby brain corals, previously reported as *Diploria strigosa* and *D. clivosa* now under the accepted binomial name *Pseudodiploria strigosa* and *P. clivosa* (Dana, 1846), and for *Madracis auretenra* (Locke, Weil & Coates, 2007) previously reported under the synonym *M. mirabilis* (sensu Wells, 1973).
- In several reports (1999, 2001a, 2009, 2016) the fire corals, *Millepora spp* were included under a "Hydrocorals" benthic category. In all other reports, the data on percent cover by *Millepora spp*. was included as part of the "stony corals" category. Readers should be advised of this when comparing the live coral cover between annual monitoring surveys.

Fish

Since the 2018 report, taxonomic updates on fish species names have been applied to the five-band surgeonfish, *Acanthurus bahianus*, now reported as *A. tractus*, and the striped parrotfish, *Scarus iserti* now reported as *S. iseri*. *Acanthurus tractus* was revalidated based on genetic and morphological data (Bernal and Rocha, 2011). *Acanthurus bahianus* is now considered to be endemic to Brazil. *Scarus iserti* is now considered a synonym of *S. iseri* (Rocha et al., 2012). Previous reports of the coney (*Cephalopholis fulva*, Linnaeus, 1758), graysby (*Cephalopholis cruentatus*, Lacepede, 1802) and sharknose goby, *Elacatinus evelynae* (Bohlke and Robins, 1968) under their synonyms *Epinephelus fulva*, *E. cruentatus* and *Gobiosoma evelynae*, respectively have been reverted to their presently accepted names *C. fulva* (Linnaeus, 1758), *C. cruentata* (Lacepede, 1802) and *E. evelynae* (Bohlke and Robins, 1968; in Froese and Pauly, 2018).

Invertebrates

In the 2018 PRCRMP Final Report (Garcia-Sais et al., 2018) density data for motile megabenthic invertebrates were reported from 20x3m belt-transects. In all previous reports, including this 2024 PRCRMP Final Report motile megabenthic invertebrates were reported from the 10x3m belt-transects.

Sampling Station Names and Codes

The monitoring station at Guánica's shelf-edge, previously referred to both as Guánica's Shelf-edge Reef (Garcia-Sais et al., 2015) and Efra's Wall Reef (Garcia-Sais et al. 2017) has been (since the 2019 report) named as Beril de Guánica with the code BERI20.

Data Availability

Data collected since 1999 as part of the PRCRMP has been compiled and is now publicly available for download. Downloadable files include a data dictionary, all benthic and fish data (including biomass estimations derived from fish size-frequency data), and a Site Classification Database including various PRCRMP metadata. These data are available through the File Transfer Protocol (FTP) at the following link: https://www.nodc.noaa.gov/archive/arc0147/0204647/3.3/data/0-data/. This data is regularly updated as PRCRMP monitoring events revised by DNER staff. The PRCRMP database has also been translated following the Darwin Core Standard (DwC) and is available for web map visualization in the Marine Biological Observation Network (MBON) Data Portal at the following link: https://mbon.ioos.us/?ls=h5ELVXyv#map. For further questions regarding the PRCRMP database access contact DNER Coral Reef Specialist

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III. Executive Summary

A total of 21 reef stations were surveyed between May and August 2025 as part of the PRCRMP 2025 monitoring event. Recurrent monitoring surveys were performed at TRES05, TRES10, and TRES20 in Rincon, TOUR10, TOUR20, and TOUR30 in Mayaguez, BOTE15, BOTE20, and CANO30 in Isla Desecheo, DOMI05 in Carolina, CIBU05 in Vega Baja, CABE05, PALT10, PALN20, and DIAB05 in Fajardo, LPEN05, CROS10, and DAKI20 in Isla de Culebra, ESPE10, CANJ20, and SECO30 in Isla de Vieques. Baseline characterizations were performed off Boca de Cangrejos (CANG05, CANG10, and CANG20), off Punta Las Marias (MARI10 and MARI20), and off El Escambrón (ESCA05, ESCA10 and ESCA20).

Determinations of the percent substrate cover by sessile-benthic categories were produced from sets of five replicate 10m-long permanent transects per reef station based on a continuous (chain-link) intercept technique. Visual inspections of stony coral colonies intercepted by transects were performed to provide estimates of prevalence by infectious diseases and/or bleaching. Reef fishes and motile megabenthic invertebrates (lobster, queen conch, large crabs, squids, cleaner shrimps, and long spined sea urchins) were surveyed from 10 x 3m (30m^2) belt-transects centered on the same array of five 10m-long transects used for benthic characterizations. Belt-transects were expanded to 20 x 3m (60m^2) for density and size determinations of commercially important fishes, including the larger reef herbivores such as parrotfishes (Scaridae) and doctorfishes (Acanthuridae).

Reef substrate cover by stony corals averaged 6.01%, ranging from a maximum of 15.68% at SECO30 to a minimum of 1.47% at TRES05. Reef substrate cover by stony corals declined in 20 out of the 21 reef stations surveyed in 2025 relative to the previous 2023 survey, including statistically significant differences (ANOVA; $p < 0.05$) at 10 reef stations. The mean percent change of reef substrate cover by stony corals between the 2025 and the previous 2023 survey was -45.72%. The highest reductions of cover were measured at TRES05 (-94.34%), BOTE20 (-86.39%), TOUR30 (-78.29%), and CANJ20 (-75.53%). These data constitute further evidence of an ongoing island-wide chronic degradation of coral reef communities associated with drastic reductions of substrate cover by live stony corals. The current status of reef substrate cover losses by stony coral relative to baseline surveys for the set of 21 reef stations surveyed in 2025 stands at -78.55%. The largest reductions of cover have been measured at BOTE20 (-96.90%), TRES05 (-96.07%), DOMI05 (-94.38%), ESPE10 (-92.84%), and CANO30 (-91.45%).

Loss of reef substrate cover by live stony corals was 60.0% higher (-61.98%) in west coast reefs (Mayaguez, Rincon, Isla Desecheo) than in east coast reefs (Fajardo, Isla de Culebra, Isla de Vieques, Carolina) (mean: -36.98%), in contrast to the observed pattern in the 2021 and 2022 surveys, when east coast reefs exhibited the largest reduction of substrate cover by live stony corals. A similar pattern was evidenced in relation to the prevalence of coral disease infections, which averaged 8.20% for west coast reefs, compared to 3.3% for east coast reefs in 2023. Given the strong relationship between the prevalence of coral disease infections (including SCTLD) and loss of reef substrate cover by live stony corals in 2023, we suggest that the marked geographical pattern of live coral loss depicts a progressive outburst and contagion of coral disease infections that appear to have travelled in a westerly direction across the Puertorrican coastlines after 2021 with lingering effects up until 2025. The exceptionally high sea surface temperatures recorded from May thru October 2023 that prompted the 2023 "global coral bleaching event" had very severe effects upon Puertorrican west coast reefs included in our PRCRMP, such as TRES05, TOUR30, TOUR20, and TOUR10 that had been relatively resilient to coral bleaching and disease related mortalities until the previous 2023 survey.

The general decline of stony coral cover was largely related to the reduction of cover by *Orbicella* spp. (mean: -48.6%), the dominant coral species in nine of the 21 reef stations surveyed in 2025, but particularly with the decline of cover by *Orbicella* spp. from west coast reefs (-71.0%), as compared to east coast reefs (-36.2%). In addition to the marked decline of cover by *Orbicella* spp., former top ten massive coral species in terms of reef substrate cover evidenced drastic reductions during the 2025 survey relative to the previous 2023 survey. These included: *Acropora palmata* (-98.5%), *Porites porites* (-82.6%), and *P. astreoides* (-38.1%). Taxonomic phase shifts in which losses of reef substrate cover by previously dominant (massive) star corals (*Orbicella* spp.) have resulted in branching corals (*Porites porites, P. astreoides, Madracis sp.*) replacing *Orbicella* spp. as the dominant stony coral species now include a total of eight reef stations within the set of 21 PRCRMP stations surveyed in 2025. The density of soft corals declined by 5.9% in 2025 relative to the previous 2023 survey, which is indicative that the marked previous losses measured during the 2018 – 2021 reef monitoring period were driven by extreme physical disturbances caused by hurricanes and other storm events but are now stable within sampling variability error.

Fish community structure evidenced marked increments of density (mean change: 114.8%) and species richness (mean change: 8.9%) during the most recent 2025 survey relative to the previous 2023 survey for the same set of reef monitoring stations. Fish density increments were measured from 15 stations, and such density increments were statistically significant (ANOVA; $p < 0.05$) in seven out of the 21 monitoring stations. Fish community density increments were strongly driven by density increments of numerically dominant schooling fishes, such as masked goby (*Coryphopterus personatus*), blue chromis (*Chromis cyanea*), creole wrasse (*Clepticus parrae*), and bluehead wrasse (*Thalassoma bifasciatum*). In the case of the three former species, such increments were largely associated with a strong recruitment of juveniles forming large schooling aggregations. Fish density was also influenced by an overall increment of species richness measured in 16 out of the 21 reef station matrix. The observed increments of fish density and species richness is indicative of a full recuperation from the drastic declines measured after the pass of Hurricanes Irma and Maria in 2017 and winter storm Riley in 2018. Given the drastic losses of live coral cover from most reef stations surveyed, increments of fish density and species richness suggest that such variations are up to now independent from live coral cover at the community level.

Fish size data, as evidenced by the occurrence of recruitment (1 - 5cm), juvenile, and adults (including terminal phase males) show that most of the reefs surveyed function as recruitment, nursery, and residential habitats for a wide variety of the larger reef fish herbivores, such as parrotfishes (*Scarus spp, Sparisoma spp*), and doctorfishes (*Acanthurus spp*). Mid-sized and large carnivores, including the nurse shark (*Ginglymostoma cirratum*), Nassau, red hind, yellowfin, coney and graysby groupers (*Epinephelus striatus, E. guttatus*, *Cephalopholis fulva, C. cruentata*), schoolmaster, lane, mutton, and yellowtail snappers (*Lutjanus apodus, L. synagris, L. analis, Ocyurus chrysurus*), queen triggerfish (*Balistes vetula*), hogfish (*Lachnolaimus maximus*), lionfish (*Pterois sp*.), jacks (*Caranx* spp.), great barracuda (*Sphyraena barracuda*), and cero mackerel (*Scomberomorus regalis*) were observed as juvenile and/or adults in many of the reefs surveyed without any evident pattern associated with depth, geographical location, and/or distance from shore. Large demersal predators were generally absent or observed in very low densities within belt-transect areas indicative of the still critical condition of these populations, particularly the large groupers (*Epinephelus spp, Mycteroperca spp*), snappers (*Lutjanus spp*.), and sharks (Carcharhinidae, Sphyrnidae).

The long spined urchin (*Diadema antillarum)* was the most prominent motile megabenthic invertebrate observed within belt-transects in nine out of the 21 reef stations surveyed with maximum density at CABE05 (3.0 Ind/30m^2).

Reefs surveyed in the San Juan – Carolina shelf are largely drowned eolianite structures with minimal carbonate buildup contributed by corals, perhaps with the exception of DOMI05 which still retains significant topographic relief contributed by relict (standing dead) elkhorn coral colonies (*Acropora palmata*). The most prominent reef formation found along the San Juan – Carolina coastline is an intermittent ridge of submerged and emergent rock promontories that run roughly parallel to the shoreline providing (shoreline) protection from wave action and hard substrate for colonization by benthic algae and encrusting reef biota. Live stony coral cover was largely associated with encrusting colonies of mustard-hill coral (*Porites astreoides*), symmetrical brain coral (*Pseudodiploria strigosa*), great star coral (*Montastraea cavernosa*), and greater starlet coral (*Siderastrea siderea*). Substrate cover by live stony corals was highest at MARI20 (9.12%), and lowest at CANG10 (3.40%). Reef topographic relief and benthic habitat complexity of biogenic origin was mostly contributed by basket sponges and erect soft corals (gorgonians). Giant basket sponge (*Xestospongia muta*) was the main contributor to the substrate cover by sponges in six out of the eight reef stations surveyed off the San Juan and Carolina coastlines with maximum cover at MARI20 (6.32%). Mean density of soft corals at CANG05 (36.4 Col/Transect) is now the highest in the PRCRMP.

Fish density and species richness in the San Juan – Carolina reefs surveyed varied largely in relation to the availability of topographic relief and benthic habitat complexity, and the influence of schooling coastal pelagic populations, particularly jacks (*Caranx ruber, C. crysos*). Due to the prevailing high wave and surge energy demersal reef fishes concentrated in substrate discontinuities such as holes, crevices, and rocky outcrops. Fish density ranged between a maximum of 106.4 Ind/30m^2 at ESCA10 and a minimum of 29.2 Ind/30m^2 at DOMI05. Fish species richness was highest at ESCA05 (19.0 Spp/30m^2) and lowest at DOMI05 (6.6 Spp/30m^2). The higher fish density and species richness at ESCA10 and ESCA05 reef stations appeared to be associated to the higher protection and habitat complexity provided by aggregate reef formations, in contrast to the low relief colonized pavement habitats that prevailed off ESCA20, Punta Las Marias (MARI20, MARI10), and Boca de Cangrejos (CANG20, CANG10, CANG05). The lowest fish densities and species richness measured at DOMI05 were influenced by the prevailing strong wave and surge action, the very shallow depth, and the massive loss of live coral and topographic relief due to breakage and erosion of the elkhorn (*Acropora palmata*) coral buildup.

IV. Resumen Ejecutivo

Un total de 21 estaciones arrecifales fueron monitoreadas entre mayo y agosto 2025 como parte del evento PRCRMP 2025. Monitoreos recurrentes fueron realizados en TRES05, TRES10, y TRES20 en Rincon, TOUR10, TOUR20, y TOUR30 en Mayaguez, BOTE15, BOTE20, y CANO30 en Isla Desecheo, CIBU05 en Vega Baja, DOMI05 en Carolina, CABE05, PALT10, PALN20, y DIAB05 en Fajardo, LPEN05, CROS10, y DAKI20 en Isla de Culebra, ESPE10, CANJ20, y SECO30 en Isla de Vieques.

Las determinaciones de porciento de cobertura por categorías bénticas en sustratos arrecifales se produjeron mediante la técnica de intercepto contínuo con cadena en grupos de cinco transectos permanentes replicados de 10m de largo por estación. Todas las colonias de corales pétreos interceptadas fueron visualmente inspeccionadas para determinar presencia de enfermedades infecciosas y/o blanqueamiento y sus respectivas tasas de prevalencia (%) por estación. Determinaciones de la composición taxonómica, densidad y riqueza de especies de peces e invertebrados megabénticos mótiles (langostas, carruchos, cangrejos grandes, camarones limpiadores, y erizos) se basaron en censos visuales de cinco transectos de correa de 10m de largo x 3m de ancho centralizados en los mismos transectos utilizados para caracterizaciones bénticas. Se extendieron estos transectos de correa a 20m de largo x 3m de ancho para incluir especies de peces de importancia comercial (incluyendo peces cotorros y médicos) y estimados visuales de sus respectivos tamaños.

La cobertura promedio de sustratos arrecifales por corales pétreos fue de 6.01%, y varió ente un máximo de 15.68% en SECO30 y 1.47% en TRES05. Reducciones en los porcientos de cobertura de corales pétreos fueron medidas en 20 de las 21 estaciones arrecifales estudiadas, comparados a las del censo previo en el 2023, incluyendo diferencias estadísticamente significativas en 10 estaciones. El cambio neto en porciento de cobertura promedio por corales pétreos para las 21 estaciones entre el censo 2025 y el previo de 2023 fue de -45.72%. Las mayores diferencias fueron medidas en TRES05 (-94.34%), BOTE20 (-86.39%), TOUR30 (-78.29%), y CANJ20 (-75.53%). Estos datos evidencian el estado crítico prevaleciente en los arrecifes de coral de Puerto Rico asociado a las pérdidas masivas de cobertura por corales pétreos vivos. El estado actual de cambios en cobertura promedio de corales pétreos vivos para las 21 estaciones arrecifales incluidas en el censo PRCRMP 2023 relativo a los censos originales (baseline) es de -78.55%. Las mayores reducciones de cobertura han sido medidas en BOTE20 (-96.90%), TRES05 (-96.07%), DOMI05 (-94.38%), ESPE10 (-92.84%), y CANO30 (-91.45%).

Las reducciones en cobertura por corales pétreos en estaciones arrecifales de la costa oeste (Mayaguez, Rincon, Isla Desecheo) fueron 60.0% mas altas (promedio: -61.98%), comparadas con las estaciones de la costa este (Fajardo, Isla de Culebra, Isla de Vieques, Carolina) (promedio: -36.98%), contrario al patrón observado en los censos del PRCRMP 2021 y 2022, en los cuales los arrecifes de la costa este mostraron las mayores reducciones en cobertura por corales pétreos. Un patrón similar fue evidenciado en relación a la prevalencia de enfermedades infecciosas de corales, las cuales promediaron 8.20% en las estaciones arrecifales de la costa oeste, comparados al promedio de 3.30% en las estaciones de la costa este. Dada la estrecha relación entre la prevalencia de enfermedades en corales (incluyendo SCTLD) y las reducciones observadas en cobertura de corales vivos, se sugiere que el marcado patrón geográfico en reducción de cobertura por corales pétreos refleja una progresión direccional en contagios desplazada hacia el oeste desde el 2021, con efectos hasta el censo mas reciente del 2025. Las temperaturas excepcionalmente altas registradas entre mayo y octubre, 2023 que dispararon el “evento global de blanqueamiento de corales 2023” tuvieron un efecto severo sobre los arrecifes de coral incluidos en el PRCRMP, particularmente sobre TRES05, TOUR30, TOUR20, y TOUR10, los cuales habían sido bastante resistentes a eventos previos de blanqueamientos y mortalidades de coral relacionadas a enfermedades.

La reducción total en porcentajes de cobertura por corales pétreos estuvo relacionado mayormente a reducciones en cobertura de corales estrellados, *Orbicella* spp. (promedio: -48.6%) y particularmente a las reducciones en cobertura de estos en estaciones de la costa oeste (-71.0%), en comparación con las reducciones de este complejo de especies en estaciones de la costa este (-36.2%). Otras especies de corales pétreos, ubicadas entre las primeras 10 en relación a su cobertura promedio original en el PRCRMP evidenciaron reducciones drásticas en el censo 2025, en relación al censo anterior del 2023. Las mismas incluyen a *Acropora palmata* (-98.5%), *Porites porites* (-82.6%), y *P. astreoides* (-38.1%). Al igual que en censos previos, las reducciones en porcentajes de cobertura por corales pétreos fueron parcialmente reemplazadas por cobertura de algas bénticas. Las reducciones drásticas en porcentajes de cobertura de corales masivos como *Orbicell*a spp. han resultado en que especies ramificados como *P. porites*, *P. astreoides, y M. auretenra* se hayan posicionado como las especies de corales pétreos dominantes en ocho de las 21 estaciones arrecifales monitoreadas en este censo 2025. Las densidades de corales blandos se redujeron 5.9% en el censo 2025, relativo al censo anterior 2023, lo cual es indicativo de que las reducciones mayores observadas en censos realizados durante el periodo 2018 al 2021 fueron causados por las condiciones de oleaje extremo asociado a huracanes y ahora se han estabilizado dentro de los márgenes de error del muestreo.

La estructura de la comunidad de peces registró en el censo del 2025 aumentos en densidad (promedio: 114.8%) y riqueza de especies (promedio: 8.9%) relativo al censo previo del 2023. Aumentos en densidad promedio fueron medidos en 15 estaciones, incluyendo aumentos estadísticamente significativos en siete de las 21 estaciones monitoreadas. Los aumentos en densidad de la comunidad de peces fueron influenciados por aumentos medidos en poblaciones numericamente dominantes con distribuciones agregadas, tales como *Thalassoma bifasciatum, Coryphopterus personatus, Chromis cyanea,* y *Clepticus parrae.* En el caso de las últimas tres especies, los aumentos medidos se relacionan fuertemente al reclutamiento masivo de individuos formando densas agregaciones (enjambres) en los arrecifes. Los aumentos en densidad de peces registrados fueron además influenciados por aumentos en la riqueza de especies medidos en 16 de las 21 estaciones monitoreadas en el 2025. Esto es indicativo de una completa recuperación de las especies desplazadas a partir del paso de los huracanes Irma y María en el 2017, y de la tormenta Riley en el 2018. Los incrementos en densidad y riqueza de especies de peces ante las drásticas reducciones en cobertura de corales pétreos vivos sugieren que tales variaciones de la comunidad de peces han sido, al menos hasta el presente, independientes de la cobertura de coral vivo.

La presencia de estadios reclutas (1 - 5cm), juveniles, y adultos para una gama amplia de especies de peces herbívoros grandes, tales como cotorros (Scaridae), y médicos (Acanthuridae) indican que la mayoría de los arrecifes estudiados sirven como hábitats de reclutamiento, criadero y residencia para estas familias. Peces carnívoros de tamaños medianos y grandes, incluyendo el tiburón gata (*Ginglymostoma cirratum*), los meros criollo, cabrilla, guajil, cabrilla roja y cabrilla enjambre (*Epinephelus striatus, E. guttatus*, *Mycteroperca venenosa*, *Cephalopholis fulva, C. cruentata*), pargos amarillo, arrayao, sama y colirubia (*Lutjanus apodus, L. synagris, L. analis, Ocyurus chrysurus*), peje puerco (*Balistes vetula*), capitán (*Lachnolaimus maximus*), péz león (*Pterois sp*.), jureles (*Caranx* spp.), barracuda (*Sphyraena barracuda*), y sierra carita (*Scomberomorus regalis*) se observaron en etapas juveniles y/o adultas sin mostrar ningún patrón evidente de distribución con profundidad, localidad geográfica, y/o cercanía de la costa. Depredadores demersales grandes fueron observados en muy bajas densidades o ausentes de las estaciones estudiadas. Estos datos son indicativos del estado crítico de las poblaciones de peces demersales grandes, particularmente meros (*Epinephelus spp., Mycteroperca spp*.), pargos (*Lutjanidae*) y tiburones (Carcharhinidae, Sphyrnidae). El erizo de espinas largas, *Diadema antillarum* fue la especie de invertebrados mótiles megabénticos mas abundante en el censo 2025 con una densidad maxima de 3.0 Ind/30m^2 en CABE05.

Los arrecifes en las costas de San Juan y Carolina caracterizados por primera vez en el 2025 son mayormente formaciones de eolianita con pocas contribuciones biogénicas a la topografia arrecifal, con la excepción de DOMI05 que aún retiene estructuras biogénicas contribuídas por el coral cuerno de alce (*Acropora palmata*), ahora muerto y en proceso de erosión. La formación arrecifal mas prominente en la costa de San Juan - Carolina es una fila intermitente de estructuras emergentes y sumergidas distribuidas de forma casi paralela a la orilla la cual sirve de protección costera al oleaje y provee un sustrato para el crecimiento de algas bénticas y colonización por biota arrecifal incrustante. La cobertura de superficie arrecifal por corales pétreos estuvo mayormente relacionada a especies con crecimiento incrustante, tales como *Porites astreoides*, *Pseudodiploria strigosa*, *Montastraea cavernosa* y *Siderastrea siderea*. Las coberturas promedio mas altas se midieron en MARI20 (9.12%), MARI10 (6.58%), y ESCA05 (6.39%), y las mas bajas fueron en CANG10 (3.40%) y DOMI05 (3.57%). Esponjas de canasta (*Xestospongia muta*) y corales blandos erectos (gorgonios) fueron los mayores contribuidores biogénicos a la topografia arrecifal. La densidad promedio de corales blandos en CANG05 (37.6 Col/Transect) es la mas alta medida hasta el presente en el PRCRMP.

La densidad y riqueza de especies de peces en los arrecifes de San Juan y Carolina variaron mayormente en relación al relieve topográfico, la complejidad estructural béntica, y la penetración de cardúmenes de peces pelágicos, particularmente jureles (Carangidae). Dada la alta fuerza del oleaje y la resaca resultante los peces se concentraron en irregularidades del fondo marino, tales como grietas, y promontorios que proveen microhabitáculos. La densidad promedio varió entre un máximo de 106.4 Ind/30m^2 en ESCA10 a un mínimo de 29.2 Ind/30m^2 en DOMI05. La riqueza de especies fué mas alta en ESCA05 (19.0 Spp/30m^2) y mas baja en DOMI05 (6.6 Spp/30m^2). Las mayores densidades y riqueza de especies medidas en ESCA10 y ESCA05 se asociaron a la mayor protección y microhabitaculos disponibles en formaciones arrecifales agregadas, comparados a formaciones de pavimentos de bajo relieve. Las densidades y riqueza de especies mínimas en DOMI05 se relacionan al fuerte oleaje, poca profundidad, y la pérdida masiva de relieve topográfico arrecifal asociado a la muerte y ruptura de corales y la erosión.

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V. Introduction

The Puerto Rico Coral Reef Monitoring Program (PRCRMP) sponsored by NOAA Coral Reef Conservation Program (CRCP) and administered by the PR Department of Natural and Environmental Resources (PRDNER) started in 1999 with baseline characterizations of reef substrate cover by sessile-benthic categories and determinations of fish and motile megabenthic invertebrate taxonomic composition and densities. Annual monitoring events were conducted on a total of 15 reefs stations between 2003 and 2015. In 2016, the PRCRMP was modified to expand the geographical range and number of reef monitoring sites to achieve a 42-reef station framework, with alternate year monitoring surveys at each station. This is the PRCRMP 2025 Final Report that includes monitoring data and analyses of 21 reef stations surveyed between March and July 2023 (TRES05, TRES10, TRES20, TOUR10, TOUR20, TOUR30, BOTE15, BOTE20, CANO30, CIBU05, DOMI05, CABE05, DIAB05, PALT10, PALN20, LPEN05, CROS10, DAKI20, ESPE10, CANJ20, and SECO30), and baseline characterizations of reef stations off the San Juan and Carolina coastlines (MARI10, MARI20, CANG05, CANG10, CANG20, ESCA05, ESCA10, ESCA20).

Puertorrican reefs included in the PRCRMP have shown variable responses to a multiplicity of environmental stressors, such as heat-stress induced coral bleaching, coral disease infections (including SCTLD), exotic species invasions, hurricanes, winter storms, and stormwater discharges, among others. Coastal reefs influenced by estuarine conditions and reef stations in deeper waters of the insular shelf were more resilient to the 2005 coral bleaching event than shelf-edge and oceanic island reefs with clear waters at similar depths (Garcia-Sais et al., 2017b). Hurricanes Irma and Maria had a severe effect largely on sessile-benthic communities on shallow reefs (<5m depths), whereas reefs deeper in the water column exhibited lower or no measurable mechanical damage, but a general reduction of fish species richness and fish population densities declines were measured throughout reefs in the PRCRMP (Garcia-Sais et al., 2018, 2019, 2020).

Coral disease infections bloomed after the 2019 coral bleaching event. Mayor losses of live stony coral cover (mean: -25.73%) were measured on PRCRMP reefs on the East coast in 2021 associated with a mean 6.14% prevalence of coral disease infections, whereas the reductions of live stony coral cover on reefs of the west coast averaged -7.40% associated with disease prevalence of 1.81% (Garcia-Sais et al., 2021). In 2022, a -27.22% decline of reef substrate cover by stony corals on South coast reefs was measured associated with a mean coral disease prevalence of 23.97% (Garcia-Sais et al., 2022). West coast reefs showed the highest losses of stony coral cover in 2023 (mean: -37.47%) compared to east coast reefs (mean: -5.42%), in contrast to the observed pattern in the 2021 and 2022 surveys (Garcia-Sais et al., 2023). A similar pattern was observed in relation to the prevalence of coral disease infections, which averaged 8.20% on west coast reefs, compared to 3.3% in east coast reefs in 2023. The marked geographical pattern of stony coral cover decline was indicative of a progressive contagion of coral disease infections that appeared to have dispersed in a westerly direction across the Puertorrican southern coastline. Reductions of stony coral cover between the 2022 and the previous 2021 surveys were strongly influenced by an overall 23.5% decline of cover by *Orbicella* spp., precisely the species complex mostly affected by infectious diseases, and particularly the most affected by apparent SCTLD infections (Garcia-Sais et al., 2023).

A drastic -93.18% loss of reef substrate cover by live stony corals was reported for Dominos Reef (DOMI05) in 2021 (Garcia-Sais et al., 2021). This was the top PRCRMP reef station in terms of live coral cover by 2018 with an average substrate cover of 58.34%. Elkhorn coral, *Acropora palmata* (an ESA listed species) was representative of 89.9% of the total cover by stony corals at DOMI05. The massive loss of live coral at DOMI05 was associated with a localized impact of extreme rainfall and stormwater discharges associated with the pass of Tropical Storm Isaias in August 2020 (Hernandez-Delgado et al., 2020; Garcia-Sais et al., 2021, 2023). No other PRCRMP reef, including reefs with high cover by *A. palmata* suffered such impact during such period.

Marked reductions of fish density and species richness were documented and directly related to the extreme physical disturbances affecting Puertorrican reefs between 2016 - 2018 (Garcia-Sais et al., 2017, 2018, 2019). Statistically significant declines reef fish density was reported for 25 of the 42 reef stations surveyed between 2016, and the 2017 and 2018 monitoring surveys (Garcia-Sais et al., 2017, 2018). Differences were largely associated with density declines of small, numerically dominant water column fishes, particularly the masked goby (*Coryphopterus personatus*). A generalized decline of fish species richness that was statistically significant for seven reef stations also contributed to the widespread density declines and attributed to the vulnerability of small water-column fishes to surge and abrasion effects associated with extreme physical/oceanographical disturbances. A strong, yet partial recuperation of fish densities and species richness was reported during the 2021 and 2022 surveys associated with the replenishment of numerically dominant small reef fish populations (Garcia-Sais et al. 2021, 2022).

Variations of fish density and fish species richness between the 2023 and previous 2021 and 2022 monitoring surveyed were relatively small and statistically insignificant.

The 2025 monitoring report follows-up on the response of coral reef communities within the PRCRMP to the impacts of extreme heat stress associated with the period from mid-May through late November 2023, when maximum monthly means SST's were exceeded in Puerto Rico accumulating up to 19 degree-heating weeks (NESDIS, 2024), triggering the worst coral bleaching event yet recorded in the Northern Hemisphere (Goreau and Hayes, 2024). Complete data sets for all reef sites can be found in previous PRCRMP annual monitoring reports (García-Sais et al., 2001a, 2001b, 2001c, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2014, 2015, 2016, 2017a, 2018, 2019, 2020a, 2021, 2022a, 2022b, 2023, 2024).
A comprehensive database with all quantitative transect data on percent cover by benthic categories, and taxonomic composition, density, and size of fishes collected since 1999 has been prepared and is available in Microsoft Access and available in the Marine Biodiversity Observation Network and Ocean Biodiversity Information System platforms.

VI. PR Coral Reef Monitoring Program - Research Synthesis (1999 - 2023)

Since the start of this monitoring program in 1999, coral reef systems in Puerto Rico have shown a variety of ecological health trends. Coastal shallow reefs of the south coast, such as CORA10 in Guánica and WEST10 in Isla Caja de Muerto in Ponce exhibited a moderate, yet statistically significant decline of live stony coral cover between their 1999 - 2001 baseline survey(s) and 2005. During a similar timeframe, reefs in the oceanic islands of Mona (CARM05, MUJE20) and Desecheo (CANO20, BOTE20, BOTE15), as well as shelf-edge reefs in Mayaguez (TOUR 30, TOUR20, TOUR10), and Ponce (DERR20, CDM10), and reefs all around Vieques (Garcia-Sais et al. 2000, 2001d, 2004) maintained stable stony coral cover.

A sharp decline of live coral cover was measured from reefs in Ponce (DERR20), Isla Desecheo (CANO30, BOTE20, BOTE15), and Mayaguez (TOUR10) during the 2006 monitoring survey after a severe regional coral bleaching event that affected reef systems in the northern Caribbean during late 2005 (Miller et al., 2006; Hernández et al., 2006; García-Sais et al., 2008; Weil et al., 2009; Eakin et al., 2010). Posterior monitoring surveys in Isla de Mona (Garcia-Sais et al., 2010) and Vieques (Garcia-Sais et al., 2014) detected marked reductions of coral cover in the 25 – 50% range previously noted for reefs in Desecheo and Ponce, suggesting that such declines of coral cover were associated with the 2005 coral bleaching event. Sibling species of boulder star coral (*Montastraea annularis* and *M.*

faveolata; genus now changed to *Orbicella spp.*) were the most vulnerable stony coral species to the bleaching event. Thus, reef systems strongly dominated in terms of substrate cover by these species, such as those in the oceanic islands of Mona and Desecheo, the shelf-edge reefs of Ponce (DERR20), TOUR10 in Mayaguez, and those in Vieques were the most severely affected.

A pattern of lower coral mortality with increasing depth, from 20m to 30m was observed from Tourmaline Reef stations in Mayaguez (TOUR30, TOUR20, TOUR10), Puerto Canoas/Puerto Botes Reef stations in Isla Desecheo (CANO30, BOTE20, BOTE15), and the Canjilones (CANJ20) and Boya Esperanza (ESPE10) reefs in Vieques in 2006 after the coral bleaching event. The Tres Palmas Reef system in Rincon, dominated in terms of substrate cover by elkhorn coral (*Acropora palmata*) at depths of 1 - 3m (TRES05), and by *Montastraea cavernosa* at 10m (TRES10) did not show any statistically significant decline of stony coral cover. Reefs located near the coastline and/or influenced by estuarine conditions (PALO05, RESU10) in the Cabo Rojo shelf exhibited low or negligible impacts to their mean stony coral cover after the 2005 bleaching event. A negative correlation between a satellite-derived light attenuation coefficient (Kd 490) and the percent stony coral loss was found, suggesting that protection from incident light provided both from water turbidity and increasing depths contributed to the protection of corals from bleaching induced mortality after the 2005 regional event (Garcia-Sais et al., 2017b).

After two consecutive years of measuring what appeared to be lingering effects of the 2005 coral bleaching event, variable but consistent increments of stony coral cover were measured from a subset of eight PRCRMP stations considered as impacted reefs (Garcia-Sais et al., 2017b, 2016 and references therein). These included CANO30, BOTE15, CORA10, DERR20, WEST10, TOUR30, TOUR20, and TOUR10. Increments of reef substrate cover by stony corals, while not statistically significant for all reef stations, represented recuperation trends of corals after the 2005 regional bleaching event at these stations. A positive relationship was observed between stony coral cover increments at reefs impacted by bleaching and Kd 490, suggesting that in most instances, estuarine conditions influencing reefs near the coast provided more favorable conditions for coral recuperation of reef substrate cover. Since variations of chlorophyll-a concentrations (influenced by phytoplankton biomass) explained more than 90% of the spatial variability associated with light attenuation (turbidity) in the vicinity of our monitored reef stations (Garcia-Sais et al., 2017b), it is possible that the higher increments of coral cover measured in estuarine influenced reefs were driven by higher plankton food availability. It is important to note that more than half (27 out of 42) of the currently monitored PRCRMP stations do not have pre-2005 historical data to determine potential recovery trends from the regional coral bleaching event.

During September 2017, two category 4 - 5 hurricanes (Irma and Maria) impacted the Puertorrican coastlines, and during March 2018 an extreme event of exceptionally high waves associated with winter storm Riley impacted the north and west coasts of Puerto Rico. Impacts of these extreme climatological events upon coral reef communities included in the PRCRMP framework were analyzed by Garcia-Sais et al. (2018, 2019). Statistically significant differences of total stony coral cover were evidenced between the 2016 baseline and the 2018 monitoring surveys at reef stations of Isla de Vieques (ESPE10 and CANJ20), Isla de Culebra (LPEN05), and between the previous 2015 and the 2018 monitoring surveys at reef stations of Isla Desecheo (BOTE15 and BOTE20). In all cases, differences were associated with a decline of coral cover in 2018 relative to previous survey(s). Loss of total stony coral cover was measured in 17 of the 19 reef stations surveyed in 2018 where previous assessments were available for comparison. The mean reduction of coral cover from the 17-reef station data set was -18.02%. The largest losses of stony coral cover were measured at LPEN05 in Isla de Culebra (-51.7%), DIAB05 in Fajardo (-38.9%), and BOTE20 in Isla Desecheo (-33.7%). Finger coral (*Porites porites*) and lobed star coral (*Orbicella annularis*) were the main species associated with loss of substrate cover, but other species also contributed to the decline of cover by stony corals.

Differences of erect soft coral densities between monitoring surveys were statistically significant at eight reef stations, all of which resulted from declining densities measured in 2018 and 2019 (Garcia-Sais et al., 2018, 2019). The general decline of stony coral cover and erect soft coral densities appeared related to mechanical breakage and/or detachment and overturn of colonies due to extreme surge, scouring, and/or abrasion effects that may have prevailed during the pass of hurricanes (Irma and/or Maria) in September 2017, and/or winter storm Riley, particularly impacting shallow reefs of the north and west coasts of PR in March 2018, prior to our reef monitoring survey.

Prevalence of stony coral disease infections increased by 271%, from a mean of 1.31% in 2017 to a mean of 4.86% in 2019 on a similar set of reef stations surveyed. The sharp increment of disease prevalence was largely related to infection(s) affecting the massive starlet coral (*Siderastrea siderea*) that represented 37.0% of the total infected coral colonies intercepted by transects in 2019 (Garcia-Sais et al., 2017, 2019). The sharp increase in coral disease prevalence detected in 2019 (Garcia-Sais et al., 2019) coincided with the onset of an extensive coral bleaching event that affected shallow and upper-mesophotic coral reef communities in Puerto Rico (Weil et al., 2019; Garcia-Sais et al., 2020b) and may have triggered the sharp increment of prevalence by disease infections in stony corals.

From the entire set of 42 reef stations monitored during 2021, a strong geographic pattern emerged relative to the loss of stony coral cover between the 2021 and the previous 2018/19 survey(s) where reef stations from the east coast (Fajardo, Culebra, Vieques) lost 3.22 times more live coral cover (mean: -26.75%), than reef stations from the west coast (Desecheo, Rincon, Mayaguez, Cabo Rojo) (mean: -8.30%), and 2.56 times more coral cover than south coast reefs (Parguera, Guánica, Guayanilla, Ponce, Salinas) (mean: -10.45%). In support of the marked geographic pattern of stony coral decline it was found that east coast reefs (Fajardo, Culebra, Vieques) exhibited an average coral disease prevalence (mean: 12.03%) that was 4.6 times higher than the average for west coast reefs (Desecheo, Rincon, Mayaguez, Cabo Rojo) (mean: 2.61%). The south coast reefs exhibited an intermediate disease prevalence of 8.71% that was strongly influenced by a 40.0% disease prevalence at RATO05 (the highest in the 2021 PRCRMP) and mostly related to infections on massive starlet coral (*Siderastrea siderea*), the dominant coral species at that reef station. West coast reefs showed the highest losses of stony coral cover in 2023 (mean: -37.47%) compared to east coast reefs (mean: -5.42%), in contrast to the observed pattern in the 2021 and 2022 surveys. A similar pattern was noted in relation to the prevalence of coral disease infections, which averaged 8.20% on west coast reefs, compared to 3.3% in east coast reefs in 2023. The marked geographical pattern of stony coral cover decline was indicative of a progressive contagion of coral disease infections that appeared to have dispersed in a westerly direction across the Puertorrican southern coastline (Garcia-Sais et al., 2023).

A drastic decline of reef substrate cover by stony corals was reported for DOMI05, a shallow fringing reef located off the Carolina-San Juan coastline that was mostly related to the mortality of elkhorn coral (*Acropora palmata*), an Endangered Species Act listed species that represented 90% of the total cover by stony corals at DOMI05 during its 2018 baseline survey (Garcia-Sais et. al., 2022). All the elkhorn coral colonies along transects and throughout the entire reef system suffered mortality. Standing, recently dead colonies of other stony corals (*Pseudodiploria strigosa, Agaricia agaricites*, *Porites astreoides*), and soft corals (e.g., *Antillogorgia* spp., *Gorgonia sp.*) were also noted. The massive loss of live corals (stony and soft) from DOMI05 appeared related to a localized stressor in the Carolina-San Juan coastline, since such impacts on acroporid corals and/or soft corals were not evidenced from any other reef station included in the 2021 PRCRMP monitoring survey. The monitoring observations at DOMI05 in October 2021 are consistent with reports of a large-scale mortality of stony corals (particularly *Acropora* spp.), invertebrates, and fishes from El Escambrón and Piedra La Ocho reefs off San Juan, associated with extreme coastal flooding caused by Tropical Storm Isaias in July 2020 (Hernandez-Delgado, 2020).

Continued degradation of the Puertorrican coral reefs was evidenced during the 2022 and 2023 surveys when reef substrate cover by live stony corals declined in 37 out of the 42 reef stations surveyed relative to the previous 2021 survey when the 42 reef stations were monitored including statistically significant differences at RATO05, BOYA20, MLAN10, TOUR20, TRES20, and TRES10. The highest reductions of cover were measured at TRES20 (-74.84%), TOUR20 (-60.56%), MLAN10 (-53.77), CIBU05 (-44.92%), and RATO05 (-44.40%). Disease infections (including SCTLD) appeared to be the main driver of substrate cover loss by stony corals. Prevalence of disease infections increased by 195.9% between 2022 (mean: 21.91%) and the previous 2021 survey (mean: 7.42%) for a similar set of monitoring stations. SCTLD infections not previously noted for any coral colonies in 2021 (or earlier surveys) were noted on a total of 63 out of the 823 intercepted colonies for a SCTLD disease prevalence of 7.65% in 2022. Reductions of stony coral cover between the 2022 and the previous 2021 surveys were strongly influenced by an overall 23.5% decline of cover by *Orbicella* spp., precisely the species complex mostly affected by infectious diseases (62 colonies), and particularly the most affected by apparent SCTLD infections (44 colonies).

During the previous 2024 survey reef substrate cover by live stony corals declined in 20 out of the 21 reef stations monitored with an average reduction of -45.31% relative to the previous 2022 survey for a similar set of stations. The drastic decline of substrate cover by live stony corals was not species specific, but rather measured across most species intercepted by transects, with major species contributions to the overall loss of cover by *Orbicella* spp. (-38.1%), *Porites astreoides* (-48.7%), *P. porites* (-78.1%), *Agaricia agaricites* (-99.4%), *Siderastrea siderea* (-48.7%), and *Colpophyllia natans* (-100.0%). The main driver of the decline of reef substrate cover by stony corals and the marked loss of coral species intercepted by transects measured during the 2024 survey appeared to be the lingering effects of coral disease infections (including SCTLD) that averaged an unprecedented 21.8% in 2022, perhaps exacerbated by additional disease related mortalities following what NOAA has referred to as the “2023 global coral bleaching event” with severe bleaching effects on Puertorrican coral reefs during the period of October 2023 thru March 2024, but still with lingering effects thru 2024.

A total of 215 species of diurnal, non-cryptic fish species have been identified by the PRCRMP during all survey years (1999 – 2024). In general, fish populations presented a trend of fluctuating (statistically significant) differences of density and species richness within belt-transects (Esteves, 2013, García-Sais et al., 2019 and reference therein). Variations between surveys have been mostly associated with fluctuations of density by numerically dominant populations that exhibit highly aggregated distributions, such as the masked goby (*Coryphopterus personatus*), blue chromis (*Chromis cyanea*), blue-head wrasse (*Thalassoma bifasciatum*), and creole wrasse (*Clepticus parrae*). Such fluctuations appear to be related to density-independent factors influencing recruitment patterns of these short-lived populations (Garcia-Sais, 2010; Esteves, 2013). Variations also appear to be driven by physical forces, such as wave action affecting the reef during field surveys. This has been observed to be particularly relevant for shallow reefs (< 20 m) and more critically determinant for *Acropora* reefs, such as TRES05, GALL05, MLAN05, and AURO05. Statistically significant reductions of fish density and species richness also appear strongly related to hurricane and/or other extreme wave action events (Garcia-Sais et al., 2017a, 2018, 2019). Depth, distance from shore, and substrate rugosity have been documented to be the main factors explaining the variations of taxonomic composition and relative abundance of fish species at the PRCRMP reefs studied (Garcia-Sais, 2010; Esteves, 2013).

VII. Approach and Methodology

A. Sampling Design

A total of 21 reef stations were surveyed between May and August 2025 as part of the PRCRMP 2024-25 monitoring event. Recurrent monitoring surveys were performed at TRES05, TRES10, and TRES20 in Rincon, TOUR10, TOUR20, and TOUR30 in Mayaguez, BOTE15, BOTE20, and CANO30 in Isla Desecheo, DOMI05 in Carolina, CIBU05 in Vega Baja, CABE05, PALT10, PALN20, and DIAB05 in Fajardo, LPEN05, CROS10, and DAKI20 in Isla de Culebra, ESPE10, CANJ20, and SECO30 in Isla de Vieques.

Baseline characterizations were performed off the Carolina and San Juan coastlines off Boca de Cangrejos (CANG05, CANG10 and CANG1), off Punta Las Marias (MARI10 and MARI20), and off El Escambrón (ESCA05, ESCA10 and ESCA20). The location of PRCRMP regular monitoring stations and of stations where baseline characterizations were performed as part of the 2025 survey is shown in Figure 1. Data on survey dates, station codes, depths, and geographic coordinates of reef stations surveyed in the PRCRMP 2025 event are presented in Table 1.

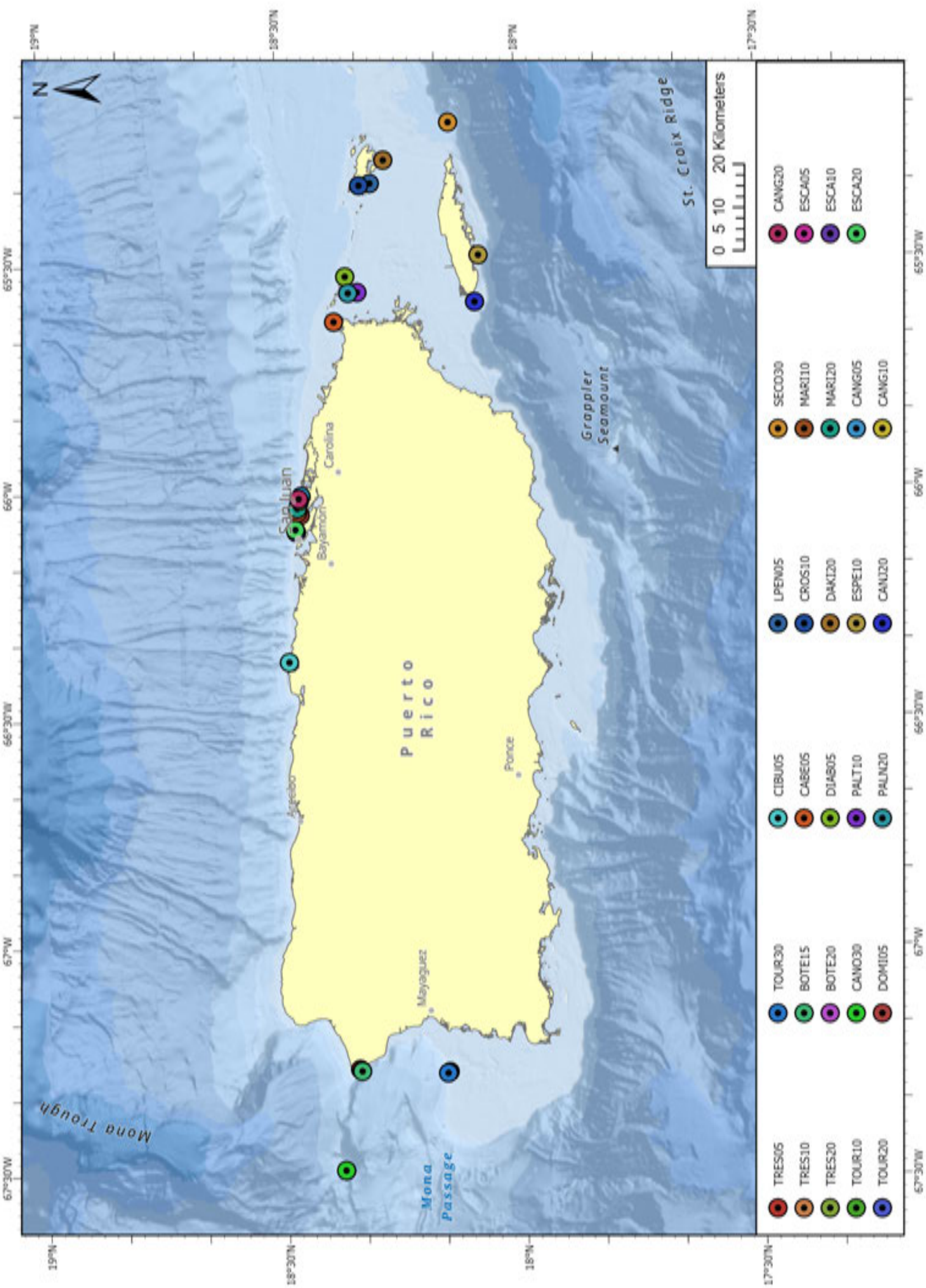


Figure 1. Map showing location of reef monitoring stations. PRCRMP 2025

Table 1. Geographic coordinates, station codes, and mean depths of coral reef stations included in the 2025 PRCRMP monitoring survey

Site	Reef Station	Station Code	Baseline Survey	2025 Survey Date	Mean Depth (m)	Latitude	Longitude
Isla Desecheo	Puerto Botes	BOTE15	2004	5/23/25	14.2	18.3820	-67.4883
	Puerto Botes	BOTE20	2000	5/23/25	17.5	18.3816	-67.4886
	Puerto Canoas	CANO30	2004	5/9/25	25.1	18.3820	-67.4883
Fajardo	Las Cabezas	CABE05	2018	6/21/25	5.98	18.3854	-65.6297
	Cayo Diablo	DIAB05	2016	6/21/25	5.2	18.3603	-65.5309
	Palominito	PALT10	2016	6/21/25	10.7	18.3354	-65.5656
	Palomino	PALN20	2016	6/22/25	15.7	18.3547	-65.5671
Mayaguez	Tourmaline	TOUR10	1999	6/7/25	11.0	18.1630	-67.2737
	Tourmaline	TOUR20	2004	6/7/25	18.7	18.1652	-67.2752
	Tourmaline	TOUR30	2004	6/10/25	27.9	18.1664	-67.2763
Rincon	Tres Palmas 5m	TRES05	2015	6/29/25	1.64	18.3507	-67.2669
	Tres Palmas 10m	TRES10	2004	6/29/25	9.39	18.3473	-67.2700
	Tres Palmas 20m	TRES20	2004	6/29/25	17.46	18.3465	-67.2712
Culebra	Luis Pena 5m	LPEN05	2016	7/12/25	4.26	18.3049	-65.3277
	Carlos Rosario 10m	CROS10	2016	7/12/25	9.10	18.3278	-65.3320
	Dakity 20m	DAKI20	2016	7/12/25	18.44	18.2759	-65.2773
Vieques	Boya Esperanza 10m	ESPE10	2001	7/13/25	7.90	18.0806	-65.4879
	Canjilones 20m	CANJ20	2001	7/13/25	15.12	18.0896	-65.5901
	El Seco 30m	SECO30	2011	7/13/25	5.20	18.1387	-65.1971
Vega Baja	Cibuco 5m	CIBU05	2011	7/24/25	2.04	18.4892	-66.3738
Carolina	Dominos 5m	DOMI05	2018	8/15/25	1.50	18.4622	-66.0517
	Maria Grande 10m	MARI10	2025	8/14/25	12.10	18.46755	-66.04616
	Maria Grande 20m	MARI20	2025	8/14/25	17.90	18.46803	-66.03696
	Boca de Cangrejos 5m	CANG05	2025	8/14/25	3.30	18.45999	-66.00982
	Boca de Cangrejos 10m	CANG10	2025	8/15/25	9.10	18.46359	-66.02025
	Boca de Cangrejos 15m	CANG15	2025	8/14/25	16.40	18.46499	-66.01605
San Juan	El Escambron 5m	ESCA05	2025	8/15/25	4.50	18.47055	-66.08865
	El Escambron 10m	ESCA10	2025	8/15/25	9.10	18.47114	-66.08888
	El Escambron 20m	ESCA20	2025	8/15/25	17.60	18.47294	-66.08353

The PRCRMP follows a depth, distance from shore and geographical (east-west; north-south) sampling design that includes some of the main oceanographic gradients that appear to drive the ecological health and community structure of neritic coral reefs in Puerto Rico. Neritic coral reefs included in this monitoring program are all shallower than 40m, and thus lie within the Caribbean Surface Mixed Layer water mass with pycnocline at depths between 45 – 70 m. Due to the permanent stratification forces acting on this water mass, oceanic waters around Puerto Rico remain highly oligotrophic, and the coastal estuarine influence of river discharge, watershed runoff, and resuspension/remineralization processes from the insular shelf produce marked inshore-offshore gradients of water turbidity associated with dissolved and particulate organic and inorganic sources.

Coral reefs located to the east of the mainland, such as those in the Cordillera de Fajardo (PALN20, PALT10, DIAB05, CABE05), and the islands of Vieques (CANJ20, ESPE10, and SECO30), and Culebra (DAKI20, CROS10, LPEN05) are at the head of the current and receive minor estuarine influence from land masses. Likewise, reefs located in the oceanic islands Desecheo (CANO30, BOTE20, BOTE15), and Mona (CARM10, MUJE20, SARD30) also far from estuarine influences. Shelf-edge reefs (BOYA20, BERI20, TOUR30) associated with the mainland are intermediate across this inshore-offshore gradient and their estuarine influence is variable, being higher in the west and north coasts, and lower in the south coast due to the presence/absence of major rivers. The natural exponential decline of light penetration with increasing depth creates another relevant gradient that needs to be addressed in the understanding of potential causes of reef degradation and management regulations. Thus, the PRCRMP includes vertically (depth) stratified sampling designs on several reef sites. Similar depth formats on the east, west and south coasts allow for comparative analyses between depths and across natural turbidity gradients associated with riverine influences and island mass effects. Baseline characterizations of additional reef stations along the Carolina and San Juan coastlines were included in this (PRCRMP 2025) survey to expand such depth-stratified sampling design for the north coast.

A. Sessile-benthic Reef Communities

Sets of five 10m long permanent transects were established during baseline surveys at coral reef stations. Transects were positioned non-randomly in areas visually considered to be of optimal coral growth within similar depths (+/- 3 m) and reef physiographic zones. Transect mean depths were determined from the five depth measurements taken at the start rebar marker, but depths may vary along transect paths. All transects were permanently marked with steel rebars set on naturally occurring crevices or holes in abiotic sections of the reef substrate at both ends. Wherever possible, the starting point of the transect was marked with a rebar on a reef structure of high topographic relief to facilitate visual recognition during monitoring surveys. A reference line was tied between the two end-markers to identify transect paths during monitoring activities and removed upon survey completion. Individual geographic coordinates were obtained for all transects at each reef station with a time-synchronized GPS placed inside a zip-lock bag and installed on a floater. Coordinates were taken from the starting rebar of each transect.

Sessile-benthic reef communities were characterized by the continuous intercept chain-link method (as modified from Porter, 1972), following the CARICOMP (1994) protocol. This method provides information on the percent linear cover by sessile-benthic biota and other substrate categories along transects. It allows construction of reef community profiles by assignment of metric units to each substrate transition, which serves as a high precision baseline for monitoring. The chain has 1.42cm long links, marked every 10 links for facilitating underwater counting. The exact position of the chain is guided by a series of steel nails set into available hard (abiotic) substrates along transects. There are 704 chain links over a perfectly flat reef surface. Link counts above 704 are produced by substrate (topographic) relief along transects. The total links above 704 were multiplied by the link length (1.42cm) to provide estimates of substrate rugosity for each transect. Individual measurements of substrate categories, as recorded from the number of chain links were sorted, added, and divided by the total distance (in chain links) on each transect to calculate the cumulative percent linear cover by each substrate category.

Soft corals, except for encrusting forms (e.g., *Erythropodium caribaeorum, Briareum asbestinum*) were counted as number of colonies intercepted per transect (Col/Transect), whenever any of their branches crossed the transect reference line. Live stony coral colonies under the transect line were counted and examined visually for prevalence of apparent infectious diseases and/or bleaching. Colonies of similar coral species growing close together and sharing attachment surfaces were counted as individual colonies if separated by distance of 15 cm or more.

Diseased colonies on each transect were identified and counted. Preliminary field identifications of potential diseases were made whenever possible following the photographic guidelines by Raymundo et al. (2008). The percent coral disease prevalence was reported from the total number of diseased colonies divided by the total number of colonies intercepted by the five transects at each station.

During conditions of extreme wave and surge action, such as those occurring during hurricanes and/or exceptionally high North Atlantic swells, rebar transect markers may become detached from the reef structure. In such cases, rebars were re-installed in the same place without any alteration of the transect path. In cases where the reef structure supporting the rebar was physically displaced, overturned, or collapsed, the transect path was identified using the remaining marker and the sequence of existing nails and continued until a 10m linear path was reached. A new rebar marker was installed at the transect end point whenever the original rebar was lost in the sand or could not be found. In extreme cases where neither the transect rebars or the guide nails could be found, a new transect or a new set of permanent transects were constructed within the same general vicinity of the reef station previously surveyed. During the 2024 monitoring survey all transect markers were found and there was no need for rebar replacements nor re-positioning.

Temporal variations (between surveys) of the percent reef substrate cover by stony and soft corals were tested by Factorial Analysis of Variance (ANOVA) procedures on real values (un-transformed data). ANOVA p-values of < 0.05 were used to establish significant differences between surveys. The mean square error of the One-way ANOVAs was used to determine the 95% confidence intervals (CI) to allow pair-way comparisons between annual surveys. The percent changes of substrate categories between surveys were calculated as Percent Change = (y2 – y1/y1) *100. Reports of percent cover to second decimal units are for format uniformity and do not imply precision of measurements to such units.

B. Reef Fishes and Motile Megabenthic Invertebrates

Demersal, diurnal non-cryptic reef fishes and motile megabenthic invertebrates (lobsters, queen conch, large crabs, cleaner shrimps, squids, urchins) were surveyed by sets of five 10m-long by 3m wide (30m^2) belt-transects centered along the reference line of transects used for sessile-benthic characterizations at each reef station. The 10 x 3m belt transects were expanded to 20 x 3m (60m^2) to provide additional information on density and size distributions of fishes of commercial value (snappers, groupers, hogfishes, barracuda, jacks, mackerels, sharks) and/or fish species considered to be the larger reef herbivores (parrotfishes, doctorfishes).

Each transect was surveyed for 10 - 12 minutes depending on the complexity of the fish community on each transect. The initial minute was dedicated to detection of transitory species that may swim away from divers (e.g., snappers, jacks, mackerels, groupers, hogfish, large parrotfishes, etc.). During the next four minutes, the diver swam over both sides of the transect area counting fishes that form schooling aggregations over the reef (e.g., *Chromis spp., Clepticus parrae, Bodianus*, etc.) and other transitory species as they entered the survey area, including the wrasses (e.g., *Thalassoma, Halichoeres spp.*) which tend to be attracted to divers and thereby, may increase in density during the survey. A second run over both sides of transects was performed during the next two minutes to count demersal and territorial fishes (e.g., *Stegastes spp*, *Gramma loreto*, squirrelfishes, etc.) that remained within the transect area. Small gobies (e.g., *Coryphopterus spp*., *Elacatinus* spp.) associated with coral heads on both sides of transects were counted on the next two minutes. The last three minutes were dedicated to survey large commercially important fishes and/or larger reef fish herbivores.

Fork length (cm) was used to report fish sizes. Life history designations, such as recruit, juvenile, adult, and terminal phase male (TPM) were included for parrotfishes (Scaridae) based on the available information on length at maturity (Froese and Pauly, 2019). The recruitment juvenile designation was assigned to the smallest detectable fish size in the 1-5cm range (C1). Trophic classifications (zooplanktivores, herbivores, opportunistic carnivores, spongivores, corallivores) applied to fish species within 10 x 3m belt-transects follow feeding habits information from Randall (1967) and/or Froese and Pauly (2019). Reference information on length at maturity, maximum length and feeding habits for fish species identified within belt-transects in the PRCRMP 2022 survey is included as Appendix 1.

Temporal variations of fish density and species richness were tested by one-way factorial Analysis of Variance (ANOVA) procedures on real values (untransformed data) for each reef station. Temporal variations of fish density and species richness were evaluated using only the data from 3m x 10m belt-transects. Pairwise comparisons of annual values were based on 95% CI calculated from the mean square error of the ANOVA tests.

VIII. Results and Discussion - Monitoring of Coral Reef Communities

1.0 Tres Palmas Reef 5m (TRES05)

1.1 Physical Description

The rocky shoreline of the Tres Palmas Marine Reserve leads to a narrow backreef lagoon with coarse sandy sediments. The lagoon is a semi-protected environment associated with a former extensive elkhorn coral (*Acropora palmata*) reef system that developed along a bedrock platform fringing the shoreline. The reef top is distributed at depths ranging between 1 - 4m. The branching elkhorn coral colonies were large, rising more than one meter from the hard ground platform almost to the surface and wide, with thickets extending more than two meters horizontally in many cases. At present most of the elkhorn coral is dead and showing signs of rapid bioerosion. Sand pools and channels separate the reef where the hard ground platform breaks up. Interspersed within the *A. palmata* biotope are abundant colonies of encrusting corals, mostly *Pseudodiploria clivosa, P. strigosa* and *Porites astreoides*, but most are now dead and overgrown by algae. A set of five permanent transects were installed during the 2015 baseline survey at depths between 1.5 – 1.8m. Panoramic views of the reef community at TRES05 during the 2025 survey are presented as Photo Album 1. The location of sampling stations is shown in Figure 2.

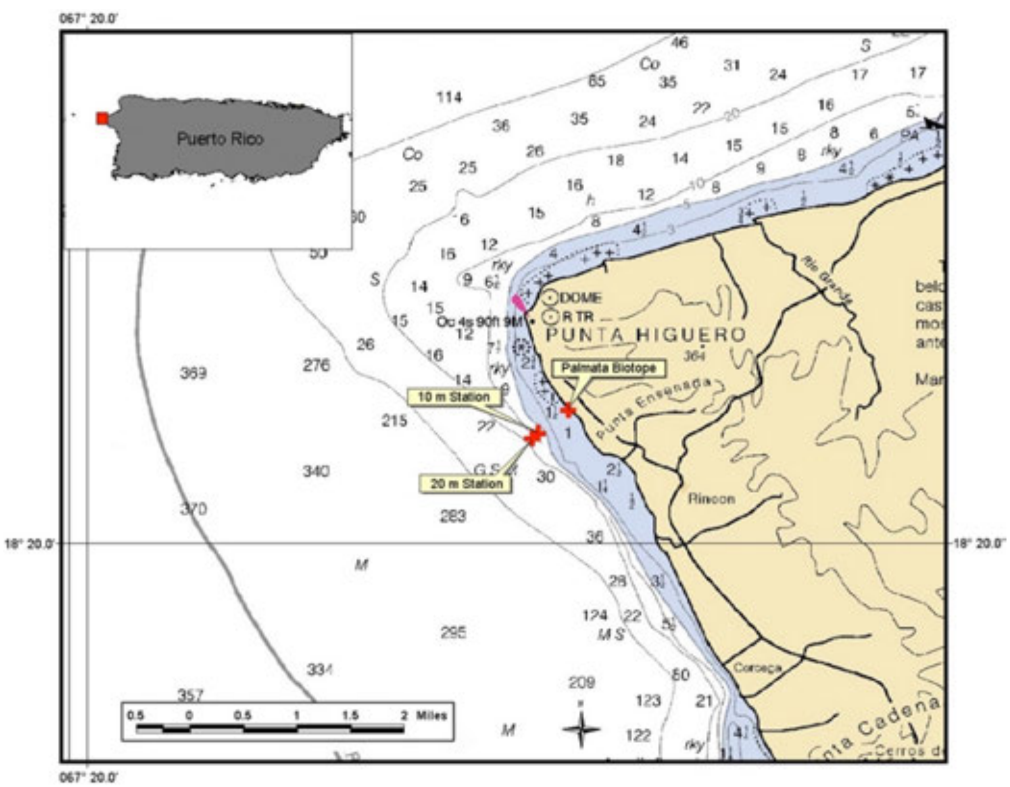


Figure 2. Location of coral reef monitoring stations off Tres Palmas, Rincón. PRCRMP 2025

1.2 Sessile Benthic Reef Community

Benthic algae, comprised of a mixed assemblage of red crustose, turf, and coralline macroalgae were the dominant sessile-benthic category of reef substrate cover at TRES05 with a combined mean cover of 64.26% (Table 2). The encrusting crustose calcareous red alga, *Ramicrusta* sp. was the main component of this assemblage with a mean cover of 33.18%, representing 51.63% of the total cover by benthic algae. Reef substrate cover by *Ramicrusta* sp. increased by 216.8% during the 2021 survey relative to the 2019 survey and has maintained its increasing trend colonizing dead coral substrates at TRES05 until the present 2025 survey. Turf algae, a mixed assemblage of short brown and red algae were observed in all transects with a mean substrate cover of 27.71%, or 44.68% of the total cover by benthic algae. One large patch of cyanobacteria, growing as a reddish carpet over sandy substrate was intercepted by one transect with a mean cover of 0.79% (Table 2).

Stony coral cover averaged 1.46% (range: 0 – 4.29%) with a mean of 1.0 Col/Transect. Knobby brain coral (*Pseudodiploria clivosa*) was the dominant species with a mean substrate cover of 0.86%, representative of 58.90% of the total cover by stony corals (Table 2). Knobby brain coral was represented (in transects) by only one relatively large colony in transect three. Two additional coral species (*Acropora palmata, Porites astreoides*) were also intercepted by transects with a combined mean cover of 0.61%. Intercepted elkhorn coral (*A. palmata*) colonies were observed as small live fragments thriving within recently dead large standing colonies, typically in colony sections protected (partially shaded) from direct solar radiation. Extensive sections of dead *A. palmata* and many colonies of brain corals (*Diploria* spp., *Pseudodiploria* spp.) were observed recently dead and overgrown by *Ramicrusta* sp., turf algae, and other encrusting biota along transects and in nearby reef areas. Coral disease infections were not observed in any of the five total stony coral colonies intercepted by transects during the 2025 survey (Appendix 2).

The encrusting colonial zoanthid (*Palythoa caribaeorum)* was intercepted by four transects with a mean cover of 6.07%. Small colonies of erect soft corals (gorgonians) were observed along transects with a mean density of 1.0 Col/transect. Encrusting soft corals were not observed along transects. Small sponges were observed in two transects with a mean cover of 0.38%. Abiotic categories, largely associated with reef overhangs produced by growth of now dead standing elkhorn coral, averaged a reef substrate cover of 27.00% and strongly contributed to a mean rugosity of 2.78m (Table 2).

Table 2. Percent reef substrate cover by sessile-benthic categories at TRES05, Rincon. PRCRMP 2025

TRES05						
Survey Date: 6/29/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**1.82**	**1.82**	**1.52**	**1.52**	**1.52**	**1.64**
Rugosity (m)	1.89	3.87	2.08	2.92	3.16	**2.78**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	25.09	19.48	23.99	26.33	30.74	**25.12**
Sand				5.42		**1.08**
Gaps/Holes			2.55	1.41		**0.79**
Total Abiotic	**25.09**	**19.48**	**26.54**	**33.15**	**30.74**	**27.00**
Benthic Algae						
Ramicrusta spp.	21.91	39.96	38.47	24.16	41.38	**33.18**
Turf (mixed) with sediment	35.22	20.69	12.63	24.27	11.49	**20.86**
Turf (mixed)	16.84	1.82	8.00	9.43	3.19	**7.85**
CCA (total)		1.01	1.62	0.87	0.96	**0.89**
Jania spp.			2.09	0.87	1.49	**0.89**
Peyssonnelia spp.		0.40	0.81	0.43	0.53	**0.44**
Dictyota spp.				0.76		**0.15**
Total Benthic Algae	**73.97**	**63.87**	**63.62**	**60.78**	**59.04**	**64.26**
Cyanobacteria	**0.00**	**0.00**	**0.00**	**0.00**	**3.94**	**0.79**
Stony Corals						
Pseudodiploria clivosa			4.29			**0.86**
Acropora palmata				1.73		**0.35**
Porites astreoides				1.30		**0.26**
Total Stony Coral	**0.00**	**0.00**	**4.29**	**3.03**	**0.00**	**1.46**
# Coral Colonies /Transect	**0**	**0**	**1**	**4**	**0**	**1.00**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
# Erect Soft Coral Colonies/Transect	**0**	**5**	**3**	**1**	**1**	**2.00**
Zoanthids						
Palythoa caribaeorum		**16.45**	**5.56**	**2.06**	**6.28**	**6.07**
Soft Corals						
Plexaura homomalla		0.20				**0.04**
Total Soft Corals		**0.20**				**0.04**
Sponges						
Ircinia felix	0.94					**0.19**
Verongula spp.				0.54		**0.11**
Ircinia spp. brown				0.43		**0.09**
Total Sponges	**0.94**	**0.00**	**0.00**	**0.98**	**0.00**	**0.38**

Figure 3 shows the variations of reef substrate cover by the main sessile-benthic categories between monitoring surveys at TRES05. The most relevant change of benthic community structure at TRES05 is related to the massive decline of reef substrate cover by live stony corals measured during the most recent 2025 survey. Coral cover declined 30.60% between the 2015 baseline and the 2023 survey, but due to the high variability of substrate cover within replicate transects differences were statistically insignificant. During the 2025 survey, live coral cover declined 94.34% relative to the previous 2023 survey, from 25.97% in 2023 to only 1.47% in 2025. Differences were statistically significant (ANOVA; $p < 0.0001$; see Appendix 3) and driven by a 98.49% decline of cover by the dominant species *A. palmata* (Figure 4).

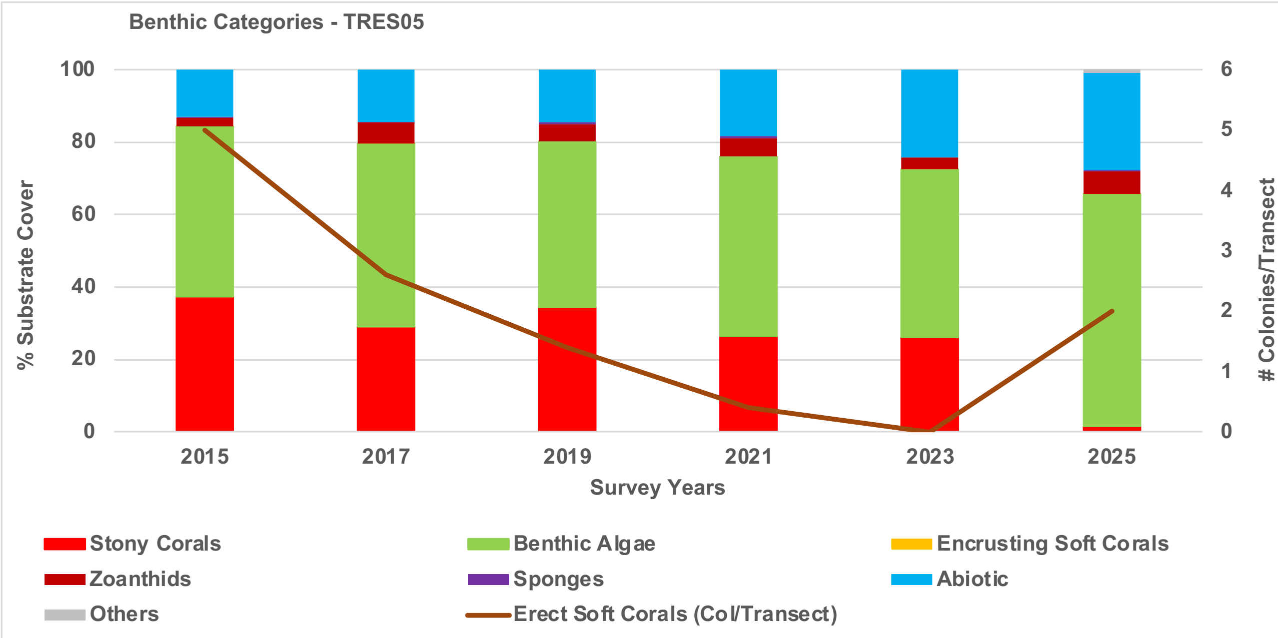


Figure 3. Monitoring trends (2015 – 2025) of mean substrate cover by sessile-benthic categories at TRES05, Rincon. PRCRMP 2025

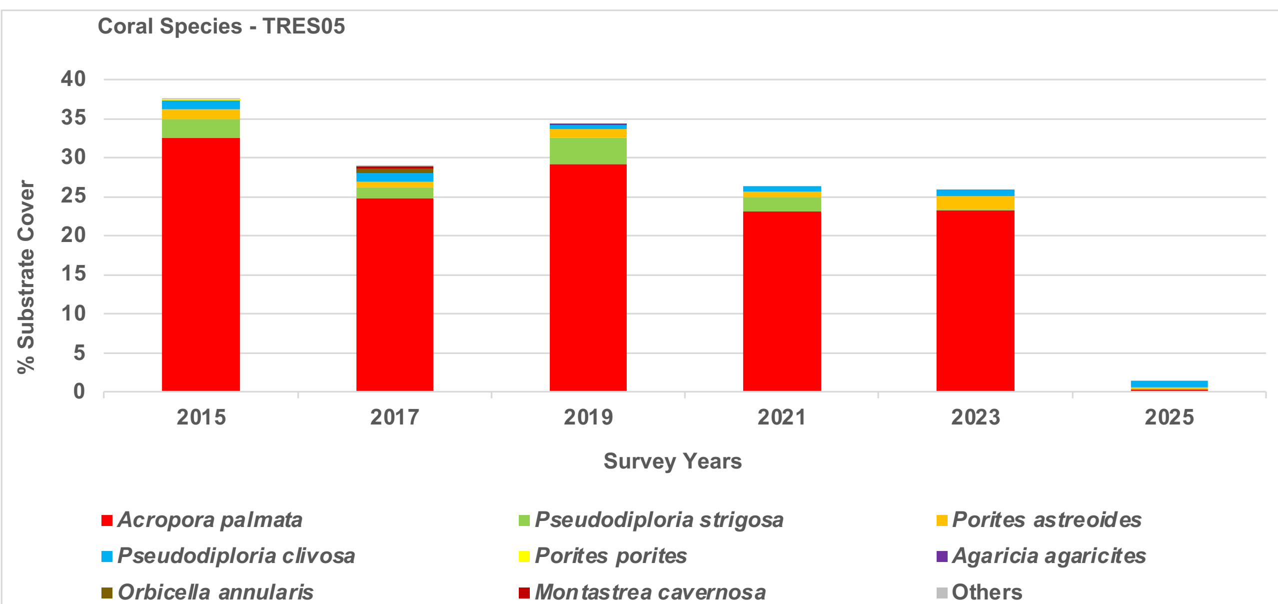


Figure 4. Monitoring trends (2015 – 2025) of mean substrate cover by stony coral species at TRES05, Rincon. PRCRMP 2025

The drastic demise of live coral cover at TRES05 measured during the 2025 survey was observed to be widespread across other sections of the reef and not a localized effect within transect areas. This condition was probably driven by the 2023 global coral bleaching event (Goreau and Hayes, 2024), when SSTs were exceeded in Puerto Rico from mid-May until November, accumulating up to 19 degree-heating weeks (DHW) by late October (NESDIS, 2024). Increments of reef substrate cover by benthic algae (37.98%), and encrusting zoanthids (82.8%) were measured during the 2025 survey relative to the previous 2023 survey.

Previous to the 2025 survey, the main temporal variations of the sessile-benthic community structure at TRES05 were related to the density of erect soft corals and the relative composition of benthic algae taxonomic components. Statistically significant differences of soft coral densities between monitoring surveys were found (ANOVA, $p < 0.001$; Appendix 4), related to a sharp decline (-46.15%) between the 2017 survey (2.6 Col/Transect), and the 2019 survey (1.4 Col/ Transect) (Figure 3). The change of density may have been driven by the extreme wave and surge energy associated with the direct impact of Hurricane Maria in 2017, and/or winter storm Riley in 2018. During the 2025 survey, new colonies of erect soft corals have colonized available substrates at TRES05 increasing to mean densities of 2.0 col/transect.

Reef substrate cover by benthic algae remained relatively stable across all monitoring surveys at TRES05 until 2023 (range of means = 45.65 - 50.57%) but marked variations were noted regarding the relative composition of taxonomic components. The red crustose calcareous alga, *Ramicrusta sp*. was first intercepted by transects in 2017 with a mean substrate cover of 0.19% but increased to a mean cover of 12.45% in the 2021 survey and has kept its increasing trend until the present 2025 survey with an overall increment of 114.32% relative to 2017. Ramicrusta sp. is now the dominant benthic algal component, which implies a taxonomic phase shift in terms of benthic algal community structure at TRES05. Proportional reductions of reef substrate cover by turf algae and stony corals have been measured. Fluctuations in cover by brown fleshy macroalgae (*Dictyota sp*.) have been previously reported and appear to be related to a seasonal pattern influenced by strong wave action associated to Atlantic winter swells.

1.3 Reef Fishes and Motile Megabenthic Invertebrates

A total of 23 fish species were observed within belt-transects at TRES05 during the 2025 survey with a mean density of 45.6 Ind/30m^2, and a mean species richness of 9.4 Spp/30m^2 (Table 3). The numerically dominant species were the bluehead wrasse (*Thalassoma bifasciatum*) and the dusky damselfish (*Stegastes adustus*), with a combined mean density of 28.8 (Ind/30m^2), representative of 63.2% of the total fish density within belt-transects. In addition to the aforementioned species, the yellowtail damselfish (*Microspathodon chrysurus*), and the red-lip blenny (*Ophioblennius atlanticus*) were present in all five transects with a combined density of 5.4 Ind/30m^2, or 11.8% of the total individuals. Schooling aggregations of striped, french, and caesar grunts (*Haemulon chrysargyreum, H. flavolineatum, H. carbonarium*) were observed close to the bottom below large elkhorn coral arms. One schooling aggregation of large adult yellowtail parrotfishes (*Sparisoma rubripinne*) was also present. Motile megabenthic invertebrates were not observed within belt-transects during the 2025 survey (Table 3). Adult spiny lobsters (*Panulirus argus*), rock lobsters (*P. guttatus*), and sea urchins (*Diadema antillarum, Eucidaris tribuloides, Echinometra lucunter*) have been previously reported from this reef (García-Sais et al., 2017).

Fish community structure at TRES05 was strongly represented by small opportunistic carnivores (SOC) which feed on small benthic invertebrates that become exposed upon disturbances due to wave action. The opportunistic carnivore assemblage included 10 species, including four of the top six numerically dominant species (e.g. *Thalassoma bifasciatum, Halichoeres bivittatus, Ophioblennius atlanticus* and *Haemulon chrysargyreum*). The SOC assemblage presented a combined density of 27.2 Ind/30m^2, representative of 59.8% of the total fish density within belt-transects. Herbivores (HER) were represented by nine species, including territorial damselfishes (Pomacentridae), doctorfishes (Acanthuridae), and parrotfishes (Scaridae), with a combined mean density of 16.9 Ind/30m^2, representative of 37.1% of the total fish density. Large carnivores (LC) included the schoolmaster and mahogany snappers in 3m x 10m belt-transects (*Lutjanus apodus, L. mahogoni*) with a combined density of 0.4 Ind/60m^2 (Table 3). Juvenile and adult graysbys (*Cephalopholis cruentata*), mahogany snappers (*Lutjanus mahogoni*), and adult yellowtail snappers (*Ocyurus chrysurus*), coneys (*C. fulva*), lionfishes (*Pterois spp*.), and jacks (*Caranx crysos, C. ruber*) were observed within extended belt-transects (3m x 20m) with a combined density of 6.4 Ind/60m^2 (Table 4).

Table 3. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at TRES05, Rincon. PRCRMP 2025

TRES05							
Survey Date: 6/2/25	**Belt-Transects (3x10m)**			**Trophic**			**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	11	9	9	49	7	**17.0**	SOC
Stegastes adustus	9	11	13	14	12	**11.8**	HER
Halichoeres bivittatus	5	7		2	1	**3.0**	SOC
Microspathodon chrysurus	2	2	2	4	4	**2.8**	HER
Ophioblennius atlanticus	3	3	3	2	2	**2.6**	SOC
Haemulon chrysargyreum		1	3		6	**2.0**	SOC
Acanthurus tractus	4					**0.8**	HER
Halichoeres maculipinna	3			1		**0.8**	SOC
Abudefduf saxatilis				1	3	**0.8**	ZPL
Myripristis jacobus	3					**0.6**	SOC
Haemulon flavolineatum				3		**0.6**	SOC
Acanthurus coeruleus		2				**0.4**	HER
Sparisoma viride				1	1	**0.4**	HER
Sparisoma rubripinne	1					**0.2**	HER
Lutjanus mahogoni		1				**0.2**	LC
Halichoeres radiatus		1				**0.2**	SOC
Haemulon carbonarium			1			**0.2**	SOC
Stegastes variabilis			1			**0.2**	HER
Haemulon macrostomum			1			**0.2**	SOC
Lutjanus apodus				1		**0.2**	LC
Scarus vetula				1		**0.2**	HER
Kyphosus sectatrix					1	**0.2**	ZPL
Acanthurus chirurgus					1	**0.2**	HER
Density (Ind/30m2)	41	37	33	79	38	**45.6**	
Richness (Species/30m2)	9	9	8	11	10	**9.4**	

The larger reef herbivores were numerically dominated by parrotfishes (Scaridae), including five species and 42 individuals with a combined density of 8.4 Ind/60m^2 (Table 4). Doctorfishes were also prominent, represented by blue tangs (*Acanthurus coeruleus*) and ocean surgeons (*A. tractus*) with a combined density of 3.2 Ind/60m^2. Recruitment, juvenile, and adult stages of a wide assemblage of doctorfishes and parrotfishes have been observed within transects in previous monitoring surveys (Garcia-Sais et al., 2023 and references therein) indicative that TRES05 functions as an important recruitment, nursery, and residential habitat for a diverse assemblage of the larger reef fish herbivores.

Monitoring trends of mean fish density and species richness at TRES05 are shown in Figure 5. Fish density means have fluctuated between 34.4 – 74.0 Ind/30m^2 and species richness have fluctuated between 8.8 – 12.4 Spp/30m^2. Differences of both fish density and species richness between monitoring surveys were statistically insignificant (ANOVA, p > 0.05; Appendices 5-6). Density fluctuations of numerically dominant species with aggregated distributions such as bluehead wrasse (*Thalassoma bifasciatum*), explain most of the density variability between monitoring surveys. During the 2025 survey, mean fish density (45.6 Ind/30m^2), and mean species richness (9.4 Spp/30m^2) are well within the range of previous monitoring surveys, indicative of a relatively stable fish community structure at TRES05 despite the massive losses of live coral cover, particularly elkhorn coral (*Acropora palmata*). This may be an indication of the relevance of the physical structure as residential habitat for shallow reef fishes, and attests to the potential functionality and desirability of reef restoration by artificial structures as the bioerosion of the existing coral reef buildup accelerates due to the absence of live coral growth and extreme wave action seasonally prevailing at TRES05.

Table 4. Size distributions of commercially important fishes and the larger reef herbivores observed within 20m x 3m belt-transects at TRES05, Rincon. PRCRMP 2025

TRES05							
Survey Date: 6/29/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	12					1	Juvenile
Acanthurus coeruleus c1	3		1				Recruit
Acanthurus coeruleus c2	10		1				Juvenile
Acanthurus coeruleus c3	13			1			Adult
Acanthurus tractus c2	10	1					Juvenile
Lutjanus apodus c4	18		1				Juvenile
Lutjanus apodus c6	27				1		Adult
Lutjanus mahogoni c4	18		1				Juvenile
Lutjanus synagris c3	15					1	Juvenile
Lutjanus synagris c5	25					1	Adult
Scarus vetula c3	12				1		Juvenile
Sparisoma rubripinne c5	5-25			5			Adult
Sparisoma viride c1	5					1	Recruit
Sparisoma viride c3	15				1		Juvenile
	Totals	1	4	6	3	4	

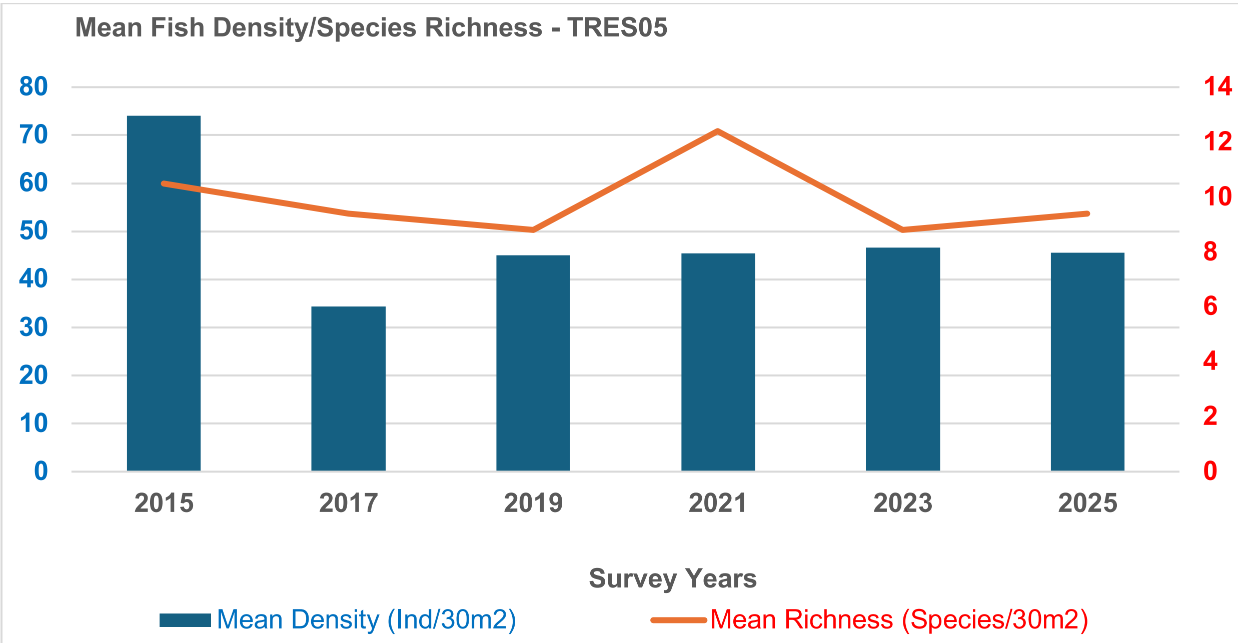
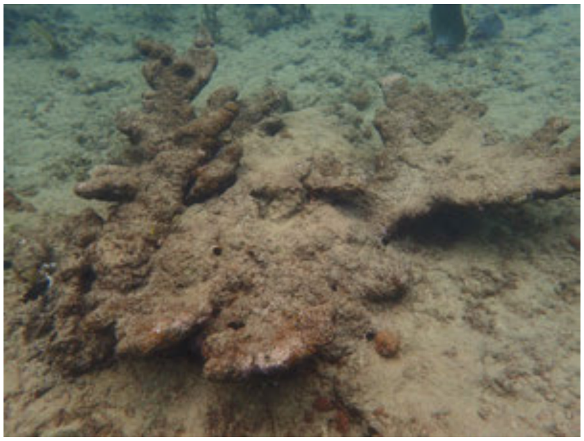
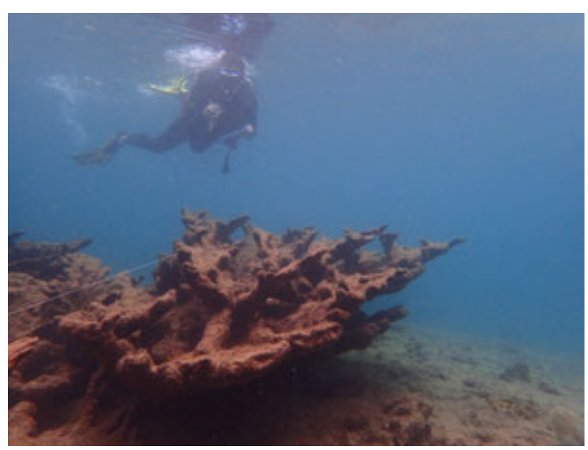
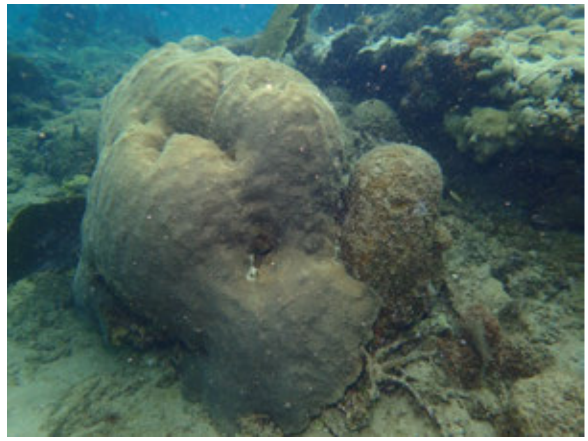


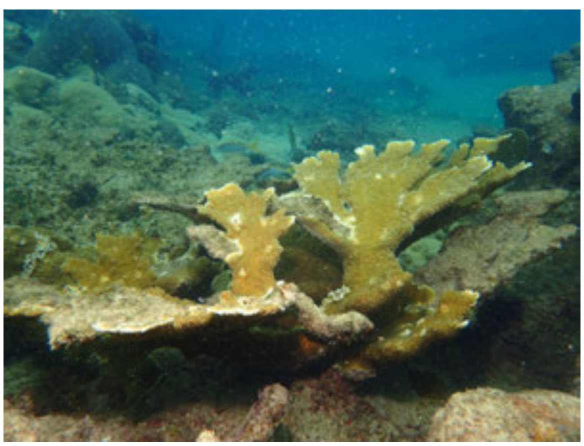
Figure 5. Monitoring trends (2015 – 25) of mean fish density and species richness within 10m x 3m belt-transects at TRES05, Rincon. PRCRMP 2025

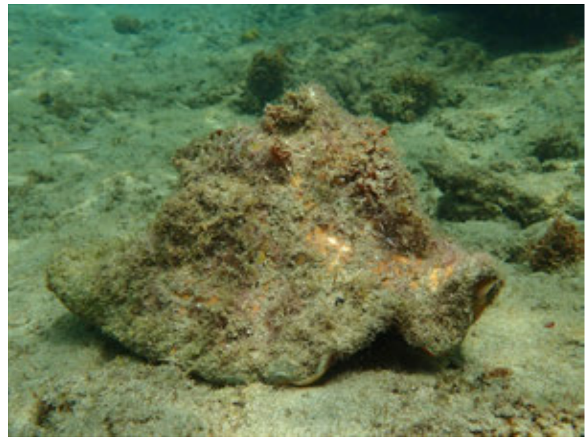
Photo Album 1. TRES05

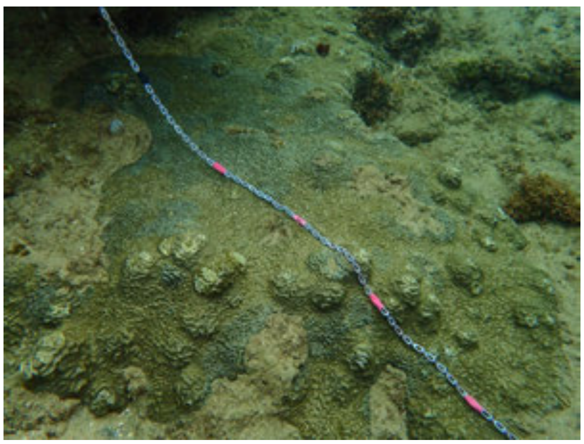


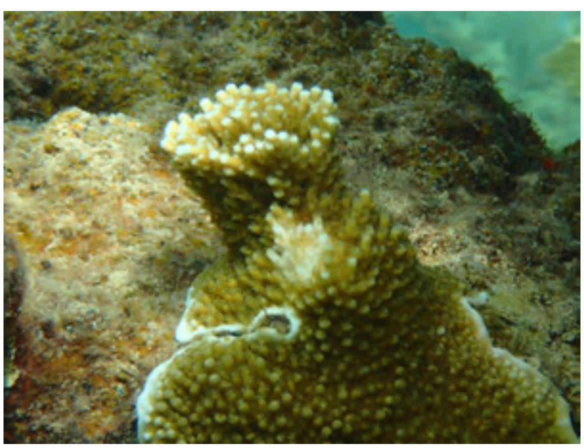






2.0 Tres Palmas Reef 10m (TRES10)

2.1 Physical Description

A series of submerged patch reefs are found in the Tres Palmas outer shelf, at about 0.5 kilometers east from the shelf-edge. Patch reefs are associated with an irregular and discontinuous line of hard ground promontories that rise from a sandy bottom at depths of 12 - 15m (Figure 2). Our permanent transects were installed during the baseline survey in 2004 within one of these patch reef promontories at a depth of 9.09 – 9.70m running parallel to each other east to west over the reef top (TRES10). The reef rises from the bottom as a vertical wall on the eastern end, forming a sloping terrace toward the west. The east wall is about 5m high and exhibits deep crevices and overhangs. At the top, the reef platform is mostly flat, with some depressions, but without any prominent pattern of spurs and/or grooves. Panoramic views of the reef community at TRES10 during the 2025 survey are presented as Photo Album 2.

2.2 Sessile-benthic Community

Benthic algae, comprised by a mixed assemblage of fleshy brown (*Dictyota sp*), turf, red crustose coralline (*Ramicrusta sp, Peyssonnelia sp.),* and red coralline (CCA mixed) algae presented the highest percent of reef substrate cover by sessile-benthic categories at TRES10 during the 2025 monitoring survey with a combined mean cover of 61.54% (range: 49.61 – 71.71%). Y-twig alga (*Dictyota sp*.) was the main component of the benthic algal assemblage with a mean cover of 42.17%, representative of 68.52% of the total cover by benthic algae. Turf algae, coralline algae (CCA, mixed), and the red crustose encrusting alga (*Ramicrusta* sp) were intercepted by all transects with a combined mean cover of 18.5%, representative of 30.06% of the total benthic algae. Large patches of reddish cyanobacteria were observed in all transects growing intermixed with the turf algae and over sandy sections with a mean substrate cover of 22.00% (Table 5).

A dense and diverse assemblage of erect soft corals was the most prominent feature of the sessile-benthic reef community at TRES10. Erect soft corals were present at all transects surveyed with a mean density of 20.40 Col/Transect (range: 15 – 25 Col/Transect) and due to their large size and high density contributed markedly to the reef habitat structural and biological complexity, providing protective habitat for fishes. The most abundant taxa included the common sea fan (*Gorgonia ventalina*), and sea rods (*Eunicea*, *Plexaurella sp*., *Antillogorgia acerosa*) among others. The colonial zoanthid, *Palythoa caribaeorum* was intercepted by two transects with a mean substrate cover of 0.47%.

Table 5. Percent reef substrate cover by sessile-benthic categories at TRES10, Rincon. PRCRMP 2025

TRES10						
Survey Date: 6/29/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	9.7	9.7	9.09	9.39	9.09	**9.39**
Rugosity (m)	1.76	0.89	1.42	1.28	1.89	**1.45**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	1.19	1.67	4.29	1.12	1.30	**1.91**
Sand			0.61			**0.12**
Total Abiotic	**1.19**	**1.67**	**4.90**	**1.12**	**1.30**	**2.04**
Benthic Algae						
Dictyota spp.	34.64	42.54	39.71	45.53	48.41	**42.17**
Turf (mixed) with sediment	9.76	3.47	14.83	12.78	14.49	**11.07**
Turf (mixed)	1.67		1.84	8.19	6.24	**3.59**
Ramicrusta spp.	0.83	1.29	7.35	4.59	0.94	**3.00**
CCA (total)	0.95	1.93	0.37	0.62	0.35	**0.84**
Peyssonnelia spp.	1.43		0.98		0.71	**0.62**
Jania spp.	0.36		0.49			**0.17**
Gracilaria spp.		0.39				**0.08**
Total Benthic Algae	**49.64**	**49.61**	**65.56**	**71.71**	**71.14**	**61.54**
Cyanobacteria	30.24	32.65	17.89	12.03	17.20	**22.00**
Stony Corals						
Porites astreoides	1.07	3.73	1.84	3.10	2.71	**2.49**
Siderastrea siderea			2.57	2.23	3.53	**1.67**
Stephanocoenia intersepta	2.62	0.00	0.25	0.99		**0.77**
Millepora alcicornis	0.60	0.39	0.74		0.24	**0.39**
Orbicella faveolata	1.79					**0.36**
Madracis decactis	0.95					**0.19**
Diploria labyrinthiformis		0.90				**0.18**
Montastraea cavernosa		5.40	0.25	0.62		**1.25**
Total Stony Corals	**7.02**	**10.41**	**5.64**	**6.95**	**6.48**	**7.30**
# Coral Colonies /Transect	6	11	7	8	8	**8.00**
# Diseased Coral Colonies/Transect	1	1	0	0	0	**0.40**
# Erect Soft Coral Colonies/Transect	15	25	21	17	24	**20.40**
Soft Corals						
Gorgonia ventalina		0.26			0.35	**0.12**
Zoanthids						
Palythoa caribaeorum	0.24			2.11		**0.47**
Ascidians						
Ascidian spp.				0.62		**0.12**
Anemones						
Lebrunia neglecta						**0.00**
Sponges						
Neopetrosia spp. smooth	3.21	2.96	3.19		0.59	**1.99**
Xestospongia muta	4.76		0.49		0.24	**1.10**
Amphimedon compressa	0.71	0.39	1.10	0.99	1.77	**0.99**
Cinachyrella kuekenthali	0.60			1.99	0.35	**0.59**
Aplysina cauliformis	2.14		0.25	0.25		**0.53**
Agelas spp.		0.64			0.24	**0.18**
Aiolochroia crassa				0.87		**0.17**
Sponge spp.			0.12	0.62		**0.15**
Agelas conifera		0.26			0.35	**0.12**
Mycale laevis	0.24		0.25			**0.10**
Agelas dispar		0.39				**0.08**
Ircinia felix		0.39				**0.08**
Verongula spp.		0.39				**0.08**
Monanchora arbuscula			0.37			**0.07**
Niphates erecta				0.25		**0.05**
Niphates caribica			0.25			**0.05**
Total Sponges	**11.67**	**5.40**	**6.00**	**4.96**	**3.53**	**6.31**
Diseased Corals						
Porites astreoides		1				**0.20**
Stephanocoenia intersepta	1					**0.20**

Stony corals were represented in transects by seven scleractinians and one hydrocoral (*Millepora alcicornis*) with a combined substrate cover of 7.30% (range: 5.64 – 10.41%) and a mean density of 8.0 Col/Transect (Table 5). Stony corals occurred mostly as isolated encrusting colonies of typically small size and moderate to low vertical relief. Mustard-hill coral (*Porites astreoides*), and massive starlet coral (*Siderastrea siderea*) were the dominant stony coral species in terms of reef substrate cover with a combined mean of 4.16%, representative of 56.99% of the total cover by stony corals. Several recently dead large colonies of grooved brain coral (*Pseudodiploria labyrinthiformis*), boulder brain coral (*Colpophyllia natans*), and pillar coral (*Dendrogyra cylindrus*) were observed with significant contributions to the reef topographic relief but now overgrown by benthic algae and/or cyanobacteria. Infectious diseases were observed affecting two stony coral colonies (*1-P. astreoides; 1-S. intercepta)* out of the 40 colonies intercepted by transects during the 2025 survey (disease prevalence = 5.00%, see Appendix 2).

Sponges were also prominent at TRES10 with at least 16 species intercepted by transects and a mean substrate cover of 6.31%. *Neopetrosia* spp., *Xestospongia muta,* and *Amphimedon compressa* were the dominant species in terms of reef substrate cover with a combined mean of 4.08%, representative of 64.66% of the total. The giant barrel sponge (*X. muta*) was present in three transects and provided substantial topographic relief at TRES10. In general, sponges were represented by small encrusting species with relatively low substrate cover. Total abiotic cover averaged 2.04%, contributed by reef overhangs and sand. Mean reef rugosity averaged 1.45m, indicative of the relatively flat seascape with only minor contributions of sedimentary features and/or stony coral buildups.

Variations of reef substrate cover by the main sessile-benthic categories between monitoring surveys at TRES10 are shown in Figure 6. Differences were statistically significant (ANOVA; $p< 0.0001$; Appendix 3), mostly driven by a 49.01% decline measured during the 2023 survey relative to the previous 2021 survey and a 16.0% decline measured in 2021 survey relative to the previous 2019 survey (Garcia-Sais et al, 2022). During the 2025 survey, stony coral cover declined 14.32% relative to the previous 2023 survey resulting in an overall stony coral cover decline of -65.11% relative to the baseline mean cover measured in 2015. The marked decline of live stony coral cover was associated with colony mortality and demise from transects by previously prominent species, such as *Colpophyllia natans, Orbicella spp.*, and *Dendrogyra cilindrus*. Also, sharp reductions of cover by *Montastraea cavernosa* (-58.47%), and *Pseudodiploria strigosa* (-98.92%) were measured during the 2025 and 2025 surveys relative to the previous surveys (Figure 7).

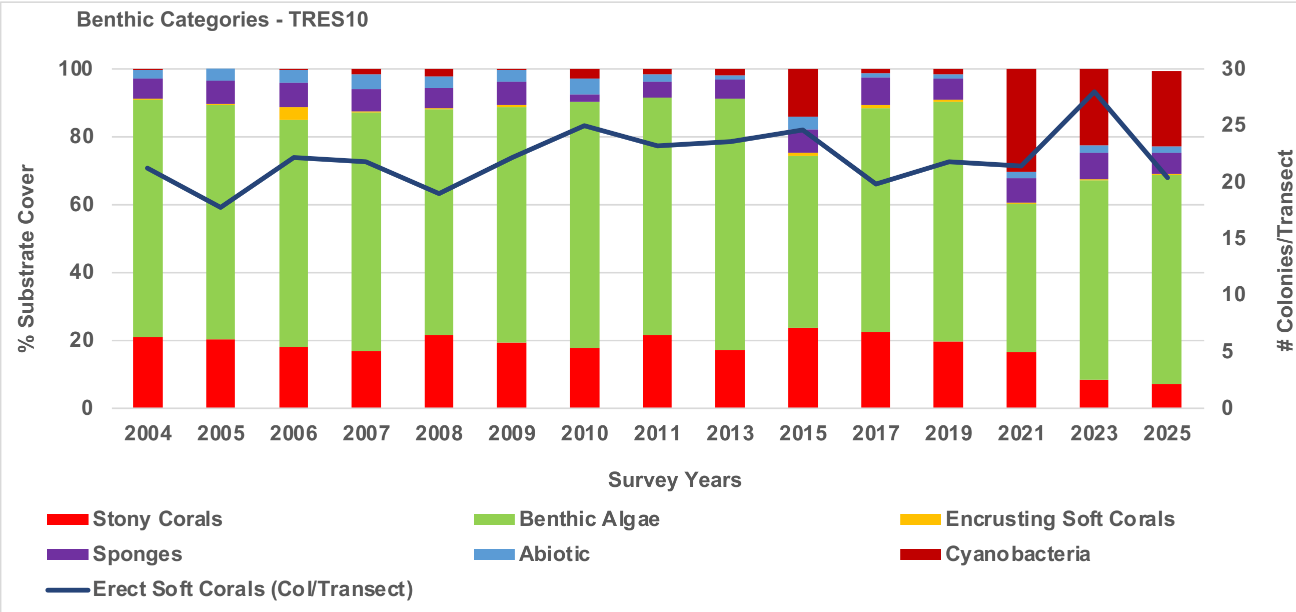


Figure 6. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at TRES10, Rincon. PRCRMP 2025

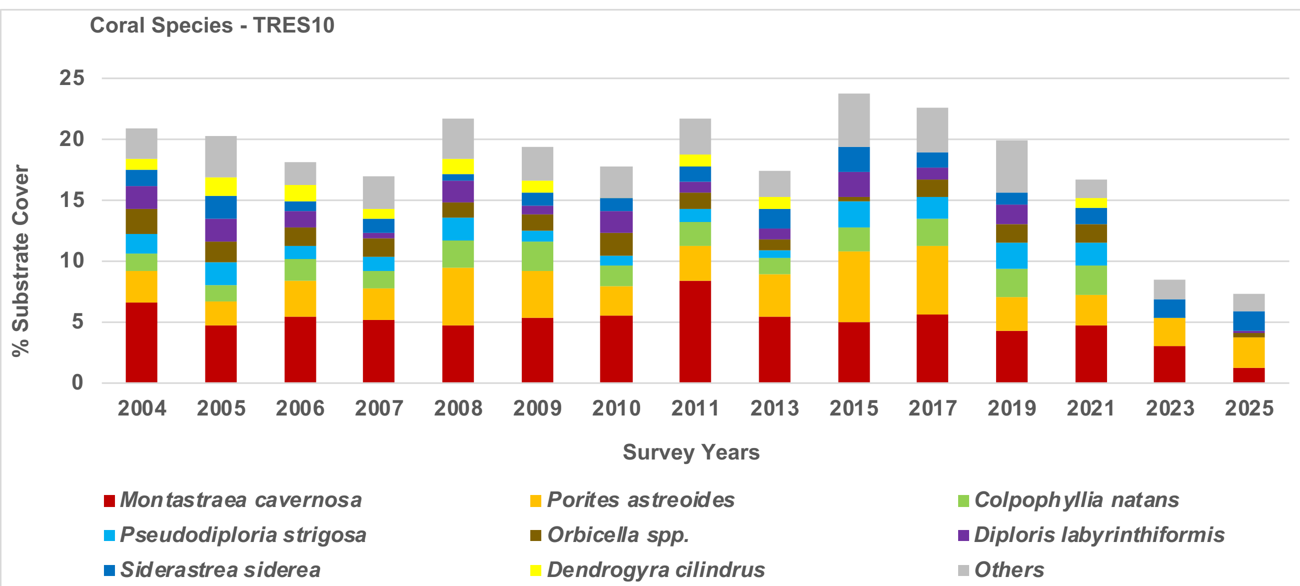


Figure 7. Monitoring trends (2004 – 2025) of mean substrate cover by stony coral species at TRES10, Rincon. PRCRMP 2025

The marked decline of reef substrate cover by live stony corals at TRES10 appears to be associated with infectious coral diseases perhaps triggered by heat stress. Coral disease prevalence increased from 2.08% in 2021 to 8.82% in 2023. We suggest that at some time between the 2021 and 2023 monitoring surveys coral disease prevalence may have been much higher and the main causal factor of coral mortality since many coral colonies were observed recently dead still standing but overgrown by benthic algae and/or cyanobacteria in 2023, including 14 previously intercepted by line transects. During the 2025 survey coral disease were noted on two colonies (1-*Porites astreoides*, 1-*Stephaocornia intercepta*), resulting in a disease prevalence of 5.00% (Appendix 2).

Another significant change of benthic community structure detected at TRES10 include the marked increment of cover by cyanobacteria since the 2021 survey (Figure 6), reaching a peak substrate cover in the most recent 2025 survey (mean: 22.00%). High cyanobacterial cover has shown to be an ephemeral condition previously described from reefs under the PRCRMP and associated with massive coral mortality (Garcia-Sais et al., 2006, 2007, 2008, 2023). Cyanobacteria typically grows as a reddish slimy mat over reef substrates and thus, it is very susceptible to detachment by wave and/or surge action. Further monitoring will be required to establish if the increment of cyanobacterial cover is a transitory feature, or a more permanent condition of the reef benthic community structure at TRES10.

2.3 Fishes and Motile Megabenthic Invertebrates

A total of 31 fish species were identified from TRES10 during the 2025 survey with a mean density of 89.6 Ind/30 m^2 (range: 55 - 108 Ind/30 m^2) and a mean species richness of 16.6 Spp/30m^2 (range: 14 – 19 Spp/30m^2). The bluehead wrasse (*Thalassoma bifasciatum*) and the bicolor damselfish (*Stegastes partitus*) were (as in previous surveys) the numerically dominant species within belt-transects with mean densities of 33.0 and 22.8 Ind/30 m^2, respectively (Table 6). The combined density of these two-species (55.8 Ind/30 m^2) represented 62.3% of the total fish density within belt-transects. In addition to the two-aforementioned species, another six species were observed within at least four belt-transects. These included the coney (*Cephalopholis fulva*), red-band parrotfish (*Sparisoma aurofrenatum*), yellowhead wrasse (*Halichoeres garnoti)*, harlequin bass (*Serranus tigrinus*), and the beaugregory and dusky damselfishes (*Stegastes leucostictus, S. adustus*). Motile megabenthic invertebrates were not observed.

Table 6. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at TRES10, Rincon. PRCRMP 2025

TRES10							
Survey Date: 6/2/25	**Belt-Transects (3x10m)**			**Trophic**			**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	39	12	43	46	25	**33**	SOC
Stegastes partitus	12	23	27	36	16	**22.8**	ZPL
Caranx ruber	12		30			**8.4**	LC
Halichoeres garnoti	3	2	4	1	3	**2.6**	SOC
Sparisoma aurofrenatum	2	3	4	2	1	**2.4**	HER
Cephalopholis fulva	3	4	2	1	1	**2.2**	LC
Stegastes leucostictus	2	1	3	2	1	**1.8**	HER
Scarus iseri		2	3		4	**1.8**	HER
Serranus tigrinus	1	1	1	2	2	**1.4**	SOC
Chromis cyanea				1	6	**1.4**	ZPL
Scarus spp.				7		**1.4**	HER
Acanthurus tractus	2			2	2	**1.2**	HER
Scarus taeniopterus	1		5			**1.2**	HER
Stegastes adustus	1	2	1		1	**1**	HER
Chaetodon capistratus			1	2	1	**0.8**	COR
Cephalopholis cruentata	1	1		1		**0.6**	LC
Holocentrus rufus		1	1		1	**0.6**	SOC
Acanthurus coeruleus			1		2	**0.6**	HER
Ocyurus chrysurus			1		2	**0.6**	LC
Stegastes variabilis				1	2	**0.6**	HER
Halichoeres maculipinna	1		1			**0.4**	SOC
Haemulon flavolineatum	1	1				**0.4**	SOC
Epinephelus guttatus		1		1		**0.4**	LC
Acanthurus chirurgus			1	1		**0.4**	HER
Myripristis jacobus				1	1	**0.4**	SOC
Canthigaster rostrata	1					**0.2**	SOC
Scomberomorus regalis		1				**0.2**	LC
Aulostomus maculatus			1			**0.2**	SOC
Amblycirrhitus pinos			1			**0.2**	SOC
Sparisoma viride				1		**0.2**	HER
Pomacanthus arcuatus					1	**0.2**	SPO
Density (Ind/30m2)	82	55	131	108	72	**89.6**	
Richness (Species/30m2)	15	14	19	17	18	**16.6**	

The high energy environment at the TRES10 reef top is an ideal habitat for small opportunistic carnivores which feed on small benthic invertebrates that become exposed upon disturbances of the substrate due to wave action. The small carnivore assemblage included 10 species and a combined density of 39.4 Ind/30m^2, representative of 44.0% of the total fish density within belt-transects (Table 6). The assemblage included wrasses (Labridae), small groupers and seabasses (Serranidae), grunts (Haemulidae), squirrelfishes (Holocentridae), trumpetfishes (Aulostomidae), puffers (Tetraodontidae), and hawkfishes (Cirrhitidae). Zooplanktivores were represented by two species (*Stegastes partitus, Chromis cyanea*) with a combined density of 24.2 Ind/30m^2, or 27.0% of the total fish density. Herbivores were represented by parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with 11 species and a combined mean density of 12.6 Ind/30m^2, or 14.1% of the total individuals within 3m x 10m belt-transects.

The taxonomic composition, density, and size distribution of fishes of commercial value, including the larger reef herbivores are presented in Table 7. Mid-size and large demersal predators were represented by 15 coneys (*Cephalopholis cruentatus*), two red hinds (*Epinephelus guttatus*), three yellowtail snappers (*Ocyurus chrysurus*), one mahogany snapper (*Lutjanus mahogoni*), a school of juvenile bar jacks (*Caranx ruber*), and one juvenile cero mackerel (*Scomberomorus cavalla*) with a combined mean density of 16.2 Ind/60m^2. Coneys were observed in a wide range of sizes including both juvenile and full adult stages. Red hinds were also represented by juvenile and individuals indicative of the relevance of TRES10 as a recruitment and residential habitat for these grouper species and other commercially important predators.

The larger reef fish herbivores included two species of doctorfishes (Acanthuridae) and five species of parrotfishes (Scaridae). The most abundant were the redband parrotfish (*Sparisoma aurofrenatum*), and the ocean surgeon (*Acanthurus tractus*) both with a total of 13 individuals (2.6 Ind/60m^2). Both of these species were observed in both juvenile and adult stages and appear to spend their entire life cycle at TRES10 along with several other species of doctorfishes and parrotfishes previously reported (Garcia-Sais et al., 2023 and references therein).

Fish density and species richness have shown wide fluctuations at TRES10 with a period of higher richness and mean density between 2004 – 2006, and a period of both lower richness and density between 2007 - 2023 (Figure 8). The temporal variations of both fish density and species richness between surveys were statistically significant (ANOVA, $p < 0.0001$, Appendices 5 and 6). TRES10 is seasonally exposed to very high wave energy and the surge conditions that prevail during such events appear to displace small water-column fishes away from the reef. Variations observed during the monitoring program are in the 2-fold range for species richness, and in the 3-fold range for mean density. The 2025 mean fish density (89.6 Ind/30m^2) and species richness (16.6 Spp/30m^2) both fall at the higher end of the range of previous surveys, including significantly higher density relative to the previous 2023 survey (see Appendix 5). A 23.9% increase of species richness relative to the previous 2023 survey was also observed. Given the massive losses of live coral at TRES10 such increments of density and species richness attest to the relevance of the physical structure as habitat for the resident fish community and the desirability and functionality of artificial structures for the maintenance and restoration of shallow fish communities.

Table 7. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at TRES10, Rincon. PRCRMP 2025

TRES10							
Survey Date: 6/29/25		Belt-Transects (3m x 20m)					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	12, 13			1	1		Juvenile
Acanthurus coeruleus c3	2-15, 2 12, 14	1	1		1	2	Adult
Acanthurus tractus c2	10				1		Juvenile
Acanthurus tractus c3	4-15, 3-14, 11, 2-13	2		1	4	3	Juvenile
Acanthurus tractus c4	18, 16	1	1				Adult
Caranx ruber c2	57-10	12		30		15	Recruit
Cephalopholis cruentata c2	8	1					Juvenile
Cephalopholis cruentata c6	28		1				Adult
Cephalopholis fulva c2	2-7, 9	1	1	1			Juvenile
Cephalopholis fulva c3	13, 15		2				Juvenile
Cephalopholis fulva c4	18, 20	2					Adult
Cephalopholis fulva c5	24, 22, 2-25		1	1	1	1	Adult
Cephalopholis fulva c6	2-26, 2-30		1	2		1	Adult
Epinephelus guttatus c5	24		1				Juvenile
Epinephelus guttatus c7	32				1		Adult
Lutjanus mahogoni c4	18	1					Juvenile
Ocyurus chrysurus c5	25			1			Adult
Ocyurus chrysurus c8	2-40					2	Adult
Scarus iseri c2	3-7			3			Juvenile
Scarus iseri c3	12					1	Juvenile
Scarus iseri c4	5-16, 2-17	1	2			4	Adult
Scarus iseri c6	26	1					Adult
Scarus spp. c1	7-3				7		Recruit
Scarus taeniopterus c1	3-5			3			Recruit
Scarus taeniopterus c2	7, 2-8	1		2			Juvenile
Scomberomorus regalis c7	35		1				Juvenile
Sparisoma aurofrenatum c1	3-3, 5		1	3			Recruit
Sparisoma aurofrenatum c2	2-6, 2-7, 10	2	2		1		Juvenile
Sparisoma aurofrenatum c3	12			1			Juvenile
Sparisoma aurofrenatum c5	22, 25, 23				2	1	Adult
Sparisoma viride c1	3				1		Recruit
	Totals	**26**	**15**	**49**	**20**	**30**	

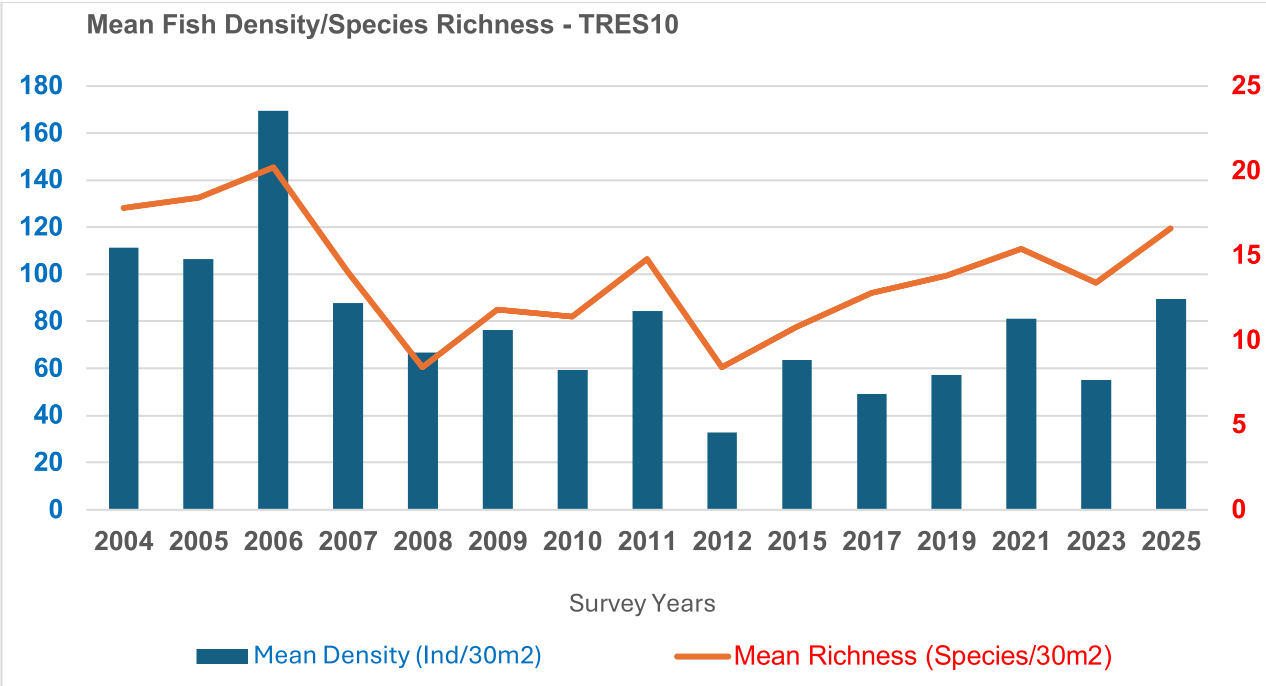
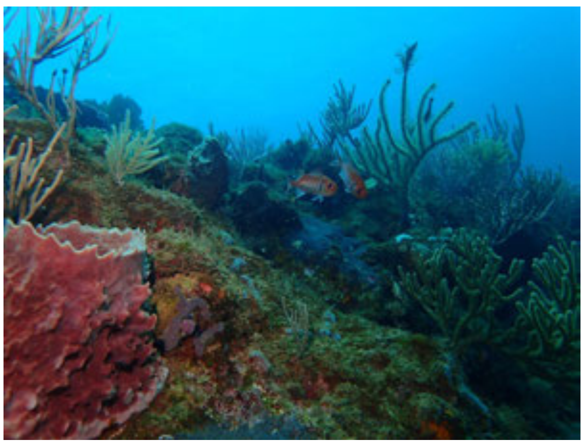


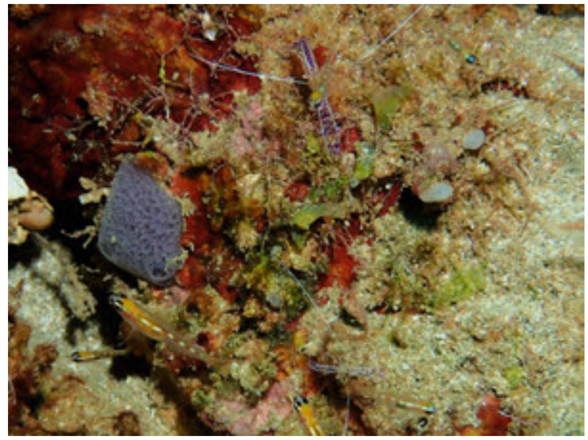
Figure 8. Monitoring trends (2004 – 25) of mean fish density and species richness within 10m x 3m belt-transects at TRES10, Rincon. PRCRMP 2025

Photo Album 2. TRES10







Palmas 20m – TRES20

3.1 Physical Description

A diffuse "spur-and-groove" coral reef formation is found associated with the shelf-edge off Tres Palmas within a depth range of 18 - 23m. Irregular, low relief spurs separated by narrow sand channels are oriented perpendicular to the shelf-edge. The shelf breaks in a series of irregular steps, forming narrow terraces at depths from 23 – 40m. The baseline survey of TRES20 was performed in 2004. Permanent transects were installed at depths between 16.97m and 17.88m in two sections of the reef separated by a sand patch. The location of monitoring stations is shown in Figure 2. Panoramic views of the reef community are shown in Photo Album 3.

3.2 Sessile-benthic Reef Community

Benthic algae were the dominant sessile-benthic component in terms of reef substrate cover at TRES20 during the 2025 monitoring survey with an average of 73.16% (range: 64.41 – 79.96%). The encrusting fan alga (*Lobophora* sp.), and the fleshy brown Y-twig alga (*Dictyota* sp.) were the main components of the benthic algal assemblage with a combined mean cover of 37.71%, representative of 51.5% of the total cover by benthic algae (Table 8).Red fleshy macroalga (*Gracilaria* sp.), and the red crustose alga (*Peyssonnelia* sp.) were also prominent with a combined mean cover of 12.93%, representative of 17.7% of the total cover by benthic algae. Patches of cyanobacteria were observed in all five transects with a mean cover of 4.31%.

A total of seven stony coral species were intercepted by line transects at TRES20 during the 2025 survey with a mean substrate cover of 3.47%, and a mean density of 4.20 Col/Transect (Table 8). Stony corals occurred mostly as small to moderate size mound shaped and encrusting colonies, including a visually large amount of recently dead colonies overgrown by benthic algae and/or cyanobacteria. Mustard-hill coral (*Porites astreoides*) was the dominant species in terms of reef substrate cover with a mean of 0.97%, representative of 28.0% of the total cover by stony corals. Boulder and mountainous star corals (*Orbicella franksi, O. faveolata*) the previously dominant stony coral species at TRES20 until the 2023 survey presented live colonies in only one and two transects, respectively, with a combined substrate cover of 0.90%. Great star coral (*Montastraea cavernosa*), and the branching fie coral (*Millepora alcicornis*) were intercepted by four transects each, with mean cover of 0.67% and 0.33%, respectively. Apparent coral disease infections were observed on three (1-P. astreoides; 1-O. faveolata; 1-S. siderea) of the total of 21 stony coral colonies intercepted by transects at TRES20 during the 2025 survey (Appendix 2).

Table 8. Percent reef substrate cover by sessile-benthic categories at TRES20, PRCRMP. 2025

TRES20			**Transects**			
Survey Date: 6/29/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**17.88**	**16.97**	**17.58**	**17.58**	**17.27**	**17.46**
Rugosity (m)	2.85	2.04	2.14	4.71	2.60	**2.87**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	6.64	11.40	7.27	4.47	2.22	**6.40**
Total Abiotic	**6.64**	**11.40**	**7.27**	**4.47**	**2.22**	**6.40**
Benthic Algae						
Lobophora spp.	36.38	38.60	47.17	26.17	40.22	**37.71**
Dictyota spp.	21.13	11.51	17.07	14.27	29.89	**18.78**
Gracilaria spp.	15.03	19.19	0.58	8.94	3.00	**9.35**
Peyssonnelia spp.	3.59	6.28	1.96	4.85	1.22	**3.58**
Turf (mixed)		1.16		4.76	1.78	**1.54**
Turf (mixed) with sediment		0.70		5.23	0.78	**1.34**
CCA (total)	3.81			0.19		**0.80**
Halimeda spp.					0.33	**0.07**
Total Benthic Algae	**79.96**	**77.44**	**66.78**	**64.41**	**77.22**	**73.16**
Cyanobacteria	5.45	3.49	2.65	6.18	3.78	**4.31**
Stony Corals						
Porites astreoides	1.53	1.16		0.38	1.78	**0.97**
Montastraea cavernosa	0.33		2.08	0.95		**0.67**
Orbicella faveolata			0.58	0.67	1.78	**0.60**
Millepora alcicornis	0.33		0.81	0.38	0.11	**0.33**
Siderastrea siderea		0.81		0.76		**0.32**
Orbicella franksi			1.50			**0.30**
Madracis decactis		0.47	0.23	0.10		**0.16**
Stephanocoenia intersepta	0.65					**0.13**
Total Stony Corals	**2.83**	**2.44**	**5.19**	**3.24**	**3.67**	**3.47**
# Coral Colonies /Transect	**3**	**3**	**5**	**6**	**4**	**4.20**
# Diseased Coral Colonies/Transect	**0**	**1**	**1**	**1**	**0**	**0.60**
# Erect Soft Coral Colonies/Transect	**17**	**9**	**14**	**21**	**16**	**15.40**
Soft Corals						
Briareum asbestinum	0.44		0.35			**0.16**
Erythropodium caribaeorum			0.35			**0.07**
Total Soft Corals	**0.44**	**0.00**	**0.69**	**0.00**	**0.00**	**0.23**
Anemones						
Lebrunia neglecta	**0.00**	**0.70**	**0.00**	**0**	**0.00**	**0.14**
Ascideans						
Ascidian spp.	0.22					**0.04**
Sponges						
Xestospongia muta	3.05		6.46	5.23		**2.95**
Agelas sceptrum		1.28	3.23	3.62	4.33	**2.49**
Agelas conifera			6.23	5.80	0.22	**2.45**
Amphimedon compressa	0.22	1.63	0.35	1.05	2.56	**1.16**
Svenzea zeai				0.67	2.89	**0.71**
Iotrochota birotulata		0.23		2.28	0.22	**0.55**
Aplysina cauliformis			0.23	0.38	1.22	**0.37**
Agelas citrina			0.35	1.05		**0.28**
Niphates erecta	0.33	0.23			0.44	**0.20**
Aiolochroia crassa				0.95		**0.19**
Ectyoplasia ferox					0.89	**0.18**
Agelas dispar				0.67		**0.13**
Spheciospongia vesparium	0.65					**0.13**
Scopalina ruetzleri			0.58			**0.12**
Aplysina insularis	0.22				0.33	**0.11**
Ircinia strobilina		0.47				**0.09**
Callyspongia plicifera		0.35				**0.07**
Sponge spp.		0.35				**0.07**
Total Sponges	**4.47**	**4.53**	**17.42**	**21.69**	**13.11**	**12.24**
Diseased Corals						
Porites astreoides		1				**0.20**
Orbicella faveolata			1			**0.20**
Siderastrea siderea				1		**0.20**

Erect soft corals were moderately abundant, with an average of 15.4 Col/transect. The main assemblage included sea plumes (*Allotogorgia acerosa, P. americana*), knobby sea rods, (*Eunicea spp*.), and the common sea fan (*Gorgonia ventalina*). The deep-water sea fan (*Iciligorgia schrammi*) was common at the shelf-edge, particularly at the edge of rock walls and crevices. Due to their relatively large size and density erect soft corals contributed markedly to the benthic habitat complexity at TRES20. Small patches of encrusting soft corals (*Erythropodium caribaeorum, Briareum asbestinum)* were intercepted by two transects with a combined mean cover of 0.23%. Sponges were represented by at least 18 species intercepted by transects with a combined cover of 12.24%. Tube sponges (*Agelas spp*) were the dominant assemblage with a combined substrate cover of 5.35%, representative of 43.7% of the total cover by sponges. The giant barrel sponge (*Xestospongia muta*) was intercepted by three transects with a mean cover of 2.95% and contributed substantially to the reef topographic relief and benthic habitat complexity.

Abiotic cover largely contributed by reef overhangs and sand averaged 6.40% Reef substrate rugosity averaged 2.87m influenced mostly by sedimentary features of the shelf with minor contributions of stony corals, soft corals, and sponges. Large coral buildups contributing reef topographic relief were not observed.

Variations of reef substrate cover by sessile-benthic categories between monitoring surveys at TRES20 are presented in Figure 9. Large scale, statistically significant declines of reef substrate cover by live stony corals were measured during the previous 2023 and most recent 2025 monitoring surveys at TRES20 relative to the 2021 survey (ANOVA; p = 0.0001, see Appendix 3). Live stony coral cover declined 84.0%, from 23.53% in 2021 to 3.47% in 2025, driven by a 65.0% reduction of intercepted colonies, from 60 in 2021 to 21 in 2025 (Figure 10). The difference of substrate cover by stony corals was associated with an overall decline of cover by all coral species previously intercepted by transects, including the disappearance of 10 out of the 16 species intercepted in the 2021 monitoring survey (Garcia-Sais et al., 2022). These included prominent species such as *Meandrina meandrites*, *Pseudodiploria strigosa*, *Colpophyllia natans*, and *Diploria labyrinthiformis*, among others. Reef substrate cover by the *Orbicella* spp. complex, comprised by *O. franksi* and *O. faveolata*, declined 91.2% from 10.21% in 2021 to 0.90% in 2025 resulting in a taxonomic phase shift of dominance of reef substrate cover by stony coral species, as now *Porites astreoides* is the dominant stony coral in terms of reef substrate cover at TRES20 (Figure 10).

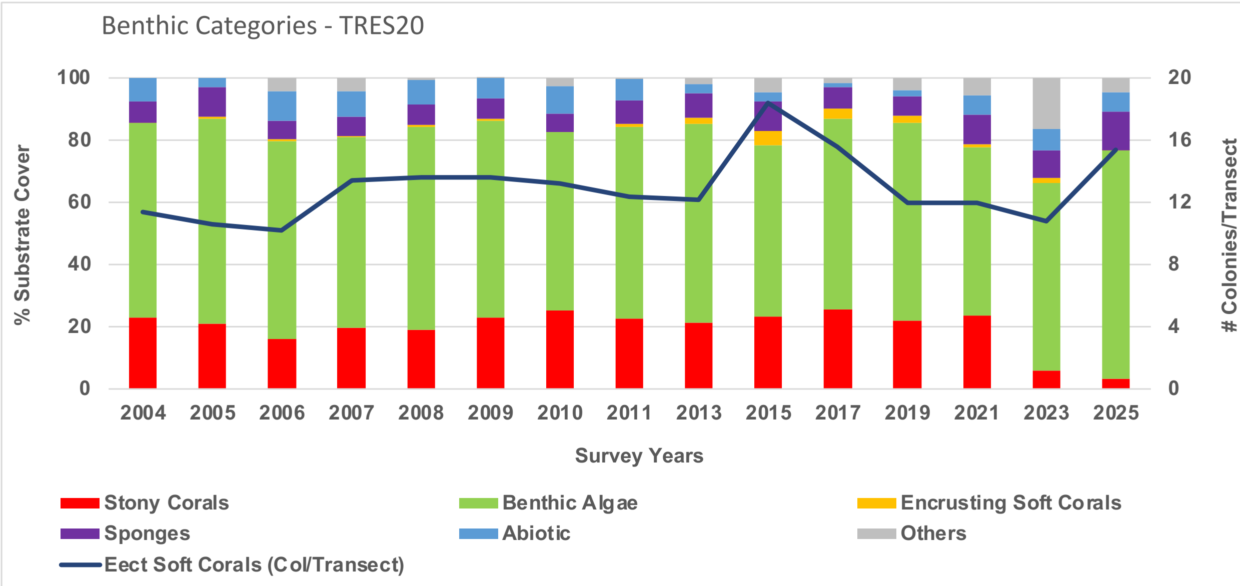


Figure 9. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at TRES20, Rincon. PRCRMP 2025

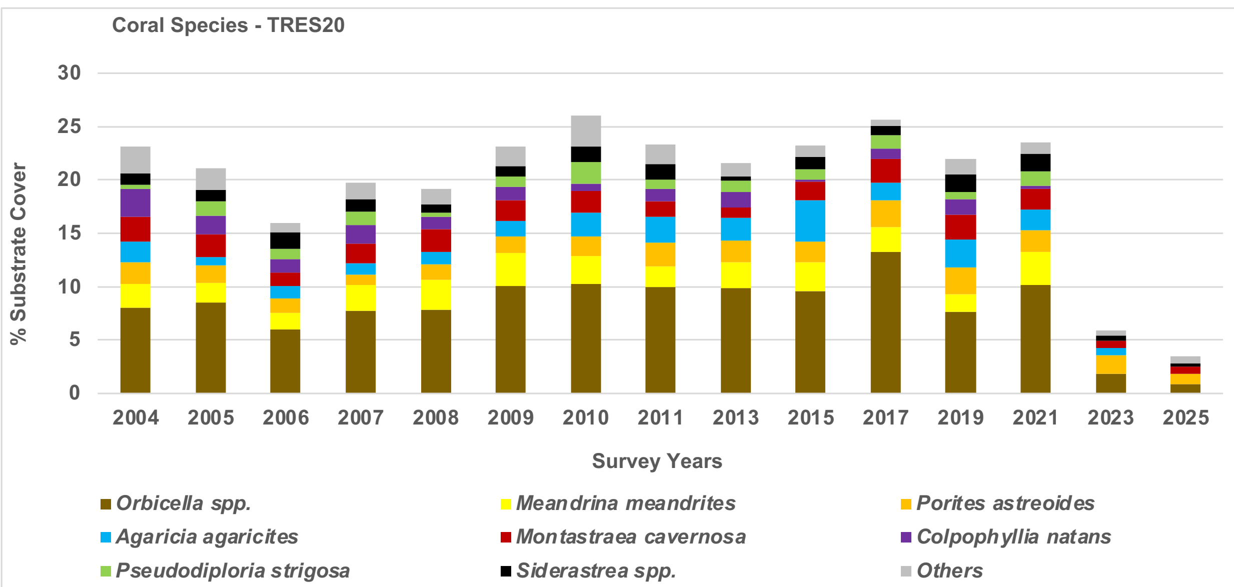


Figure 10. Monitoring trends (2004 – 2025) of mean substrate cover by stony coral species at TRES20, Rincon. PRCRMP 2025

Coral disease infections, following prolonged periods of high water temperatures are suggested as the main causal factor for the decline of reef substrate cover by stony corals and the overall loss of live stony coral colonies and species from transects at TRES20. At least one infection by what appeared to be SCTLD on *O. faveolata* was noted in one transect during the 2023 survey, but other stony coral infections were noted outside transects.

3.3 Fishes and Motile Megabenthic Invertebrates

A total of 46 fish species were identified within belt-transects from TRES20 during the 2025 survey with a mean density of 153.0 Ind/30m^2 (range: 86 – 248 Ind/30m^2) and a mean species richness of 20.6 Spp/30m^2 (Table 9). The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 60.8 Ind/30m^2, representative of 39.7% of the total fish density. An assemblage of five additional species were observed in all five transects with a combined mean density of 54.0 Ind/30m^2, or 35.3% of the total. These included the bluehead and yellowhead wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*), bicolor damselfish (*Stegastes partitus*), blue chromis (*Chromis cyanea*), and the squirrelfish (*Holocentrus rufus*). Creole wrasse (*Clepticus parrae)* were also prominent as large streaming schools were observed over four belt-transects resulting in a mean density of 7.6 Ind/30m^2. Motile megabenthic invertebrates were not observed within belt-transects during the 2025 survey at TRES20.

Zooplanktivores, represented by four of the top five numerically dominant fish species within 3m x 10m belt-transects (e. g. *Coryphopterus personatus, Stegastes partitus, Chromis cyanea, Clepticus parrae*) were the main trophic assemblage at TRES20 with a combined mean density of 100.2 Ind/30m^2, or 65.5% of the total fish density. Opportunistic carnivores were also highly prominent with 21 species and a combined density of 36.0 Ind/30m^2, representative of 23.5% of the total. The assemblage included wrasses (Labridae), goatfishes (Mullidae), squirrelfishes (Holocentridae), triggerfishes (Balistidae), grunts (Haemulidae), basslets (Grammatidae), puffers (Tetraodontidae), seabasses and hamlets (Serranidae), hawkfishes (Cirrhitidae), trumpetfishes (Aulostomidae), and porcupinefishes (Diodontidae). Parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) comprised the main herbivorous assemblage with nine species and a combined mean density of 11.6 Ind/30m^2, representative of 7.6% of the total fish density. Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by one species each and a combined density of 1.2 Ind/30m^2 (Table 9).

Mid-sized and large demersal carnivores included the coney (*Cephalopholis fulva*), graysby (*C. cruentata*), lionfish (*Pterois* spp.), yellowtail and mahogany snappers (*Ocyurus chrysurus, Lutjanus mahogoni*), and the blue runner and bar jacks (*Caranx crysos, C, ruber*) with a combined density of 6.4 Ind/60m^2 (Table 10). Schoolmaster snappers (*L. apodus*), red hind (*Epinephelus guttatus*), great barracuda (*Sphyraena barracuda*), and cero mackerels (*Scomberomorus regalis*) represent large demersal and pelagic predators that have been previously reported from TRES20 (Garcia-Sais et al., 2023 and references therein).,

Table 9. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at TRES20, Rincon. PRCRMP 2025

TRES20							
Survey Date: 6/2/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	120	12	17	60	95	**60.8**	ZPL
Stegastes partitus	27	19	13	14	18	**18.2**	ZPL
Thalassoma bifasciatum	38	4	3	25	6	**15.2**	SOC
Chromis cyanea	16	1	8	2	37	**12.8**	ZPL
Clepticus parrae	13		6	3	16	**7.6**	ZPL
Halichoeres garnoti	2	3	4	11	5	**5.0**	SOC
Mulloidichthys martinicus		20				**4.0**	SOC
Stegastes leucostictus	2	4	3	4	1	**2.8**	HER
Scarus spp.	12					**2.4**	HER
Sparisoma aurofrenatum	3		3	2	2	**2.0**	HER
Holocentrus rufus	1	2	3	1	2	**1.8**	SOC
Caranx ruber		2		5		**1.4**	LC
Coryphopterus lipernes			4	2		**1.2**	SOC
Melichthys niger	1			2	3	**1.2**	SOC
Haemulon flavolineatum		3	2	1		**1.2**	SOC
Gramma loreto		6				**1.2**	SOC
Cephalopholis cruentata	1	1	2	1		**1.0**	LC
Acanthurus coeruleus	1	1	1		2	**1.0**	HER
Acanthurus tractus	1		1	2	1	**1.0**	HER
Scarus taeniopterus		1	4			**1.0**	HER
Haemulon chrysargyreum		5				**1.0**	SOC
Myripristis jacobus			3		1	**0.8**	SOC
Ocyurus chrysurus	3	1				**0.8**	LC
Chaetodon capistratus	2	2				**0.8**	COR
Haemulon aurolineatum		4				**0.8**	SOC
Sparisoma viride			2		1	**0.6**	HER
Scarus iseri			2		1	**0.6**	HER
Chromis multilineata				3		**0.6**	ZPL
Canthigaster rostrata		1	1	1		**0.6**	SOC
Caranx crysos				2		**0.4**	LC
Neoniphon marianus	1		1			**0.4**	SOC
Hypoplectrus unicolor		1				**0.2**	SOC
Amblycirrhitus pinos			1			**0.2**	SOC
Hypoplectrus nigricans			1			**0.2**	SOC
Lutjanus mahogoni			1			**0.2**	LC
Chromis insolata				1		**0.2**	ZPL
Cephalopholis fulva				1		**0.2**	LC
Pterois volitans				1		**0.2**	LC
Hypoplectrus chlorurus					1	**0.2**	SOC
Aulostomus maculatus	1					**0.2**	SOC
Microspathodon chrysurus	1					**0.2**	HER
Pseudupeneus maculatus	1					**0.2**	SOC
Diodon holocanthus	1					**0.2**	SOC
Holacanthus tricolor		1				**0.2**	SPO
Anisotremus virginicus		1				**0.2**	SOC
Density (Ind/30m2)	248	95	86	144	192	**153.0**	
Richness (Species/30m2)	21	22	23	21	16	**20.6**	

The larger reef fish herbivore assemblage was represented by parrotfishes (Scaridae) and doctorfishes (Acanthuridae) within extended belt-transects with combined densities of 3.2 Ind/60m^2 and 5.2 Ind/60m^2, respectively. Both parrotfishes and doctorfishes were observed in a wide range of sizes and life stages indicative that they spend most of their life cycle as residents of TRES20. Predominantly adult stages of demersal and pelagic predators were observed during this and previous surveys (Garcia-Sais et al. 2019 and references therein) are indicative that TRES20 is also a foraging and residential habitat for reef fish predators.

Table 10. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at TRES20, Rincon. PRCRMP 2025

TRES20							
Survey Date: 6/29/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c2	7, 2-10		1	1		1	Juvenile
Acanthurus coeruleus c3	14, 15, 13	1	1			1	Adult
Acanthurus tractus c3	2-15, 4-12, 14, 2-13	3	1	2	1	2	Juvenile
Acanthurus tractus c4	16				1		Adult
Caranx crysos c5	3-25				3		Adult
Caranx crysos c8	36	1					Adult
Caranx ruber c5	2-25, 6-30		2	1	5		Adult
Cephalopholis cruentata c2	8, 10			2			Juvenile
Cephalopholis cruentata c3	2-15,	2					Juvenile
Cephalopholis cruentata c4	20, 16, 18		1		1	1	Adult
Cephalopholis fulva c4	20				1		Adult
Lutjanus mahogoni c3	13, 15			2			Juvenile
Lutjanus mahogoni c4	18, 20				2		Juvenile
Lutjanus mahogoni c5	25			1			Adult
Ocyurus chrysurus c4	16, 2-18, 20		1	2	1		Adult
Pterois spp. c5	23, 25				2		Adult
Pterois spp. c7	35				1		Adult
Scarus iseri c2	7, 10			1		1	Juvenile
Scarus iseri c4	2-18	1		1			Adult
Scarus spp. c1	12-3	12					Recruit
Scarus taeniopterus c2	8, 3-10, 9		8	3	1		Juvenile
Scarus taeniopterus c4	17			1			Adult
Scarus taeniopterus c6	26			1			Terminal
c1	2-5	1		1			Recruit
c2	2-8, 2-6, 9	1		1	2	1	Juvenile
c3	2-15	1	1				Juvenile
c4	2-20, 16		1	1		1	Adult
c5	25	1					Adult
Sparisoma viride c2	8			1			Juvenile
Sparisoma viride c3	3-12			1	1	1	Juvenile
Sparisoma viride c7	2-35				1	1	Terminal
	Totals	**24**	**17**	**23**	**23**	**10**	

Annual variations of mean fish density and species richness between monitoring surveys at TRES20 are presented in Figure 11. Statistically significant differences of both fish density and species richness were found between monitoring surveys (ANOVA; $p < 0.001$, Appendices 5 and 6). Differences were related to higher densities during 2004 - 2006, 2009, and 2021, relative to 2012, 2017, and 2019. Differences were largely associated to density fluctuations of masked goby (*Coryphopterus personatus*), a numerically dominant species that forms swarms of dozens to hundreds of individuals below coral ledges, over live corals, and near the reef sand-coral interface. The dynamics of inter-annual density variations for this species has not been studied, but this is a small water column species that appears to be vulnerable to strong surge and abrasion conditions that may be prompted by wave action.

A general decline of *Coryphopterus personatus* density was reported for most reef stations under the PRCRMP after the pass of Hurricane Maria in 2017 (Garcia-Sais el al., and references therein) probably associated with physical displacement or mortality induced by the extreme surge and abrasion effects caused by the hurricane. A bold recuperation of masked goby was observed during the 2021 survey, driving an 148.1% increase of total fish density relative to the previous 2019 survey, but densities of *C. personatus* declined again by 66.5% relative to the previous 2021 survey, contributing, along with other numerically dominant species (*Chromis cyanea, Thalassoma bifasciatum, Halichoeres garnoti*) to an overall decline of the fish density. These species are not commercially exploited and thus, do not suffer from fishing mortality. During the 2025 survey density of C. personatus increased by 109.6% relative to the previous 2023 survey, driving the overall increase of fish density in 2025.

Differences of fish species richness between monitoring surveys were statistically significant (ANOVA, $p = 0.005$; Appendix 6) but only related to the lower richness in 2012 relative to the period of peak richness between 2004 and 2007 (Figure 11). Surveys in 2017 and 2019 evidenced even lower mean species richness than in 2012, but the variability within replicate transects was higher than in 2012. Physical conditions at the time of survey play an important role as a driver of fish density and species richness fluctuations. The effect of Hurricane Maria and/or winter storm Riley may have had a more severe impact over small water column fishes than the typical range of physical stress experienced by such small fishes on a regular basis at TRES20, which may explain the low species richness measured in 2019. The 33.5% density and 6.8% species richness increments measured in 2025 appear to support the relevance of the physical habitat despite the massive losses of live coral habitat at TRES20.

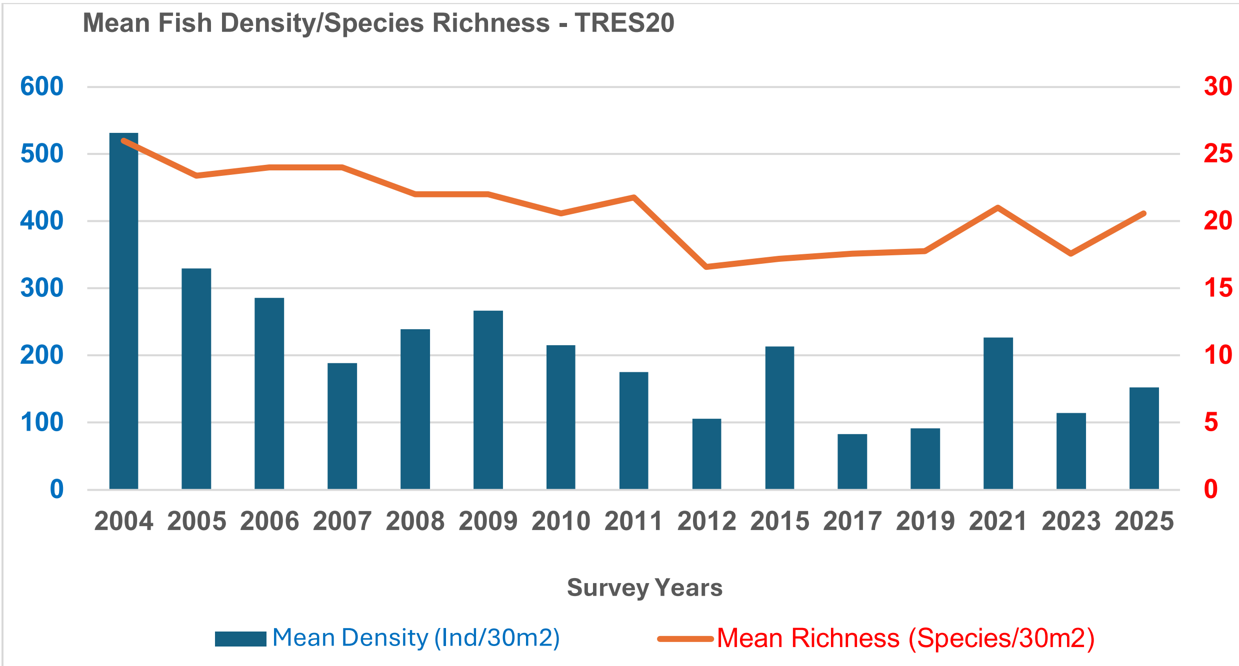
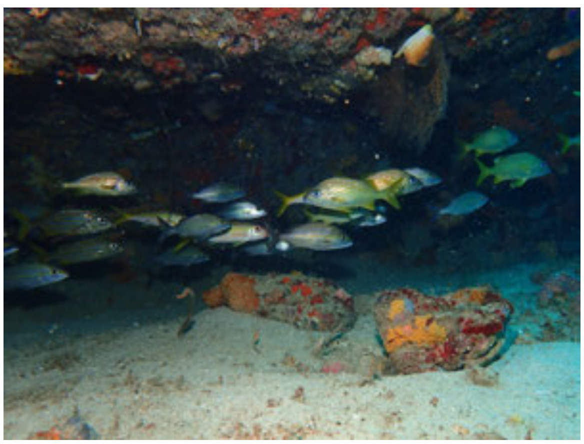
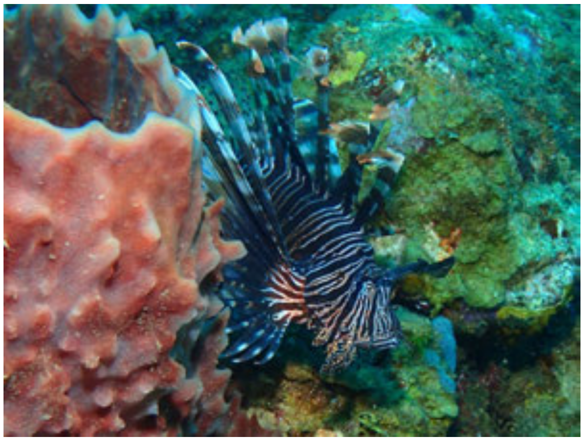
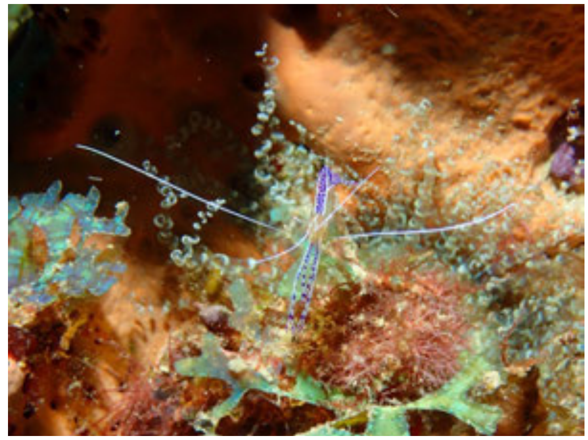


Figure 11. Monitoring trends (2004 – 25) of mean fish density and species richness within 10m x 3m belt-transects at TRES20, Rincon. PRCRMP 2025

Photo Album 3. TRES20







4.0 Tourmaline Reef 10m (TOUR10)

4.1 Physical Description

Tourmaline Reef located due west of Bahía Bramadero; Cabo Rojo was designated as a Natural Reserve in 1996 in recognition of its ecological value as the most important coral reef system of the west coast of Puerto Rico. The reef sits at the northern section of the Cabo Rojo platform, approximately five miles away from the coastline (Figure 12). At depths of approximately 10m, TOUR10 features low to moderate relief and a well-defined "spur-and-groove" formation that runs perpendicular to the shelf-edge and ends in a sandy basin at a depth of 14.0m. Spurs are about 1 - 3 m tall, separated by coralline sand and coral rubble deposited at the grooves. Stony corals grow on top of the spurs and along the walls in massive, branching, and encrusting colonies. Soft corals are common and a visually prominent feature of the reef benthos. A set of five permanent transects were established on top of the spurs during the baseline characterization in 1999 by García-Sais et al. (2001). Panoramic views of the reef community at TOUR10 during the 2025 survey are presented in Photo Album 4.

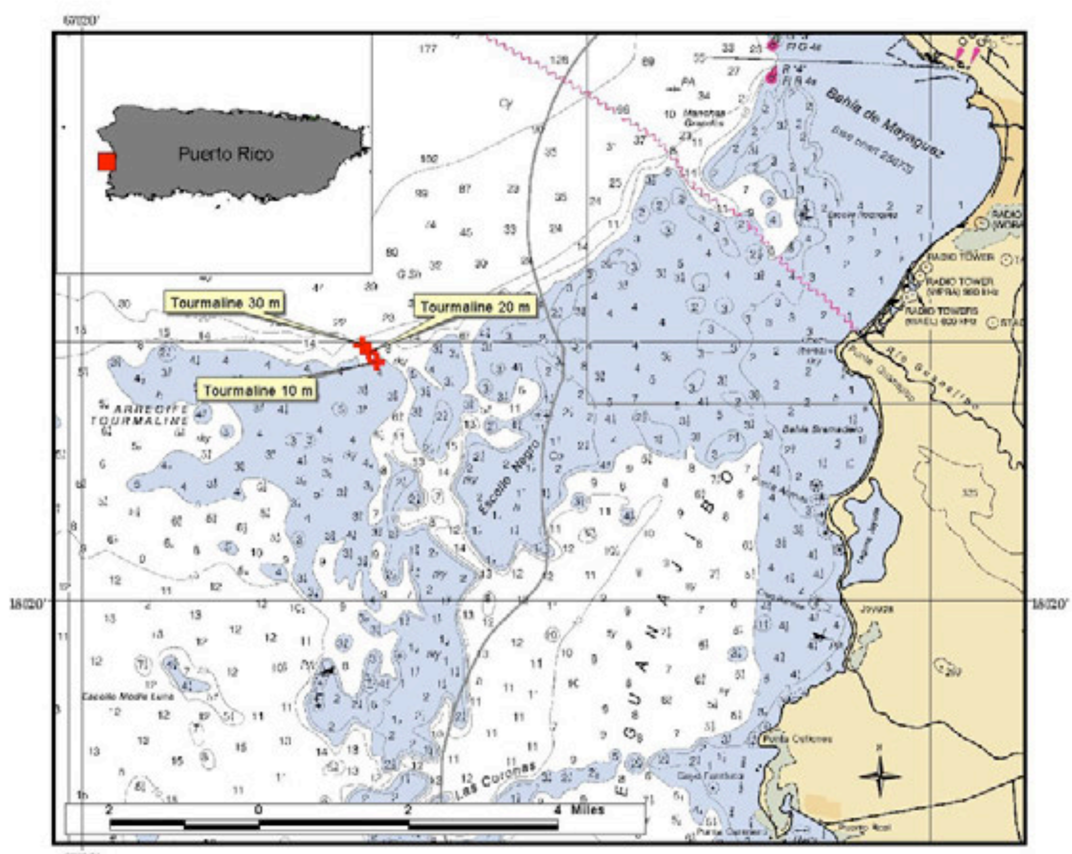


Figure 12. Location of coral reef survey stations at Tourmaline Reef, Mayagüez. PRCRMP 2025

4.2 Sessile-benthic Reef Community

Benthic algae, comprised by an assemblage of turf (mixed), fleshy brown (*Dictyota* sp*., Lobophora* sp.), red crustose (*Ramicrusta* sp., *Peyssonnelia* sp.), and green calcareous macroalgae (*Halimeda* sp.) were the dominant sessile-benthic category in terms of reef substrate cover at TOUR10 with a combined mean cover of 71.40% (range: 46.17 – 83.86%). Turf algae, a mixed assemblage of short filamentous red and brown macroalgae was the main component with a mean substrate cover of 24.72%, representative of 34.6% of the total cover by benthic algae (Table 11). Turf algae was found overgrowing rocky substrates, as well as dead coral sections and other hard ground. The brown fleshy y-twig alga (*Dictyota* sp.) and the encrusting fan-leaf alga (*Lobophora* sp.) were both intercepted by all five transects with a combined mean cover of 36.86%, or 51.6% of the total cover by benthic algae. *Ramicrusta sp*. was observed growing encrusted over dead coral sections in all five transects with mean cover of 8.41%, or 11.78% of the total cover by benthic algae. Cyanobacterial mats averaged 2.28%.

A total of seven stony coral species were intercepted by transects with a combined mean substrate cover of 11.48% (range: 1.46 – 38.85%) and an average of 6.6 Col/Transect (Table 11). Stony corals occurred as massive (*Orbicella spp.*, *Montastraea cavernosa*), branching (*Madracis spp.),* and mound shaped colonies (*P. astreoides, M. cavernosa*). Yellow pencil coral (*Madracis auretenra*), growing as a very large branching colony in one transect was the numerically dominant species in terms of mean coral cover (mean: 6.85%), representing 59.67% of the total live coral cover. Mustard-hill coral (*Porites astreoides)* was the only species intercepted by all five transects with a mean substrate cover of 1.95%, or 16.99% of the total cover by stony corals. Mountainous, boulder, and lobed star corals (*Orbicella faveolata*, *O. annularis, O. franksi*) were also intercepted by transects at TOUR10 resulting in a mean combined cover of 2.24% for the *Orbicella spp*. complex (Table 11). A total of 33 stony coral colonies were intercepted by transects, none of which were observed with apparent disease infections. Three colonies were observed partially bleached or pale, including 1- *O. annularis*, 1- O. franksi, and 1- *P. astreoides*.

Erect soft corals were moderately abundant with an average of 15.6 Col/Transect and along with stony corals were the most visually prominent invertebrate assemblage of the reef benthos. Encrusting soft corals were represented by the corky sea-finger (*Briareum asbestinum*) and the encrusting gorgonian (*Erythropodium caribaeorum*) with a combined reef substrate cover of 1.51%. Sponges were represented by seven species and a combined mean cover of 2.37%. Small encrusting colonies prevailed with minor contributions to the reef topographic relief and habitat complexity. Abiotic cover associated with reef overhangs averaged 10.84%. Reef rugosity averaged 3.05m largely influenced by live and standing dead coral colonies.

Table 11. Percent reef substrate cover by sessile-benthic categories at TOUR10, Mayagüez. PRCRMP 2025

TOUR10						
Survey Date: 6/07/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**10.91**	**10.91**	**10.91**	**10.91**	**11.21**	**10.97**
Rugosity (m)	2.49	2.43	2.33	3.93	4.04	**3.05**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	8.97	9.23	7.72	18.99	9.27	**10.84**
Total Abiotic	**8.97**	**9.23**	**7.72**	**18.99**	**9.27**	**10.84**
Benthic Algae						
Turf (mixed)	16.93	17.79	60.16	16.18	12.56	**24.72**
Dictyota spp.	14.57	2.03	1.70	37.49	45.26	**20.21**
Lobophora spp.	44.06	17.23	6.47	3.42	12.06	**16.65**
Ramicrusta spp.	7.85	6.19	9.99	11.76	6.28	**8.41**
CCA (total)		2.59				**0.52**
Halimeda spp.			0.57	1.51		**0.42**
Peyssonnelia spp.	0.45	0.34	0.23		0.20	**0.24**
Macroalgae spp.			1.14			**0.23**
Total Benthic Algae	**83.86**	**46.17**	**80.25**	**70.35**	**76.37**	**71.40**
Cyanobacteria	**3.36**	**0.00**	**4.54**	**1.31**	**2.19**	**2.28**
Stony Corals						
Madracis auretenra		34.23				**6.85**
Porites astreoides	1.12	1.01	0.79	3.12	3.69	**1.95**
Orbicella faveolata		1.13	3.75	1.21		**1.22**
Orbicella annularis		2.48			0.40	**0.58**
Orbicella franksi				0.00	2.19	**0.44**
Montastraea cavernosa				1.41	0.30	**0.34**
Madracis decactis	0.34		0.23			**0.11**
Total Stony Corals	**1.46**	**38.85**	**4.77**	**5.73**	**6.58**	**11.48**
# Coral Colonies/Transect	**3**	**8**	**4**	**9**	**9**	**6.60**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**1**	**2**	**0.60**
# Erect Soft Coral Colonies/Transect	**16**	**9**	**11**	**19**	**23**	**15.60**
Soft Corals						
Briareum asbestinum	1.79	0.79	0.34	2.31	2.09	**1.47**
Erythropodium caribaeorum	0.22					**0.04**
Total Soft Corals	**2.02**	**0.79**	**0.34**	**2.31**	**2.09**	**1.51**
Zoanthids						
Palythoa caribaeorum	0.11			0.50		**0.12**
Sponges						
Neopetrosia spp. smooth		0.23	0.57	0.30	2.69	**0.76**
Aplysina fistularis		3.04				**0.61**
Amphimedon compressa			1.36	0.30		**0.33**
Agelas conifera		1.46				**0.29**
Mycale laevis		0.23	0.45		0.20	**0.18**
Niphates erecta	0.22				0.60	**0.16**
Scopalina ruetzleri				0.20		**0.04**
Total Sponges	**0.22**	**4.95**	**2.38**	**0.80**	**3.49**	**2.37**
Bleached Corals						
Porites astreoides				1		
Orbicella annularis					1	
Orbicella franski					1	

Figure 13 shows the monitoring trends of reef substrate cover by sessile-benthic categories from TOUR10, including the baseline survey of 1999 and 15 annual monitoring surveys (2004 - 25). Overall, differences of reef substrate cover by live corals were not statistically significant (ANOVA; p = 0.138, Appendix 3). During the 2006 monitoring survey, mean live coral cover declined 22.43%, from 44.14% in 2005 to 34.24%. This decline was measured after the regional coral bleaching event that affected most of the northern Caribbean Sea (Garcia-Sais et al, 2008). At the community level, the variation of total coral cover was not statistically significant, perhaps due to the high variability associated with the magnitude (not direction) of the variations within transects. At the population level, a statistically significant decline of live coral cover was found for *Orbicella annularis* (complex) (ANOVA; p= 0.028), the dominant coral species in terms of reef substrate cover at TOUR10 (García-Sais et al., 2006). Reef substrate cover by *O. annularis* declined 46.0% between 2005 and 2006 and was the main driver of the overall decline of live coral from TOUR10 (Figure 14). After 2009, the *O. annularis* species complex presented a consistent pattern of increasing reef substrate cover until the 2011 survey and remained virtually stable until 2019. During the 2021 survey the mean cover by stony corals declined 14.7%. Such decline, although statistically insignificant due to the overall high sampling variability was presumably related to the 2019 coral bleaching event. Lingering effects of the 2019 bleaching event were still evident at TOUR10 during the 2021 survey as a coral bleaching prevalence of 8.8% was reported (Garcia-Sais et al., 2021).

During the most recent 2025 monitoring survey, reef substrate cover by stony corals at TOUR10 declined 59.90%, from 28.63% in 2023 to 1.48% in 2025. Such difference was statistically insignificant due to the high sampling variability within replicate transects (ANOVA; p= 0.167; Appendix 3) but contributed to an overall stony coral cover decline of 76.43% from the baseline cover of 48.71% in 1999. The reduction of cover by stony corals in 2025 was associated with sharp reductions of cover by several of the most prominent coral species including *Porites astreoides* (-63.82%), and *Madracis auretenra* (-27.58%), and the demise of live colonies of finger coral (*P. porites*), lettuce coral (*Agaricia* spp.), pillar coral (*Dendrogyra cilindrus*), and boulder brain coral (*Colpophyllia natans*) from transects (Figure 14). Given the observed SCTLD infections of *Orbicella* spp. colonies during the 2023 survey it is here suggested that coral disease infections, perhaps exacerbated by the 2024 global ocean warming event may have been the main causal factor for stony coral mortality and loss of reef substrate cover.

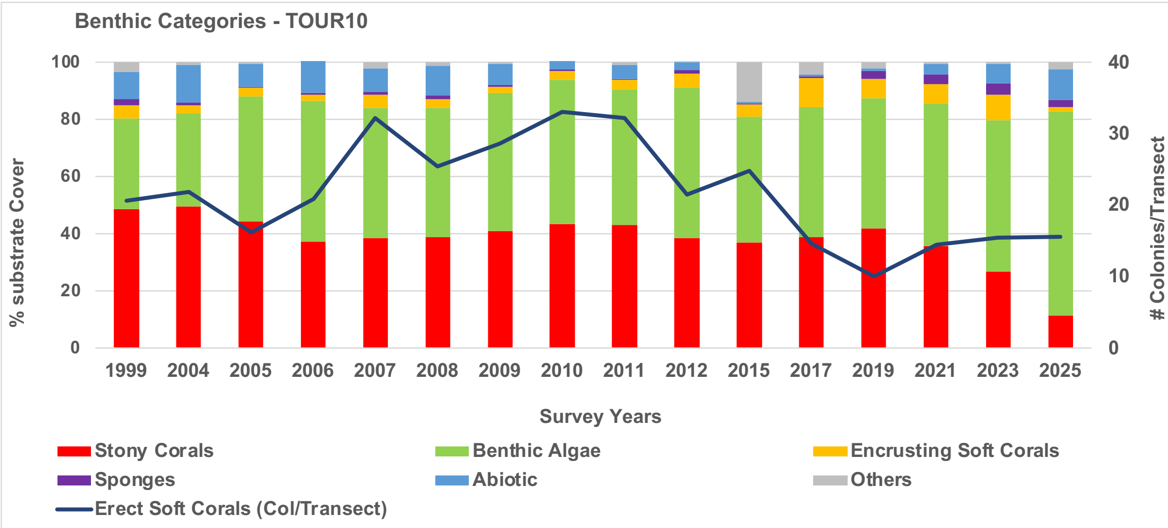


Figure 13. Monitoring trends (1999 – 2025) of mean substrate cover by sessile-benthic categories at TOUR10, Mayagüez. PRCRMP 2025

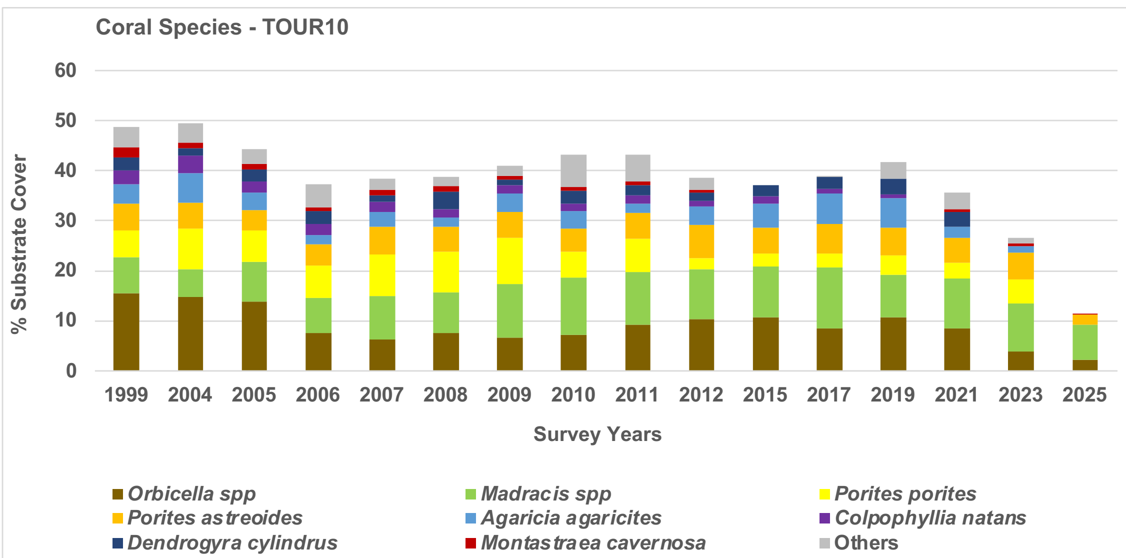


Figure 14 Monitoring trends (1999 – 2025) of mean substrate cover by stony coral species at TOUR10, Mayagüez. PRCRMP 2025

Statistically significant differences of erect soft coral densities were found at TOUR10 (ANOVA, $p < 0.0001$; Appendix 4). Erect soft corals increased during 2007 and remained relatively high and stable until 2015. The increasing density trend may have been prompted by increased substrate availability provided by stony corals after their marked decline of substrate cover after the 2005 regional coral bleaching event. Erect soft corals declined again in 2017 after the pass of Hurricanes Mathew and Maria in 2016 and 2017, respectively. During 2025, a small density increment was measured, but such difference was statistically insignificant (Appendix 4).

3.3 Fishes and Motile Megabenthic Invertebrates

A total of 29 fish species were identified within belt-transects from TOUR10 in the 2025 survey with a mean density of 111.2 Ind/30 m^2 (range: 50 – 191 Ind/30m^2) and a mean species richness of 17.4 Spp/30m^2 (Table 12). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 24.4 Ind/30m^2, representing 21.9% of the total within belt-transects. In addition to *T. bifasciatum*, seven species were present in all five transects with a combined density of 35.0 Ind/30m^2, or 31.5% of the total fish density. These included the bicolor damselfish (*Stegastes partitus*), yellowhead wrasse (*Halichoeres garnoti*), princess, stoplight, redband, and recruitment juvenile parrotfishes (*Scarus taeniopterus, Sparisoma viride, S. aurofrenatum, Scarus* spp.). Schooling aggregations of juvenile blue chromis (*Chromis cyanea*) and creole wrasse (*Clepticus parrae*) were also prominent within belt-transects. Motile megabenthic invertebrates were not observed within belt-transects at TOUR10 during the 2023 survey.

The trophic structure of the fish community at TOUR10 was dominated by demersal and pelagic zooplanktivores (ZPL), including three of the four numerically dominant species such blue chromis (*C. cyanea*), creole wrasse (*Clepticus parrae*), and bicolor damselfish (*S. partitus*) with a combined density of 44.4 Ind/30m^2, representative of 39.9% of the total individuals (Table 12). Small, opportunistic carnivores (SOC) included six species with a combined density of 32.2 Ind/30m^2, representative of 29.0% of the total fish density within belt-transects. The assemblage was comprised by wrasses (Labridae), grunts (Haemulidae), seabasses and hamlets (Serranidae), and squirrelfishes (Holocentridae). Herbivores (HER) were represented within belt-transects by six species of parrotfishes (Scaridae), two species of doctorfishes (Acanthuridae) and three species of damselfishes (Pomacentridae), with a combined density of 29.6 Ind/30m^2, or 26.6% of the total individuals. Corallivores (Chaetodontidae), and spongivores (Pomacanthidae) were represented by five species within belt-transects with a combined density of 3.4 Ind/30m^2, or 3.1% of the total density.

Mid-sized and large carnivores were represented by juvenile and adult graysbys (*Cephalopholis cruentata*), juvenile red hind (*Epinephelus guttatus*), one adult Nassau grouper (*E. striatus*), one yellowtail snapper (*Ocyurus chrysurus*), one lionfish (*Pterois* sp.), and one adult bar jack (*Caranx ruber*) with a cumulative density of 2.0 Ind/30m^2 (Table 13). Juvenile and adult red hinds (*E. guttatus*), Nassau (*E. striatus*), and yellowfin groupers (*M. venenosa*), schoolmaster, and mahogany snappers (*Lutjanus apodus, L. mahogoni*) represent large demersal predators previously reported for this reef (Garcia-Sais et al., 2017 and references therein). Schools of mackerel scad (*Decapterus macarellus*), creole wrasse (*Clepticus parrae*) and ballyhoo, (*Hemiramphus ballyhoo*) serve as forage for pelagic predators, such as cero mackerels (*Scomberomorus regalis*), great barracuda (*Sphyraena barracuda*), and blue runners (*Caranx crysos*) previously reported at TOUR10 (Garcia-Sais et al., 2017 and references therein).

Table 12. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3 x 10m belt-transects at TOUR10, Mayaguez. PRCRMP 2025

TOUR10							
Survey Date: 6/07/25	**Belt-Transects (3x10m)**						**Trophic**
Species	T1	T2	T3	T4	T5	**Mean**	**Level**
Thalassoma bifasciatum	24	40	5	35	18	**24.4**	SOC
Chromis cyanea		55		32		**17.4**	ZPL
Clepticus parrae			3	80		**16.6**	ZPL
Stegastes partitus	7	37	3	2	3	**10.4**	ZPL
Halichoeres garnoti	6	12	3	5	2	**5.6**	SOC
Scarus taeniopterus	16	3	9	15	5	**9.6**	HER
Scarus spp.		21				**4.2**	HER
Sparisoma viride	2	5	1	3	2	**2.6**	HER
Stegastes leucostictus	5	1	1	3	2	**2.4**	HER
Stegastes adustus	4		7		1	**2.4**	HER
Sparisoma aurofrenatum	1	3	3	1	4	**2.4**	HER
Acanthurus tractus	2	3	2	2	1	**2.0**	HER
Acanthurus coeruleus	2	2		3	2	**1.8**	HER
Haemulon flavolineatum		2	2	3		**1.4**	SOC
Cephalopholis cruentata	1		1	1	2	**1.0**	LC
Scarus iseri	1	2			2	**1.0**	HER
Chaetodon capistratus	1	1		1	2	**1.0**	COR
Holacanthus tricolor	1	2		1	1	**1.0**	SPO
Stegastes planifrons			4		1	**1.0**	HER
Pomacanthus arcuatus			3			**0.6**	SPO
Pomacanthus paru			2		1	**0.6**	SPO
Serranus tigrinus	1				1	**0.4**	SOC
Epinephelus striatus	1					**0.2**	LC
Scarus vetula		1				**0.2**	HER
Hypoplectrus puella		1				**0.2**	SOC
Epinephelus guttatus			1			**0.2**	LC
Ocyurus chrysurus				1		**0.2**	LC
Chaetodon striatus					1	**0.2**	COR
Holocentrus rufus					1	**0.2**	SOC
Density (Ind/30m2)	**75**	**191**	**50**	**188**	**52**	**111.2**	
Richness (Species/30m2)	**17**	**17**	**17**	**17**	**19**	**17.4**	

Parrotfishes (*Scarus taeniopterus, S. iseri, S. vetula*, *Sparisoma viride, S. aurofrenatum*) and doctorfishes (*Acanthurus chirurgus, A. coeruleus, A. tractus*) were the numerically dominant assemblage of large reef herbivores and/or commercially important fishes observed within belt-transects at TOUR10 (Table 13). Parrotfishes presented a combined density of 19.8 Ind/60m^2, whereas doctorfishes presented a combined density of 6.2 Ind/60m^2. Size distributions were in general indicative that TOUR10 functions as a recruitment and residential habitat for both parrotfishes and doctorfishes. Recruitment juveniles (1–5cm) of *A. coeruleus*, *S*. *viride*, *S aurofrenatum*, and *Scarus spp.* were observed. Terminal phase males of S. viride, *S. aurofrenatum*, and *S. taeniopterus* were observed within extended belt-transects during the 2025 and previous surveys at TOUR10 (Garcia-Sais et al., 2023 and references therein).

Annual monitoring trends of fish density and species richness are presented in Figure 15. Fish density fluctuations at TOUR10 were statistically insignificant (ANOVA; p = 0.179; Appendix 5). A trend of lower fish densities prevailed during the four previous monitoring surveys (2017, 2019, 2021, 2023) with the three lowest densities observed since the baseline survey in 1999. It is suggested that such recent decline of fish densities has been influenced by physical factors associated with the pass of hurricanes (e. g. Mathew in 2016, Maria in 2017) and /or winter storm Riley in 2018. Such extreme wave action events imposed conditions of surge, scouring and turbulent/advective flows that small numerically dominant fishes (e.g. *Coryphopterus personatus, Chromis cyanea, Clepticus parrae*, juvenile *Sparisoma* spp., *Scarus* spp.) may be unable to withstand and are displaced off the reef, potentially resulting in mortality and population decline.

During the 2025 survey, amidst the massive losses of live coral cover, peak mean fish density (111.2 Ind/30m^2) was measured at TOUR10 evidencing the relevance of the physical habitat and the structural habitat complexity contributed by algae and other benthic components, such as sponges and soft corals in support of the reef fish community. Differences of fish species richness between monitoring surveys were statistically significant (ANOVA; p< 0.001, Appendix 6), driven by a sharp decline of species in 2008 and 2010, and also during the previous four surveys, from 2017 - 2023 relative to all other surveys. Such declines coincided with low densities of numerically dominant species such as *Coryphopterus personatus, Chromis cyanea,* and/or *Clepticus parrae*. It is possible that density fluctuations of these forage species affect the presence of predators, and thus influence fish species richness at the community level (cascading effects). During the

2025 survey the mean fish species richness (18.4 Spp/30m^2) was within the range of previous surveys and statistically higher than during the previous 2023 survey (Appendix 6).

Table 13. Size-frequency distributions of commercially important fishes observed within 20 x 3m belt-transects at TOUR10, Mayagüez. PRCRMP 2025

TOUR10							
Survey Date: 6/07/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	10	1					Juvenile
Acanthurus coeruleus c1	5		1				Recruit
Acanthurus coeruleus c2	7, 3-8, 2-10	1	2		1	2	Juvenile
Acanthurus coeruleus c3	2-15, 14, 2-12	1	1		3	1	Juvenile
Acanthurus coeruleus c4	18				1		Adult
Acanthurus tractus c2	8, 4-10	1	1	1	1	1	Juvenile
Acanthurus tractus c3	11, 6-12, 2-14, 15,	3	1	3	2	1	Juvenile
Acanthurus tractus c4	2-17		2				Adult
Caranx ruber c8	38		1				Adult
Cephalopholis cruentata c2	8, 2-9	1		1		1	Juvenile
Cephalopholis cruentata c3	13					1	Juvenile
Cephalopholis cruentata c6	28				1		Adult
Epinephelus guttatus c4	20			1			Juvenile
Epinephelus striatus c8	40	1					Adult
Ocyurus chrysurus c4	18				1		Adult
Pterois spp. c4	20			1			Adult
Scarus iseri c2	10					1	Juvenile
Scarus iseri c3	12, 2-14, 2-15	1	2	1		1	Juvenile
Scarus iseri c4	20, 16					2	Adult
Scarus spp. c1	28-2		21		7		Recruit
Scarus taeniopterus c2	2-6, 6-7, 13-8, 7-10	2	3	11	7	5	Juvenile
Scarus taeniopterus c3	12		1				Juvenile
Scarus taeniopterus c4	18				1		Terminal
Scarus vetula c3	14		2				Juvenile
c1	3-3, 3-4, 5		2	2		3	Recruit
c2	8, 9	1				1	Juvenile
c3	15, 14		1		1		Juvenile
c4	2-16, 17, 20	2		2			Adult
Sparisoma aurofrenatum	22					1	Terminal
Sparisoma viride c1	3-3, 4		2		1	1	Recruit
Sparisoma viride c2	7, 8	1	1				Juvenile
Sparisoma viride c3	2-12		1			1	Juvenile
Sparisoma viride c4	16		1				Adult
Sparisoma viride c5	2-25	1		1			Adult
Sparisoma viride c6	30		1				Adult
Sparisoma viride c7	32, 35, 33	1			2		Terminal
Sparisoma viride c8	36	1					Terminal
	Totals	**19**	**47**	**24**	**29**	**23**	

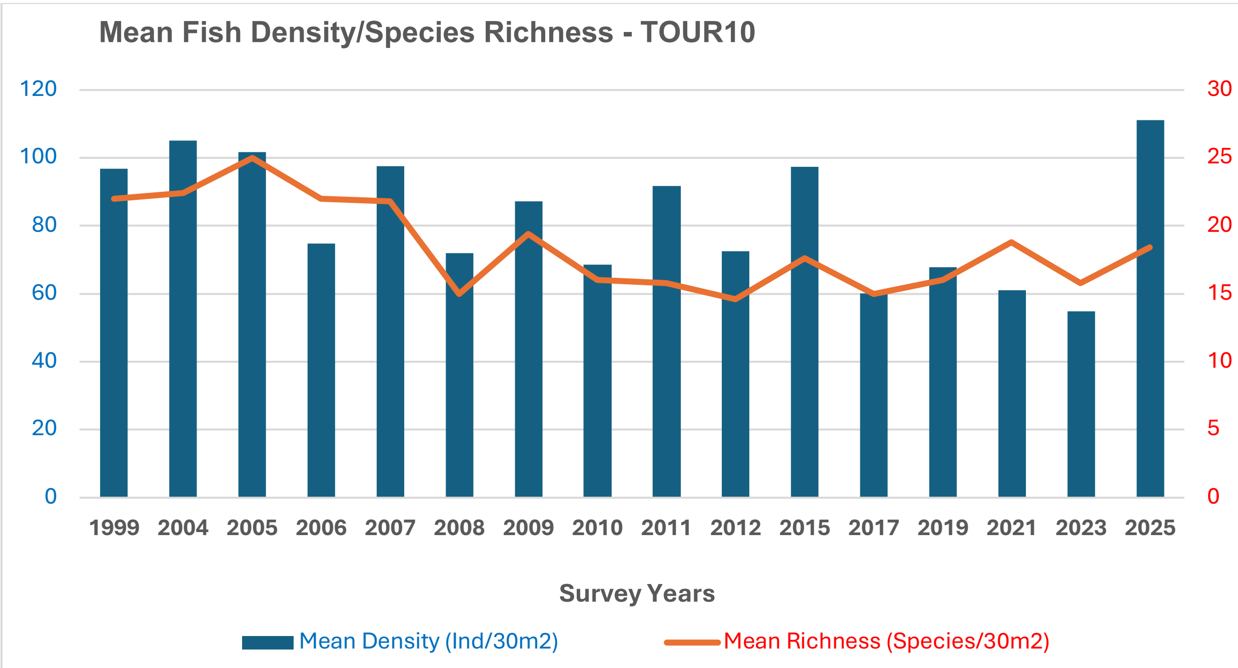


Figure 15. Monitoring trends (1999 – 2025) of mean fish density and species richness at TOUR10, Mayagüez. PRCRMP 2025

Photo Album 4. TOUR10









5.0 Tourmaline 20m (TOUR20)

5.1 Physical Description

Tourmaline outer shelf reef is separated from the shelf-edge by an irregular fringe of sandy-silt bottom. Submerged at a depth of 16m, the reef extends down a narrow and abrupt slope to a depth of 21m. A rugged and diffuse "spur-and-groove" formation of massive coral buildup is the main structural feature of the reef. The spurs are rather narrow (< 2 m) and rise from the sandy channels or grooves about 2 – 3m. At the deeper edge of the reef massive coral colonies have grown close together forming large coral promontories that partially mask the spur and groove pattern. Permanent transects were installed on top of consecutive spurs at depths between 18.5 – 18.8m during the baseline survey in 2004 (Garcia-Sais et al., 2004). Panoramic views of the reef community at TOUR20 during the 2025 survey are presented in Photo Album 5.

5.2 Sessile-benthic Reef Community

Benthic algae, comprised by fleshy brown (*Lobophora sp., Dictyota sp.*), turf (mixed), red crustose (*Peyssonnelia sp., Ramicrusta sp.*), and red coralline (CCA, mixed) algae were the dominant sessile-benthic component in terms of substrate cover at TOUR20 with an average of 67.51% (range: 55.54 – 81.24%). Encrusting fan-leaf alga (*Lobophora* sp.) was the main component of the benthic algal assemblage with a mean cover of 56.97%, representative of 84.39% of the total cover by benthic algae (Table 14). Turf algae comprised by a mixed assemblage of short articulated algae were observed in all five transects with a mean cover of 5.06%. Peyssonnelid algae, including *Ramicrusta* sp. were intercepted in all five transects with a combined cover of 4.15%, representative of 6.15% of the total cover by benthic algae.

Four scleractinian coral species and one hydrocoral (*Millepora alcicornis*) were intercepted by line transects during the 2025 survey at TOUR20 (Table 14) with a combined substrate cover of 3.54% (range: 2.37 – 5.37%). Stony corals occurred as massive (*Orbicella faveolata*), branching (*Madracis spp.*), and mound shaped colonies (*P. astreoides*). Mountainous star coral (*O. faveolata*) was the dominant species in terms of reef substrate cover with a mean of 1.96%, representing 55.37% of the total cover by stony corals. In addition to *O. faveolata*, mustard-hill coral (*P. astreoides*) was intercepted by three transects with a mean substrate cover of 0.88%. A total of 21 stony coral colonies were intercepted by transects, none of which were observed to be affected by coral disease infections (Appendix 2). Three coral colonies (3- *O. faveolata*) were observed partially bleached or pale (bleaching prevalence= 14.28%).

Table 14. Percent reef substrate cover by sessile-benthic categories at TOUR20, Mayagüez. PRCRMP 2025

TOUR20						
Survey Date: 6/07/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	18.48	18.79	18.79	18.79	18.79	**18.73**
Rugosity (m)	5.15	6.94	4.87	7.12	6.13	**6.04**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	14.51	34.88	25.14	26.33	26.04	**25.38**
Sand				4.25		**0.85**
Recently dead coral (total)		0.33				**0.07**
Gaps/Holes					0.17	**0.03**
Total Abiotic	**14.51**	**35.21**	**25.14**	**30.58**	**26.22**	**26.33**
Benthic Algae						
Lobophora spp.	64.97	49.26	54.71	57.48	58.42	**56.97**
Turf (mixed)	9.89	3.88	4.80	2.29	3.56	**4.88**
Peyssonnelia spp.	3.79	1.74	5.37	4.50	4.95	**4.07**
Dictyota spp.	1.94	0.66	1.88		0.17	**0.93**
CCA (total)	0.65		0.56		0.78	**0.40**
Turf (mixed) with sediment					0.87	**0.17**
Ramicrusta spp.				0.41		**0.08**
Total Benthic Algae	**81.24**	**55.54**	**67.33**	**64.68**	**68.75**	**67.51**
Cyanobacteria				**1.47**		**0.29**
Stony Corals						
Orbicella faveolata	1.11	3.39	4.05	0.90	0.35	**1.96**
Porites astreoides	0.74			1.06	2.60	**0.88**
Madracis decactis		1.82		0.41		**0.45**
Madracis carmabi	1.11					**0.22**
Millepora alcicornis		0.17				**0.03**
Total Stony Corals	**2.96**	**5.37**	**4.05**	**2.37**	**2.95**	**3.54**
# Coral Colonies/Transect	**4**	**6**	**2**	**6**	**3**	**4.20**
#Bleached CoralColonies/Transect	**1**	**2**	**0**	**0**	**0**	**0.60**
# Erect Soft Coral Colonies/Transect	**5**	**5**	**5**	**3**	**3**	**4.20**
Soft Corals						
Briareum asbestinum	1.20	1.57	0.75	0.16	0.61	**0.86**
Total Soft Corals	**1.20**	**1.57**	**0.75**	**0.16**	**0.61**	**0.86**
Anemones						**0.00**
Lebrunia neglecta		0.17				**0.03**
Sponges						
Dictyonella funicularis			2.54	0.49		**0.61**
Aiolochroia crassa		1.16				**0.23**
Iotrochota birotulata					0.95	**0.19**
Cliona caribbaea		0.83				**0.17**
Sponge spp.		0.17		0.16	0.35	**0.14**
Monanchora arbuscula			0.19			**0.04**
Niphates erecta					0.17	**0.03**
Scopalina ruetzleri	0.09					**0.02**
Mycale laevis				0.08		**0.02**
Total Sponges	**0.09**	**2.15**	**2.73**	**0.74**	**1.48**	**1.44**
Bleached Corals						
Orbicella faveolata	1	2				

Vertically projected soft corals were moderately abundant at TOUR20 with an average of 4.2 Col/Transect. Some of the most common taxa included sea fans (*Gorgonia ventalina*) and sea plumes (*Antillogorgia sp*.). The encrusting species, *Briareum asbestinum* was intercepted by all five transects with a mean substrate cover of 0.86% (Table 14). Colonies of bushy black coral (*Antipathes caribbeana*) and wire coral (*Stichopathes lutkeni*) were present at the reef base and associated with reef crevices and overhangs. Sponges were represented by nine species along transects with a mean cover of 1.44%. Reef overhangs associated with ledges of massive coral buildups averaged a substrate cover of 18.73% and contributed markedly to the reef rugosity of 6.04m. Total abiotic cover averaged 26.33% (Table 14).

Figure 16 shows the variations of mean percent substrate cover by the main sessile-benthic categories from TOUR20. Reef substrate cover by hard corals showed a gradual decline from a baseline mean of 31.79 % in 2004 to a minimum of 22.80% in 2007. Such decline was probably associated with coral bleaching-induced mortalities after the regional event of late August 2005, with lingering effects down to 2008. After 2010 live coral cover maintained an increasing trend until the 2017 survey, evidencing a recuperation of 34.45 % from its lowest cover in 2010 and approaching its baseline cover at 31.79%. The combined reef substrate cover by *Orbicella spp*, previously described as the *O. annularis* complex was the main driver of the declining trend of live coral between 2004 and 2007 and also of its recent recuperation trend because they were and still are the dominant coral species complex at TOUR20.

After 2017, consecutive reductions of reef substrate cover by stony corals have been measured at TOUR20, including a 60.56% decline in 2023, relative to the previous 2021 survey, and the most recent decline of -64.92% in 2025 relative to the previous 2023 survey. This implies a large-scale degradation of the stony coral community. Differences of substrate cover by stony corals were highly significant (ANOVA; $p < 0.001$; Appendix 3) and associated with a 85.47% reduction of cover by the *Orbicella* spp. complex, and the disappearance from transects of previously prominent species, such as *Colpophyllia natans*, *Porites porites*, *Agaricia agaricites*, *Pseudodiploria strigosa*, and *Meandrina meandrites* (Figure 17). The density of stony corals intercepted by transects at TOUR20 declined by 34.38%, from 32 in 2023 to 21 in 2025. It is possible that the high bleaching prevalence measured from TOUR20 since the 2021 survey triggered coral disease infections leading to the massive coral mortality measured in 2023 and 2025.

Statistically significant differences of erect soft coral densities have also been measured from TOUR20 (ANOVA; $p < 0.001$, Appendix 4). Differences were associated with a density increase in 2007 that may have been influenced by the loss of stony coral cover in 2006 after the 2005 regional coral bleaching event. The decline in 2017 may have been influenced by detachment of colonies during the pass of hurricane Mathew off the south coast in late 2016. During the 2025 survey density of soft corals declined by 58.85% relative to the previous 2023 survey. Many colonies were observed standing dead suggesting recent mortality, perhaps related to the 2024 global ocean warming and related disease infections.

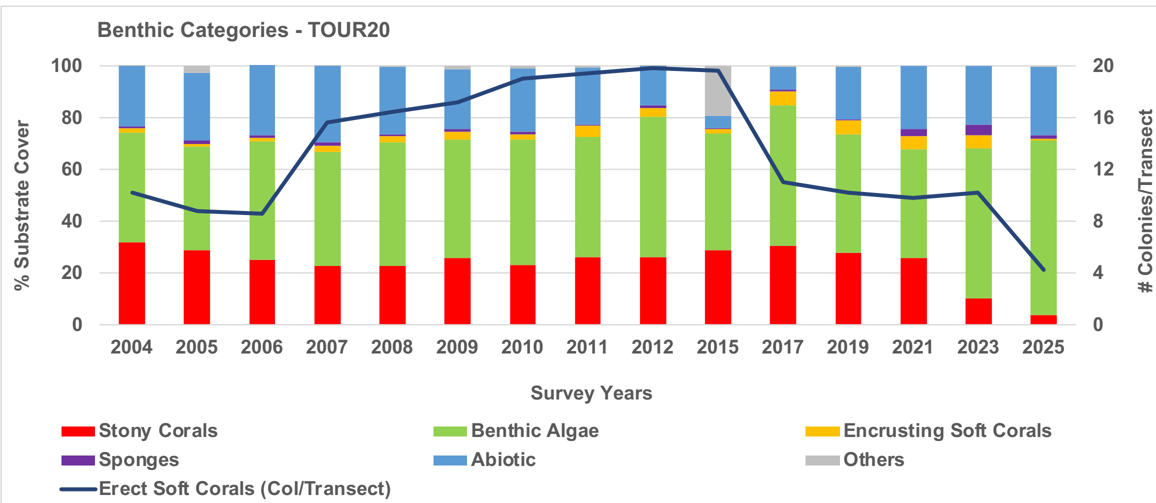


Figure 16. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at TOUR20, Mayagüez. PRCRMP 2025

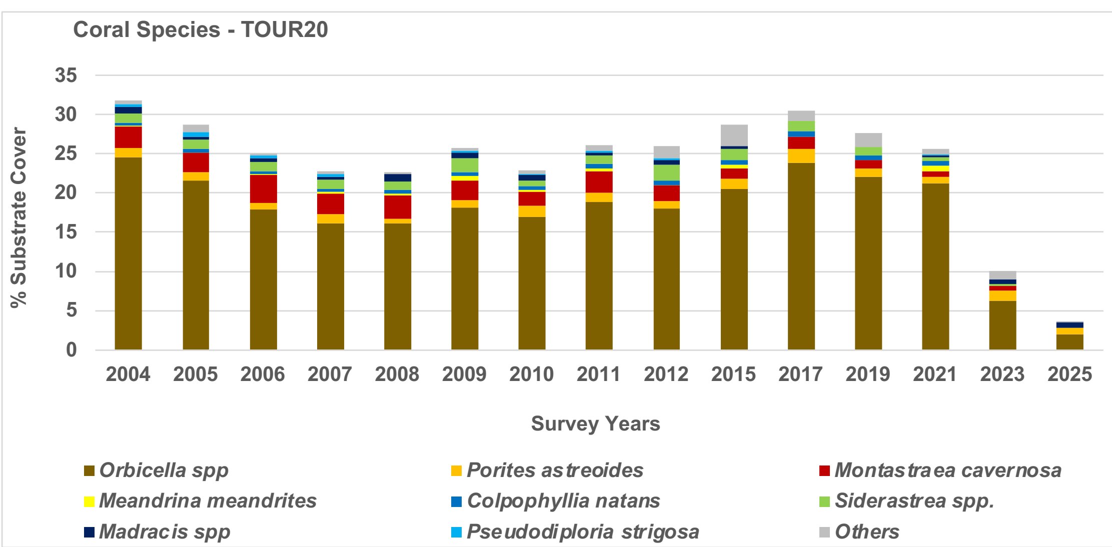


Figure 17. Monitoring trends (2004 – 2025) of mean substrate cover by stony coral species at TOUR20, Mayagüez. PRCRMP 2025

5.3 Fishes and Motile Megabenthic Invertebrates

A total of 34 fish species were identified within belt-transects from TOUR20 during 2025 with a mean abundance of 100.8 Ind/30m^2 (range: 67 - 130 Ind/30m^2), and a mean species richness of 16.4 Spp/30m^2 (Table 15). The creole wrasse (*Clepticus parrae*) was the numerically dominant species within belt-transects with a mean density of 24.2Ind/30m^2, representative of 24.0% of the total fish density. Creole wrasses were observed as streaming schools of hundreds of adult individuals in midwater occasionally approaching the reef benthos and belt-transect areas. Schooling aggregations of masked goby (*Coryphopterus personatus*) and bluehead wrasse (*Thalassoma bifasciatum*) were also prominent with a combined density of 54.0 Ind/30m^2, representative of 53.6% of the total individuals within belt-transects. Four additional species were observed in at least four transects with a combined density of 7.0 Ind/30m^2, representative of 6.9% of the total density. These included the bicolor damselfish (*Stegastes partitus*), doctorfish (*Acanthurus chirurgus*), and the princess parrotfish and redband parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum*). Motile-megabenthic invertebrates were not observed within belt-transects during the 2025 survey at TOUR20.

The fish community was numerically dominated by zooplanktivores (ZPL), strongly influenced by mean densities of creole wrasse (*Clepticus parrae*), masked goby (*Coryphopterus personatus*), bicolor damselfish (*Stegastes partitus*), and blue chromis (*Chromis cyanea*), with a combined density of 66.8 Ind/30m^2, representative of 66.3% of the total individuals within belt-transects (Table 15). Small opportunistic carnivores (SOC) were represented by 13 species with a combined density of 24.2 Ind/30m^2, or 24.0% of the total. The assemblage included wrasses (Labridae), goatfishes (Mullidae), basslets (Grammatidae), gobies (Gobiidae), puffers (Tetraodontidae), grunts (Haemulidae), squirrelfishes (Holocentridae), and hamlets (Serranidae). Parrotfishes (*Scarus spp., Sparisoma spp*.), doctorfishes (*Acanthurus spp*.) and damselfishes (*Stegastes spp*.), comprised the main herbivorous fish assemblage with six species and a combined abundance of 6.2 Ind/30m^2, or 6.2% of the total individuals. Corallivores (*Chaetodon sp., Prognathodes sp.*), and spongivores (*Holacanthus sp, Pomacanthus sp*) were present with a combined density of 2.2 Ind/30m^2.

Mid-size and large demersal carnivores/piscivores included the Nassau, yellowfin, yellowmouth, and graysby groupers (*Epinephelus striatus, Mycteroperca venenosa, M. interstitialis,* and *C. cruentata*), queen triggerfish (*Balistes vetula*), hogfish (*Lachnolaimus maximus*), mutton sand yellowtail snappers (*Lutjanus analis, Ocyurus chrysurus*), and juvenile bar jack (*Caranx ruber*) with a combined density of 2.2 Ind/60m^2 (Table 16). Other large demersal predators, such as the red hind (*E. guttatus*), and the cubera, dog, and schoolmaster snappers (*Lutjanus cyanopterus*, *L. jocu*, *L. apodus*) were previously reported at TOUR20 (García-Sais et al, 2023 and references therein). Pelagic predators, including the great barracuda (*Sphyraena barracuda*) and cero mackerel (*Scomberomorus regalis*) were observed outside transects during the 2025 and previous surveys (Garcia-Sais et al., 2021).

Table 15. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3 x 10m belt-transects at TOUR10, Mayaguez. PRCRMP 2025

TOUR20							
Survey date: 6/07/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Clepticus parrae	39	22	28	15	17	**24.2**	ZPL
Coryphopterus personatus	40	75	45	12	16	**37.6**	ZPL
Thalassoma bifasciatum	7	10	34	23	8	**16.4**	SOC
Stegastes partitus	2	4	4	1	3	**2.8**	ZPL
Chromis cyanea	4		1	6		**2.2**	ZPL
Acanthurus chirurgus	3	3	2	1	1	**2.0**	HER
Halichoeres garnoti			1	3	4	**1.6**	SOC
Stegastes leucostictus	2	1	3	1		**1.4**	HER
Mulloidichthys martinicus	1		1		5	**1.4**	SOC
Gramma loreto		2	3	2		**1.4**	SOC
Sparisoma aurofrenatum	1	1	1	1		**0.8**	HER
Acanthurus coeruleus	1	3				**0.8**	HER
Chaetodon capistratus	1	1			2	**0.8**	COR
Coryphopterus lipernes		3			1	**0.8**	SOC
Canthigaster rostrata		1		2	1	**0.8**	SOC
Prognathodes aculeatus		1		1	1	**0.6**	COR
Sparisoma viride			1	2		**0.6**	HER
Acanthurus tractus				1	2	**0.6**	HER
Haemulon flavolineatum	1	1				**0.4**	SOC
Holacanthus tricolor		1		1		**0.4**	SPO
Myripristis jacobus			1		1	**0.4**	SOC
Pomacanthus paru			1		1	**0.4**	SPO
Balistes vetula	1					**0.2**	LC
Epinephelus striatus		1				**0.2**	LC
Cephalopholis cruentata			1			**0.2**	LC
Holocentrus rufus			1			**0.2**	SOC
Hypoplectrus unicolor			1			**0.2**	SOC
Pseudupeneus maculatus				1		**0.2**	SOC
Caranx ruber				1		**0.2**	LC
Neoniphon marianus				1		**0.2**	SOC
Ocyurus chrysurus					1	**0.2**	LC
Lachnolaimus maximus					1	**0.2**	LC
Lutjanus analis					1	**0.2**	LC
Bodianus rufus					1	**0.2**	SOC
Density (Ind/30m2)	**103**	**130**	**129**	**75**	**67**	**100.8**	
Richness (Species/30m2)	**13**	**16**	**17**	**18**	**18**	**16.4**	

Parrotfishes (Scaridae), represented by four species and doctorfishes (*Acanthuridae*), represented by three species were the main reef fish herbivores at TOUR20 during the 2025 survey with combined densities of 10.6 Ind/60m^2, and 5.6 Ind/60m^2, respectively (Table 16). Recruitment stages (1 – 5cm) of redband, stoplight and princess parrotfishes (*Sparisoma aurofrenatum, S. viride, Scarus taeniopterus*), and terminal phase males of *S. viride* and *S. aurolineatum* were observed. Juvenile and adult stages of doctorfish (Acanthurus chirurgus) and blue tang (A. coeruleus) were also present within extended belt-transects. The size distribution data shows that TOUR20 functions both as a recruitment and residential habitat for parrotfishes and doctorfishes.

Table 16. Size-frequency distributions of commercially important fishes observed within 20 x 3m belt-transects at TOUR20, Mayagüez. PRCRMP 2025

TOUR20							
Survey Date: 6/07/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	8, 9	2					Juvenile
Acanthurus chirurgus c3	11, 12, 6-13, 4-14, 15	1	3	4	2	3	Juvenile
Acanthurus coeruleus c2	10		1				Juvenile
Acanthurus coeruleus c3	14, 11, 2-15	1	2		1		Juvenile
Acanthurus coeruleus c4	3-16, 2-17		2			3	Adult
Acanthurus tractus c2	9				1		Juvenile
Acanthurus tractusc3	12, 13					2	Juvenile
Balistes vetula c9	45	1					Adult
Caranx ruber c2	10				1		Juvenile
Cephalopholis cruentata c3	11			1			Juvenile
Epinephelus striatus c12	60		1				Adult
Epinephelus striatus c9	45		1				Adult
Lachnolaimus maximus c10	50					1	Adult
Lutjanus analis c10	50					1	Adult
Mycteroperca interstitialis c8	40	1					Adult
Mycteroperca venenosa c11	55			1			Adult
Ocyurus chrysurus c3	15					1	Juvenile
Ocyurus chrysurus c4	20					1	Adult
Scarus iseri c3	2-12				2		Juvenile
Scarus taeniopterus c1	8-5	8					Recruit
Scarus taeniopterus c2	4-6, 4-7, 12-8, 6-10	3	1	3	7	8	Juvenile
Scarus taeniopterus c3	2-12, 13, 2-15,	2	1	1		1	Juvenile
Scarus taeniopterus c5	25	1					Adult
Sparisoma aurofrenatum c1	2-5			1	1		Recruit
Sparisoma aurofrenatum c3	12		1				Juvenile
Sparisoma aurofrenatum c5	22, 25, 23	1	1		1		Terminal
Sparisoma viride c1	3			1			Recruit
Sparisoma viride c4	20				1		Adult
Sparisoma viride c5	25			1			Adult
Sparisoma viride c6	26					1	Adult
Sparisoma viride c7	33				1		Terminal
	Totals	**21**	**14**	**13**	**18**	**22**	

Differences of fish density and species richness between monitoring surveys at TOUR20 were both statistically significant (ANOVA; $p < 0.0001$, see Appendices 5 and 6). Density variations were associated with peaks in 2005, 2006, 2008, 2011 and 2015 relative to other monitoring surveys, but particularly relative to the previous four surveys (e. g. 2017, 2019, 2021 and 2023) (Figure 18). Density peaks were largely driven by high prevalence of schooling aggregations of masked goby (*Coryphopterus personatus*). The mean fish density measured during the 2021 and 2023 surveys (46.8 and 37.8 Ind/30m^2) represents the lowest fish density surveyed from TOUR20 since the baseline survey in 2004. This was influenced by very low densities of *C. personatus*, relative to previous surveys, but also from an overall density decline of small water column species, such as chromis, wrasses, damselfishes, and juvenile parrotfishes. This community structure scenario might be related to major physical disturbances impacting neritic reefs, such as extreme wave action associated with hurricanes (e. g. Mathew in 2016, Maria in 2017) and/or winter storms (e. g. Riley in 2018), as turbulent surge and scouring may have displaced small fishes unable to avoid such physical advective forces. During the 2025 survey mean fish density increased 2.7-fold relative to the previous 2023 survey, and species richness increased by 12.3% despite the bold and continuous degradation of live coral cover. Such density increase was driven by *C. personatus*, but with marked contributions by other species as well. The pattern appears to be associated with the physical conditions at the time of survey and potential cascading effects driven by the availability of forage species, such as C. personatus, and other small demersal fishes.

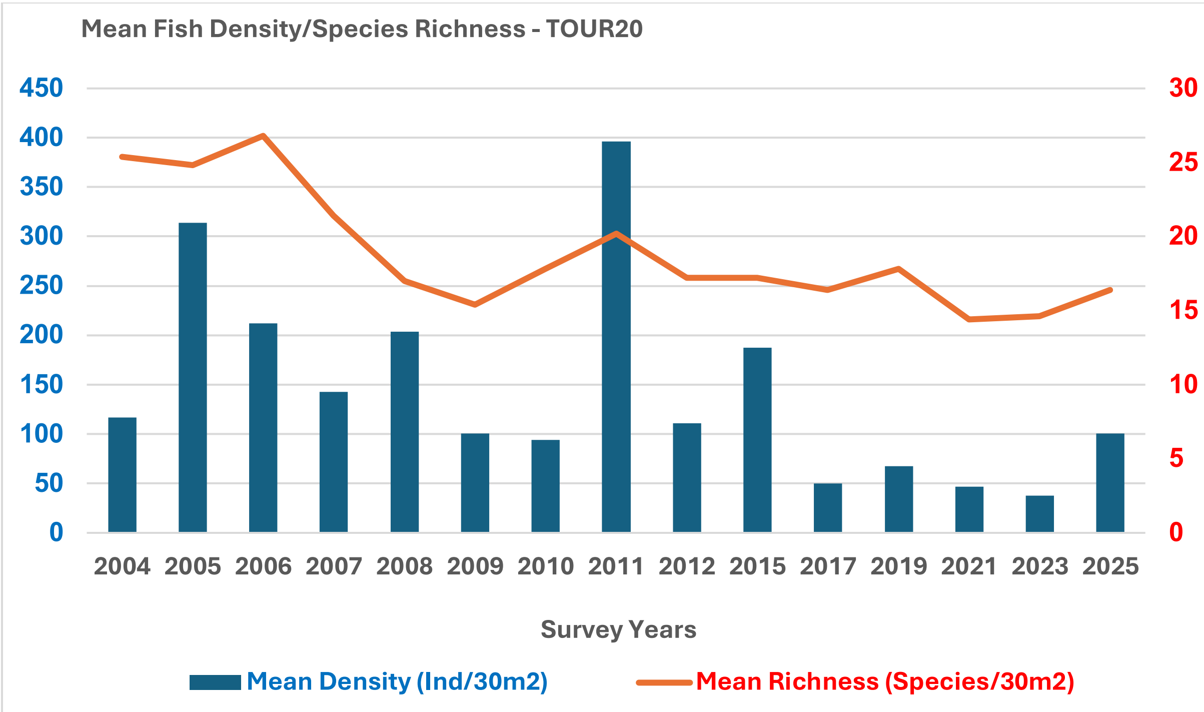


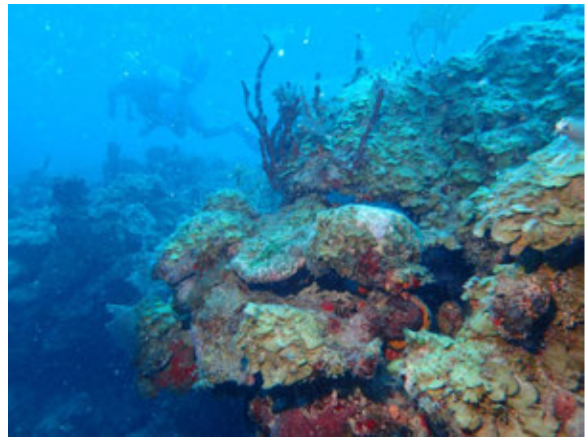
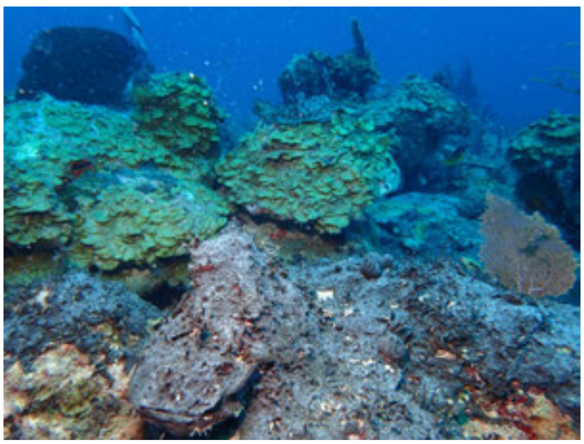
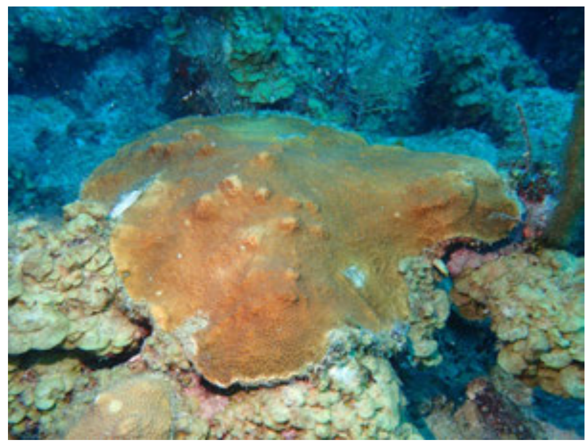
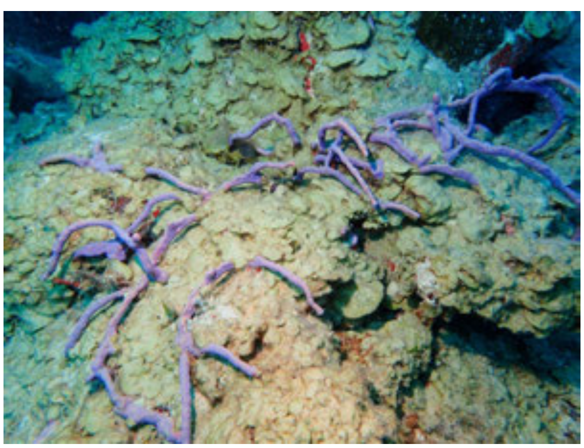
Figure 18. Monitoring trends (2004 – 2025) of mean fish density and species richness at TOUR20, Mayagüez PRCRMP 2025

Photo Album 5. TOUR20








6.0 Tourmaline 30m (TOUR30)

6.1 Physical Description

Tourmaline is a submerged coral reef system comprised by a series of narrow hard ground terraces or steps fringing the edge of the Mayagüez Bay shelf along a depth range of 10 - 32 m. The reef starts at a depth of 10m with a well-defined spur-and-groove formation that follows a gentle slope towards the north (TOUR10). A more irregular spur-and-groove reef formation of massive coral buildup is found at a depth of 17m, extending due north to a depth of 21m (TOUR20). The third and last hard ground terrace (TOUR30) is narrow, breaking abruptly from 22m down to 32m along an irregular slope with high topographic relief given by large, massive coral colonies. The baseline survey of TOUR30 was performed in 2004 (Garcia-Sais et al., 2004). Permanent transects were oriented south - north, perpendicular to the shelf-edge and on top of the spurs at a depth of 28 - 30m. Panoramic views of the reef community during the 2025 survey at TOUR30 are presented in Photo Album 6.

6.2 Sessile-Benthic Reef Community

Benthic algae comprised by an assemblage of turf (mixed), crustose red (*Peyssonnelia sp., Ramicrusta sp*.), fleshy brown (*Dictyota sp.*), and red coralline (CCA), macroalgae were the dominant sessile-benthic category in terms of reef substrate cover at TOUR30 with a combined mean cover of 54.24% (range: 46.32 – 63.01%). Turf algae, a mixed assemblage of short red and brown algae was the dominant component with a mean cover of 28.20%, representative of 51.99% of the total cover by benthic algae (Table 17). Peyssonnelid algae were intercepted by all five transects with a combined mean substrate cover of 10.33%, representative of 19.04% of the total cover by benthic algae. Substrate cover by cyanobacterial mats averaged 3.05%.

A total of seven stony coral species were intercepted by transects during the 2025 survey at TOUR30 (Table 17). Reef substrate cover by stony corals averaged 2.21% (range: 0.84 – 4.44%), with a mean of 3.0 Col/Transect. Mountainous star coral (*Orbicella faveolata*) was the dominant species with a mean substrate cover of 1.15%, representative of 52.04% of the total cover by stony corals. Mustard-hill coral (*Porites astreoides*) was intercepted by three transects with a mean cover of 0.24%, or 10.86% of the total cover. A total of 15 stony coral colonies were intercepted by transects none of which were observed affected by coral diseases nor bleached (see Appendix 2).

Table 17. Percent reef substrate cover by sessile-benthic categories at TOUR30, Mayagüez. PRCRMP 2025

TOUR30						
Survey Date: 6/10/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	28.48	28.48	28.18	27.27	27.27	**27.94**
Rugosity (m)	5.06	4.28	5.15	5.06	4.48	**4.81**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	23.23	30.49	26.34	34.29	39.46	**30.76**
Sand		1.67		1.39	5.51	**1.71**
Gaps/Holes		1.27				**0.25**
Total Abiotic	**23.23**	**33.43**	**26.34**	**35.69**	**44.97**	**32.73**
Benthic Algae						
Turf (mixed) with sediment	24.72	32.94	35.58	25.56	20.31	**27.82**
Peyssonnelia spp.	8.83	7.35	11.74	11.52	11.03	**10.09**
Dictyota spp.	8.46	12.25	7.76	11.06	9.86	**9.88**
Macroalgae spp.	17.10	2.94	2.68		2.90	**5.12**
CCA (total)	1.58				0.39	**0.39**
Turf (mixed)	1.39	0.49				**0.38**
Ramicrusta spp.	0.93				0.29	**0.24**
Lobophora spp.					1.16	**0.23**
Halimeda spp.					0.39	**0.08**
Total Benthic Algae	**63.01**	**55.98**	**57.76**	**48.14**	**46.32**	**54.24**
Cyanobacteria	**3.07**	**5.20**	**4.44**	**1.67**	**0.87**	**3.05**
Stony Corals						
Orbicella faveolata	0.56		1.94	0.56	2.71	**1.15**
Agaricia grahamae		0.78	1.02			**0.36**
Porites astreoides	0.28		0.28	0.65		**0.24**
Agaricia lamarcki			1.20			**0.24**
Madracis carmabi		0.49				**0.10**
Stephanocoenia intersepta					0.48	**0.10**
Montastraea cavernosa					0.10	**0.02**
Total Stony Corals	**0.84**	**1.27**	**4.44**	**1.21**	**3.29**	**2.21**
# Coral Colonies/Transect	**2**	**2**	**6**	**2**	**3**	**3.00**
#Bleached CoralColonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
# Erect Soft Coral Colonies/Transect	**6**	**7**	**6**	**5**	**6**	**6.00**
Soft Corals						
Briareum asbestinum	2.04		1.66		2.71	**1.28**
Erythropodium caribaeorum			0.46	3.16		**0.72**
Eunicea flexuosa				0.28		**0.06**
Total Soft Corals	**2.04**	**0.00**	**2.13**	**3.44**	**2.71**	**2.06**
Sponges						
Agelas conifera	1.21		0.46	2.79		**0.89**
Svenzea zeai		0.49	1.76	1.86		**0.82**
Spheciospongia vesparium				3.44		**0.69**
Iotrochota birotulata	0.65	0.29	0.37	0.46	1.26	**0.61**
Sponge spp.	1.95		0.92			**0.58**
Neopetrosia spp. smooth	2.14	0.49				**0.53**
Plakortis spp.	0.19	1.67	0.37	0.28		**0.50**
Neopetrosia proxima		0.49		1.02		**0.30**
Clathria spp.	0.37		0.46			**0.17**
Aplysina cauliformis		0.49	0.18			**0.14**
Monanchora arbuscula	0.56					**0.11**
Ectyoplasia ferox	0.46					**0.09**
Amphimedon compressa	0.28					**0.06**
Mycale laevis		0.20				**0.04**
Agelas sceptrum					0.19	**0.04**
Scolymia cubensis					0.19	**0.04**
Smenospongia conulosa					0.19	**0.04**
Desmapsamma spp.			0.18			**0.04**
Niphates erecta			0.18			**0.04**
Total Sponges	**7.81**	**4.12**	**4.90**	**9.85**	**1.84**	**5.70**

Erect soft corals were present in all transects with an average of 6.0 Col/Transect (Table 17). Encrusting species, such as the corky sea-finger (*Briareum asbestinum),* and the encrusting gorgonian (*Erythropodium caribaeorum)* were intercepted by three and two transects, respectively and with a combined reef substrate cover of 2.00%. Colonies of bushy black coral (*Antipathes caribbeana*) and wire coral (*Stichopathes lutkeni*) were present outside transects at a depth of 32m. Encrusting and erect sponges were represented by 19 species along transects with an average substrate cover of 5.70%. *Agelas conifera*, *Svenzea zeai*, and *Spheciospongia vesparium* were the most prominent in terms of reef substrate cover with a combined mean of 2.40%, or 42.10% of the total cover by sponges. The abiotic category was highly prominent with a mean substrate cover of 32.73%, largely contributed by reef overhangs (mean: 30.76%) produced by large, massive stony coral buildups mostly dead or in advanced deterioration stages at present. Such massive coral buildups contributed to a mean rugosity of 4.81m.

Temporal variations of mean reef substrate cover by the main sessile-benthic categories at TOUR30 are presented in Figure 19. Differences of stony coral cover between monitoring surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 3). Differences were related to the drastic decline of live stony coral cover during the previous 2023 survey and the most recent 2025 survey. Live coral cover declined 40.92% in 2023 relative to the 2021 survey and then declined 78.29% in 2025 relative to the previous 2023 monitoring survey. The mean percent cover by stony corals remained stable at TOUR30 during the period between the baseline survey in 2004 and 2010. Since then, consistent increments of coral cover were measured until 2017. The increase of coral cover was associated with increments by the two dominant species, the *Agaricia spp.* assemblage, of which *A. grahamae* was the main component, and *Orbicella faveolata* (Figure 20). After 2017, consistent declines of stony coral cover were measured in the 2019, 2021, 2023, and the most recent 2025 survey.

The decline of stony coral cover measured during the 2019 survey may have been influenced by the effects of hurricane Maria in September 2017 and/or of winter storm Riley in March 2018. Both events impacted neritic coral reef communities with exceptionally high wave action and reductions of the reef substrate cover by stony corals may have been related to the scouring and abrasion caused by wave action. The subsequent decline of live coral cover measured in 2021 may have been driven by the strong bleaching event that started in late October 2019 continuing until February-March 2020. Lingering effects of the 2019-20 bleaching event were observed at TOUR30 during the 2021 survey with a coral bleaching prevalence of 8.6% (Garcia-Sais et al., 2021). It is possible that the marked decline of stony coral cover measured in 2023 relative to the previous 2021 survey may have been related to coral disease infections (unknown pathogens) triggered by the 2019 bleaching event. The largest reduction of reef substrate cover stony corals was measured on *Orbicella faveolata* (-67.9%), one of the species observed to be affected by coral disease infections in the 2023 survey (see Appendix 2).

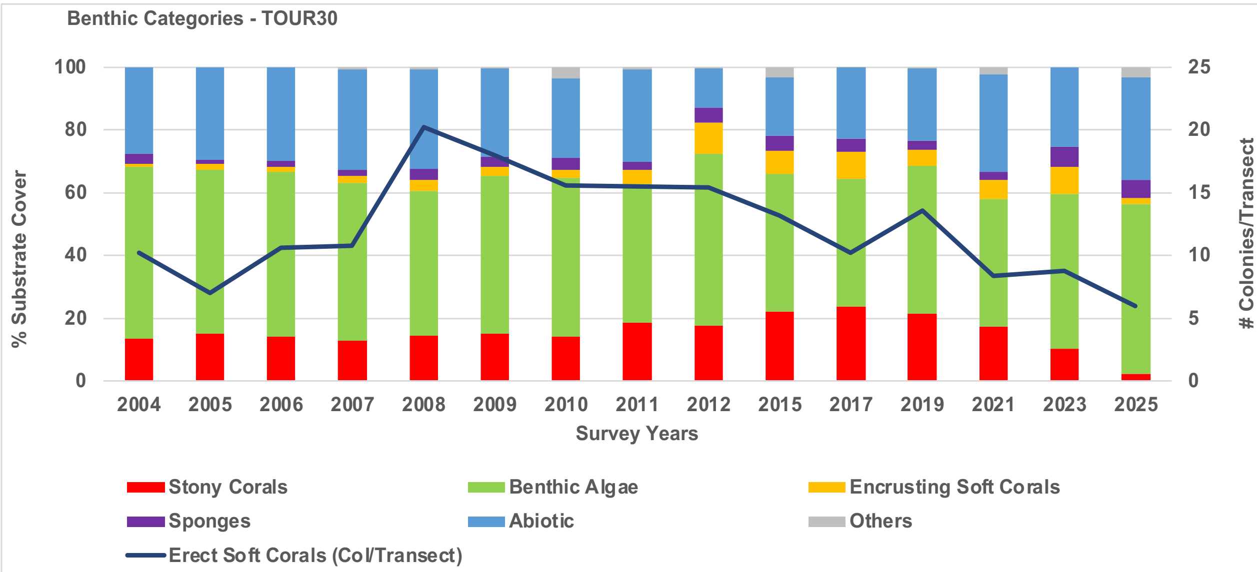


Figure 19. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at TOUR30, Mayagüez. PRCRMP 2025

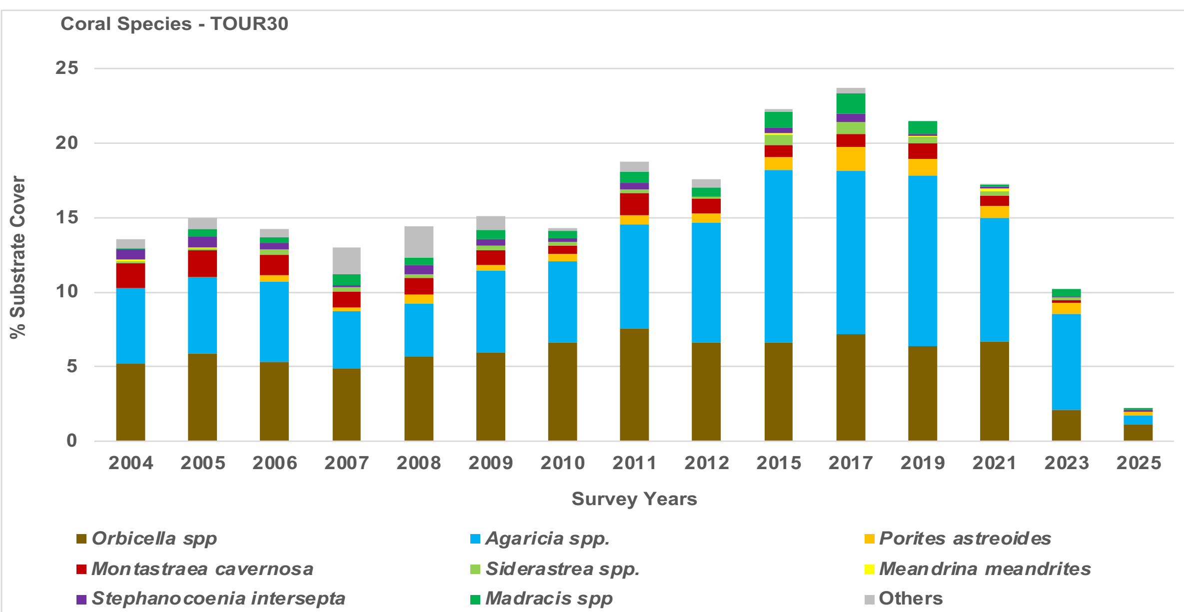


Figure 20. Monitoring trends (2004 – 2025) of mean substrate cover by hard coral species at TOUR30, Mayagüez. PRCRMP 2025

Temporal variations of erect soft coral densities between monitoring surveys were detected at TOUR30 (ANOVA; $p < 0.001$; Appendix 4), associated to higher densities measured during the 2008 – 2012 period relative to the most recent 2019 - 2025 period (Figure 19). The lower densities measured after 2019 may have been influenced by strong wave action events, including the pass of Hurricane Mathew in 2016, Hurricane Maria in 2017, and winter storm Riley in 2018.

6.3 Fishes and Motile Megabenthic Invertebrates

A total of 41 fish species were observed within belt-transects at TOUR30 during the 2025 monitoring survey with a mean density 114.2 Ind/30m^2 (range: 72 - 144 Ind/30m^2) and a mean species richness of 18.6 Spp/30m^2 (Table 18). The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 52.0 Ind/30m^2, representative of 45.5% of the total fish density. Schooling aggregations of creole wrasse (*Clepticus parrae*), blue chromis (*Chromis cyanea*), and tomtate (*Haemulon aurolineatum*) were also prominent with a combined density of 31.2 Ind/30m^2, representative of 27.3% of the total individuals within transects. In addition to masked goby, another three species were observed in all five belt-transects surveyed. These included the princess parrotfish (*Scarus taeniopterus*), yellowhead wrasse (*Halichoeres garnoti*) and beaugregory (*Stegastes leucostictus*). Motile megabenthic invertebrates were not observed within belt-transects.

Zooplanktivores (ZPL), comprised by the three top numerically dominant species (*Coryphopterus personatus*, *Clepticus parrae*, *Chromis cyanea*) were the main trophic component within belt-transects at TOUR30 during the 2025 survey with a combined density of 78.4 Ind/30m^2, representative of 68.7% of the total fish density (Table 18). A diverse assemblage of small opportunistic carnivores (SOC) were also prominent with 16 species and a combined density of 21.0 Ind/30m^2, or 18.4% of the total individuals. The assemblage included grunts (Haemulidae), wrasses (Labridae), basslets (Grammatidae), squirrelfishes (Holocentridae), gobies (Gobiidae), hamlets and seabasses (Serranidae), goatfishes (Mullidae), puffers (Tetraodontidae), and trumpetfishes (Aulostomidae).Herbivores (HER) were represented by parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with six species and a combined density of 11.0 Ind/30m^2, or 9.6% of the total individuals. Spongivores (*Pomacanthus* sp., *Holacanthus* spp.) and corallivores (*Chaetodon* spp.) were represented by five species and a combined density of 1.6 Ind/30m^2.

Table 18. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at TOUR30, Mayagüez. PRCRMP 2025

TOUR30							
Survey Date: 6/10/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	15	35	70	80	60	**52.0**	ZPL
Clepticus parrae	19			32	26	**15.4**	ZPL
Chromis cyanea	7	3	27	1	5	**8.6**	ZPL
Haemulon aurolineatum	30		5	1		**7.2**	SOC
Scarus taeniopterus	8	8	5	6	1	**5.6**	HER
Halichoeres garnoti	3	1	4	2	7	**3.4**	SOC
Thalassoma bifasciatum	2		5	3		**2.0**	SOC
Sparisoma aurofrenatum	2	7		1		**2.0**	HER
Stegastes leucostictus	2	1	2	1	3	**1.8**	HER
Haemulon flavolineatum	1	2	2		3	**1.6**	SOC
Gramma loreto	1	1	2	3		**1.4**	SOC
Myripristis jacobus	2	1	2		1	**1.2**	SOC
Chromis multilineata			4	2		**1.2**	ZPL
Acanthurus coeruleus		1	1	1	2	**1.0**	HER
Holocentrus rufus		4			1	**1.0**	SOC
Stegastes partitus			1	2	2	**1.0**	ZPL
Coryphopterus spp.				3	1	**0.8**	SOC
Chaetodon capistratus		2			1	**0.6**	COR
Cephalopholis cruentata		1	1	1	0	**0.6**	LC
Coryphopterus lipernes					3	**0.6**	SOC
Lutjanus synagris	1	1				**0.4**	LC
Pomacanthus arcuatus	2					**0.4**	SPO
Hypoplectrus puella		1	1			**0.4**	SOC
Pseudupeneus maculatus			1	1		**0.4**	SOC
Acanthurus tractus			1	1		**0.4**	HER
Mycteroperca venenosa	1					**0.2**	LC
Ocyurus chrysurus	1					**0.2**	LC
Chaetodon striatus	1					**0.2**	COR
Holacanthus ciliaris	1					**0.2**	SPO
Canthigaster rostrata	1					**0.2**	SOC
Epinephelus striatus		1				**0.2**	LC
Acanthurus chirurgus		1				**0.2**	HER
Aulostomus maculatus		1				**0.2**	SOC
Caranx ruber			1			**0.2**	LC
Holacanthus tricolor			1			**0.2**	SPO
Bodianus rufus				1		**0.2**	SOC
Hypoplectrus chlorurus				1		**0.2**	SOC
Epinephelus guttatus				1		**0.2**	LC
Canthidermis sufflamen					1	**0.2**	ZPL
Mulloidichthys martinicus					1	**0.2**	SOC
Balistes vetula					1	**0.2**	LC
Density (Ind/30m2)	**100**	**72**	**136**	**144**	**119**	**114.2**	
Richness (Species/30m2)	**19**	**18**	**19**	**20**	**17**	**18.6**	

Mid-size and large demersal carnivores included the Nassau, red hind, yellowfin, and graysbe groupers (*Epinephelus striatus, E. guttatus, Mycteroperca venenosa, Cephalopholis cruentata*), queen triggerfish (*Balistes vetula*), hogfish (*Lachnolaimus maximus*), yellowtail, schoolmaster and lane snappers *(Ocyurus chrysurus, Lutjanus apodus, L. synagris*), and bar jacks (*Caranx ruber*) with a combined density of 3.4 Ind/60m^2 (Table 19). Juvenile and adult parrotfishes (*Sparisoma spp, Scarus sp*), and doctorfishes (*Acanthurus spp.*) comprised the main large reef herbivore taxa with mean combined densities of 7.4 and 2.6 Ind/60m^2, respectively (Table 19).

Table 19. Size-frequency distributions of commercially important fishes observed within 20 x 3m belt-transects at TOUR30, Mayagüez. PRCRMP 2025

TOUR30							
Survey Date: 6/10/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	2-12, 2-15	1	2	1			Juvenile
Acanthurus coeruleus c4	4-16, 2-17, 18	1	1	1	2	2	Adult
Acanthurus tractus c3	15, 12			1	1		Juvenile
Balistes vetula c8	40					1	Adult
Caranx ruber c5	21			1			Adult
Cephalopholis cruentata c2	10, 9			1	1		Juvenile
Cephalopholis cruentata c4	16, 20		1	1			Adult
Epinephelus guttatus c8	36				1		Adult
Epinephelus striatus c10	46		1				Adult
Epinephelus striatus c12	60					1	Adult
Lachnolaimus maximus c10	48				1		Adult
Lutjanus apodus c8	40	1					Adult
Lutjanus synagris c2	10		1				Juvenile
Lutjanus synagris c4	20	1					Adult
Mycteroperca venenosa c10	46	1					Adult
Mycteroperca venenosa c11	55					1	Adult
Ocyurus chrysurus c5	25	1					Adult
Ocyurus chrysurus c6	28					1	Adult
Scarus taeniopterus c2	5-6, 6-8, 8-10	8		6	5		Juvenile
Scarus taeniopterus c3	15, 12			1	1		Juvenile
Scarus taeniopterus c4	18					1	Terminal
Scarus taeniopterus c5	25		1				Terminal
Sparisoma aurofrenatum c2	4-8, 6		5				Juvenile
Sparisoma aurofrenatum c3	12, 15		2				Juvenile
Sparisoma aurofrenatum c4	2-18	1			1		Adult
Sparisoma aurofrenatum c5	22, 23			1	1		Terminal
Sparisoma viride c5	25				1		Adult
Sparisoma viride c6	26		1				Adult
Sparisoma viride c7	33					1	Terminal
	Totals	**15**	**15**	**14**	**15**	**8**	

Annual fluctuations of mean fish density and species richness are shown in Figure 21. Differences of fish density and species richness between monitoring surveys were statistically significant (ANOVA; $p < 0.0001$, Appendices 5 and 6). Density was higher during the survey period of 2005 - 2008, and again in 2011, relative to 2012, and the 2017 - 2023 survey period. In all cases, differences were largely driven by density fluctuations of masked goby (*Coryphopterus personatus*), which is a schooling species numerically dominant within belt-transects. Declining densities of masked goby after 2017 may have been influenced by the extremely strong wave action, along with associated surge and scouring effects caused by the pass of hurricane Maria in 2017, and/or winter storm Riley in 2018. Given the numerical prominence of masked goby as a potential forage species, relevant cascading effects associated with the sharp density fluctuations of this species may be influencing the temporal pattern of fish species richness at TOUR 30. During 2025, mean fish density (114.2 Ind/30m2) increased 2.73-fold relative to the previous 2023 survey, strongly influenced by a weak pulse of abundance of masked goby, but still within the lower density range of previous surveys (Figure 21).

Fluctuations of fish species richness appeared to be influenced by variable physical conditions at the time of surveys, particularly during and after extreme climatological events, such as hurricanes (Irma and Maria in 2027) and winter storm Riley (in 2018) due to advective and turbulent forces acting upon small water column species. During the 2025 survey, mean species richness increased 31.0% relative to the previous survey despite massive losses of live coral cover at TOUR30. This suggests that the remaining topographic relief from the coral buildup, and the habitat complexity contributed by sponges, erect soft corals, and benthic algae still function as a critical habitat for reef fishes.

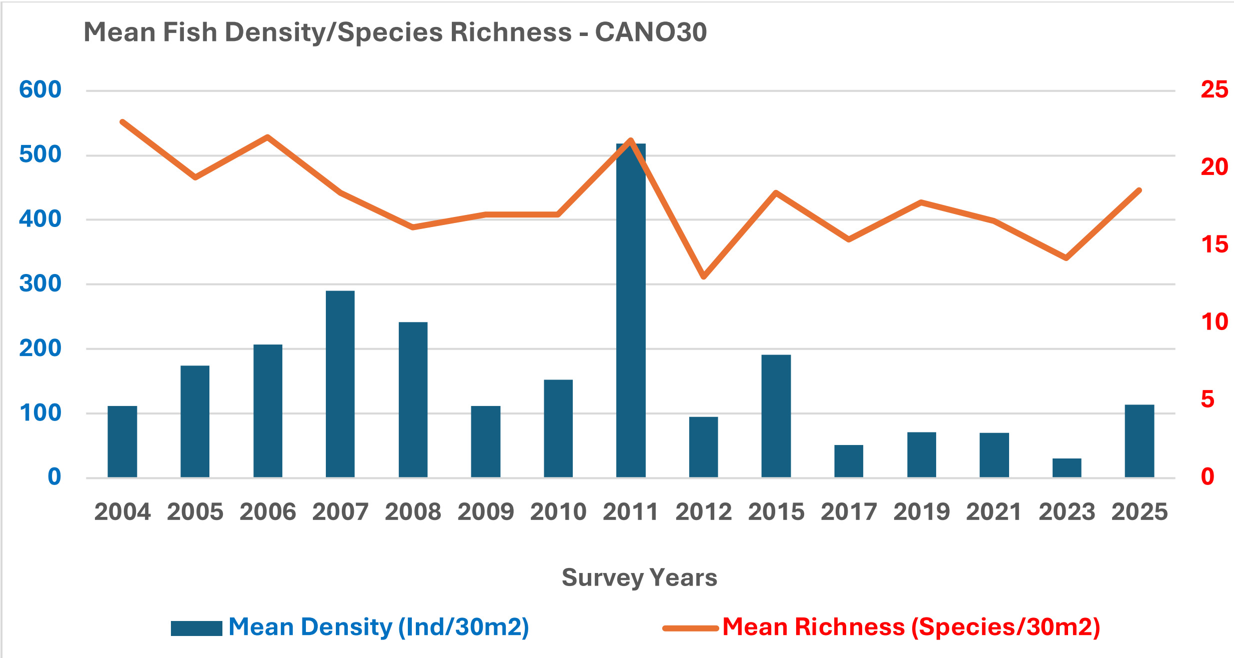
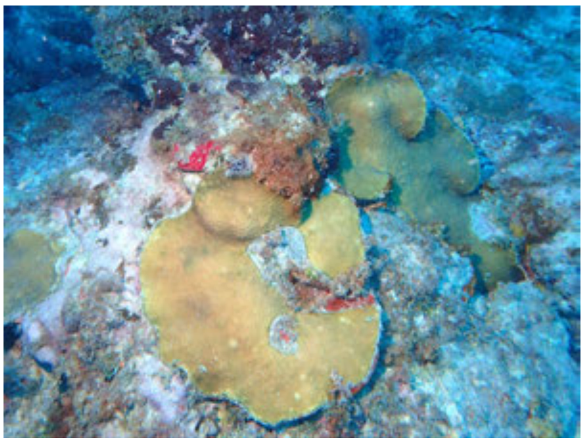


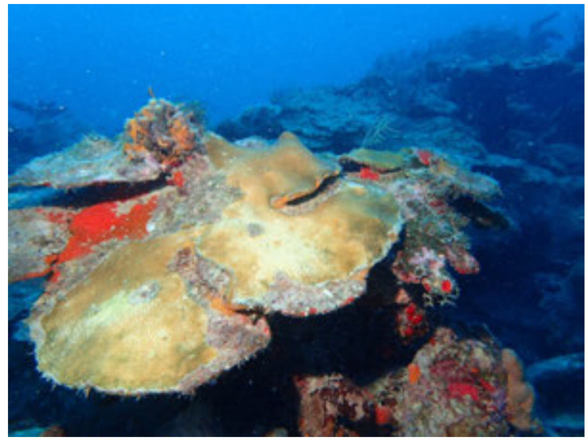
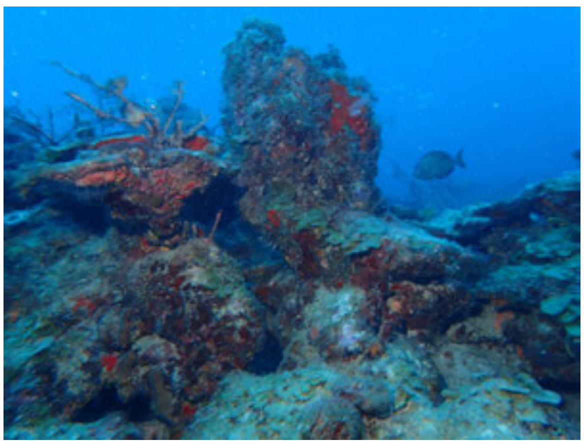
Figure 21. Monitoring trends (2004 – 2025) of mean fish density and species richness at TOUR30, Mayagüez. PRCRMP 2025

Photo Album 6. TOUR30








7.0 Puerto Botes Reef 15m, Isla Desecheo (BOTE15)

7.1 Physical Description

Isla Desecheo is an oceanic island in Mona Passage, located approximately nine nautical miles due west off Rincón, northwest coast of Puerto Rico (Figure 22). The island, which used to be a U. S. Navy shooting range during the Second World War, was designated as a Natural Reserve in 1999. Marine communities at Isla Desecheo are influenced by clear waters, strong currents, and seasonally high wave action from North Atlantic winter swells.

The rocky shoreline off Puerto Botes leads to a gently sloping hard ground terrace colonized by corals and other encrusting biota. With increasing depth, the hard ground terrace breaks into several large promontories with a marked increment of stony coral buildup. The southern section of the terrace presents a more abrupt slope from the shoreline towards deeper waters and is heavily colonized by soft corals. The baseline characterization of BOTE15 was performed in August 2004. Five permanent transects were installed along the northern section almost parallel to each other oriented north-south at depths of 13.6 – 14.5m. Panoramic views of the coral reef community at BOTE15 during the 2025 survey are presented in Photo Album 7.

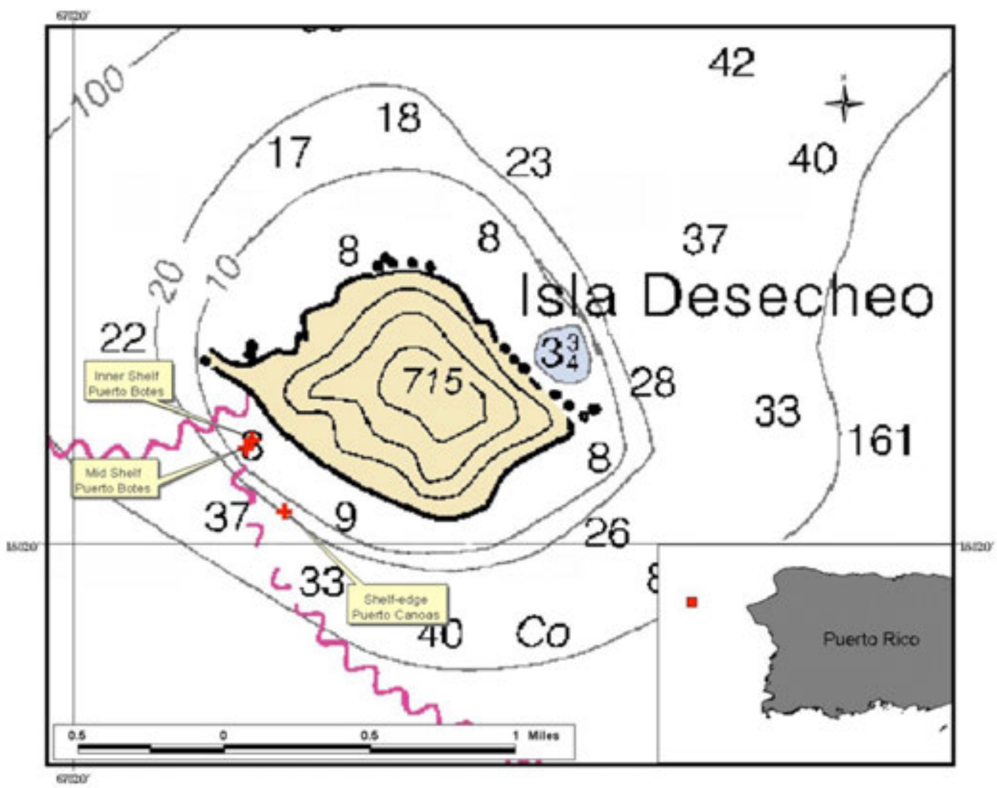


Figure 22. Location of coral reef survey stations at Puerto Botes (BOTE15, BOTE20), and Puerto Canoas (CANO30), Isla Desecheo. PRCRMP 2025

7.2 Sessile-benthic Reef Community

Benthic algae, comprised by a mixed assemblage of turf (mixed), fleshy brown, red coralline (CCA, mixed), and red crustose macroalgae were the main sessile-benthic category at BOTE15 during the 2025 monitoring survey with a combined mean reef substrate cover of 81.39% (range: 76.33 – 85.66%). Fleshy brown macroalgae, comprised by *Dictyota sp, Lobophora sp*. and *Stypopodium sp*. were the dominant component of the benthic algae with a combined mean cover of 52.62%, representative of 64.6% of the total cover by benthic algae (Table 20). Turf algae, a mixed assemblage of short articulated brown and red algae were intercepted by all transects with a mean cover of 24.76%, representative of 30.4% of the total cover by benthic algae. Encrusting patches of red crustose (*Peyssonnelia* sp., *Ramicrusta* sp.), and coralline algae (CCA, mixed assemblage) were present in four and three transects, respectively with a combined mean cover of 3.97%. Cyanobacterial patches were present with a mean substrate cover of 0.31%.

A total of six stony corals, including one hydrocoral (*Millepora alcicornis*) were intersected by transects at BOTE15 during the 2025 monitoring survey (Table 20). Mean reef substrate cover by the total stony coral assemblage was 3.09% (range: 0.81 – 5.92%). Mustard-hill coral (*Porites astreoides*) was the dominant species with a mean cover of 2.32%, representative of 75.1% of the total cover by stony corals and the only species intercepted by all five transects. Colonies typically exhibited encrusting growth and small to moderate sizes, perhaps as adaptations to the strong wave and surge action seasonally acting at the shallower reef zone of Isla Desecheo. A total of 24 stony coral colonies were intercepted, none of which were observed to be affected by coral disease infections. (Appendix 2).

Sponges were a prominent component of the reef benthos at BOTE15 with substantial contributions to the reef topographic relief and structural habitat complexity. A total of 19 species were intercepted by transects with a mean substrate cover of 10.31% (Table 20). The giant basket sponge (*Xestospongia muta)* was the dominant taxa in terms of ref substrate cover with a mean cover of 1.89%, representative of 18.3% of the total cover by sponges and the main contributor of topographic relief at BOTE15. The *Agelas* spp. assemblage included three species with a combined mean cover of 2.13%, or 20.6% of the total cover by sponges. Reef substrate cover by abiotic categories averaged 4.92%, contributed by reef overhangs and sand patches. The mean rugosity was 3.45m.

Table 20. Percent reef substrate cover by sessile-benthic categories at BOTE15, Isla Desecheo. PRCRMP. 2025

BOTE15			**Transects**			
Survey date: 5/23/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**14.5**	**14.2**	**14.5**	**14.2**	**13.6**	**14.20**
Rugosity (m)	3.72	3.86	3.92	2.05	3.68	**3.45**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	3.88	3.74	2.52	5.92	4.81	**4.17**
Sand				3.72		**0.74**
Total Abiotic	**3.88**	**3.74**	**2.52**	**9.64**	**4.81**	**4.92**
Benthic Algae						
Dictyota spp.	25.10	30.30	20.42	36.59	22.42	**26.97**
Lobophora spp.	10.82	13.74	33.70	28.80	26.41	**22.69**
Turf (mixed)	15.41	15.76	19.22	5.57	12.08	**13.61**
Turf (mixed) with sediment	21.22	20.91	1.01	10.57	2.05	**11.15**
Stypopodium spp.	3.78	3.74	5.03	0.81	1.43	**2.96**
CCA (total)		0.81	1.31		10.44	**2.51**
Peyssonnelia spp.			0.60	1.28	2.66	**0.91**
Ramicrusta spp.		0.40			2.35	**0.55**
Jania spp.			0.20			**0.04**
Total Benthic Algae	**76.33**	**85.66**	**81.49**	**83.62**	**79.84**	**81.39**
Cyanobacteria	**0.00**	**0.00**	**0.50**	**0.00**	**1.02**	**0.31**
Stony Coral						
Porites astreoides	3.57	1.82	4.12	0.23	1.84	**2.32**
Siderastrea siderea	1.43	0.20	0.30			**0.39**
Millepora alcicornis	0.71					**0.14**
Orbicella faveolata				0.58		**0.12**
Stephanocoenia intersepta	0.20				0.20	**0.08**
Pseudodiploria strigosa		0.20				**0.04**
Total Stony Coral	**5.92**	**2.22**	**4.43**	**0.81**	**2.05**	**3.09**
# Coral Colonies/Transect	**6**	**3**	**7**	**3**	**5**	**4.80**
#Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
# Erect Soft Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
Sponges						
Xestospongia muta	1.22		8.25			**1.89**
Ircinia campana	3.98				4.09	**1.61**
Aiolochroia crassa	4.80	2.53				**1.46**
Agelas citrina			1.91	1.74	1.84	**1.10**
Agelas conifera				0.35	3.79	**0.83**
Aplysina cauliformis	2.24	0.20	0.30	0.23		**0.60**
Svenzea zeai				2.67		**0.53**
Verongula reiswigi		2.53				**0.51**
Aplysina insularis	1.02	0.71				**0.35**
Neopetrosia spp. smooth	0.31		0.60		0.51	**0.28**
Agelas spp.					1.02	**0.20**
Cinachyrella kuekenthali		1.01				**0.20**
Ircinia strobilina					0.82	**0.16**
Petrosia pellasarca		0.71				**0.14**
Smenospongia aurea		0.71				**0.14**
Biemna caribea				0.58		**0.12**
Ptilocaulis walpersii				0.35		**0.07**
Spirastrella coccinea	0.31					**0.06**
Sponge spp.					0.20	**0.04**
Total Sponges	**13.88**	**8.38**	**11.07**	**5.92**	**12.28**	**10.31**

Figure 23 presents the variations of the mean substrate cover by sessile-benthic categories between monitoring surveys at BOTE15. Reef substrate cover by stony corals, sponges and benthic algae remained virtually stable between the 2004 baseline and the 2005 monitoring survey. Differences during 2005 were all within 1% of the baseline and statistically insignificant (García-Sais et al., 2005a). A reduction 49.2% of mean stony coral cover, from 19.5% in 2005 to 9.9% was measured in the 2006 monitoring event. Corresponding increments of substrate cover by benthic algae and abiotic categories were also recorded. An additional decline of 17.3% of mean stony coral cover was measured during the 2007 survey. An increasing trend of coral cover, influenced by increments of cover by *Orbicella spp.* (complex) and *P. astreoides* were measured (Figure 24) during the period between 2010 - 2015, but differences were not statistically significant. The increasing trend of stony coral cover ended in 2018 with a 28.6% decline that may have been influenced by effects of Hurricane Maria in 2017, and/or winter storm Riley in 2018.

The historical decline of stony coral cover at BOTE15 was largely associated with a reduction of cover by the previously dominant species complex of *Orbicella spp.* which collapsed from a mean of 11.5% in 2005 to a mean of 2.6% in 2006 (Figure 24). Additional declines of substrate cover down to a minimum of 1.5% were measured for *O. annularis* complex until the 2009 survey. During the period between 2010 to 2018, mustard-hill coral (*Porites astreoides*) was the dominant stony coral species in terms of reef substrate cover at BOTE15 which implied a taxonomic phase shift of the sessile-benthic community structure. Reef substrate cover by stony corals declined 17.0% in 2021, relative to the mean cover in 2018. The difference was largely associated with the marked decline of cover (55.4%) by mustard-hill coral (*Porites astreoides*) that may have been influenced by a strong coral bleaching event that affected coral communities in Puerto Rico since October 2019. Coral bleaching down to a depth of 50m was reported by Garcia-Sais et al. (2020b). The massive, statistically significant reductions (ANOVA; $p < 0.0001$, see Appendix 3) of reef substrate cover by stony corals measured since the 2015 survey until the most recent 2025 survey have resulted in an overall decline of -83.9% of mean cover relative to the 2004 baseline. Given the high prevalence of infectious coral diseases (10.34%) measured from BOTE15 during the 2021 survey (Garcia-Sais et al., 2022) it is here suggested that such diseases, perhaps influenced by the bleaching conditions that started in 2019 and were exacerbated by the 2023 global coral bleaching event (Goreau and Hayes, 2024) stand as the main factor of stony coral cover loss. Loss of reef substrate cover by stony corals has been replaced by an overall increase of 27.4% of cover by benthic algae and a1.9-fold increase of cover by sponges.

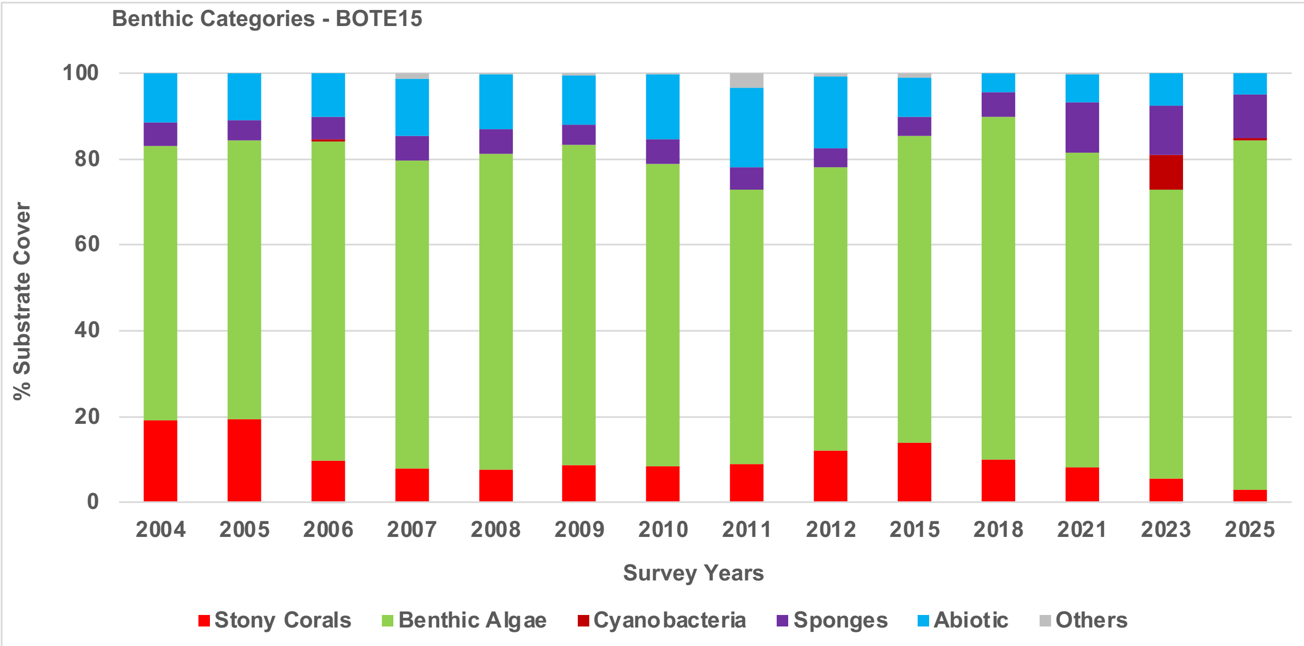


Figure 23. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at BOTE15, Isla Desecheo. PRCRMP 2025

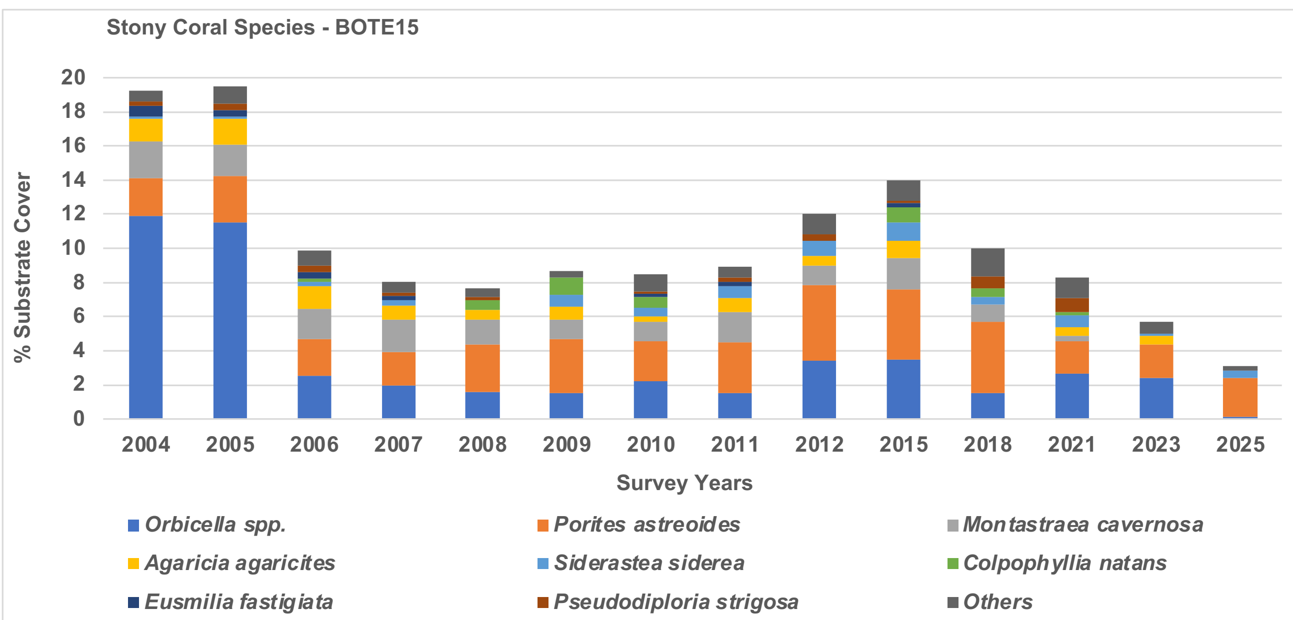


Figure 21. Monitoring trends (2004 – 2025) of mean substrate cover by stony coral species at BOTE15, Isla Desecheo. PRCRMP 2025

7.3 Fishes and Motile Megabenthic Invertebrates

A total of 34 fish species were identified within belt-transects from BOTE15 during the 2025 monitoring survey with a mean fish density of 329.0 Ind/30m^2 (range: 142 - 629 Ind/30m^2), and a mean species richness of 17.0 Spp/30m^2 (range: 12 - 22 Spp/30m^2) (Table 21). Fish density was strongly influenced by large schools of recruitment juvenile creole wrasse (*Clepticus parrae*) swarming over the reef within two belt-transects, contributing a mean density of 180.0 Ind/30m^2, representative of 54.7% of the total density. Six species were observed in all five transects with a combined mean density of 126.2 Ind/30m^2, representative of 38.4% of the total fish density. The assemblage included the bluehead wrasse (*Thalassoma bifasciatum*), blue chromis (*Chromis cyanea*), bicolor damselfish (*Stegastes partitus*), coney (*Cephalopholis fulva*), and redband parrotfish (*Sparisoma aurofrenatum*). Motile megabenthic invertebrates were not observed within belt-transects (Table 21).

The fish trophic structure at BOTE15 was dominated in terms of fish density by zooplanktivores (ZPL) represented within belt-transects by three out of the four numerically dominant species with a combined density of 244.2 Ind/30m^2, representative of 74.2% of the total individuals (Table 21). The ZPL assemblage was largely driven by the mean density of juvenile creole wrasse (*Clepticus parrae*), with additional strong contributions by blue chromis (*Chromis cyanea*), and bicolor damselfish (*Stegastes partitus*), and lesser contributions of brown chromis (*C. multilineata*), and sergeant major (*Abudefduf saxatilis*).

Small opportunistic carnivores (SOC) were also prominent with 16 species and a combined density of 73.4 Ind/30m^2, or 22.3% of the total fish density. The assemblage included four species of wrasses (Labridae), one basslet (Grammatidae), two gobies (Gobiidae), two small seabasses (Serranidae), two squirrelfishes (Holocentridae), one puffer (Tetraodontidae), two box fishes (Ostraciidae), two triggerfishes (Balistidae), and one drum (Sciaenidae). Herbivores (HER) were comprised by seven species, including parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with a combined density 7.2 Ind/30m^2, representative of 2.2% of the total individuals. Spongivores were represented by the tail-light filefish (*Cantherhines macrocerus*) with a mean density of 0.2 Ind/30m^2.

Table 21. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at BOTE15, Isla Desecheo. PRCRMP 2025

BOTE15							
Survey Date: 5/23/25	**Belt-Transects (3 x 10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Clepticus parrae			400		500	**180.0**	ZPL
Thalassoma bifasciatum	62	45	30	40	11	**37.6**	SOC
Chromis cyanea	18	20	42	44	37	**32.2**	ZPL
Stegastes partitus	38	39	33	23	22	**31.0**	ZPL
Halichoeres garnoti	25	21	15	25	17	**20.6**	SOC
Halichoeres maculipinna	5		6	6		**3.4**	SOC
Gramma loreto				2	14	**3.2**	SOC
Coryphopterus spp.	12			3		**3.0**	SOC
Sparisoma aurofrenatum	1	4	3	3	2	**2.6**	HER
Cephalopholis fulva	1	5	2	2	1	**2.2**	LC
Scarus iseri			1	2	5	**1.6**	HER
Bodianus rufus	2		2		3	**1.4**	SOC
Sparisoma atomarium	3			2		**1.0**	HER
Serranus baldwini	1	2			1	**0.8**	SOC
Acanthurus chirurgus		1	1	1	1	**0.8**	HER
Microspathodon chrysurus			2		2	**0.8**	HER
Chromis multilineata			4			**0.8**	ZPL
Acanthurus coeruleus	1	1	1			**0.6**	HER
Cephalopholis cruentata		1	1		1	**0.6**	SOC
Elacatinus evelynae		2			1	**0.6**	SOC
Myripristis jacobus				1	2	**0.6**	SOC
Xanthichthys ringens	1				1	**0.4**	SOC
Holocentrus rufus	1			1		**0.4**	SOC
Canthigaster rostrata	1		1			**0.4**	SOC
Lactophrys triqueter			1	1		**0.4**	SOC
Sparisoma viride			1		1	**0.4**	HER
Sphyraena barracuda	1					**0.2**	LC
Serranus tigrinus		1				**0.2**	SOC
Acanthostracion polygonius			1			**0.2**	SOC
Cantherhines macrocerus				1		**0.2**	SPO
Lutjanus apodus					1	**0.2**	LC
Abudefduf saxatilis					1	**0.2**	ZPL
Equetus punctatus					1	**0.2**	SOC
Kyphosus spp.					1	**0.2**	LC
Density (Ind/30m2)	**173**	**142**	**547**	**157**	**626**	**329.0**	
Richness (Species/30m2)	**16**	**12**	**19**	**16**	**22**	**17.0**	

Mid-sized and large demersal and pelagic predators observed within 3m x 20m belt-transects included 13 coneys (*Cephalopholis fulva*), three graysbys (*C. cruentata*), two schoolmaster snappers (*Lutjanus apodus*), one red hind (*Epinephelus guttatus*), one great barracuda (*Sphyraena barracuda*), and one cero mackerel (*Scomberomorus regalis*) with a combined density of 4.2 Ind/60m^2 (Table 22). Yellowtail snappers (*Ocyurus chrysurus*), nurse sharks (*Ginglymostoma cirratum*), green morays (*Gymnothorax funebris*), and African pompanos (*Alectis ciliaris*) represent other large demersal and/or pelagic predators previously reported from BOTE15 (Garcia-Sais et al., 2023 and references therein).

Table 22. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at BOTE15, Isla Desecheo. PRCRMP 2025

BOTE15							
Survey Date: 5/23/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	2-14, 12, 3-15		1	3	1	1	Juvenile
Acanthurus chirurgus c4	18				1		Adult
Acanthurus coeruleus c3	15			1			Juvenile
Acanthurus coeruleus c4	20, 18, 16	1	1		1		Adult
Cephalopholis cruentata c4	18		1				Adult
Cephalopholis cruentata c5	23, 22			1		1	Adult
Cephalopholis fulva c2	10				1		Juvenile
Cephalopholis fulva c3	2-12, 2-15		1		1	2	Juvenile
Cephalopholis fulva c4	18, 20		2				Adult
Cephalopholis fulva c5	2-25, 22, 21, 23	1	2	2			Adult
Cephalopholis fulva c6	28	1	1				Adult
Epinephelus guttatus c7	34		1				Adult
Lutjanus apodus c7	35					1	Adult
Lutjanus apodus c8	40					1	Adult
Scarus iseri c2	8-10, 8	3		1	1	4	Juvenile
Scarus iseri c3	12				1	1	Juvenile
Scarus iseri c4	19, 20			1	1		Adult
Scarus iseri c5	25, 23			2			Terminal
Scomberomorus regalis c10	50		1				Adult
Sparisoma aurofrenatum c1	4, 7-5	1	3	3	1		Recruit
Sparisoma aurofrenatum c2	8		1				Juvenile
Sparisoma aurofrenatum c3	2-12, 13, 14				2	2	Juvenile
Sparisoma aurofrenatum c4	20					1	Adult
Sparisoma aurofrenatum c5	25				1		Terminal
Sparisoma rubripinne c7	33	1					Adult
Sparisoma spp. (juv)	3-3, 2-4	3			2		Recruit
Sparisoma viride c2	9, 6			1		1	Juvenile
Sparisoma viride c6	30					1	Adult
Sparisoma viride c7	32					1	Adult
Sphyraena barracuda c10	46	1					Adult
	Totals	**12**	**15**	**15**	**14**	**17**	

The size distribution of midsize and large predators included both juvenile and adult stages for coneys (*Cephalopholis fulva*). Early juvenile stages of both coneys and graysbys (C. cruentata) have been reported in previous surveys (Garcia-Sais et al., 2923) indicative that recruitment habitats for these species are available at BOTE15. The large herbivore fish assemblage at BOTE15 was numerically dominated by parrotfishes (*Sparisoma* spp*.,* *Scarus* spp.) with a combined density of 7.8 Ind/60m^2. Recruitment (1-5cm), juvenile, and adult stages of several parrotfish species (*Sparisoma spp., Scarus spp*.) were observed within belt-transects during this and previous surveys (Garcia-Sais et. al. 2022 and references therein), indicative that BOTE15 is the recruitment and residential habitat for these species throughout their life history. Likewise, both early juvenile and adult stages of doctorfishes (*Acanthurus coeruleus, A. chirurgus, A. tractus*) were previously reported (Garcia-Sais et. al. 2018), indicative that BOTE15 is also functioning as a residential habitat for doctorfishes (*Acanthurus spp*.) throughout most of their life cycles.

Annual monitoring trends of fish density and species richness surveyed within 3m x 10m belt-transects are presented in Figure 25. Statistically significant differences between monitoring surveys for both fish density (ANOVA, $p < 0.001$; Appendix 5), and species richness (ANOVA, $p < 0.001$; Appendix 6) were found. Higher density was observed during 2005 and 2006, relative to 2010, 2018, and 2021. Density differences were driven by relatively higher densities of small water-column species with aggregated distributions, such as blue chromis (*Chromis cyanea*), and bluehead wrasse (*Thalassoma bifasciatum*). The lower densities of these species may be related to lingering effects of the physical disturbances affecting reef habitats at Isla Desecheo during the pass of Hurricane Maria in 2017 and/or winter storm Riley in 2018. Mean fish density during 2025 increased 2.54-fold relative to the previous 2023 and now stands as the peak mean density fish surveyed from BOTE15 (Figure 25). Mean fish species richness increased 7.6% relative to the previous 2023 survey. The increments of density and richness is indicative of a bold recuperation of the fish community at BOTE 15 after the sharp declines measured after the pass of Hurricanes Irma and Maria in 2017 and winter storm Riley in 2018. Such recuperation occurs amidst massive declines of live coral cover, suggesting that the fish community structure may be adapting to a different benthic habitat structure dominated by algae and sponges at BOTE15.

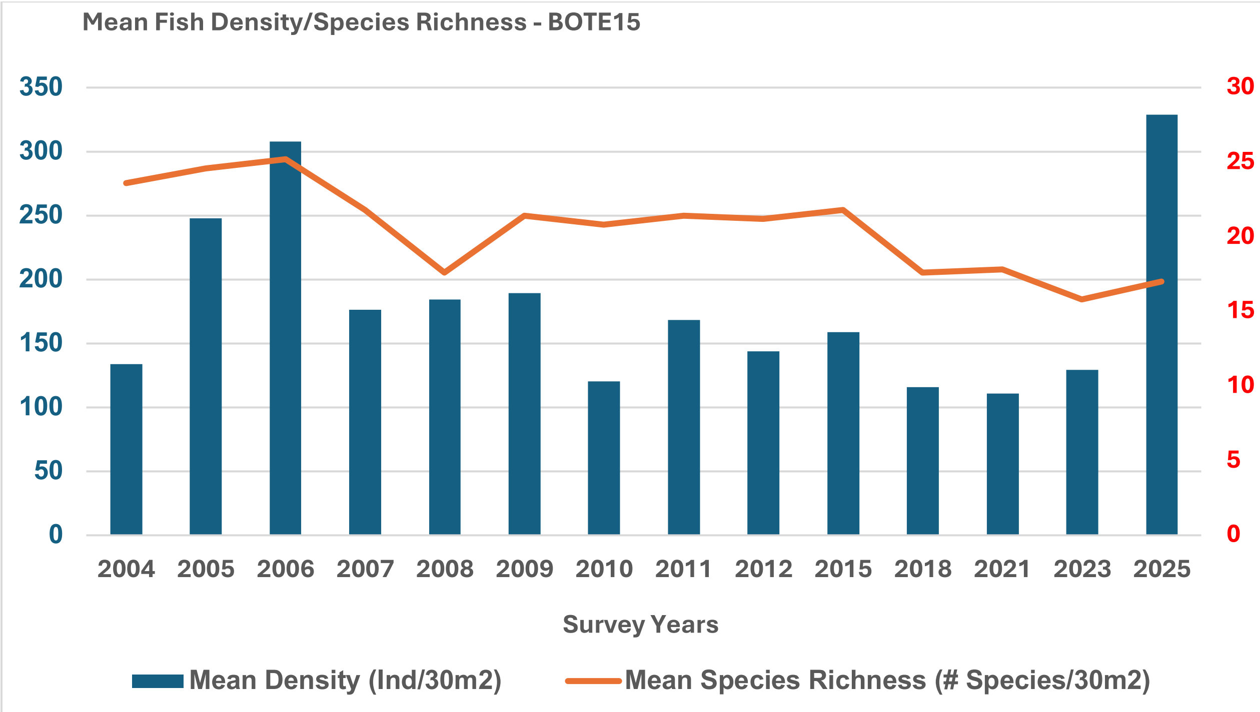
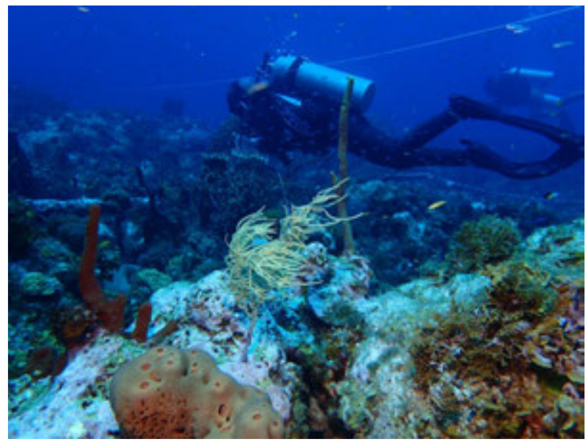


Figure 25. Monitoring trends (2004 – 2025) of mean fish density and species richness within 10m x 3m belt-transects at BOTE15, Isla Desecheo. PRCRMP 2025

Photo Album 7. BOTE15





8.0 Puerto Botes Reef 20m, Isla Desecheo (BOTE20)

8.1 Physical Description

A series of large, submerged reef patches of massive, branching, and encrusting coral buildup occupy most of the mid-shelf section off BOTE20 at depths between 17 - 23m on the west coast of Isla Desecheo (Figure 22). The coral reef system is exuberant, with large stony corals growing close together and forming large promontories that provide very high topographic relief. At some points, sand channels cut through the sloping terrace of the reef towards the shelf-edge. Permanent transects were installed over two adjacent patch reef promontories separated by a narrow sand channel. The five transects lie close to the border of each patch reef at depths between 17 -19m. The initial baseline characterization was performed in June 2000 (García-Sais et al., 2001b). Digital photos of the reef community at BOTE20 are shown in Photo Album 8.

8.2 Sessile-benthic Reef Community

Benthic algae, comprised by a mixed assemblage of fleshy brown, turf (mixed), and red coralline and crustose algae were the dominant sessile-benthic category covering reef substrate at BOTE20 during the 2023 survey with a combined mean cover of 83.24% (range: 78.52 – 86.61%). Brown fleshy macroalgae, including encrusting fan alga (*Lobophora sp.*), y-twig alga (*Dictyota sp*.), and leafy flat blade alga (*Stypopodium sp*.) were the dominant assemblage with a combined cover of 49.28%, representative of 59.2% of the total benthic algae (Table 23). Turf algae including sections packed with fine sediments were intercepted by all transects as a dense carpet overlying dead coral and other hard ground reef sections with a mean cover of 27.11%, representative of 32.6% of the total benthic algae. Red crustose coralline algae, including Peyssonnelid and other mixed crustose coralline algae (CCA mixed) were also present with a combined cover of 6.76%.

Stony corals were represented in transects by five species of scleractinians during the 2025 survey at BOTE20 with a mean reef substrate cover of 1.49% (range: 0 – 4.12%). Great star (*Montastraea cavernosa*), and mustard-hill corals (*Porites astreoides*) were the main coral species in terms of ref substrate cover with means of 0.57% and 0.49%, respectively. Reef substrate cover by finger coral (*P. porites*), the dominant species in the previous 2023 survey was intercepted in one transect with an overall mean cover of 0.07%. A total of 11 stony coral colonies were intercepted by transects, none of which were observed to be affected by coral disease infections (see Appendix 2).

Table 23. Percent reef substrate cover by sessile-benthic categories at BOTE20, Isla Desecheo. PRCRMP 2025

BOTE20			**Transects**			
Survey date: 5/23/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**17.3**	**17.5**	**17.3**	**17.6**	**17.6**	**17.46**
Rugosity (m)	3.41	4.11	4.53	2.24	2.24	**3.31**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	9.60	6.65	11.75	4.23	0.46	**6.54**
Sand					1.14	**0.23**
Total Abiotic	**9.60**	**6.65**	**11.75**	**4.23**	**1.60**	**6.77**
Benthic Algae						
Lobophora spp.	30.69	26.59	35.65	40.85	32.95	**33.34**
Turf (mixed)	26.10	29.37	30.15	16.82	19.22	**24.33**
Dictyota spp.	17.01	20.24	6.45	10.98	18.65	**14.67**
CCA (total)	5.64	4.27	2.60	13.27	3.20	**5.80**
Turf (mixed) with sediment	1.77			4.23	7.89	**2.78**
Stypopodium spp.		1.98	3.08		1.26	**1.27**
Peyssonnelia spp.	0.21	0.99	0.58	0.46	0.23	**0.49**
Ramicrusta spp.	0.52	0.89			0.92	**0.47**
Jania spp.					0.46	**0.09**
Total Benthic Algae	**81.94**	**84.33**	**78.52**	**86.61**	**84.78**	**83.24**
Cyanobacteria	**0**	**0**	**0**	**0**	**0**	**0.09**
Stony Coral						
Montastraea cavernosa					2.86	**0.57**
Porites astreoides		0.69	0.39	0.80	0.57	**0.49**
Orbicella faveolata		0.40		0.69		**0.22**
Stephanocoenia intersepta				0.34	0.34	**0.14**
Porites porites					0.34	**0.07**
Total Stony Coral	**0**	**1.09**	**0.39**	**1.83**	**4.12**	**1.49**
# Coral Colonies/Transect	**0**	**3**	**1**	**3**	**4**	**2.20**
#Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
# Erect Soft Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
Sponges						
Agelas sceptrum		5.16	3.28	1.95		**2.08**
Agelas conifera		0.50	2.70	1.14	2.17	**1.30**
Agelas citrina	0.42	0.30	1.93	1.83	0.80	**1.05**
Ircinia campana	4.80					**0.96**
Amphimedon compressa					2.29	**0.46**
Neopetrosia spp. smooth	0.94			0.23		**0.23**
Agelas spp.		0.40	0.29	0.34		**0.21**
Cinachyrella kuekenthali		0.99				**0.20**
Agelas clathrodes			0.96			**0.19**
Petrosia pellasarca					0.80	**0.16**
Agelas dispar				0.69		**0.14**
Aplysina fistularis		0.30		0.23		**0.11**
Aiolochroia crassa	0.52					**0.10**
Agelas sventres				0.46		**0.09**
Topsentia ophiraphidites					0.34	**0.07**
Aplysina cauliformis		0.30				**0.06**
Mycale laevis	0.21					**0.04**
Sponge spp.			0.19			**0.04**
Total Sponges	**6.89**	**7.94**	**9.34**	**6.86**	**6.41**	**7.49**

A total of 18 species of branching, basket, and encrusting sponges were intercepted by transects with a mean substrate cover of 7.49% (Table 23). Tube sponges, *Agelas sceptrum A. conifera, A. citrina, A. clathrodes, A. sventres*, and *A. dispar* comprised the main assemblage with a combined cover of 5.06%, or 67.6% of the total cover by sponges. Reef overhangs largely associated with (dead) skeletal buildups of *Orbicella spp.* and other massive coral species were the main contribution to the total abiotic category with a mean cover of 6.54%, or 96.6% of the total abiotic cover and contributed markedly to the reef rugosity of 3.31m (Table 23).

During the period between the baseline characterization of 2000 until the 2005 survey, stony corals represented the most prominent sessile-benthic component at BOTE20 with a mean reef substrate cover that fluctuated slightly between 47.2 - 48.0% (Figure 26). Differences of stony coral cover between monitoring surveys were minimal and statistically insignificant until the 2006 monitoring survey when coral cover declined sharply to a mean of 22.4%, a loss of 52.4% from the mean cover in 2005. Stony coral cover continued its consistent decline until 2013 to a historical minimum of 10.9%. Differences of live coral between the 2000 – 2005 and the 2006 – 2015 monitoring surveys were statistically significant (ANOVA; $p < 0.001$, Appendix 3) reflecting the acute degradation experienced by the reef system after 2005.

The downfall of stony coral cover at BOTE20 was triggered by the regional coral bleaching event that affected Puerto Rico and the USVI during late September through October 2005 (García-Sais et al., 2006; Miller et al., 2006, 2009; Hernandez-Delgado et al., 2006; Eakin et al., 2010), with lingering effects that carried further decline of cover until the 2013 monitoring survey. The bleaching event affected several coral species in variable magnitude at BOTE20 but was mostly detrimental to the dominant species in terms of substrate cover, the *Orbicella spp* complex, particularly *O. faveolata* (Figure 27). This species complex declined in substrate cover from a mean of 25.2% in 2005 to a mean of 1.2% in 2009, a highly significant reduction (ANOVA; $p < 0.001$). Due to the marked decline of the *Orbicella spp*. complex, finger coral (*Porites porites*) became the dominant species in terms of substrate cover by stony corals at BOTE20 until 2015, which implied a taxonomic phase-shift of the reef sessile-benthic community structure. Benthic algae, seemingly the fastest growing component of the sessile benthos at BOTE20 increased its substrate cover by 119.7% between the 2000 baseline survey and the present 2025 monitoring survey (Figure 26), mostly by colonizing dead coral sections.

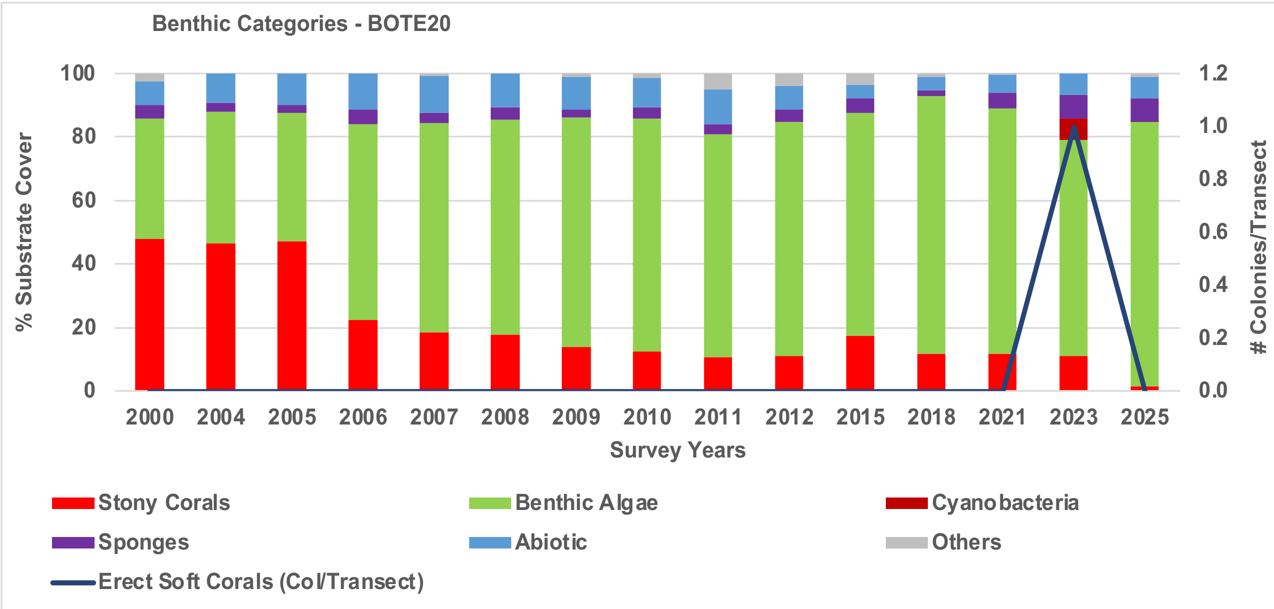


Figure 26. Monitoring trends (2000 – 2025) of mean substrate cover by sessile-benthic categories at BOTE20, Isla Desecheo. PRCRMP 2025

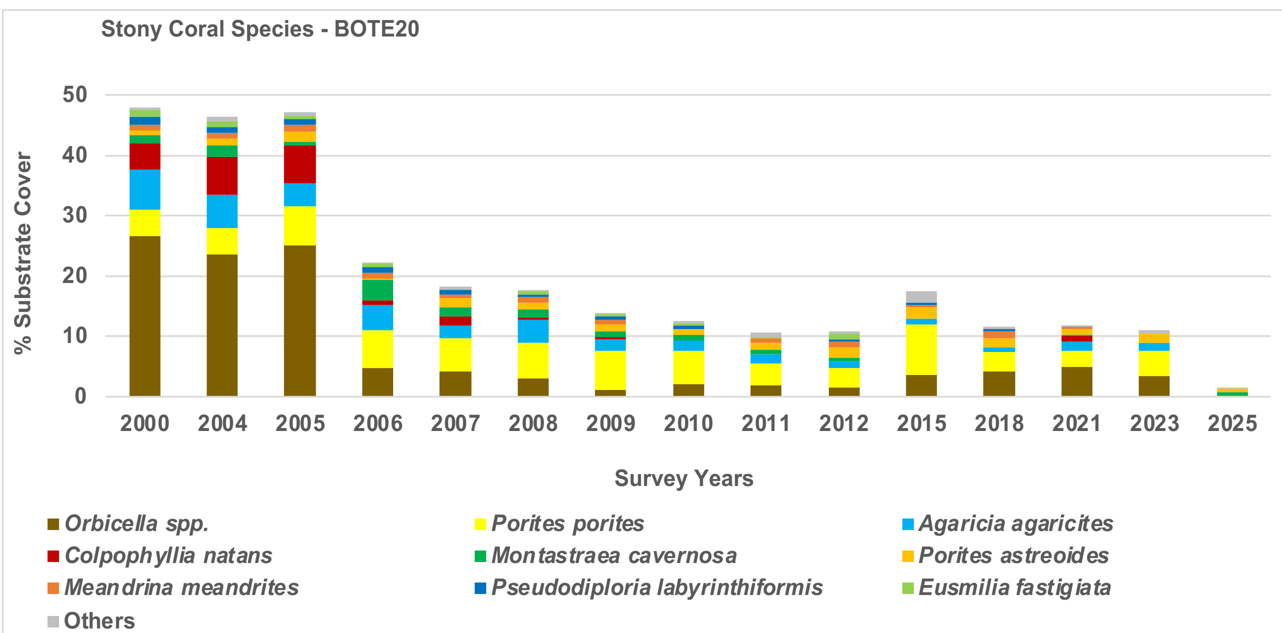


Figure 27. Monitoring trends (2000 – 2025) of mean substrate cover by stony coral species at BOTE20, Isla Desecheo. PRCRMP 2025

Stony coral cover had increased 37.0% between the 2013 and 2015 surveys, mostly driven by an increase of cover by finger coral (*Porites porites*), a species with relatively fast growth rate that had previously shown marked annual fluctuations at BOTE20 (Figure 27). During the 2018 survey, stony coral cover declined 33.5%, largely related to a 60.2% reduction of substrate cover by *P. porites*, triggering another taxonomic phase-shift of community structure as the *Orbicella spp*. complex regained its previous top rank as the dominant stony coral species in terms of reef substrate cover. The decline of cover by *P. porites* measured during the 2018 and 2021 surveys appeared to be related to extreme surge and abrasion effects associated with the pass of Hurricane Maria in September 2017 and/or winter storm Riley in March 2018. Colonies exhibited intermixed live and dead coral sections that appeared to be caused by intense sand abrasion.

During the 2025 survey, reef substrate cover by *Porites porites* declined 98.3%, from 4.18% in 2023 to 0.07% in 2025 forcing another taxonomic phase shift in dominance of stony coral species at BOTE20 and contributing to an overall reduction of -86.4% of stony coral cover relative to the previous 2023 survey (Figure 27). In addition to the loss of cover by P. porites, other relevant changes of the stony coral community structure include the loss of live colonies from permanent transects of lettuce coral (*Agaricia agaricites*). The most recent decline of reef substrate cover by stony coral cover at BOTE20 appears to be related to coral disease infections, including SCTLD (Garcia-Sais et al., 2023), perhaps driven by heat stress and associated coral bleaching events during the 2023 – 24 period.

8.3 Fishes and Motile Megabenthic Invertebrates

A total of 38 fish species were identified within belt-transects from BOTE20 during the 2025 survey with a mean density of 303.2 Ind/30m^2, and a mean species richness of 19.2 Spp/30m^2 (Table 24). An assemblage of four species with a combined density of 245.6 Ind/30m^2 accounted for 81.0% of the total fish density. The creole wrasse (*Clepticus parrae*) was the numerically dominant species with a mean density of 103.8 Ind/30m^2, representative of 34.2% of the total fish density within belt-transects. Other numerically dominant species included the blue chromis (*Chromis cyanea*), bluehead wrasse (*Thalassoma bifasciatum),* and the bicolor damselfish *(Stegastes partitus).* Motile megabenthic invertebrates were represented within belt-transects by one channel clinging crab (*Mithrax spinosissimus*) (Table 24).

Table 24. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at BOTE20, Isla Desecheo. PRCRMP 2025

BOTE20							
Survey Date: 5/23/25	**Belt-Transects (3x10m)**						**Trophic**
Fish Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Clepticus parrae	86	130	300		3	**103.8**	ZPL
Chromis cyanea	58	76	80	66	78	**71.6**	ZPL
Thalassoma bifasciatum	31	37	64	26	39	**39.4**	SOC
Stegastes partitus	20	14	28	54	38	**30.8**	ZPL
Halichoeres garnoti	11	15	18	25	8	**15.4**	SOC
Chromis multilineata	3	24	12		16	**11.0**	ZPL
Gramma loreto		15	23		5	**8.6**	SOC
Sparisoma aurofrenatum	5	1	1	3	2	**2.4**	HER
Microspathodon chrysurus	2	3	1	1	4	**2.2**	HER
Scarus taeniopterus		5		5		**2.0**	HER
Abudefduf saxatilis	2	3	2		1	**1.6**	ZPL
Coryphopterus spp.		7				**1.4**	SOC
Halichoeres maculipinna			3	4		**1.4**	SOC
Acanthurus coeruleus	1	1		3	1	**1.2**	HER
Sparisoma viride	3	1			1	**1.0**	HER
Amblycirrhitus pinos	2		1	1	1	**1.0**	SOC
Cephalopholis fulva	1	1	2			**0.8**	LC
Scarus vetula	1		1	2		**0.8**	HER
Chaetodon capistratus	2	1				**0.6**	COR
Melichthys niger	1			1	1	**0.6**	ZPL
Mulloidichthys martinicus				2	1	**0.6**	SOC
Caranx ruber	1		1			**0.4**	LC
Lactophrys triqueter		1		1		**0.4**	SOC
Cephalopholis cruentata				2		**0.4**	LC
Kyphosus spp.		1	1			**0.4**	HER
Haemulon flavolineatum		1			1	**0.4**	SOC
Holocentrus rufus		2				**0.4**	SOC
Sphyraena barracuda			1	1		**0.4**	LC
Serranus tigrinus					2	**0.4**	SOC
Myripristis jacobus		1				**0.2**	SOC
Holocentrus adscensionis		1				**0.2**	SOC
Neoniphon marianus		1				**0.2**	SOC
Scarus iseri			1			**0.2**	HER
Acanthostracion polygonius				1		**0.2**	SOC
Holacanthus tricolor				1		**0.2**	SPO
Canthigaster rostrata				1		**0.2**	SOC
Prognathodes aculeatus				1		**0.2**	COR
Elacatinus evelynae					1	**0.2**	SOC
Invertebrates							
Mithrax spinnosissimus	1					**0.2**	
Density (Ind/30m2)	**230**	**342**	**540**	**201**	**203**	**303.2**	
Richness (Species/30m2)	**17**	**23**	**18**	**20**	**18**	**19.2**	

Pelagic and demersal zooplanktivores (ZPL) were the most prominent trophic fish assemblage at BOTE20 comprised by six species, including four of the top six in terms of density within belt-transects with a combined density of 219.4 Ind/30m^2, or 72.4% of the total fish density. The ZPL assemblage included one wrasse (Labridae), four damselfishes (Pomacentridae), one goby (Gobiidae), and one triggerfish (Balistidae). Swarms of post-recruitment juvenile creole wrasse (100 – 300 individuals) were observed forming a cloud over the reef. Adult creole wrasse were also present making frequent incursions over belt-transects. Schools of early juvenile blue chromis were also observed sometimes intermixed with juveniles of creole wrasse close to reef coral heads. Both fish taxa serve as forage for pelagic predators, such as cero mackerels, black jacks, and great barracudas observed during this and previous surveys at BOTE20 (Garcia-Sais et al., 2018 and references therein). Swarms of mysid shrimps were observed below coral ledges and on reef crevices. These shrimps appear to be important forage for the demersal zooplanktivorous fishes.

Small opportunistic carnivores (SOC) were represented by 17 species with a cumulative density of 70.6 Ind/30m^2, or 23.3% of the total individuals. The SOC assemblage included wrasses (Labridae), basslets (Grammatidae), gobies (Gobiidae), hawkfishes (Cirrhitidae), goatfishes (Mullidae), boxfishes (Ostraciidae), grunts (Haemulidae), squirrelfishes (Holocentridae), seabasses (Serranidae), and puffers (Tetraodontidae). Herbivores (HER) were represented by eight species and a combined density of 10.2 Ind/30m^2, or 3.4% of the total. Parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) comprised the main herbivorous assemblage. Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by three species and a combined density of 1.0 Ind/30m^2.

Mid-sized and large carnivores were represented by three species of groupers (*Epinephelus* guttatus, Cephalopholis fulva, C. cruentata), bar jacks (Caranx ruber), and the great barracuda (Sphyraena barracuda) with a combined density of 3.4 Ind/60m^2. The most abundant was the coney (*C. fulva*) with a mean density of 1.8 Ind/60m^2, or 52.9% of the total mid-size and large demersal/pelagic carnivores (Table 25). Other top demersal and pelagic predators previously observed from BOTE20 include the nurse shark (*Ginglymostoma cirratum*), blackjack (*Caranx lugubris*), cero mackerels (*Scomberomorus regalis*), schoolmaster snapper (*Lutjanus apodus*), lionfish (*Pterois* sp.), and yellowfin grouper (*Mycteroperca venenosa*), among others (Garcia-Sais et al., 2021 and references therein).

Table 25. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at BOTE20, Isla Desecheo. PRCRMP 2025

BOTE20							
Survey Date: 5/23/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c4	3-16, 2-17, 3-18, 2-20	1	3	1	4	1	Adult
Caranx ruber c8	36, 40	1		1			Adult
Cephalopholis cruentata c3	15				1		Juvenile
Cephalopholis cruentata c4	20	1					Adult
Cephalopholis cruentata c5	22				1		Adult
Cephalopholis fulva c3	15		1				Juvenile
Cephalopholis fulva c4	18, 2-20		2	1			Adult
Cephalopholis fulva c5	23, 2-25	1	1	1			Adult
Cephalopholis fulva c6	26, 30	1					Adult
Epinephelus guttatus c8	40				1		Adult
Scarus iseri c4	16			1			Adult
Scarus taeniopterus c1	5-7, 2-8, 2-6, 10		5		5		Juvenile
Scarus taeniopterus c2	2-10			2			Juvenile
Scarus vetula c2	3-8, 2-10	1		1	3		Juvenile
Sparisoma aurofrenatum c1	4			1			Recruit
Sparisoma aurofrenatum c2	2-6, 2-8, 2-10	5				2	Juvenile
Sparisoma aurofrenatum c5	2-25			1		1	Terminal
Sparisoma viride c1	3, 5	1				1	Recruit
Sparisoma viride c2	9	0	1				Juvenile
Sparisoma viride c5	25	1					Adult
Sparisoma viride c7	2-35	1				1	Terminal
Sphyraena barracuda c10	46, 50			1	1		Adult
	Totals	**14**	**13**	**11**	**16**	**6**	

The size-distribution data for commercially important fishes, including the larger reef herbivores is indicative that BOTE20 functions as a recruitment and permanent residential habitat for several species of parrotfishes, particularly the stoplight, redband, queen, and princess parrotfishes (*Sparisoma viride, S. aurofrenatum, Scarus vetula, S. taeniopterus*). Both recruitment (< 5cm) and terminal phase male stages of *S. viride* and *S. aurofrenatum* were observed during the 2025 survey. Juvenile and adult stages of coney (*Cephalopholis fulva*) and graysbe (*C. cruentata*) were observed during the 2025 and previous surveys (Garcia-Sais et al., 2021 and references therein), suggesting that BOTE20 may be a recruitment and residential habitat for these small groupers as well. One adult red hind (*Epinephelus guttatus*) and two great barracudas (*Sphyraena barracuda*) were observed within belt-transects in the 2025 survey. Other large adult demersal and pelagic predators have been previously reported from BOTE20, including Nassau grouper (*E. striatus*), nurse shark (*Ginglymostoma cirratum*), schoolmaster and mahogany snappers (*Lutjanus apodus, L. mahogoni*), lionfish (*Pterois* spp.), and cero mackerel (*Scomberomorus cavalla*), indicative that BOTE20 is also an important residential and/or foraging habitat for large reef predators.

Variations of mean fish density and species richness between monitoring surveys at BOTE20 are presented in Figure 28. Differences between surveys of both fish density and species richness were statistically significant (ANOVA; $p < 0.001$, Appendix 5 and 6). Lower fish densities were observed during 2018 relative to 2000, 2005, 2006, 2008, 2011, and 2012 (95% CI), associated with an overall decline of small numerically dominant species with aggregated distributions, such as the masked goby (*Coryphopterus personatus*), blue chromis (*Chromis cyanea*), and the creole and bluehead wrasses (*Clepticus parrae, Thalassoma bifasciatum*). Reduced density of these species may be related to extreme physical conditions imposed by the pass of Hurricane Maria in September 2017 and/or winter storm Riley in March 2018. Fish density increased by 72.7% in 2021 indicative that a strong recuperation of the fish community was achieved between 2018 and 2021. During the 2025 survey mean fish density (303.2 Ind/30m^2) increased by 70.9% relative to the previous 2023 survey and now stands with the historical peak mean density measured at BOTE20 since the start of the monitoring program. The recent density increment was largely driven by high densities of zooplanktivorous taxa, particularly creole wrasse (*Clepticus parrae*) and blue chromis (*Chromis cyanea*) which exhibited a massive recruitment pulse during 2005 at BOTE20, but fish species richness also increased by 12.9% indicative that an increase of species within transects also influenced the overall density. Small zooplanktivorous fishes represent forage for other reef predators and may trigger cascading effects resulting in both increases of fish density and species richness.

Statistically significant differences of fish species richness at BOTE20 are associated with a pattern of lower species richness during the three previous surveys (2018 – 2023), relative to the 2012, 2015, and earlier surveys from 2004 - 2007 (Figure 28). The reduction of species richness in 2018 extending to the 2023 survey may have been influenced by the loss of species flushed from the reef during events of extreme physical stress associated with the pass of Hurricane Maria in 2017 and winter storm Riley in 2018. The most recent increments of such small reef fish components is indicative of a strong recuperation of these taxa along with the potential implications of a more complex fish community structure.

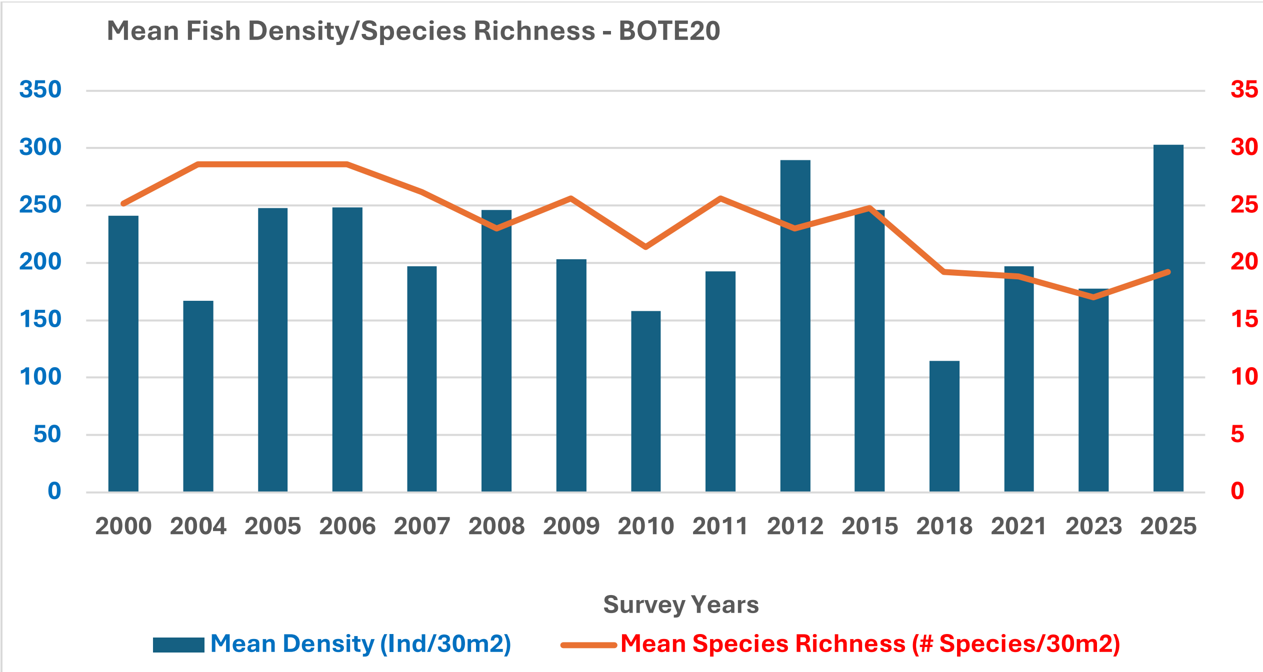
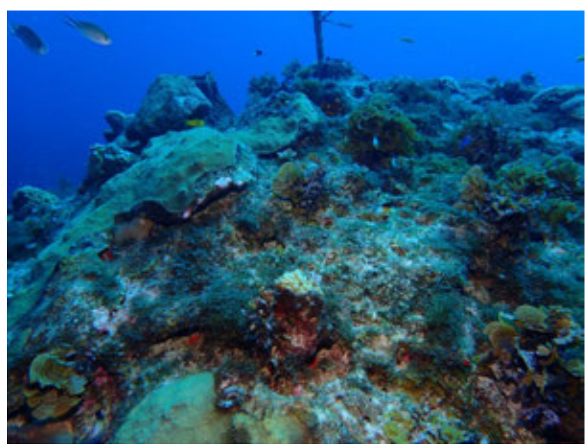
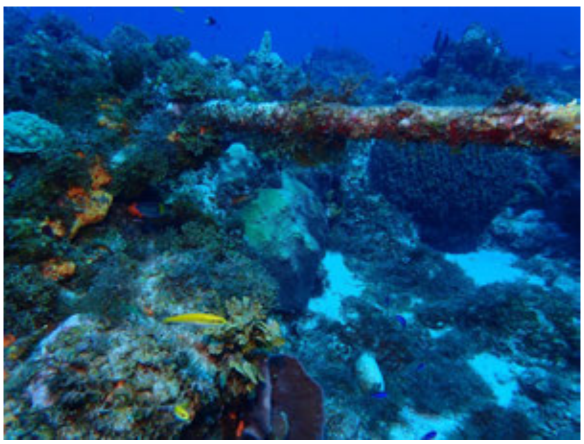
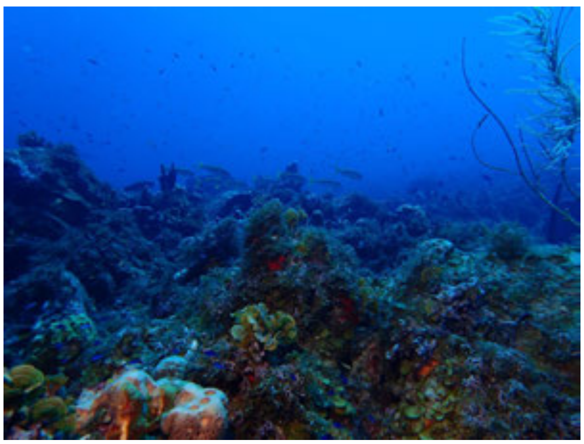


Figure 28. Monitoring trends (2000 – 2025) of mean fish density and species richness within 10m x 3m belt-transects at BOTE20, Isla Desecheo. PRCRMP 2025

Photo Album 8. BOTE20







9.0 Puerto Canoas Reef 30m, Isla Desecheo (CANO30)

9.1 Physical Description

The shelf-edge off Puerto Canoas is at the southwest end of a massive and impressive coral buildup that has developed as a series of patch reef promontories separated by coralline sand deposits. Coral promontories are typically comprised of several very large colonies of mountainous star coral (*Orbicella faveolata*). There are colonies that rise from the bottom at least four meters and extend horizontally more than 5 meters, in some instances merging with other large colonies to form continuous laminar coral formations that are unique in Puerto Rico. Toward the northern end, the shelf-edge reef platform leads to an almost vertical wall with sparse coral growth down to a depth of 40m. At the southern end, the reef platform ends in an extensive sand deposit that slopes down gently to a depth of about 70m. Our survey was performed right at the end of the reef on the southern section. Transects were installed at a depth of 25 – 30 m, bordering the edge of three of the larger massive coral promontories (Figure 22). Panoramic views of the shelf edge reef community at Puerto Canoas 30m (CANO30) during the 2025 survey are presented as Photo Album 9.

9.2 Sessile-benthic Reef Community

Benthic macroalgae, comprised by an assemblage of fleshy brown, turf, and red crustose coralline algae were the dominant sessile-benthic category in terms of ref substrate cover at CANO30 with a combined mean cover of 70.04% (Table 26). The fleshy brown assemblage comprised by encrusting fan alga (*Lobophora sp.*), and y-twig alga (*Dictyota sp.*) was the most prominent with a combined mean substrate cover of 58.03%, representative of 82.8% of the total cover by benthic algae. Turf algae, a mixed assemblage of short filamentous red and brown algae was present in all transects with a mean cover of 7.4%, or 10.6% of the total cover by benthic algae. Red crustose coralline algae (*Peyssonnelia* spp.) and other coralline algae (CCA mixed assemblage) were present with a combined cover of 4.62%.

Stony corals were represented by three scleractinians with a combined mean cover of 4.14% (range: 0 – 1.29%). Mustard-hill coral (*Porites astreoides*) was the dominant species in terms of reef substrate cover with a mean cover of 2.21%, representative of 53.4% of the total by stony corals (Table 26). A total of 23 stony coral colonies were intercepted by transects, including one colony (*1- S. siderea*) with an apparent disease infection (coral disease prevalence = 4.35%, Appendix 2). In addition, another seven colonies were observed to be bleached or pale (bleaching prevalence: 30.4%).

Table 26. Percent reef substrate cover by sessile-benthic categories at CANO30, Isla Desecheo. PRCRMP 2025

CANO30			**Transects**			
Survey date: 5/09/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**25.8**	**24.2**	**25.2**	**24.5**	**25.8**	**25.10**
Rugosity (m)	3.66	3.06	8.03	2.81	6.60	**4.83**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	17.42	5.57	23.14	3.50	10.79	**12.08**
Total Abiotic	**17.42**	**5.57**	**23.14**	**3.50**	**10.79**	**12.08**
Benthic Algae						
Lobophora spp.	49.28	57.88	30.98	57.16	51.01	**49.26**
Dictyota spp.	9.22	6.86	12.19	14.97	0.59	**8.77**
Turf (mixed)	4.41	9.32	12.11	5.25	5.40	**7.30**
Peyssonnelia spp.	2.87	2.89	2.02	1.86	6.75	**3.28**
CCA (total)	0.72	3.22	1.16		1.60	**1.34**
Turf (mixed) with sediment	0.51					**0.10**
Total Benthic Algae	**67.01**	**80.17**	**58.46**	**79.23**	**65.35**	**70.04**
Cyanobacteria	**0**	**0**	**0**	**0**	**0**	**0.00**
Stony Corals						
Porites astreoides	0.31	2.68	3.11	1.42	3.54	**2.21**
Orbicella faveolata		1.29		0.55	7.59	**1.88**
Siderastrea siderea		0.21				**0.04**
Total Stony Coral	**0.31**	**4.18**	**3.11**	**1.97**	**11.13**	**4.14**
# Coral Colonies/Transect	**1**	**6**	**6**	**2**	**8**	**4.60**
#Diseased Coral Colonies/Transect	**0**	**1**	**0**	**0**	**0**	**0.20**
# Bleached Coral Colonies/Transect	**0**	**2**	**0**	**1**	**1**	**0.80**
# Erect Soft Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
Anemones						**0.00**
Trididemnum solidum		1.29	1.09		0.59	**0.59**
Rhodactis osculifera	0.31					**0.06**
Total Anemones	**0.31**	**1.29**	**1.09**	**0.00**	**0.59**	**0.65**
Sponges						
Agelas citrina	5.43	3.32	6.52	4.04		**3.86**
Agelas conifera	3.59	2.68	2.64	0.77		**1.93**
Agelas clathrodes	1.74		2.10		5.73	**1.91**
Neopetrosia spp. smooth	1.74	0.96	1.09	0.22	3.71	**1.54**
Svenzea zeai		1.18		5.36		**1.31**
Agelas sceptrum			0.78		2.53	**0.66**
Scopalina ruetzleri	0.31		0.62			**0.19**
Neofibularia nolitangere				0.87		**0.17**
Agelas spp.		0.64			0.17	**0.16**
Ectyoplasia ferox				0.77		**0.15**
Aplysina fistularis				0.55		**0.11**
Agelas sventres			0.23			**0.05**
Aplysina cauliformis			0.23			**0.05**
Total Sponges	**12.81**	**8.79**	**14.21**	**12.57**	**12.14**	**12.10**
Diseased Corals						
Siderastrea siderea		1				
Bleached Corals						
Orbicella faveolata		2		1	4	

Octocorals were not intercepted by transects and are not common at CANO30. Branching, encrusting, and erect sponges included at least 13 species along transects with a mean cover of 12.10%. An assemblage comprised of six *Agelas spp*. was the most prominent sponge taxa at CANO30 with a combined cover of 8.57%, representative of 70.8% of the total cover by sponges. Abiotic cover mostly associated with reef overhangs averaged 12.08% and contributed to a mean reef substrate rugosity of 4.83m.

Figure 29 shows the variations of the mean percent cover by sessile-benthic categories between monitoring surveys at CANO30. Differences of mean substrate cover by stony corals, sponges, and benthic algae between the 2004 baseline and the 2005 monitoring surveys were within 1% and statistically insignificant. A sharp, statistically significant 22.0% decline of mean cover by stony corals was measured between the 2005 (48.07%) and the 2006 (37.50%) survey (ANOVA; $p < 0.0001$). The decline of coral cover was largely associated with the dominant reef building species, *Orbicella annularis* (complex), which varied from a mean cover of 32.7% in 2005 to 24.4% in 2006 (Figure 30). A mild trend of decreasing live cover was observed until the 2010 survey with a corresponding increment of substrate cover by benthic algae, cyanobacteria, sponges, and abiotic categories (Figure 29). During the 2021 survey, substrate cover by stony corals declined 17.1%, largely related to a 73.7% reduction of cover by lettuce coral (*Agaricia agaricites*), and a 45.6% reduction of cover by mustard-hill coral (*Porites astreoides*). The declining cover by these coral species was related to tissue loss and/or colony mortality after a severe bleaching event impacted coral communities in Puerto Rico from October 2019 and extending at least until February 2020 (Garcia-Sais et al., 2022).

During the 2023 and 2025 monitoring surveys, reef substrate cover by stony coral evidenced consecutive reductions of -38.7% in 2023 and of 72.5% relative to the previous 2021 and 2023 surveys, respectively (Figure 29). The overall decline was largely related to a 95.6% reduction of cover by the *Orbicella* spp. complex, and a 97.3% reduction of *Porites porites* relative to the mean cover in 2021(Figure 30). The present 2025 mean cover by stony corals (1.49%) represent a decline of 91.4% relative to the 2004 baseline (48.42%). The difference was statistically significant (ANOVA, $p < 0.0001$; Appendix 3). Given the high 2023 coral disease prevalence at CANO30 (14.00%) that included SCTLD infections on *O. faveolata* it is here suggested that such coral disease infections, perhaps triggered by the 2019 and 2023 coral bleaching events are the main causal factor of the massive degradation of stony coral cover at CANO30. Further coral degradation may be anticipated due to the high bleaching prevalence (30.4%) measured in 2025.

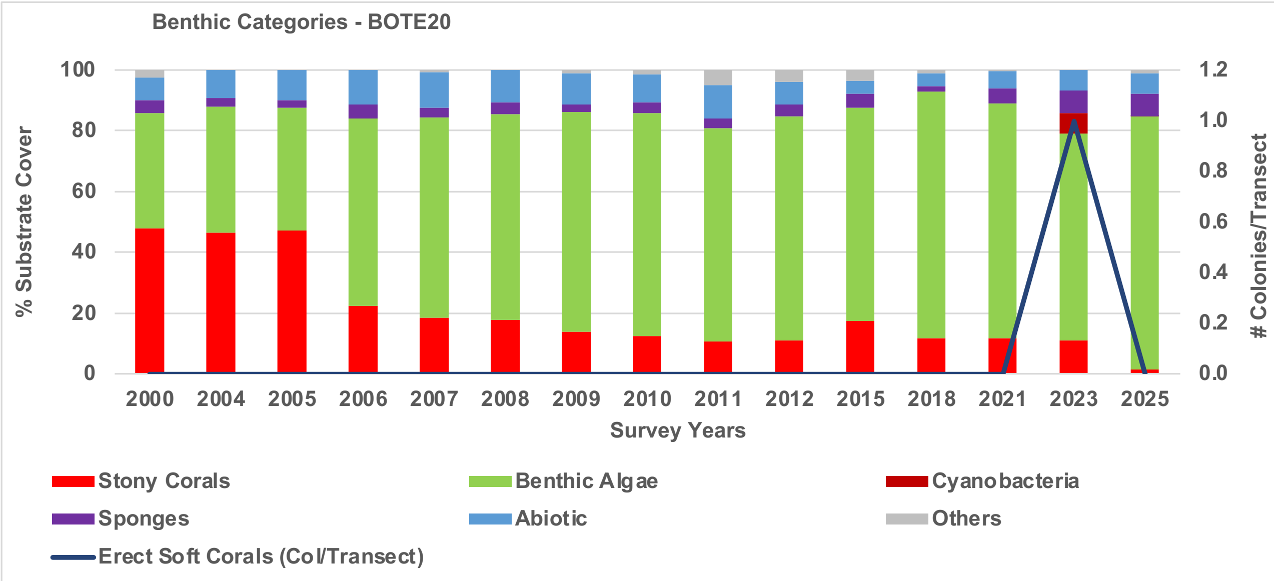


Figure 29. Monitoring trends (2004 – 2025) of mean substrate cover by sessile-benthic categories at CANO30, Isla Desecheo. PRCRMP 2025

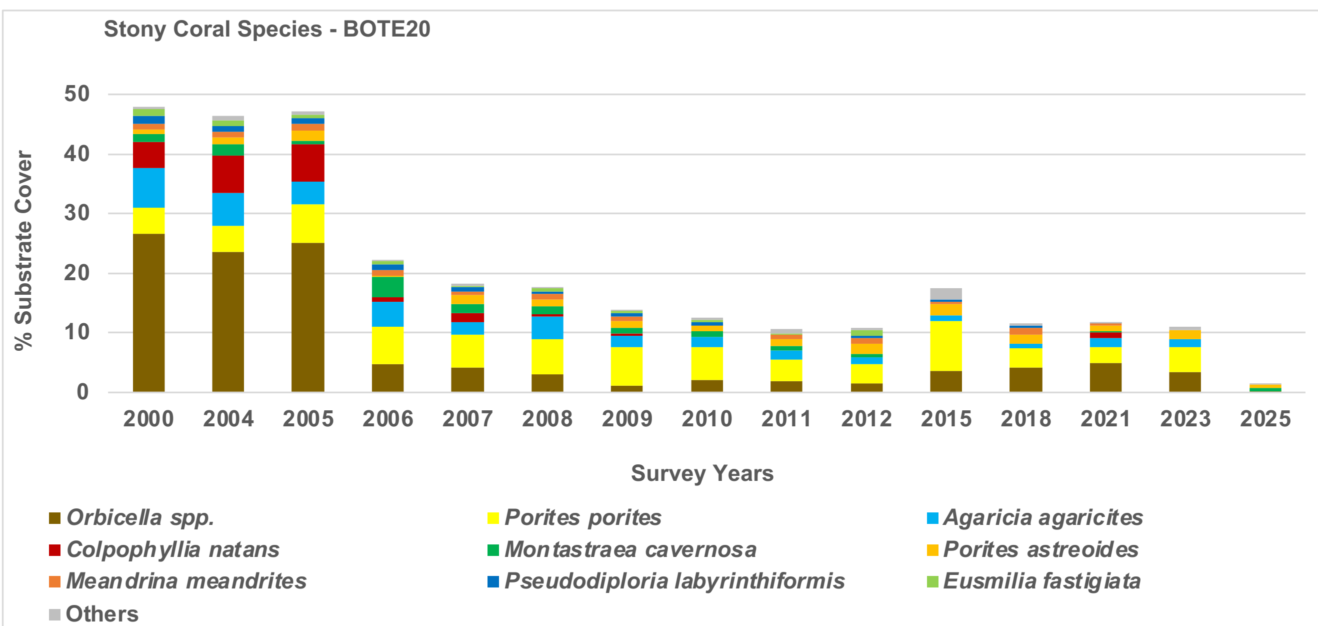


Figure 30. Monitoring trends (2004 – 2025) of mean substrate cover by stony coral species at CANO30, Isla Desecheo. PRCRMP 2025

9.3 Fishes and Motile Megabenthic Invertebrates

A total of 44 fish species were identified within belt-transects at CANO30 during the 2025 monitoring survey with a mean density of 314.2 Ind/30m^2 (range: 202 – 565 Ind/30m^2) and mean species richness of 22.8 Spp/30m^2 (range: 20 – 26 Spp/30m^2). Blue chromis (*Chromis cyanea*), masked goby (*Coryphopterus personatus),* creole wrasse (*Clepticus parrae*), and fairy basslet (*Gramma loreto*) were the numerically dominant species within transects with a combined density of 246.8 Ind/30m^2, representative of 78.5% of the total fish density (Table 27). Schooling aggregations of post recruitment (1-2 cm TL) blue chromis *and* creole wrasse were observed as dense swarms over the reef. Likewise, schooling aggregations of masked goby were observed below ledges and other protective reef habitats. In addition to aforementioned numerically dominant fish assemblage, another group of fishes were observed in all five transects with a combined density of 35.4 Ind/30m^2, or 11.3% of the total individuals. These included the bluehead and yellowhead wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*), bicolor and beaugregory damselfishes (*Stegastes partitus, S. leucostictus*), red-band parrotfish (*Sparisoma aurofrenatum*), and blue tang (*Acanthurus coeruleus*), Motile megabenthic invertebrates were nor observed within belt-transects.

Fish trophic structure at CANO30 was numerically dominated by pelagic and demersal zooplanktivores (ZPL), represented by seven species and a combined mean density of 227.4 Ind/30m^2, or 72.4% of the total individuals within 3m x 10m belt-transects. The ZPL assemblage included the top three species, and five of the top eight in terms of mean density, such as blue chromis (*Chromis cyanea*), masked goby (*Coryphopterus personatus*), and creole wrasse (*Clepticus parrae*). Small opportunistic carnivores SOC) were represented by 16 species and a combined density of 67.8 Ind/30m^2, or 21.6% of the total individuals. The assemblage included basslets (Grammatidae), wrasses (Labridae), gobies (Gobiidae), goatfishes (Mullidae), puffers (Tetraodontidae), boxfishes (Ostraciidae), squirrelfishes (Holocentridae), porcupinefishes (Diodontidae), and grunts (Haemulidae). Herbivores (HER) included parrotfishes (Scaridae), damselfishes (Pomacentridae), and doctorfishes (Acanthuridae) with a combined density of 10.2 Ind/30m^2, representing 3.2% of the total individuals. Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by three species and a combined density of 2.0 Ind/30m^2, or 0.6% of the total.

Table 27. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CANO30, Isla Desecheo. PRCRMP 2025

CANO30							
Survey Date: 5/09/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Chromis cyanea	30	70	80	48	240	**93.6**	ZPL
Coryphopterus personatus	24	42	45	66	130	**61.4**	ZPL
Clepticus parrae	58	55	45	13	90	**52.2**	ZPL
Gramma loreto	76	11	57	18	36	**39.6**	SOC
Thalassoma bifasciatum	15	9	15	5	11	**11.0**	SOC
Stegastes partitus	9	13	12	10	6	**10.0**	ZPL
Halichoeres garnoti	6	5	10	4	16	**8.2**	SOC
Chromis multilineata	6	8	16	11		**8.2**	ZPL
Sparisoma aurofrenatum	2	3	5	2	1	**2.6**	HER
Caranx lugubris		6		5	1	**2.4**	LC
Acanthurus coeruleus	2	1	2	2	3	**2.0**	HER
Elacatinus evelynae				3	7	**2.0**	SOC
Coryphopterus lipernes				5	4	**1.8**	SOC
Melichthys niger	3	2	1	2		**1.6**	ZPL
Cephalopholis cruentata	2		3	2	1	**1.6**	LC
Stegastes leucostictus	2	1	2	1	2	**1.6**	HER
Sparisoma viride	1	1	3		2	**1.4**	HER
Chaetodon capistratus	2		2		2	**1.2**	COR
Mulloidichthys martinicus	1	3	1			**1.0**	SOC
Chaetodipterus faber		5				**1.0**	LC
Kyphosus spp.	1	1		1	1	**0.8**	HER
Canthigaster rostrata	1				2	**0.6**	SOC
Lactophrys triqueter		1		1	1	**0.6**	SOC
Microspathodon chrysurus		1		2		**0.6**	HER
Neoniphon marianus		1			2	**0.6**	SOC
Bodianus rufus		2			1	**0.6**	SOC
Halichoeres maculipinna	2					**0.4**	SOC
Stegastes planifrons	2					**0.4**	HER
Holocentrus rufus	1	1				**0.4**	SOC
Lutjanus apodus		2				**0.4**	LC
Myripristis jacobus		2				**0.4**	SOC
Chaetodon striatus		2				**0.4**	COR
Holacanthus tricolor			2			**0.4**	SPO
Pterois volitans			1		1	**0.4**	LC
Scomberomorus regalis			2			**0.4**	LC
Paranthias furcifer			2			**0.4**	ZPL
Ginglymostoma cirratum					2	**0.4**	LC
Sparisoma atomarium					2	**0.4**	HER
Mycteroperca venenosa		1				**0.2**	LC
Stegastes adustus		1				**0.2**	HER
Epinephelus striatus			1			**0.2**	LC
Diodon hystrix			1			**0.2**	SOC
Holocentrus adscensionis				1		**0.2**	SOC
Anisotremus surinamensis					1	**0.2**	SOC
Density (Ind/30m2)	**246**	**250**	**308**	**202**	**565**	**314.2**	
Richness (Species/30m2)	**21**	**26**	**22**	**20**	**25**	**22.8**	

Medium and large sized carnivores were represented by 11 species and a combined density of 7.8 Ind/60m^2 (Table 28). The assemblage included Nassau, yellowfin, coneys and graysby groupers (*Epinephelus striatus*, *Mycteroperca venenosa*, *Cephalopholis fulva, C. cruentata*), schoolmaster snappers (*L. apodus*), lionfish (Tetraodontidae), nurse shark (Rhincodontidae), and black jacks (*Caranx lugubris*). The most abundant were the graysbe and the blackjack with eight individuals, each and a mean density of 1.6 Ind/60m^2. Fish size distributions are indicative that CANO30 serves as a residential and foraging habitat for large demersal and pelagic predators, mostly as adults.

Parrotfishes (Scaridae) and doctorfishes (Acanthuridae) were observed as juvenile and adult stages, including recruitment stages (1 - 5cm) of stoplight and redband parrotfishes (*Sparisoma viride, S. aurofrenatum*). Terminal male stages of stoplight, redband, and yellowtail parrotfishes were present within belt-transects. The most abundant of the larger herbivores was the blue tang was (*Acanthurus coeruleus*) with 12 individuals and a mean density of 2.4 Ind/60m^2.

Variations of mean fish density and species richness between monitoring surveys at CANO30 are presented in Figure 31. Statistically significant differences between surveys of both fish density and species richness were noted (ANOVA, $p < 0.001$; Appendices 5 and 6). Lower fish density was measured during the 2010, 2018, and 2021 surveys, relative to the period between 2004 - 2006, and 2013. Density fluctuations at CANO30 were driven by fluctuations of masked goby (*Coryphopterus personatus*), a numerically dominant species that forms large aggregations over coral heads and beneath coral ledges. Due to its small size and non-cryptic behavior, masked goby appears to be vulnerable to events of strong surge and sand abrasion caused by wave action. Extreme conditions of surge and abrasion associated with Hurricane Maria in 2017 and winter storm Riley in 2018 could have displaced masked goby and other small water column fishes away from reef habitats driving the fish community to the lowest densities recorded at CANO30 in the 2018 survey (Figure 31). Other factors associated with the plankton food web and density independent factors, such as recruitment success are also important drivers of density fluctuations by masked goby and other small zooplanktivorous fishes from CANO30. During the three most recent surveys (2021, 2023, and 2025) consecutive increments of fish density have been measured, influenced by what appears to be a partial recuperation of the small schooling fish populations.

Table 28. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CANO30, Isla Desecheo. PRCRMP 2025

CANO30							
Survey Date: 5/09/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c3	11, 2-12, 13, 14, 4-15	2	1	2	2	2	Juvenile
Acanthurus coeruleus c4	16, 18, 20				2	1	Adult
Caranx lugubris c4	7-20		6		1		Juvenile
Caranx lugubris c10	50					1	Adult
Cephalopholis cruentata c3	13, 15			2			Juvenile
Cephalopholis cruentata c4	2-18, 17, 20, 16	1		1			Adult
Cephalopholis cruentata c5	25	1			2	1	Adult
Cephalopholis fulva c4	3-20			3			Adult
Dasyatis americana c18	50	1					Adult
Epinephelus striatus c10	50, 46			2			Adult
Epinephelus striatus c18	90		1				Adult
Ginglymostoma cirratum c14	66, 70					2	Adult
Ginglymostoma cirratum c20	96	1					Adult
Lutjanus apodus c10	50		1				Adult
Lutjanus apodus c3	15				1		Juvenile
Lutjanus apodus c8	40		1				Adult
Lutjanus mahogoni c5	22			1			Adult
Mycteroperca venenosa c10	46		1				Adult
Pterois spp. c5	2-23, 25			2	1		Adult
Pterois spp. c6	28, 30, 26			2		1	Adult
Scomberomorus regalis c12	60			1			Adult
Scomberomorus regalis c18	90			1			Adult
Sparisoma aurofrenatum c1	5-5		2	2	1		Recruit
Sparisoma aurofrenatum c2	6, 3-8, 9	2	1	2		1	Juvenile
Sparisoma aurofrenatum c3	14, 15			1	1		Juvenile
Sparisoma aurofrenatum c5	21, 23	1					Terminal
Sparisoma rubripinne c7	35	1					Terminal
Sparisoma spp. c1	4, 5					2	Recruit
Sparisoma viride c1	2-5, 4		1			2	Recruit
Sparisoma viride c2	10, 6, 9	1		2			Juvenile
Sparisoma viride c3	12			1			Juvenile
Sparisoma viride c7	35		1				Terminal
	Total	**11**	**16**	**25**	**11**	**13**	

Variations of fish species richness between monitoring surveys have not been proportional neither in magnitude nor direction to the observed density fluctuations at CANO30 but rather have exhibited a gradual monotonic decline over the monitoring period, reaching a minimum in the previous 2023 survey (Figure 31). It is possible that fluctuations of masked goby and other potentially important forage species have influenced fish species richness due to trophic cascade implications related to the piscivorous food web. The reef benthic structure at CANO30 has suffered substantial degradation since its baseline survey of 2004, particularly associated with a 91.4% loss of live stony coral cover since the 2004 baseline survey. The implications upon the fish community structure are unclear due to the multiplicity of potentially relevant factors, the small samples sizes, and the high sampling variability imposed by species with aggregated distributions that introduce high variability to the within replicate transect database, but the loss of microhabitats provided by live stony corals may have affected particular fish populations that play key roles on the food web, influencing reductions of species richness. During the 2025 survey mean fish species richness (22.8 Spp/30m^2) remained essentially similar to the previous 2023 survey.

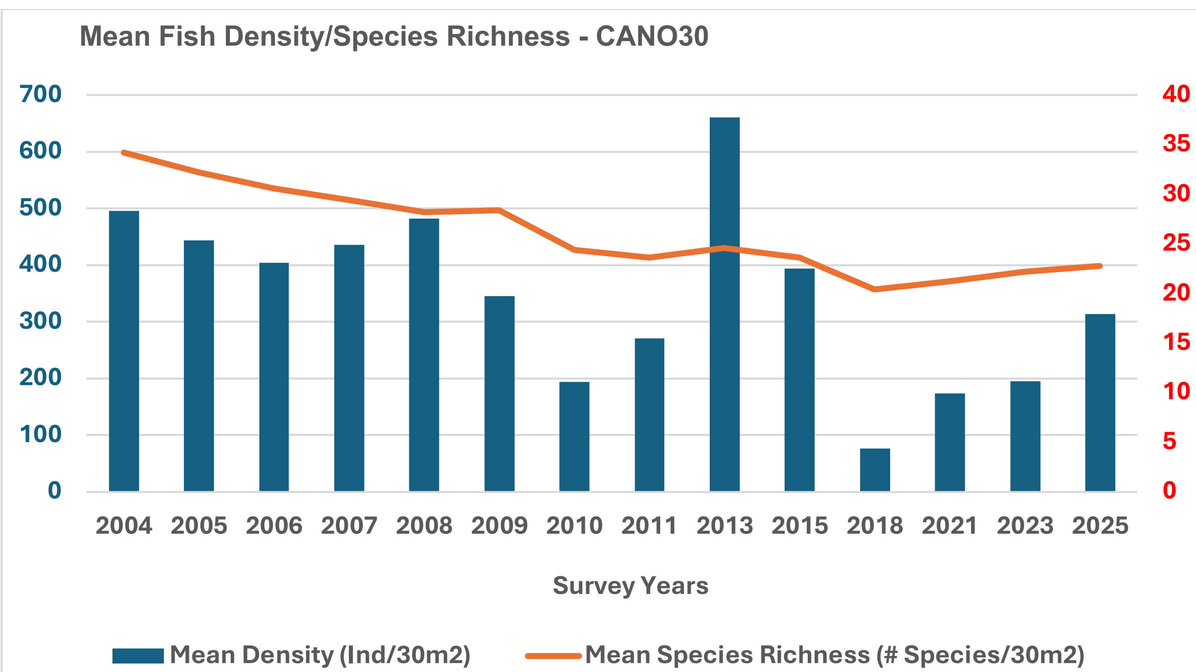
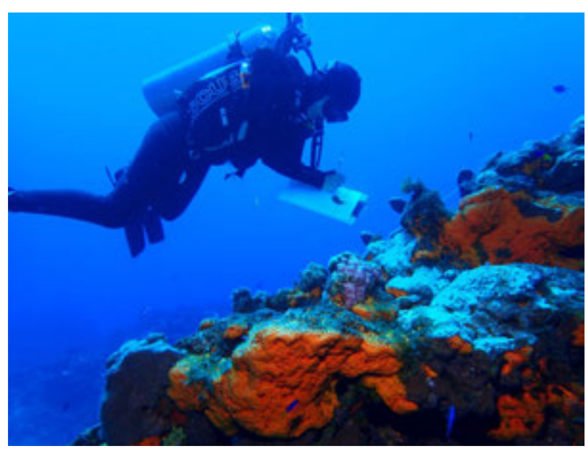


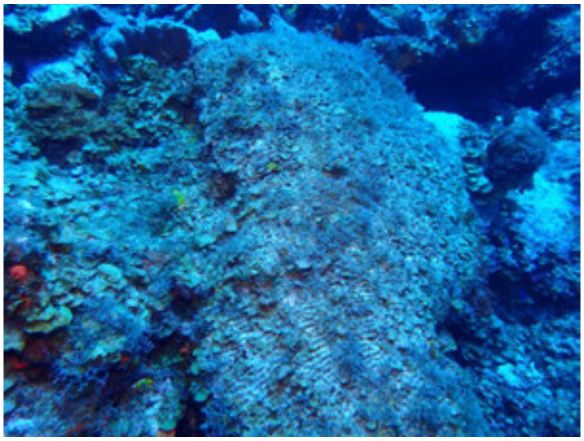
Figure 31. Monitoring trends (2004 – 2025) of mean fish density and species richness within 10m x 3m belt-transects at CANO30, Isla Desecheo. PRCRMP 2025

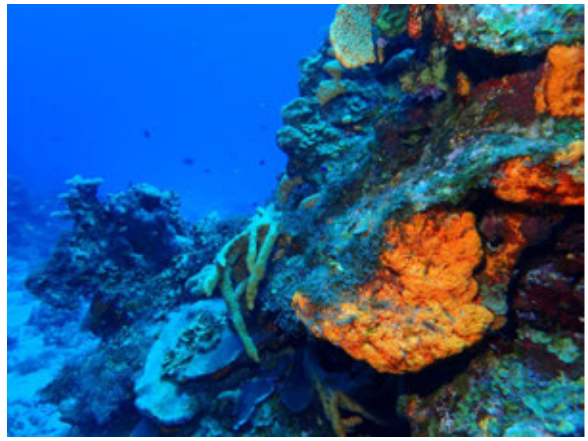
Photo Album 9. CANO30

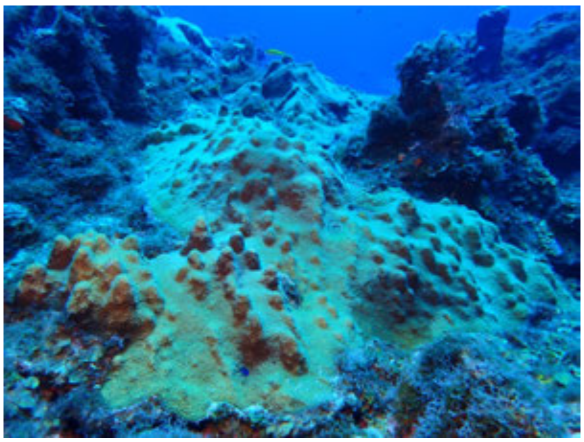


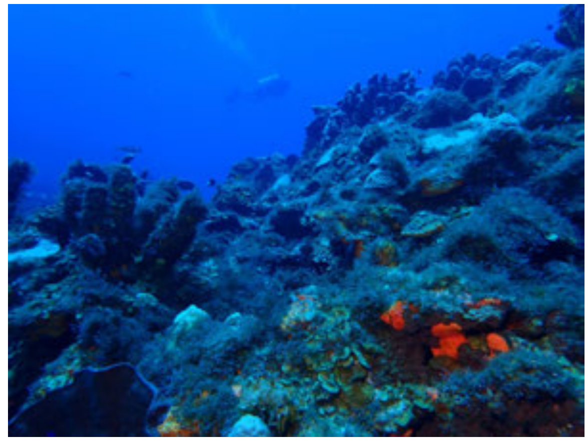










10.0 Dominos Reef, Carolina (DOMI05)

10.1 Physical Description

Fringing the Carolina-San Juan coastline are a series of submerged and emergent patch reefs of sedimentary origin which exhibit variable colonization by algae, sponges, corals, and other benthic reef biota that serve as an important habitat for fishes and invertebrates and protect the coastline from wave action and erosion. Dominos Reef (DOMI05) is one of these patch reefs, located about 0.9 NM to the northwest off Punta Las Marias, Carolina (Figure 32). The reef rises from a sandy bottom at a depth of about 7 – 9 m to a hard ground platform at a depth of 1.5 – 2.0 m. The slope is abrupt with substantial colonization by reef biota and particularly brain corals (*Pseudodiploria strigosa, P. clivosa*), and octocorals (sea plumes, sea rods, sea fans) at the edge of the reef top. The reef interface with the sandy bottom is irregular with crevices and undercuts that appeared to be erosive features of a relict structure subjected to heavy wave action. The reef top is heavily colonized by relict (recently dead) thickets of elkhorn coral (*Acropora palmata*) and sections with high density of mostly dead brain and encrusting coral colonies (*P. strigosa, P. clivosa, Porites astreoides*). The baseline survey was performed in August 2018. Transects were installed over five thickets of elkhorn coral at a depth of 1.5 m. Images of the DOMI05 reef community during the 2025 survey are shown as Photo Album 10.

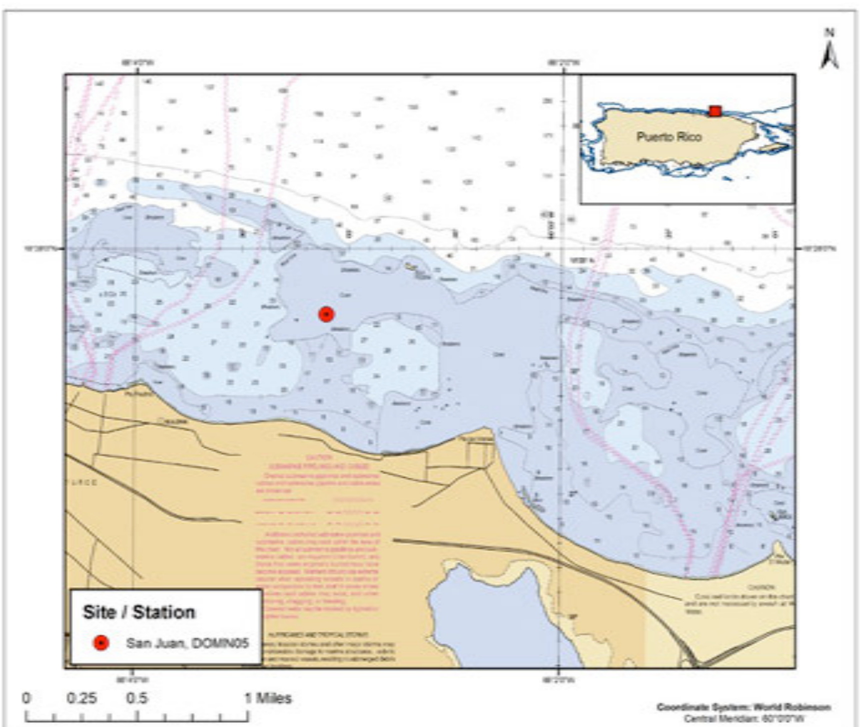


Figure 32. Location of Dominos Reef (DOMI05) station off Carolina. PRCRMP 2025

10.2 Sessile-benthic Reef Community

Benthic algae, comprised by turf, red crustose calcareous and coralline algae were the dominant sessile-benthic category intercepted by transects at DOMI05 during the 2025 monitoring survey with a combined mean cover of 76.67% (range: 69.04 – 88.24%). Turf algae, a mixed assemblage of short, articulated red and brown macroalgae were the dominant component with a mean cover of 47.26%, representative of 61.6% of the total cover by benthic algae (Table 29). Red crustose calcareous algae, *Ramicrusta sp*., and red encrusting coralline algae (CCA, mixed assemblage) were present in all five transects with a combined mean cover of 27.44%, representative of 35.8% of the total benthic algae. Fleshy brown y-twig alga (*Dictyota* sp.) was intercepted by one transect with a mean cover of 0.17%.

Four stony coral species were intercepted by transects with a mean combined cover of 3.28% (range: 0.47 – 6.17%). Knobby brain coral (*Pseudodiploria clivosa*) and finger coral (*Porites porites*) were the dominant species in terms of reef substrate cover with a combined mean of 2.35%, representative of 71.6% of the total cover by stony corals (Table 29). Standing dead thickets of elkhorn coral (*Acropora palmata*) were present in all transects colonized by turf and red crustose calcareous algae, mostly *Ramicrusta* sp. A total of 20 live stony coral colonies were intercepted by transects, none of which was observed to be affected by coral disease (Appendix 2). Small tufts of finger coral (*P. porites*) were observed as apparently new recruits in areas of coral rubble in several areas in the vicinity of permanent transects.

Erect soft coral colonies were intercepted by four out of the five transects surveyed with a mean density of 2.2 Col/Transect. Several colonies were standing dead along transects and there was a fringe of soft corals at the edge of the reef top also standing dead. Small colonies of the wide-mesh sea fan (*Gorgonia mariae*) were common throughout the reef top. The colonial zoanthid (*Palythoa caribaeorum*) was intercepted in four transects with a mean cover of 3.69%. Abiotic categories were mostly contributed by reef overhangs with a mean cover of 16.35% (Table 29).

Variations of reef substrate cover by the main sessile-benthic categories at DOMI05 during monitoring surveys (2018 – 2025) are presented in Figure 33. A drastic 93.18% decline of cover by stony corals was measured during the 2021 survey relative to the baseline 2018 survey. The difference was statistically significant (ANOVA, $p < 0.001$; Appendix 3). A corresponding increase of cover by benthic algae that included both turf and red crustose calcareous algae, mostly *Ramicrusta sp*. was measured.

Table 29. Percent reef substrate cover by sessile-benthic categories at DOMI05, Carolina. PRCRMP 2025

DOMI05			**Transects**			
Survey Date: 8/15/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	1.5	1.5	1.5	1.5	1.5	**1.50**
Rugosity (m)	1.58	1.90	3.12	2.67	2.73	**2.40**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	18.98	11.29	20.28	18.12	11.66	**16.07**
Gaps/Holes	1.21		0.21			**0.28**
Total Abiotic	**20.19**	**11.29**	**20.49**	**18.12**	**11.66**	**16.35**
Benthic Algae						
Turf (mixed)	34.34	58.35	42.26	37.79	64.58	**47.46**
Ramicrusta spp.	31.20	27.29	28.07	38.56	12.10	**27.44**
CCA (total)	2.66	2.59	0.96	1.77	0.00	**1.60**
Dictyota spp.	0.85					**0.17**
Total Benthic Algae	**69.04**	**88.24**	**71.29**	**78.12**	**76.68**	**76.67**
Stony Corals						
Pseudodiploria clivosa	4.59		1.28	0.33	0.44	**1.33**
Porites porites	0.73		0.43	1.77	2.20	**1.02**
Pseudodiploria strigosa		0.47	2.88			**0.67**
Porites astreoides	0.85		0.21		0.22	**0.26**
Total Stony Corals	**6.17**	**0.47**	**4.80**	**2.10**	**2.86**	**3.28**
# Coral Colonies/Transect	6	1	5	3	5	**4.0**
# Erect Soft Corals/Transect	4	2	2	3	0	**2.2**
Zoanthids						
Palythoa caribaeorum	4.59	0.00	3.42	1.66	8.80	**3.69**

The loss of stony coral cover was largely related to the massive mortality of elkhorn coral (*Acropora palmata*) in permanent transects and throughout the reef (Figure 34). *A. palmata* was the dominant species of the stony coral assemblage during the 2018 baseline survey at DOMI05 with a mean cover of 52.47%, representative of 89.9% of the total cover by corals (Garcia-Sais et al., 2018). Colonies of *A. palmata* were all observed standing dead covered by algae during the October 2021 survey. In addition to the drastic declines of cover by *A. palmata*, a 91.7% decline of cover by symmetrical brain coral (*Pseudodiploria strigosa*) was also measured during the 2021 survey at DOMI05 (Garcia-Sais et al., 2021). These observations are consistent with a report of mass mortalities of stony corals (particularly *A. palmata*), motile invertebrates, and fishes in the vicinity of El Escambrón and Piedra La Ocho reefs (San Juan) during the period between July 31 and August 8, 2020 (Hernández-Delgado et al., 2020). Mortalities were associated with a prolonged period of high-water turbidity, algal blooms, and surface water anoxic/hypoxic conditions following extreme rainfall and coastal flooding during and shortly after the pass of Tropical Storm Isaias during July 29-30 across the north coast of Puerto Rico (Hernández-Delgado et al., 2020).

Further changes to the benthic community structure were measured during the 2023 survey associated to a 35.6% decline of cover by knobby brain coral (*Pseudodiploria clivosa*) a small 15.7% increase of cover by finger coral (*P. porites)* during the same time frame. During the most recent 2025 survey, coral cover and the relative composition of stony coral species has remained virtually stable without any statistically significant differences (see Appendix 3). The most notable difference in community structure was a 109.6% increase in cover by the encrusting zoanthid (*Palythoa caribaeorum*) relative to the previous 2023 survey.

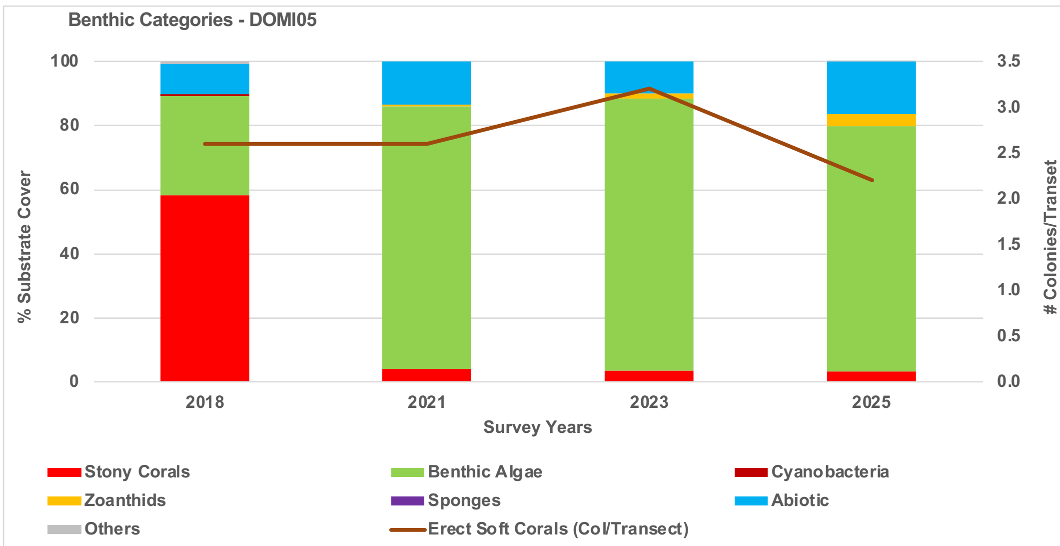


Figure 33. Monitoring trends (2018 - 25) of mean substrate cover by sessile-benthic categories at DOMI05, Carolina. PRCRMP 2025 survey

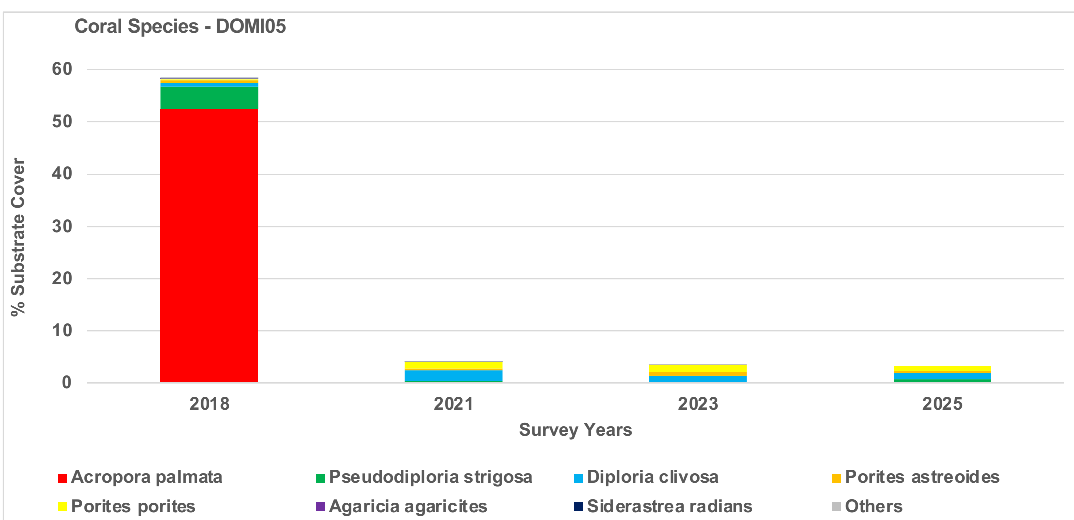


Figure 34. Monitoring trends (2018 – 25) of mean substrate cover by the main coral species intercepted by transects at DOMI05, Carolina. PRCRMP 2025 survey

21.3 Fishes and Motile Megabenthic Invertebrates

A total of 11 fish species were observed within belt-transects at DOMI05 during the 2025 monitoring survey with a mean density of 29.2 Ind/30m^2 and a mean species richness of 6.6 Spp/30m^2 (Table 30). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 9.4 Ind/30m^2, representative of 32.2% of the total fish density. In addition to the bluehead wrasse, another two species were observed within all five belt-transects with a combined density of 13.0 Ind/30m^2, or 44.5% of the total. These included the dusky damselfish (*Stegastes adustus*), and the slippery dick (*Halichoeres bivittatus*). Small mixed schools of blue tangs and ocean surgeons (*Acanthurus coeruleus, A. tractus*) were observed in transit over the reef, including some within belt-transects with a mean density of 1.4 Ind/30m^2*).* Motile megabenthic invertebrates were not observed within transects. Rock-boring urchins (*Echinometra lucunter)* were observed within and outside transects, but these small cryptic urchins have not been included in our surveys.

The fish trophic structure at DOMI05 during the 2025 survey was strongly dominated by small opportunistic carnivores (SOC) with a combined density of 15.6 Ind/30m^2, representative of 53.4% of the total fish density (Table 30). The assemblage included five species, including four wrasses (Labridae) and one mojarra (Gerreidae). Small opportunistic carnivores are common in shallow reef systems where strong wave and surge action expose benthic infauna (worms, shrimps, crabs) that represent their main diet. The herbivore assemblage (HER) was comprised by two damselfishes (Pomacentridae), two doctorfishes (Acanthuridae), and one parrotfish (Scaridae) with a combined density of 11.0 Ind/30m^2, representative of 37.7% of the total individuals within belt-transects. Large/medium sized carnivores were represented by juvenile bar jacks (*Caranx ruber*), and one juvenile schoolmaster snapper (*Lutjanus apodus*) in extended belt-transects (Table 31). Juvenile cero mackerels (*Scomberomorus regalis*) were observed outside transects near the border of the reef.

The size distribution of the larger reef herbivores observed within belt-transects at DOMI05 during the 2025 survey is shown in Table 31. Juvenile and adult doctorfishes (*Acanthurus* spp.) were the numerically dominant assemblage with a density of 2.8Ind/60m^2. Recruitment stages of the blue tang were observed during previous surveys at DOMI05 indicative that this reef functions as a recruitment, nursery, and residential habitat for this species. Juvenile parrotfishes (*Scarus taeniopterus, Sparisoma rubripinne*) were also observed within transects with a combined density of 0.6 Ind/60m^2.

Table 30. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at DOMI05, Carolina. PRCRMP 2025

DOMI0505							
Survey Date: 8/15/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	10	5	8	15	9	**9.4**	SOC
Stegastes adustus	8	9	7	8	11	**8.6**	HER
Halichoeres bivittatus	6	4	5	4	3	**4.4**	SOC
Abudefduf saxatilis	8	2		1	2	**2.6**	ZPL
Halichoeres maculipinna	2		3		2	**1.4**	SOC
Microspathodon chrysurus		1	1		2	**0.8**	HER
Acanthurus coeruleus		1		1	2	**0.8**	HER
Acanthurus tractus				2	1	**0.6**	HER
Halichoeres radiatus	1					**0.2**	SOC
Gerres cinereus	1					**0.2**	SOC
Sparisoma rubripinne			1			**0.2**	HER
Density (Ind/30m2)	36	22	25	31	32	**29.2**	
Richness (Species/30m2)	7	6	6	6	8	**6.6**	

Table 31. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at DOMI05, Carolina. PRCRMP 2025

DOMI05							
Survey Date: 8/15/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	14	0	0	0	1	0	Juvenile
Acanthurus coeruleus c2	2-8, 10	0	1	1	0	1	Juvenile
Acanthurus coeruleus c3	2-13, 3-15	2	1	0	1	1	Adult
Acanthurus tractusc2	9	0	0	0	0	1	Juvenile
Acanthurus tractusc3	11, 2-12, 14	0	1	0	3	0	Juvenile
Caranx ruber c3	3-15	3	0	0	0	0	Juvenile
Lutjanus apodus c4	20	0	0	1	0	0	Juvenile
Scarus taeniopterus c3	12, 15	0	1	0	0	1	Juvenile
Sparisoma rubripinne c2	8	0	0	1	0	0	Juvenile
	Totals	5	4	3	5	4	

Temporal variations of mean fish density measured during the 2018 baseline and three subsequent monitoring surveys at DOMI05 were small (range: 24.2 – 31.0 Ind/30m^2) and statistically insignificant (ANOVA, p = 0.282; Appendix 5) (Figure 35). The fish community was numerically dominated by species that have been resilient to the variability of physical conditions at the time of surveys, including the drastic deterioration of the benthic habitat associated with the massive loss of live stony coral cover after the 2018 baseline survey. Some of the most prominent species in terms of their mean densities within belt-transects, such as the dusky damselfish (*Stegastes adustus*), bluehead, clown, and slippery dick wrasses (*Thalassoma bifasciatum, Halichoeres maculipinna, Halichoeres bivittatus*), blue tangs (*Acanthurus coeruleus*), and the coney (*Cephalopholis fulva*) maintained or increased their densities in 2021.

The main difference between surveys was related to the motile megabenthic invertebrate community structure due to drastic decline of sea urchins, represented by three species (*Diadema antillarum, Echinometra lucunter, Eucidaris tribuloides*) with a combined density of 19.6 Ind/30m^2 during the 2018 survey. Densities of all three species declined to zero during the 2021 survey, although a few adult rock-boring urchins (*E. lucunter)* were observed outside transects. While either by tolerance or escapement the resident fishes were resilient to the causal stressor of the coral mass mortality at DOMI05, sea urchins were not. This is consistent with observations by Hernandez-Delgado (2020) of the high vulnerability of sea urchins to the water quality conditions associated with the coastal flooding caused by the pass of Tropical Storm Isaías during July - August 2020. During the 2025 survey, mean fish density (29.2 Ind/30m^2) was within the range of previous surveys (Figure 35).

Variations of fish species richness between monitoring surveys were statistically significant (ANOVA, p = 0.009; Appendix 6) associated to the higher richness in 2021 (9.00 Spp/30m^2) compared to 2023 (6.0 Spp/30m^2), and 2025 (6.6 Spp/30m^2). Differences were mostly related to the absence of species in 2023 and 2025 that were present in very low densities during the 2021 survey. These results must be evaluated with caution due to the very small sample sizes but given the drastic deterioration of the benthic habitat at DOMI05 potential limitations imposed by loss of structural habitat complexity may be having and/or may have implications for the fish community structure, both in terms of species richness and the taxonomic composition of the residential assemblage.

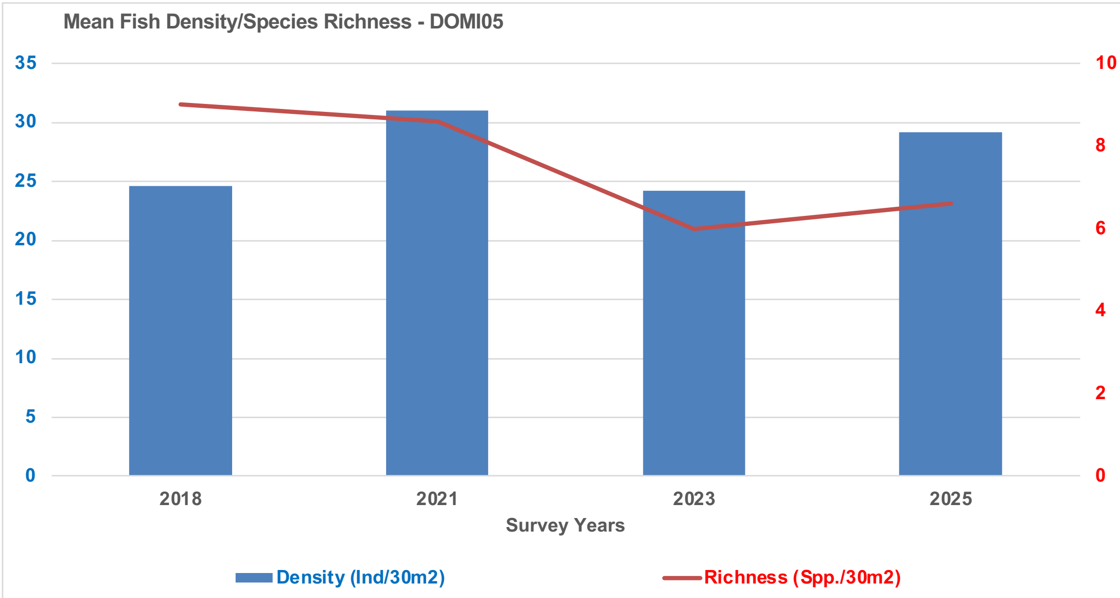
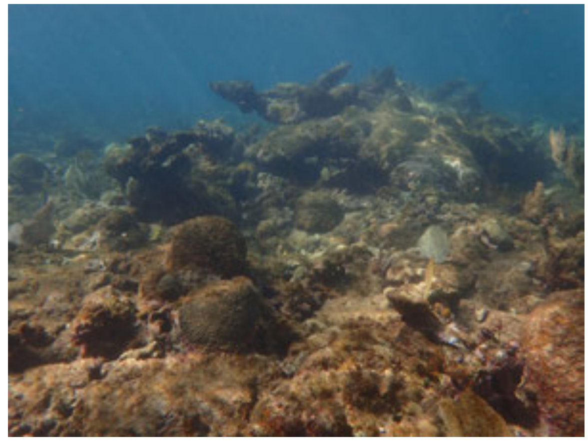


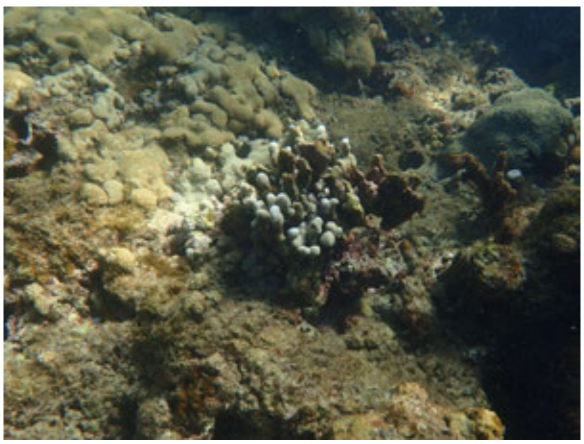
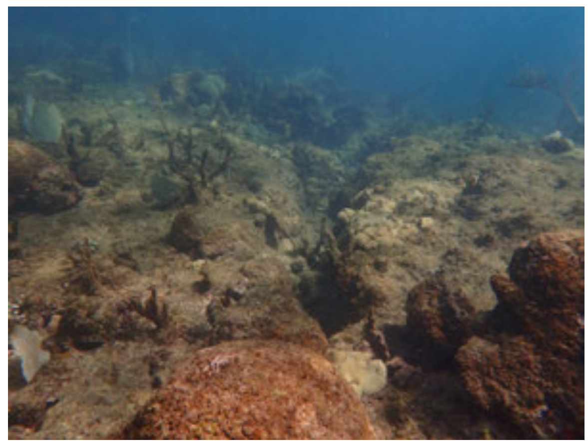
Figure 35. Monitoring trends (2018 – 25) of mean fish density and species richness within 10 x 3m belt-transects at DOMI05, Carolina. PRCRMP 2025

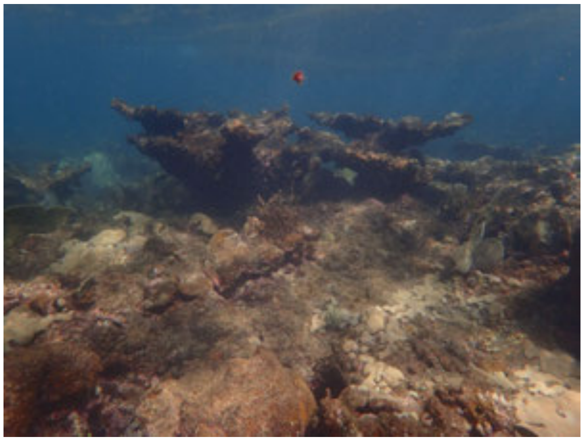
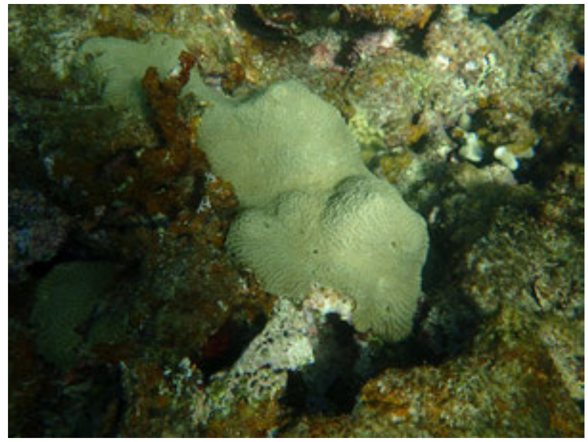
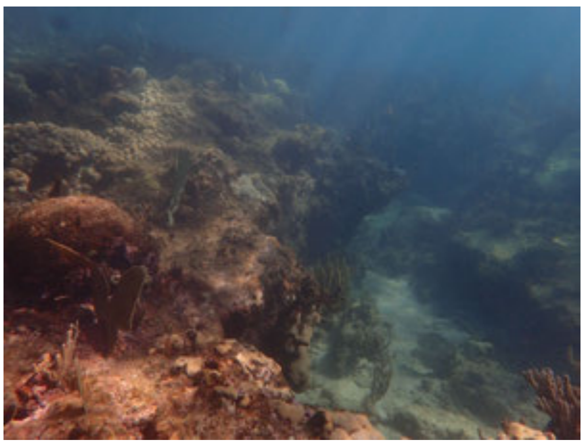
Photo Album 10. DOMI05

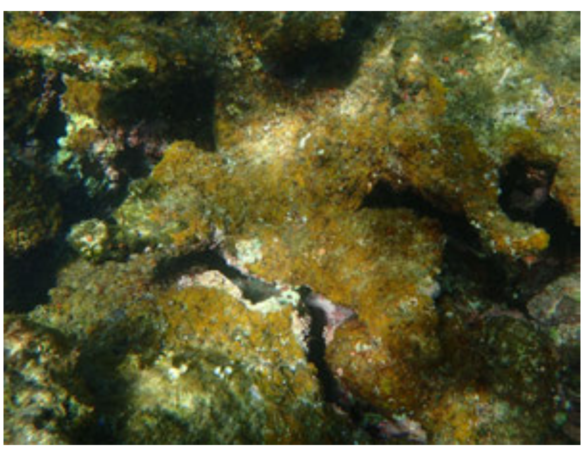










11.0 Cibuco Reef 5m, Vega Baja (CIBU05)

11.1 Physical Description

At approximately 0.5 km off the Vega Baja coastline lie a small group of emergent reefs known as Isletas de Garza (Figure 36). These appear to be relict structures of cemented sand dunes (aeolianites) that run roughly parallel to the coastline. Due west of the Isletas lies the mouth of Rio Cibuco, which discharges into a small embayment partially closed by an extensive sand bar. The reef community associated with the Isletas de Garza receives strong wave action from north Atlantic swells during the winter (October – April) and is influenced by estuarine conditions during the rainy season. Despite such environmentally rough conditions an impressive coral reef system developed along the leeward section of the Isletas, and since it lies within the Cibuco River plume we have named this system as Cibuco Reef (CIBU05). The baseline characterization of Cibuco Reef was performed during October 2011 (Garcia-Sais et al., 2012). During 2013, transect 2 could not be found and a new transect was installed in the vicinity of T2. Panoramic views of the reef community at CIBU05 taken during the 2025 monitoring survey are shown in Photo Album 11.

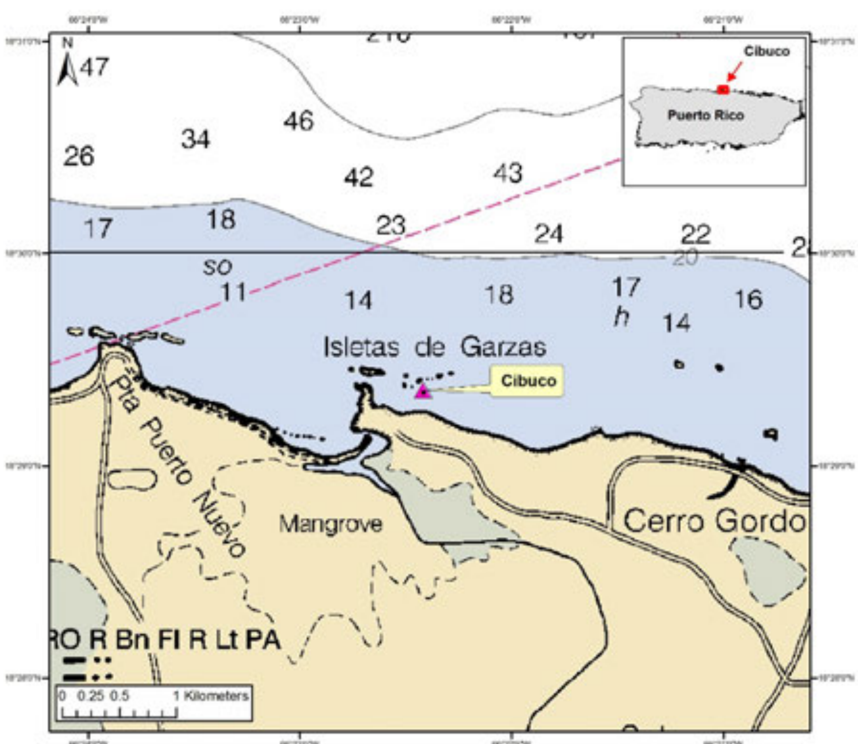


Figure 36. Location of CIBU05 at Isletas de Garza off Vega Baja in the north coast of Puerto Rico. PRCRMP 2025

10.2 Sessile-Benthic Reef Community

Benthic algae were the dominant sessile-benthic category in terms of reef substrate cover at CIBU05 during the 2025 monitoring survey with a mean cover of 59.36% (range: 36.72 – 71.07%). Red crustose calcareous algae, *Ramicrusta sp*. and other Peyssonnelid algae were the main taxonomic component with a combined mean cover of 28.95%, representative of 48.8% of the total cover by benthic algae (Table 32). Turf algae, a mixed assemblage of short brown and red algae that are highly resilient to wave action were present in all five transects with a mean cover of 23.61%, or 39.8% of the total cover by benthic algae. Most of the turf algae was packed with fine sediments, probably due to the high resuspension associated with wave action. Fleshy brown y-twig alga (*Dictyota* sp) was also intercepted by the five transects surveyed with a mean cover of 5.90%. Small tufts of green macroalgae (*Udotea* sp., *Caulerpa* sp.) were intercepted by transects with low substrate cover (< 1%). Cyanobacterial patches were intercepted by three transects with a mean cover of 3.30%.

A total of five scleractinian corals were intercepted by transects during the 2025 survey with a mean substrate cover of 15.32% (range: 0 – 38.96%). Mountainous star coral (*Orbicella faveolata*), and finger coral (*Porites porites*) *were* the main species in terms of reef substrate cover with a combined mean of 11.45%, representative of 78.2% of the total cover by stony corals (Table 32). Star corals (including *O. faveolata* and *O. annularis*) were present along transects with a combined cover of 2.81%, representative of 18.3% of the total cover by stony corals. Star corals (*Orbicella* spp.) were present mostly as mound colonies of small to moderate size, but several massive colonies, including some in advanced degradation stages were also present. Extensive thickets of finger coral were observed overlying the aeolianite rock at depths between 1 - 3 m. Thickets were at least 40 cm thick and exhibited continuous linear extensions of more than 10m (3 - 4m wide) in various reef sections. During the 2023 and 2025 survey large sections of these thickets were broken, detached, and observed lying over the sandy bottom in advanced deterioration stage. Mustard hill coral (*Porites astreoides*) were present in two transects, with a mean substrate cover of 0.32%. A total of 27 stony coral colonies were intercepted by transects, none of which were observed to be affected by coral diseases (see Appendix 2). Recently dead colonies and large sections of *O. faveolata and O. annularis* colonies were observed within transects. Widespread mortality of *Pseudodiploria strigosa* and *Siderastrea siderea* colonies within transects and throughout the reef was also evident.

Table 32. Percent reef substrate cover by sessile-benthic categories at CIBU05, Vega Baja. PRCRMP 2025

CIBU05			**Transects**			
Survey Date: 7/24/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**1.5**	**1.5**	**1.8**	**2.7**	**2.7**	**2.04**
Rugosity (m)	5.78	5.79	5.86	4.34	4.13	**5.18**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	21.56	21.54	29.13	14.55	14.17	**20.19**
Sand	2.13				3.07	**1.04**
Total Abiotic	**23.69**	**21.54**	**29.13**	**14.55**	**17.24**	**21.23**
Benthic Algae						
Ramicrusta spp.	31.32	38.74	25.24	17.68	27.85	**28.17**
Turf (mixed) with sediment	26.97	12.23	15.36	1.27	16.75	**14.52**
Turf (mixed)	0.44	6.83	2.56	10.94	21.31	**8.42**
Dictyota spp.	12.33	0.62	7.41	6.35	2.78	**5.90**
Peyssonnelia spp.		1.42	2.29	0.20		**0.78**
Turf (mixed) on *Ramicrusta*		3.37				**0.67**
Penicillus sp.		0.71	1.06	0.29	0.69	**0.55**
Udotea spp.		0.89				**0.18**
Caulerpa spp.			0.88			**0.18**
Total Benthic Algae	**71.07**	**64.80**	**54.81**	**36.72**	**69.38**	**59.36**
Cyanobacteria	**4.44**	**2.30**	**0.00**	**9.77**	**0.00**	**3.30**
Stony Corals						
Porites porites		2.39	7.24	38.96	10.60	**11.84**
Orbicella faveolata		4.96	8.56			**2.71**
Pseudodiploria strigosa		1.77				**0.35**
Porites astreoides		0.71			0.89	**0.32**
Orbicella annularis					0.50	**0.10**
Total Stony Corals	**0.00**	**9.84**	**15.80**	**38.96**	**11.99**	**15.32**
# Coral Colonies/Transect	**0**	**8**	**3**	**10**	**6**	**5.4**
# Erect Soft Coral Colonies/Transect	**3**	**0**	**0**	**1**	**0**	**0.8**
Zoanthids						
Palythoa caribaeorum		**1.33**	**0.26**			**0.32**
Soft Corals						
Erythropodium caribaeorum		0.18				**0.04**
Total Soft Corals		**0.18**				**0.04**
Sponges						
Neopetrosia spp. smooth	0.80				1.39	**0.44**
Total Sponges	**0.80**	**0.00**	**0.00**	**0.00**	**1.39**	**0.44**

Vertically projected soft corals were present in two transects with a mean density of 0.8 Colonies/Transect. Encrusting colonial soft coral (*Erythropodium caribaeorum*) and zoanthids (*Palythoa caribbea*) were also intercepted by transects at CIBU05 during the 2025 survey with a combined cover of 0.36%. Abiotic substrates were mostly contributed by reef overhangs associated with live and dead stony coral buildups with a mean cover of 20.19%. Sponges were intercepted by two transects with a mean cover of 044% (Table 32).

Temporal variations of reef substrate cover by sessile benthic categories between monitoring surveys at CIBU05 are shown in Figure 37. The most relevant change of benthic community structure at CIBU05 between monitoring surveys has been a drastic decline of reef substrate cover by live stony corals and a corresponding increment by benthic algae, particularly the red crustose coralline and encrusting *Ramicrusta* sp. Substrate cover by stony corals remained stable during the period between the 2011 baseline and the 2016 monitoring survey. A 12.1% reduction of cover was measured during the 2018 survey and related to breakage of colonies and other physical damages caused by Hurricane Maria in 2017 and/or winter storm Riley in 2018 (Garcia-Sais et al, 2018). A much larger decline of stony coral cover (-32.3%) was measured in 2021, largely related to reductions of cover by *Orbicella* spp., and *Pseudodiploria strigosa* (Figure 38). These apparently driven by massive tissue losses caused by infectious disease(s) (Garcia-Sais et al, 2022a).

The largest reduction of reef substrate cover by stony corals (-44.9%) was measured during the previous 2023 monitoring survey relative to the 2021 survey. In this case, the massive decline of cover was largely related to a 65.5% decline of cover by finger coral. The main cause of such decline of cover by finger coral appears to be physical damages associated with breakage and detachment of large colony sections from the main thicket, as this species has shown to be resilient to infectious coral diseases at this reef. It is possible that strong wave action may have caused such large-scale breakage of colonies in part because finger coral grows laterally beyond its hard ground base leaving large sections of the thicket exposed to mechanical damage.

During the 2025 survey, reef substrate cover by stony corals increased by 4.57% driven by a partial recuperation (92.5%) of finger coral (*Porites porites*), combined with a 81.5% decline of *Orbicella* spp. (Figure 38). The decline of cover by Orbicella spp. is attributed to coral diseases following the 2023 global coral bleaching event (Goreau and Hayes, 2024). Despite the high sampling variability associated with stony coral cover within replicate transects, such differences are statistically significant (ANOVA, $p < 0.0001$; see Appendix 3).

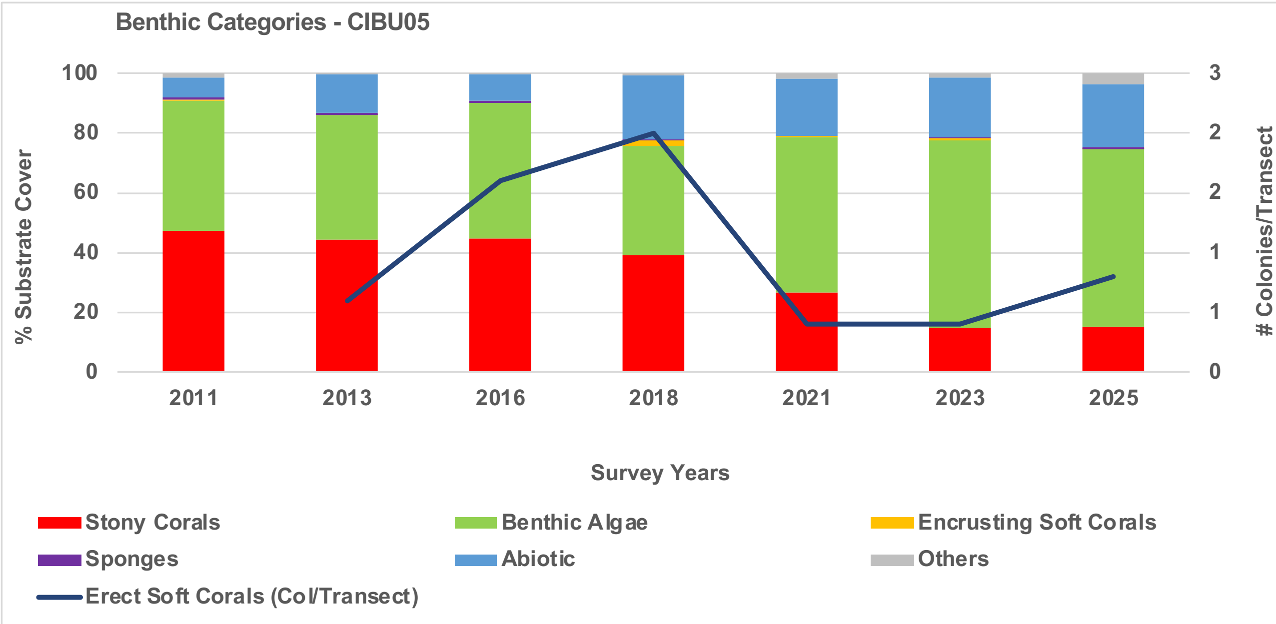


Figure 37. Monitoring trends (2011 – 2025) of mean substrate cover by sessile-benthic categories at CIBU05, Vega Baja. PRCRMP 2025

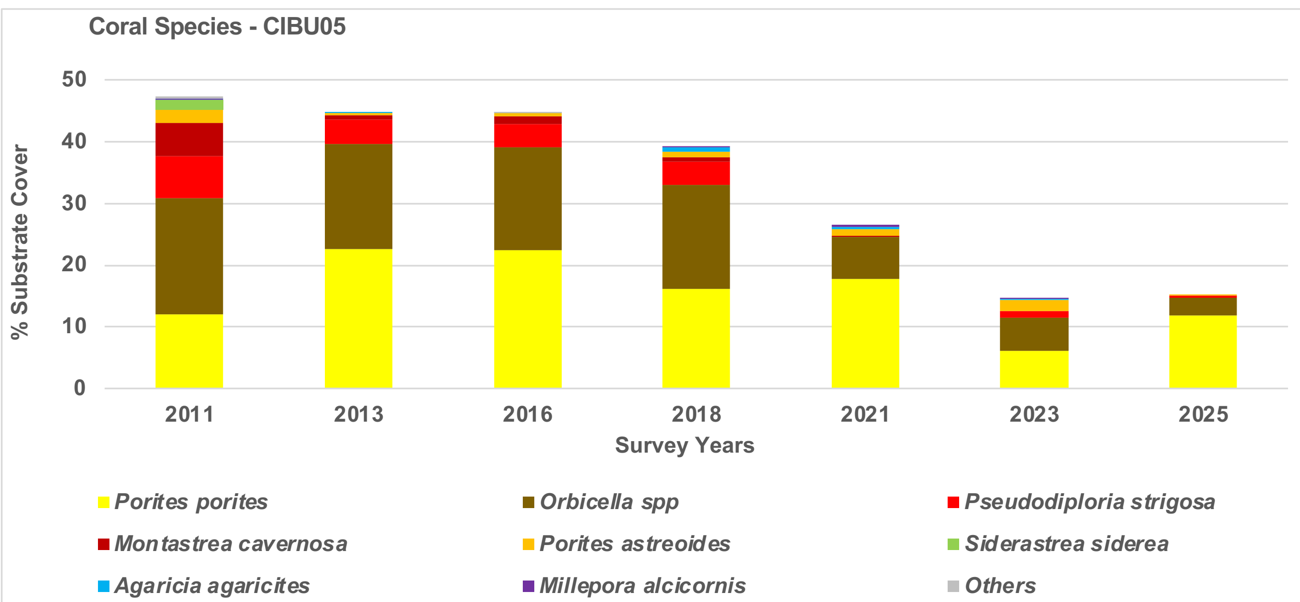


Figure 38. Monitoring trends (2011 – 2025) of mean substrate cover by stony coral species at CIBU05, Vega Baja. PRCRMP 2025

10.3 Fishes and Motile Megabenthic Invertebrates

A total of 33 fish species were identified within belt-transects at CIBU10 during the 2025 survey with a mean density of 86.2 Ind/30m^2 (range: 43 - 240 Ind/30 m^2), and a mean species richness of 16.0 Spp/30m^2 (Table 33). The dwarf herring (*Jenkinsia lamprotaenia*) and the bluehead wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with mean densities of 24.0 Ind/30m^2 and 21.4 Ind/30m^2, respectively. Their combined cover was representative of 52.7% of the total density. Part of a streaming school of dwarf herring entered one belt-transect whereas bluehead wrasse individuals were observed in all five transects. In addition to the aforementioned species an assemblage of five species were present in at least four transects and appear to be part of the residential fish community at CIBU05, these included the dusky damselfish (*Stegastes adustus*), clown wrasse (*Halichoeres maculipinna*), spanish hogfish (*Bodianus rufus*), ocean surgeon (*Acanthurus tractus*), and stoplight parrotfish (*Sparisoma viride*) with a combined cover of 17.2 Ind/30m2, representative of 20.0% of the total fish density. Schooling aggregations of yellow goatfish (*Mulloidichthys martinicus*) and french grunt (*Haemulon flavolineatum*) were observed within transects with contributions of 6.6 Ind/30m^2 and 2.6 Ind/30m^2 to the overall fish density. Motile megabenthic invertebrates were represented within belt-transects by two long-spined urchins (*Diadema antillarum*) (Table 33).

The fish trophic structure at CIBU05 was strongly comprised by small opportunistic carnivores (SOC), represented by 13 species and a combined density of 41.6 Ind/30m^2, or 48.3% of the total density. The assemblage included wrasses (Labridae), goatfishes (Mullidae), grunts (Haemulidae), mojarras (Gerreidae), squirrelfishes (Holocentridae), and puffers (Tetraodontidae). The herbivore (HER) assemblage was comprised by nine species, including three doctorfishes (Acanthuridae), three damselfishes (Pomacentridae), and three parrotfishes (Scaridae) with a combined density of 15.8 Ind/30m^2, representing 18.3% of the total individuals. Long-spined urchins (*Diadema antillarum*) also contributed to the HER trophic assemblage.

Mid-size carnivores included juvenile and adults of schoolmaster, grey, lane, and yellowtail snappers (*Lutjanus apodus, L. griseus, L. synagris, Ocyurus chrysurus*), juvenile and adult jacks (*Caranx crysos, C. ruber*), and adult coneys (*Cephalopholis fulva*) with a combined mean density of 4.8 Ind/60m^2 (Table 34). The larger reef herbivores were represented by juvenile and adult doctorfishes (*Acanthurus* spp) and parrotfishes with a combined density of 26.2 Ind/60m^2. Recruitment stages (1 – 2 cm) of stoplight parrotfish (*Sparisoma viride*) and doctorfishes (*A. tractus, A. coeruleus*) were observed within belt-transects.

Table 33. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CIBU05, Vega Baja. PRCRMP 2025

CIBU05							
Survey Date: 7/24/25	Belt-Transects (3x10m)						Trophic
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Jenkinsia lamprotaenia				120		**24.0**	ZPL
Thalassoma bifasciatum	22	9	5	61	10	**21.4**	SOC
Stegastes adustus	7	5	6	10	13	**8.2**	HER
Mulloidichthys martinicus	1		14	18		**6.6**	SOC
Halichoeres maculipinna	4	5		6	5	**4.0**	SOC
Haemulon flavolineatum		10	1	2		**2.6**	SOC
Anisotremus virginicus	8			1	2	**2.2**	SOC
Acanthurus coeruleus	3		1	5		**1.8**	HER
Acanthurus tractus	2	1	2	3	1	**1.8**	HER
Sparisoma viride	1	3	1	1	2	**1.6**	HER
Bodianus rufus		4	1	1	1	**1.4**	SOC
Halichoeres bivittatus	2	3				**1.0**	SOC
Lutjanus apodus			3	1	1	**1.0**	LC
Gerres cinereus	1			3		**0.8**	SOC
Abudefduf saxatilis	1		1	2		**0.8**	ZPL
Scarus taeniopterus		1	2		1	**0.8**	HER
Kyphosus sectatrix					4	**0.8**	ZPL
Holocentrus adscensionis	1	1	1			**0.6**	SOC
Caranx crysos		1		1	1	**0.6**	LC
Caranx ruber		1	1		1	**0.6**	LC
Microspathodon chrysurus				2	1	**0.6**	HER
Stegastes variabilis	1		1			**0.4**	HER
Canthigaster rostrata	2					**0.4**	SOC
Sparisoma rubripinne		1	1			**0.4**	HER
Pempheris schomburgkii	1					**0.2**	ZPL
Ocyurus chrysurus			1			**0.2**	LC
Lutjanus griseus			1			**0.2**	LC
Haemulon carbonarium				1		**0.2**	SOC
Haemulon chrysargyreum				1		**0.2**	SOC
Acanthurus chirurgus				1		**0.2**	HER
Melichthys niger					1	**0.2**	ZPL
Halichoeres radiatus					1	**0.2**	SOC
Cephalopholis fulva					1	**0.2**	LC
Invertebrates							
Diadema antillarum	0	0	1	0	1	**0.4**	HER
Density (Ind/30m2)	**57**	**45**	**43**	**240**	**46**	**86.2**	
Richness (Species/30m2)	**15**	**13**	**17**	**19**	**16**	**16.0**	

Table 34. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CIBU05, Vega Baja. PRCRMP 2025

CIBU05							
Survey Date: 7/24/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	11				1		Juvenile
Acanthurus coeruleus c1	3, 5, 4	2			1		Recruit
Acanthurus coeruleus c2	24-10, 7	2	1	1	1	20	Juvenile
Acanthurus coeruleus c3	3-15, 16-12, 3-14	1	3		3	15	Juvenile
Acanthurus tractus c1	5	1					Recruit
Acanthurus tractus c3	2-13, 3-12, 14	2	1	2		1	Juvenile
Acanthurus tractus c4	16	1					Adult
Caranx crysos c4	16				1		Juvenile
Caranx crysos c8	40		1				Adult
Caranx ruber c2	8		1				Juvenile
Caranx ruber c3	12			1			Juvenile
Caranx ruber c5	25, 30		1			1	Adult
Cephalopholis fulva c5	22					1	Adult
Lutjanus apodus c3	15				1		Juvenile
Lutjanus apodus c4	18, 6-20			3		4	Juvenile
Lutjanus apodus c5	2-25			2			Adult
Lutjanus apodus c6	28, 30		1			1	Adult
Lutjanus griseus c6	30, 35, 33			2		1	Adult
Lutjanus synagris c4	18	1					Adult
Ocyurus chrysurus c3	15			1			Adult
Scarus taeniopterus c2	3-8		1	2			Juvenile
Scarus taeniopterus c3	12					1	Juvenile
Sparisoma rubripinne c3	15		1				Juvenile
Sparisoma rubripinne c5	23					1	Adult
Sparisoma rubripinne c6	26			1			Adult
Sparisoma viride c1	2-3, 2-4, 5	1	1		1	2	Recruit
Sparisoma viride c2	6, 10		2				Juvenile
Sparisoma viride c4	20			1			Adult
	Totals	**11**	**14**	**16**	**9**	**48**	

The temporal variations of mean fish density and species richness between monitoring surveys at CIBU05 are presented in Figure 39. Fish density has varied between a maximum of 86.2 Ind/30m^2 during the most recent 2025 survey to a minimum of 28.6 Ind/30m^2 during the 2013 survey. Due to the high sampling variability differences of fish density between surveys were not statistically significant (ANOVA, p = 0.211; Appendix 5). Density fluctuations have been strongly influenced by the physical conditions at the time of survey, and the sporadic presence of fish schooling aggregations (e.g. *Jenkinsia lamprotaenia*, *Caranx* spp., *Mulloidichthys martinicus*, *Acanthurus* spp.).

Differences of species richness were statistically significant (ANOVA, $p < 0.0001$; Appendix 6) associated with lower values in 2013 and 2016 relative to the 2011 baseline and the most recent 2023 sand 2025 surveys. Such fluctuations are a common feature of the fish community structure in shallow reefs due to the mechanical influence of wave action on small fish individuals, particularly those that dwell in the water column out of protective microhabitats. During the 2025 survey the physical conditions were rough and the maximum fish densities were measured at CIBU05 largely driven by the presence of a large school of dwarf herring (*Jenkinsia lamprotaenia*) which is a prime forage species for jacks (*Caranx* spp.) and other reef fish piscivores, including snappers (*Lutjanus* spp.), small cero mackerels (*Scomberomorus regalis*), and great barracudas (*Sphyraena barracuda*) observed outside transects.

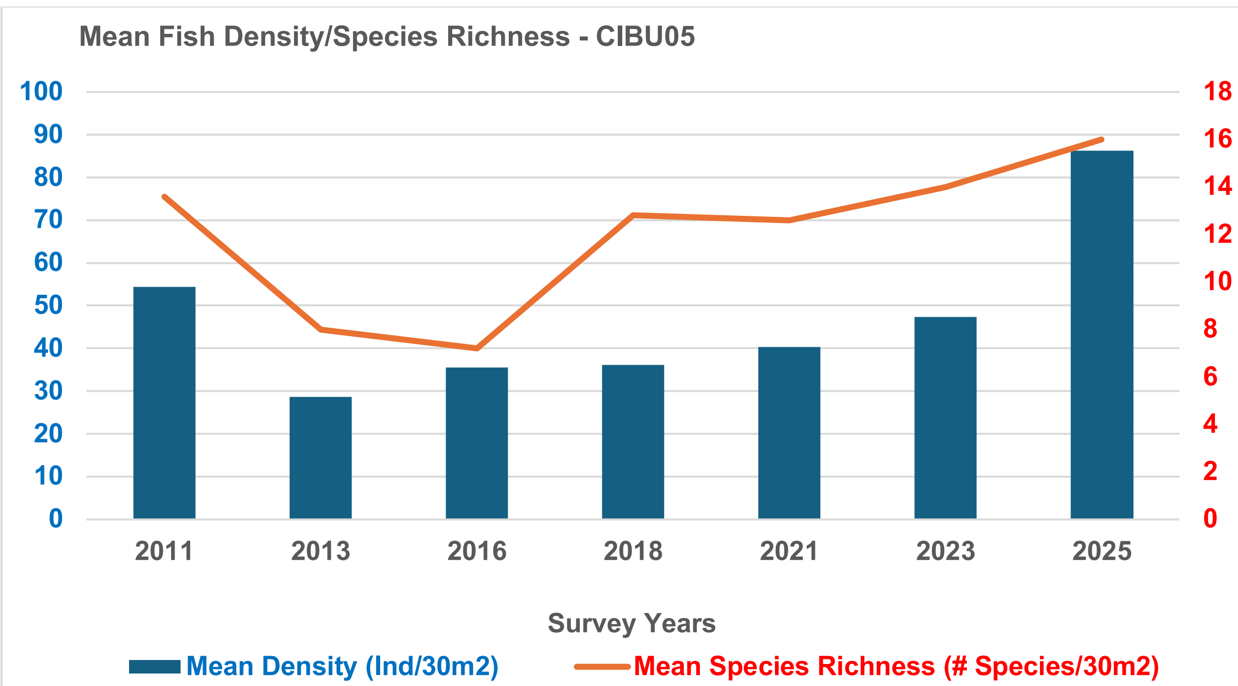
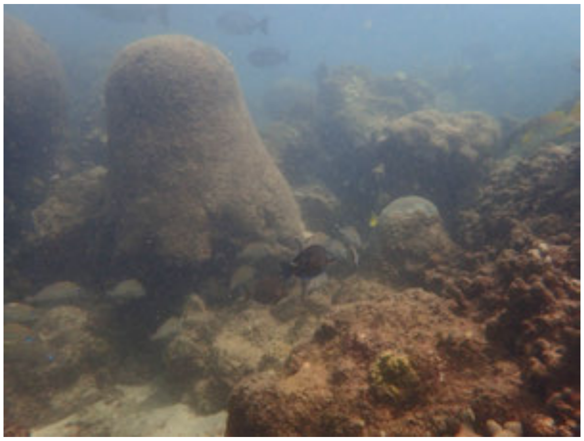
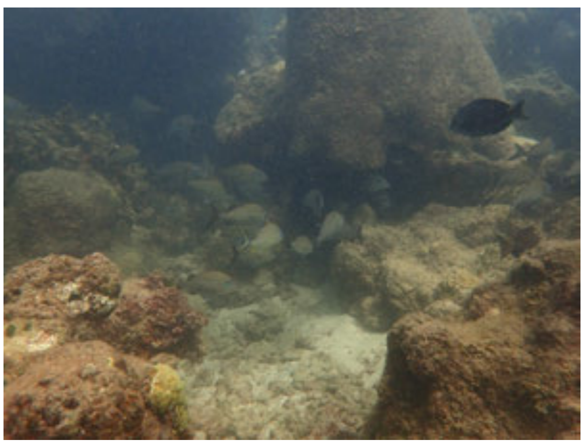
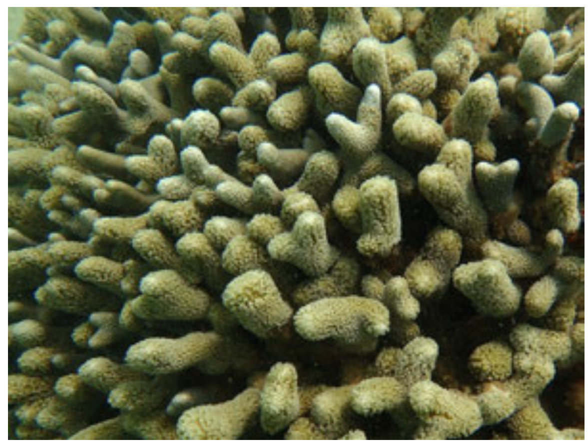


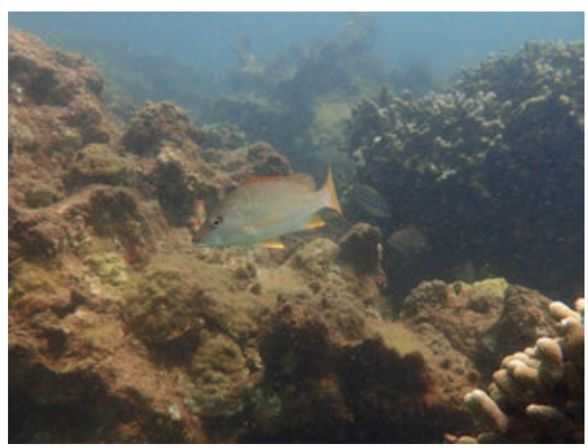
Figure 39. Monitoring trends (2011 – 2025) of mean fish density and species richness within 10 x 3m belt-transects at CIBU05, Vega Baja. PRCRMP 2025 survey.

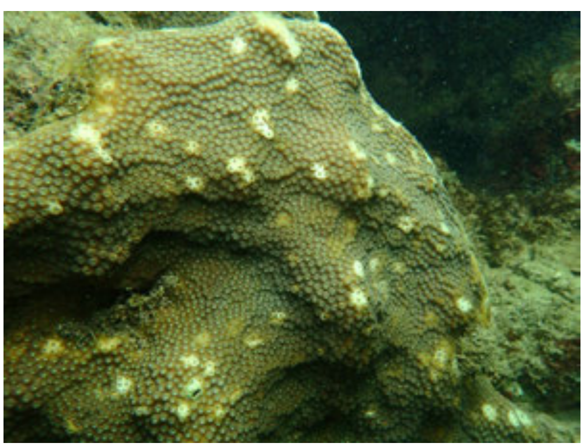
Photo Album 11. CIBU05

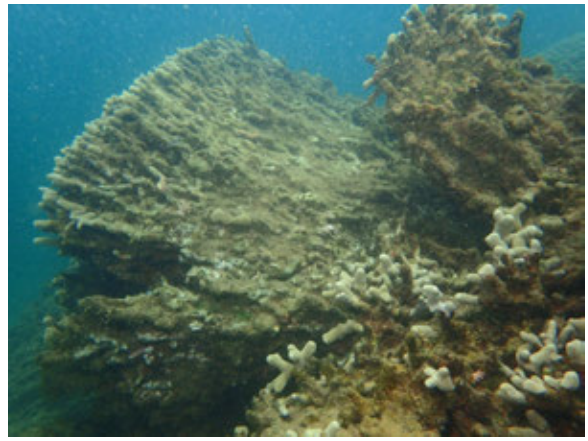


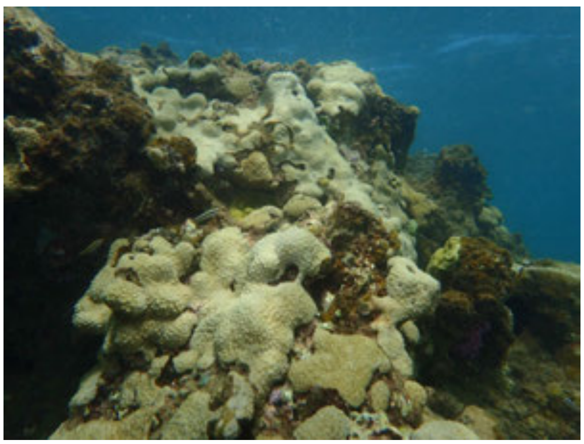


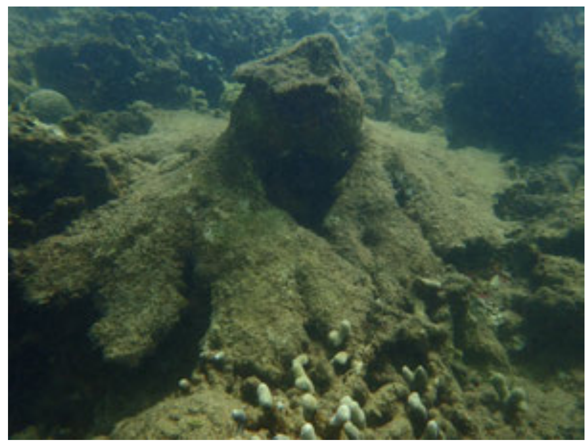


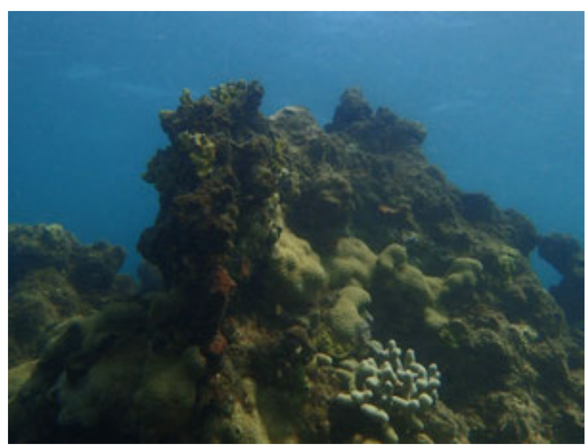












12.0 Las Cabezas Reef 5m, Fajardo (CABE05)

12.1 Physical Description

Las Cabezas Reef (CABE05) is located about 0.3 NM off the western tip of Cabo San Juan, on the easternmost corner of mainland Puerto Rico (Figure 40). The reef system is a colonized pavement habitat with minor topographic relief provided by coral heads and basket sponges. The reef community is evidently influenced by strong surge and sand abrasion due to prevailing high wave action over a relatively narrow and shallow shelf. The baseline survey of CABE05 was performed in July 2018. Permanent transects were established close to the border of the hard-ground shelf at depths of 5.8 – 6.1m. Photographic documentation of the CABE05 reef community during the 2025 monitoring survey is presented as Photo Album 12.

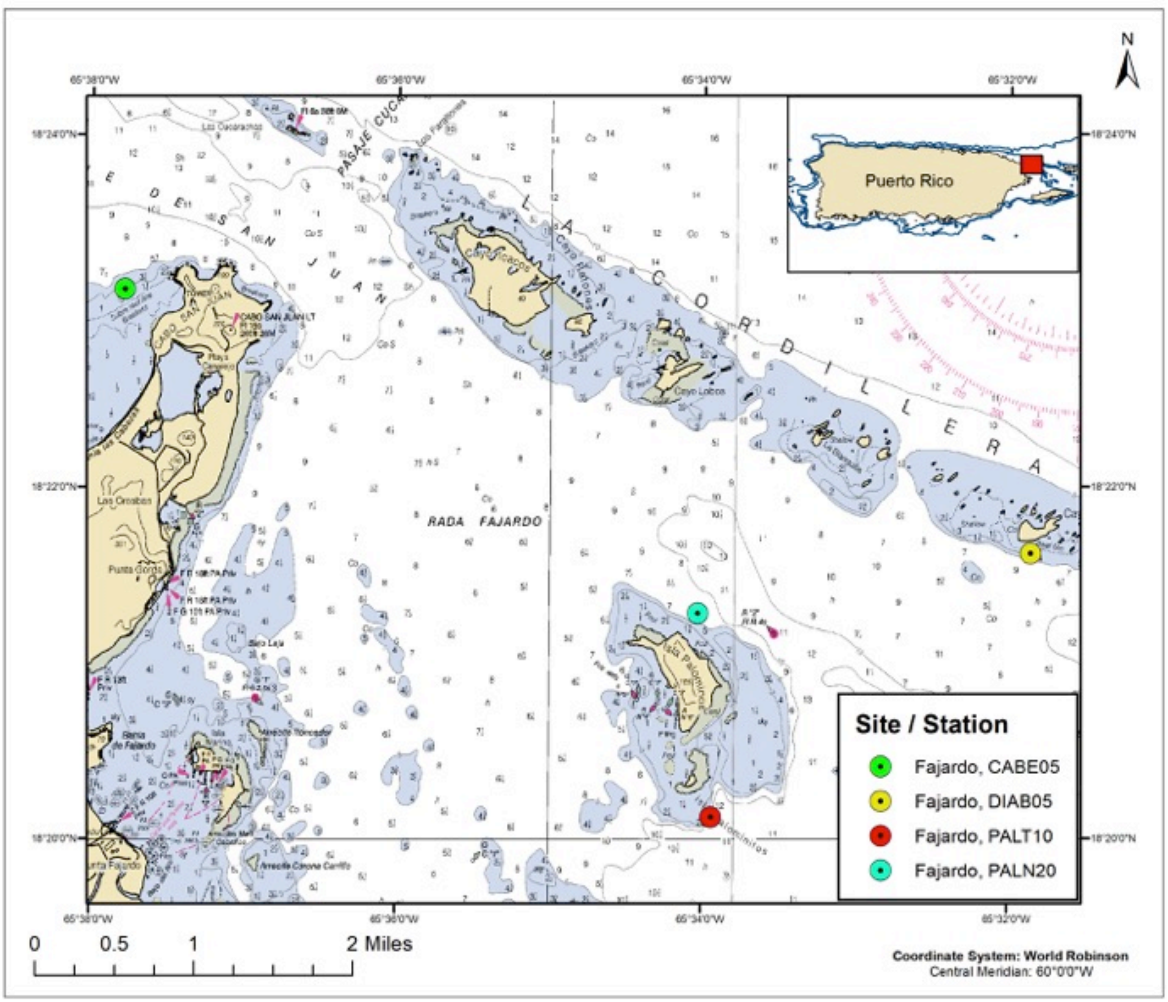


Figure 40. Location of coral reef monitoring stations within the Cordillera de Fajardo Natural Reserve. PRCRMP 2025

12.2 Sessile-benthic Reef Community

The dominant sessile-benthic category at CABE05 during the 2025 monitoring survey was benthic algae, with a mean substrate cover of 91.40% (Table 35). Benthic algae were comprised by a mixed assemblage of turf, brown fleshy (*Dictyota* sp.), red crustose coralline, (*Ramicrusta* sp., *Peyssonnelia* sp.), and green calcareous macroalgae (*Halimeda* sp.). Turf algae, a mixed assemblage of short articulate red and brown algae was the main component with a mean substrate cover of 57.20%, representative of 62.58% of the total benthic algae. Red crustose coralline algae, mostly *Ramicrusta sp*., were present in all five transects surveyed growing encrusted over available reef hard substrates, particularly dead corals, with a mean cover of 11.47%, or 12.55% of the total benthic algae. The fleshy brown, y-twig alga (*Dictyota sp.*) was also present in all transects with a mean cover of 22.56% (Table 35).

Stony corals were represented by four scleractinians intercepted by transects with a combined mean cover of 3.47% (range: 0.81 – 5.76%) (Table 35). Mustard-hill coral (*Porites astreoides*) was dominant species in terms of reef substrate cover with a mean of 2.09%, and the only species intercepted by all five transects. Symmetrical brain coral (*Pseudodiploria strigosa*), and massive starlet coral (*Siderastrea siderea*) were present in two and three transects, respectively with a combined cover of 0.98%, representative of 28.24% of the total cover by stony corals. Small colonies of staghorn coral (*Acropora cervicornis*) were observed growing in grooved and other substrate anomalies. One large colony (about one meter diameter) of staghorn coral (*A. palmata*) was observed in good health. Several other *A. palmata* colonies were observed standing dead in advanced stage of degradation. A total of 31 stony coral colonies were intercepted by transects, none of which were observed to be affected by coral disease infections (Appendix 2).

Erect soft corals were present in all five transects with a mean density of 3.6 Colonies/transect. Soft coral species identifications are not available but sea rods (*Eunicea spp*), and sea fans (*Gorgonia spp*) appeared to be the most common. One colony of the encrusting gorgonian (*Erythropodium caribaeorum*) was intercepted in one transect with a mean cover of 0.60%. The encrusting zoanthid, *Palythoa caribdea* was also intercepted by transects with a mean cover of 0.08%. At least 10 sponge species were identified along transects at CABE05 with a combined cover of 3.61%. The giant basket sponge (*Xestospongia muta*) was the dominant species in terms of reef substrate cover with a mean of 1.75% and contributed markedly to the reef topography and structural complexity.

Table 35. Percent reef substrate cover by sessile-benthic categories at CABE05, Fajardo. PRCRMP 2025

CABE05						
Survey date: 6/21/25			**Transects**			
	1	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	6.1	5.8	6.1	5.8	6.1	**5.98**
Rugosity (m)	1.76	1.41	1.20	1.17	2.17	**1.54**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang		1.60		0.38		**0.39**
Total Abiotic		**1.60**		**0.38**		**0.39**
Benthic Algae						
Turf (mixed)	12.26	50.31	68.00	59.27	3.34	**38.64**
Dictyota spp.	20.71	21.23	20.88	18.92	31.07	**22.56**
Turf (mixed) with sediment	48.33	2.58			41.89	**18.56**
Ramicrusta spp.	7.74	14.11	3.63	12.28	18.99	**11.35**
Halimeda spp.	0.48			0.38		**0.17**
Peyssonnelia spp.		0.37	0.25			**0.12**
Total Benthic Algae	**89.52**	**88.59**	**92.75**	**90.85**	**95.28**	**91.40**
Cyanobacteris						**0.00**
Stony Corals						
Porites astreoides	1.55	2.21	2.50	3.38	0.81	**2.09**
Pseudodiploria strigosa		2.21	0.88			**0.62**
Montastraea cavernosa				2.01		**0.40**
Siderastrea siderea	1.19		0.25	0.38		**0.36**
Total Stony Corals	**2.74**	**4.42**	**3.63**	**5.76**	**0.81**	**3.47**
# Coral Colonies/Transect	**7**	**6**	**9**	**7**	**2**	**6.20**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
# Erect Soft Coral Colonies/Transect	**3**	**1**	**5**	**8**	**1**	**3.60**
Soft Corals						
Erythropodium caribaeorum	2.98					**0.60**
Eunicea flexuosa					0.46	**0.09**
Eunicea spp.					0.46	**0.09**
Total Soft Corals	**2.98**	**0.00**	**0.00**	**0.00**	**0.92**	**0.78**
Ascidians						**0.00**
Ascidian spp.		0.25		0.63		**0.17**
Anemones						
Ricordea florida	0.48					**0.10**
Zoanthids						
Palythoa caribaeorum				0.38		**0.08**
Sponges						
Xestospongia muta	1.19	3.56	2.75		1.27	**1.75**
Mycale laevis	2.26		0.25	0.25	0.23	**0.60**
Monanchora arbuscula	0.48	0.98		1.00		**0.49**
Amphimedon compressa		0.37			0.69	**0.21**
Neopetrosia spp. smooth	0.36		0.38			**0.15**
Ircinia felix					0.58	**0.12**
Aplysina insularis		0.25			0.23	**0.10**
Sponge spp.				0.38		**0.08**
Verongula spp.				0.38		**0.08**
Spirastrella coccinea			0.25			**0.05**
Total Sponges	**4.29**	**5.15**	**3.63**	**2.01**	**2.99**	**3.61**

Variations of reef substrate cover by the main sessile-benthic substrate categories between the 2018 baseline and subsequent monitoring surveys at CABE05 are shown in Figure 41. The main change in the reef benthic structure was related to a drastic, statistically significant decline of substrate cover by live stony corals since the 2021 survey (ANOVA, $p < 0.001$; Appendix 3). Substrate cover by stony corals declined from a mean of 13.3% in 2018 to a mean of 4.23% in 2023, a decline of 68.2%. The marked loss of stony coral cover was largely related to the reduction of cover by the two previously dominant species, *Pseudodiploria strigosa* (-88.7%), and *Siderastrea siderea* (-91.5%), resulting in a taxonomic phase shift where *Porites astreoides* is now the dominant coral species in terms of reef substrate cover (Figure 42). Substrate cover by stony corals declined again by 17.97% in 2025 relative to the previous 2023 survey. Reductions of cover were associated largely with a 18.99% decline of cover by mustard-hill coral (*Porites astreoides*), and the disappearance from transects of live colonies of grooved brain coral (*Diploria labyrinthiformis*), and the branching fire coral (*Millepora alcicornis*).

The continued degradation of the stony coral community at CABE05 measured since the 2021 survey appears to be associated with tissue loss and mortality caused by coral disease, perhaps triggered by the coral bleaching event that affected coral communities around Puerto Rico during October 2019, extending into February 2020, and then after the 2024 global ocean warming event. The high disease prevalence measured in 2021 (37.5%) was indicative of a severe problem with coral disease infections at this reef station. Disease infections on symmetrical brain coral (*Pseudodiploria strigosa*), and massive starlet coral (*Siderastrea siderea*) during the 2018 survey reported by Garcia-Sais et al. (2018) may have resulted eventually in the continued degradation and loss of coral cover by these previously dominant species. The decline of stony coral cover has been in part compensated by increases in cover by brown fleshy macroalgae (mostly *Dictyota* sp.), and red encrusting Peyssonnelid algae (mostly *Ramicrusta* sp.).

Density variations of erect soft coral colonies between monitoring surveys have shown a small increase in density relative to the 2018 baseline survey but differences were statistically insignificant (ANOVA, $p = 0.389$; Appendix 4).

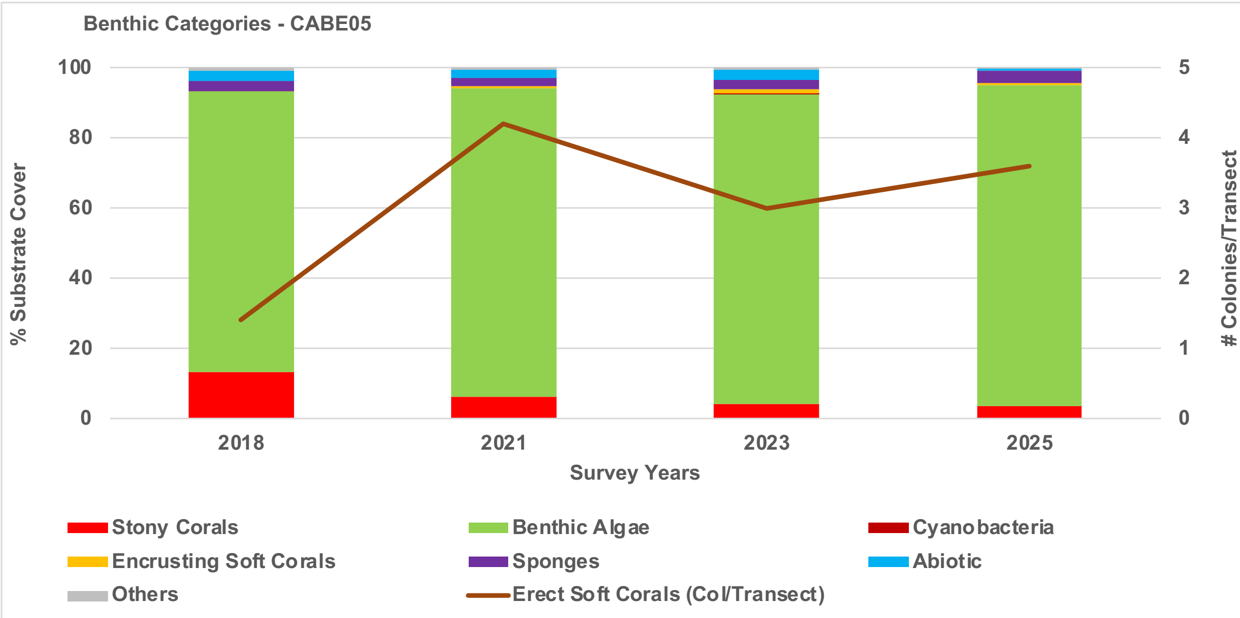


Figure 41. Monitoring trends (2016 - 2025) of mean substrate cover by sessile-benthic categories at CABE05, Fajardo. PRCRMP 2025

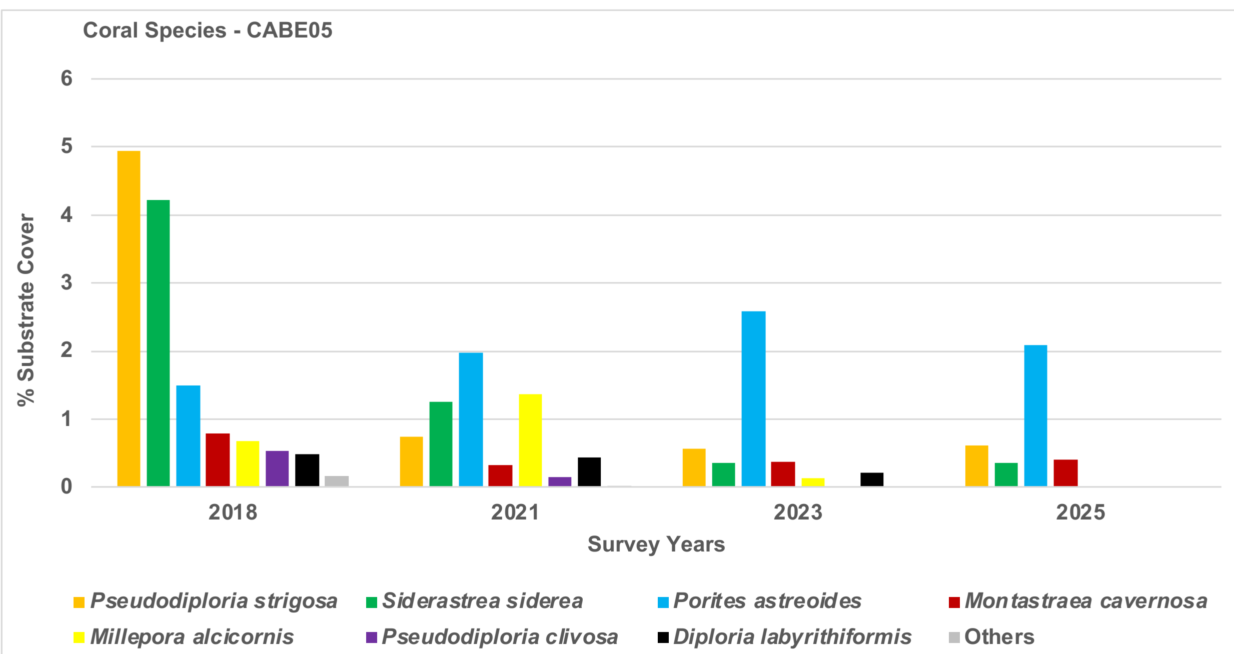


Figure 42. Monitoring trends (2016 - 2025) of mean substrate cover by the main coral species intercepted by transects at CABE05, Fajardo. PRCRMP 2025

12.3 Fishes and Motile Megabenthic Invertebrates

A total of 19 fish species were observed within belt-transects during the 2025 survey at CABE05 with a combined mean density of 42.6 Ind/30m^2 and a mean species richness of 10.0 Spp/30m^2. The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 19.4 Ind/30m^2, representative of 45.5% of the total fish density (Table 36). In addition to the bluehead wrasse, five species were present in at least four belt-transects with a combined mean density of 18.0 Ind/30m^2, representative of an additional 42.2% of the total individuals. These included the dusky damselfish (*Stegastes adustus*), black-ear, clown and slippery dick wrasses (*Halichoeres poeyi, H. maculipinna, H. bivittatus*), and ocean surgeon (*Acanthurus tractus*). Motile megabenthic invertebrates were represented within belt-transects by 15 long-spined urchins (*Diadema antillarum*) with a mean density of 3.0 Ind/30m^2, and one spider crab (*Stenorhynchus seticornis*) (Table 36).

Table 36. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CABE05, Fajardo. PRCRMP 2025

CABE05							
Survey Date: 6/21/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	19	27	22	17	12	**19.4**	SOC
Stegastes adustus	13	5	5	6	3	**6.4**	HER
Halichoeres poeyi	8	3	4	4	7	**5.2**	SOC
Acanthurus tractus	2	5	2	2	3	**2.8**	HER
Halichoeres bivittatus	4		2	1	3	**2.0**	SOC
Halichoeres maculipinna	2		1	2	3	**1.6**	SOC
Stegastes variabilis	2		3		1	**1.2**	HER
Acanthurus chirurgus		1			3	**0.8**	HER
Sparisoma rubripinne		1	1		1	**0.6**	HER
Acanthurus coeruleus		1		1	1	**0.6**	HER
Cephalopholis fulva	1	1				**0.4**	LC
Ocyurus chrysurus	1					**0.2**	LC
Canthigaster rostrata	1					**0.2**	SOC
Cephalopholis cruentata	1					**0.2**	LC
Bodianus rufus		1				**0.2**	SOC
Stegastes partitus			1			**0.2**	ZPL
Myripristis jacobus				1		**0.2**	SOC
Ophioblennius atlanticus				1		**0.2**	SOC
Chaetodon striatus				1		**0.2**	COR
Invertebrates							
Stenorhynchus seticornis		1				**0.2**	
Diadema antillarum	6	3		6		**3.0**	
Density (Ind/30m2)	54	45	41	36	37	**42.6**	
Richness (Species/30m2)	11	10	9	10	10	**10.0**	

Small opportunistic carnivores (SOC) were the dominant trophic fish assemblage at CABE05 during the 2025 survey with seven species and a combined density of 29.0 Ind/30m^2, representative of 68.1% of the total individuals within belt-transects (Table 36). The assemblage included five species of wrasses (Labridae), one blenny (Blenniidae), and one puffer (Tetraodontidae). Wrasses are small but fast and strong swimmers that thrive in high energy environments, such as CABE05 feeding upon small infaunal invertebrates and worms that become exposed with the waves and surge action. Herbivores (HER) were represented by six species, including doctorfishes (Acanthuridae), parrotfishes (Scaridae), and damselfishes (Pomacentridae) with a combined density of 12.4 Ind/30m^2, representative of 29.1% of the total fish density. Zooplanktivores (ZPL) were represented by the bicolor damselfish (*Stegastes partitus* - Pomacentridae) with a mean density of 0.2 Ind/30m^2. One coralivorous species (*Chaetodon capistratus* – Chaetodontidae) was also observed within belt-transects with a mean density of 0.2 Ind/30m^2.

The taxonomic composition and size distribution of commercially important fishes and the larger reef fish herbivores surveyed from extended belt-transects at CABE 05 during the 2025 survey is presented in Table 37. Mid-sized carnivores were represented by coney and graysby groupers (*Cephalopholis fulva, C. cruentata*), and the yellowtail and schoolmaster snappers (*Ocyurus chrysurus, Lutjanus apodus*) with a combined density of 1.4 Ind/60m^2. Red hinds (*Epinephelus guttatus*), southern stingray (*Dasyatis americana*), and the great barracuda (*Sphyraena barracuda*) are also mid-size and/or large pelagic predators previously reported at CABE05 (Garcia-Sais et al., 2023 and references therein).

The larger reef fish herbivores were mostly represented by doctorfishes with three species and 34 individuals for a combined density of 6.9 Ind/60m^2. Small recruitment and juvenile stages of the ocean surgeon (Acanthurus tractus) were the most prominent with 25 individuals, or 73.5% of the total within belt-transects (Table 37). Parrotfishes (*Sparisoma* spp.) included two species and eight individuals with a mean density of 1.5 Ind/60m2, representative of 19.0% of the total assemblage of the larger reef fish herbivores. The taxonomic composition and size distribution observations from these and previous surveys are indicative that CABE05 functions as a recruitment and residential habitat for the coney and a wide assemblage of doctorfishes and parrotfishes, and a foraging habitat for demersal and pelagic predators. Schools of sardines (*Harengula* spp.) were observed outside transects during the 2023 survey serving as forage for schooling blackfin tuna (*Thunnus albacores*).

Variations of mean fish density and species richness between monitoring surveys at CABE05 are shown in Figure 43. Differences of mean density between surveys were statistically significant (ANOVA, $p < 0.001$; Appendix 5) and related to lower density during the 2018 baseline relative to surveys performed in 2021, 2023, and 2025. Differences were associated mostly with density increments of wrasses (*Thalassoma bifasciatum*, *Halichoeres poeyi*, *H. bivittatus*) and territorial damselfishes (*Stegastes adustus*). The relatively lower density measured during the 2018 baseline may be related to stronger wave action and surge conditions compared to the more calm physical conditions at the time of the 2021, 2023, and 2025 surveys, but may also reflect a recuperation of the resident fish populations after the detriments impact of Hurricane Maria upon small fishes in Puertorrican shallow reefs (Garcia-Sais et al, 2017, 2018, 2019, 2021, 2022a). Temporal variations of fish species richness between monitoring surveys were small (range: 8.8 – 10.6 Spp/30m^2) and statistically insignificant (ANOVA, $p= 0.384$; Appendix 6). The peak mean species richness was measured during the most recent 2025 survey (10.6 Spp/30m^2).

Table 37. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CABE05, Fajardo. PRCRMP 2025

CABE05							
Survey Date: 6/21/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	5, 2					2	Recruit
Acanthurus chirurgus c2	10, 8		1			1	Juvenile
Acanthurus chirurgus c4	18		1				Adult
Acanthurus coeruleus c1	4					1	Recruit
Acanthurus coeruleus c3	15		1				Juvenile
Acanthurus tractus c1	2-2, 4-3, 2-4, 5	2	1	4	1	1	Recruit
Acanthurus tractus c2	4-6,2-8, 9, 7-10	1	4	2	2	5	Juvenile
Acanthurus tractus c3	3-12, 15		1	1	1	1	Juvenile
Cephalopholis cruentata c3	15	1					Juvenile
Cephalopholis fulva c1	5	1					Recruit
Cephalopholis fulva c2	7				1		Juvenile
Cephalopholis fulva c6	28		1				Adult
Lutjanus apodus c4	20	1					Juvenile
Ocyurus chrysurus c5	22, 25	1		1			Adult
Sparisoma aurofrenatum c4	16	1					Adult
Sparisoma rubripinne c2	8, 7			1	1		Juvenile
Sparisoma rubripinne c4	16					1	Adult
Sparisoma rubripinne c5	2-25, 22	2			1		Adult
Sparisoma rubripinne c6	30		1				Adult
	Totals	10	11	9	7	12	

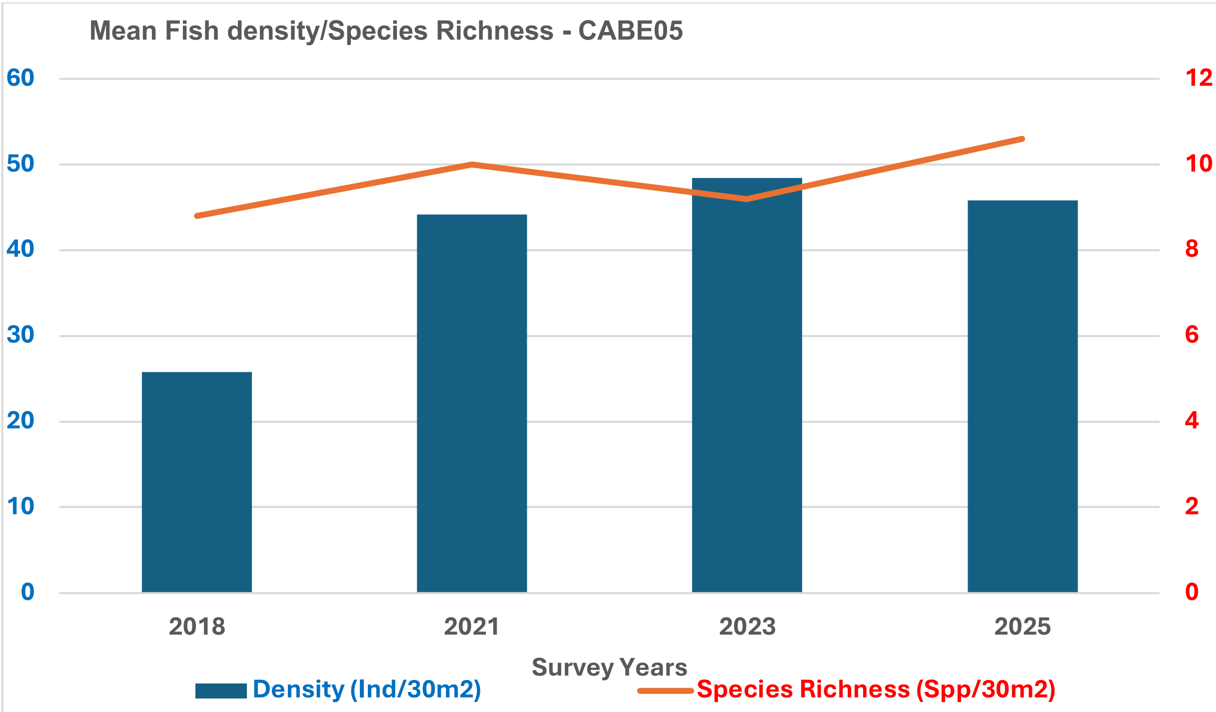
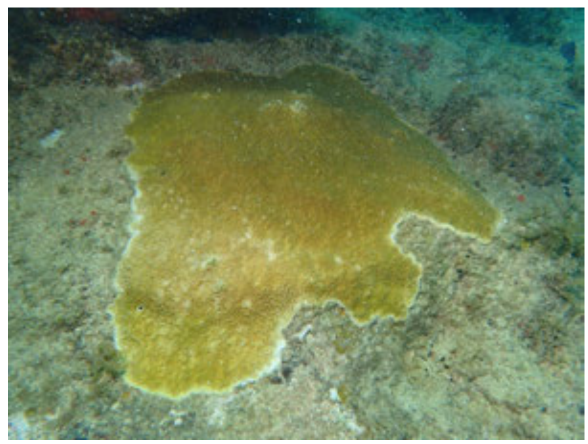


Figure 43. Monitoring trends (2018 – 2025) of mean fish density and species richness within 10 x 3m belt-transects at CABE05, Fajardo. PRCRMP 2025 survey

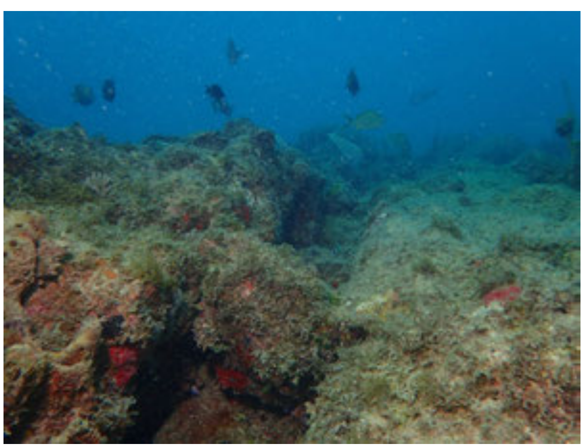
Photo Album 12. CABE05













13.0 Cayo Diablo 5m (DIAB05), Fajardo

13.1 Physical Description

Cayo Diablo is the easternmost emergent key of the "Cordillera de Fajardo" (Figure 40). It is a mostly un-vegetated island with many rocky outcrops and a sandy beach on the southeast coastline. The northern (windward) section of the island has a narrow reef platform with a rocky shoreline exposed to seasonally strong wave action. Coral reefs are found on the southern (leeward) section of the island. Patch reefs represent the main coral reef formation at Cayo Diablo. These reefs lie submerged at variable depths along the backreef zone intermixed with seagrass in some areas. Patch reefs are mostly large, mostly dead but standing *Orbicella* spp. buildups that emerge from a white coralline sandy bottom at depths of 10 -12m. The baseline survey at Cayo Diablo (DIAB05) was performed in September 2016. Transects were installed along an east-west axis on the top of adjacent patch reef promontories at a depth of 3.9 – 6.4m in the backreef zone. Images of the reef community at DIAB05 taken during the 2025 monitoring survey are presented in Photo Album 13.

13.2 Sessile Benthic Reef Community

Benthic algae, comprised by fleshy brown, turf, crustose calcareous and coralline red algae, and green calcareous macroalgae were the dominant sessile-benthic category in terms of reef substrate cover at DIAB05 during the 2025 monitoring survey with a combined mean cover of 74.56% (Table 38)). Fleshy brown y-twig alga (*Dictyota* sp.), and turf algae (mixed assemblage) were the dominant component with a combined mean cover of 56.14%, representative of 75.3% of the total reef substrate cover by benthic algae. Y-twig alga was observed growing attached as dense tufts over large sections of dead coral substrates colonized by *Ramicrusta* sp. Red encrusting crustose Peyssonnelid algae, including *Ramicrusta* sp. and *Peyssonnelia* sp. were intercepted by all five transects with a combined mean cover of 11.74%, representing 15.7% of the total cover by benthic algae. Peyssonnelid algae appeared to be mostly overgrowing dead coral sections. Turf algae, a mixed assemblage of short filamentous red and brown macroalgae were also present in all five transects with a mean substrate cover of 28.78%, or 38.6% of the total benthic algae. Green calcareous macroalgae (*Halimeda sp., Caulerpa sp.*) were observed growing in crevices and substrate depressions and intermixed with the turf algae. Patches of red slimy cyanobacteria were present in two transects with a mean reef substrate cover of 0.39% (Table 38).

Table 38. Percent reef substrate cover by sessile-benthic categories at DIAB05, Fajardo. PRCRMP 2025

DIAB05			**Transects**			
Survey date: 6/21/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**5.4**	**3.9**	**4.2**	**6.4**	**6.1**	**5.20**
Rugosity (m)	2.64	3.99	1.94	1.41	5.37	**3.07**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	6.31	4.20	1.88	10.80	20.67	**8.77**
Sand	23.70	1.30				**5.00**
Total Abiotic	**30.01**	**5.51**	**1.88**	**10.80**	**20.67**	**13.77**
Benthic Algae						
Dictyota spp.	14.95	19.82	52.87	45.89	3.28	**27.36**
Turf (mixed)	19.05	19.32	30.72	18.90	37.07	**25.01**
Ramicrusta spp.	5.54	14.41	0.23	6.38	4.37	**6.19**
Peyssonnelia spp.	3.88	3.90	6.57	8.96	4.46	**5.55**
Halimeda spp.	7.64	6.81	2.34	3.19	7.47	**5.49**
Turf (mixed) with sediment	10.85	8.01				**3.77**
CCA (total)				1.35	3.19	**0.91**
Jania spp.			0.70			**0.14**
Caulerpa spp.	0.66					**0.13**
Total Benthic Algae	**62.57**	**72.27**	**93.43**	**84.66**	**59.84**	**74.56**
Cyanobacteria	**0.78**	**0.00**	**1.17**	**0.00**	**0.00**	**0.39**
Stony Corals						
Orbicella faveolata	2.55	16.02			8.83	**5.48**
Porites porites		0.80	3.05	2.58	2.28	**1.74**
Orbicella annularis		0.50			3.92	**0.88**
Porites astreoides	1.66	0.60			1.82	**0.82**
Millepora alcicornis	1.44				0.27	**0.34**
Siderastrea siderea	0.11	1.30				**0.28**
Porites furcata		0.40	0.23			**0.13**
Pseudodiploria strigosa		0.50				**0.10**
Total Stony Coral	**5.76**	**20.12**	**3.28**	**2.58**	**17.12**	**9.77**
# Coral Colonies/Transect	**4**	**8**	**8**	**4**	**13**	**7.40**
# Diseased Coral Colonies/Transect			**1**			**0.20**
# Erect Soft Coral Colonies/Transect	**7**	**6**	**12**	**4**	**14**	**8.60**
Soft Corals						
Briareum asbestinum		0.80		0.61		**0.28**
Plexaura kukenthali	0.66					**0.13**
Antillogorgia americana				0.49		**0.10**
Eunicea flexuosa				0.37		**0.07**
Gorgonia ventalina				0.37		**0.07**
Erythropodium caribaeorum		0.30				**0.06**
Eunicea spp.			0.23			**0.05**
Antillogorgia acerosa	0.22					**0.04**
Total Soft Corals	**0.89**	**1.10**	**0.23**	**1.84**		**0.81**
# Erect Soft Coral Colonies/Transect	**10**	**5**	**2**	**14**	**1**	**6.40**
Zoanthids						**0.00**
Palythoa caribaeorum					2.00	**0.40**
Sponges						
Spirastrella hartmani		0.70				**0.14**
Aplysina cauliformis		0.30				**0.06**
Callyspongia vaginalis					0.18	**0.04**
Niphates erecta					0.18	**0.04**
Sponge *spp.*				0.12		**0.02**
Total Sponges		**1.00**		**0.12**	**0.36**	**0.30**
Bleached Corals						
Porites porites			1			**0.20**

Stony corals were represented by seven scleractinians species and one hydrocoral (*Millepora alcicornis*) with a combined mean substrate cover of 9.77% (range: 2.58 – 20.12%). Mountainous star coral (*Orbicella faveolata*) was the dominant coral intercepted by transects with a mean substrate cover of 5.48%, representative of 56.1% of the total cover by stony corals (Table 38). The sibling species *O. annularis* was intercepted by two transects contributing to a total cover by the *Orbicella* spp. complex of 6.36%, or 65.1% of the total cover by stony corals. Very large colonies of star corals (*Orbicella* spp.) were common, observed typically with large dead sections on top of the colony covered by encrusting red algae, *Ramicrusta* sp. and y-twig alga (Dictyota sp.) with live healthy sections on the sides. Finger and mustard-hill corals (*Porites porites, P. astreoides*) were intercepted by four and three transects, respectively with a combined cover of 2.56%, or 26.2% of the total. A total of 37 stony coral colonies were intercepted by transects during the 2025 survey, none of which was observed affected by coral disease infections (Appendix 2). One bleached colony (1-*P. porites*) was observed in bleached condition.

Erect soft corals were present in all transects surveyed with a mean density of 6.4 Col/Transect. Sea Rods (*Eunicea spp, Antillogorgia spp*), and sea fans (*Gorgonia ventalina*) were the most common in transects. The encrusting gorgonian (*Erythropodium caribaeorum),* and the corky sea-finger (*Briareum asbestinum)* were intercepted by one and two transects, respectively with a combined mean cover of 0.41%. Sponges were represented by five species with a combined mean cover of 0.30%. In general, sponges were present as small and mostly encrusting colonies with minor contributions to the overall reef benthic habitat complexity and topographic relief. Abiotic substrate categories were contributed by reef overhangs produced by coral buildups and sand with a combined mean substrate cover of 13.77%. The irregular coral buildups also contributed to a mean reef rugosity of 3.07m (Table38).

Temporal variations of reef substrate cover by sessile-benthic categories between monitoring surveys at DIAB05 are presented in Figure 44. The largest difference between surveys was associated with a 38.9% decline of coral cover in 2018 relative to the 2016 baseline driven by a 71.1% decline of cover by finger coral (*Porites porites*) (Figure 45). Such reductions were related to the extreme mechanical disturbance associated with the pass of hurricanes Irma and Maria in 2017 (Garcia-Sais et al., 2018). Partial recuperation of the cover by *P. porites* and *P. astreoides* was measured during the 2021 survey, contributing to an 8.8% increase of cover by stony corals. During the 2025 survey, substrate cover by stony corals declined 25.31% relative to the previous 2023 survey, adding to an overall decline of 53.23% relative to the 2016 baseline (Appendix 3).

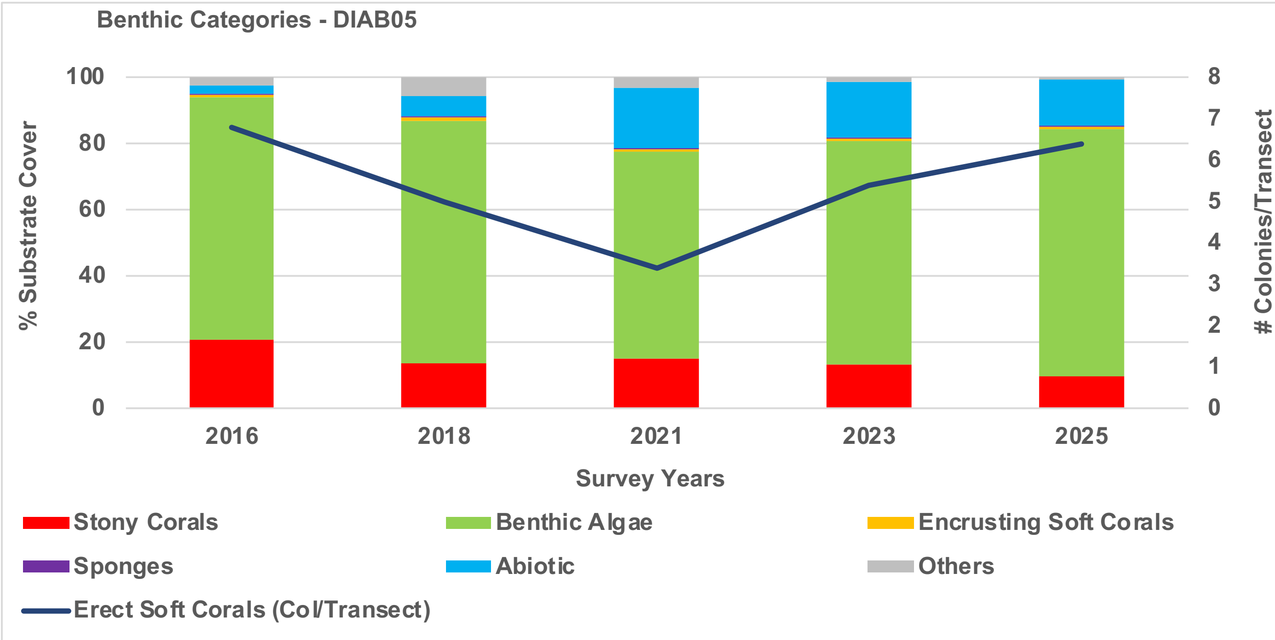


Figure 44. Monitoring trends (2016 - 2025) of mean substrate cover by sessile-benthic categories at DIAB05, Fajardo. PRCRMP 2025 survey

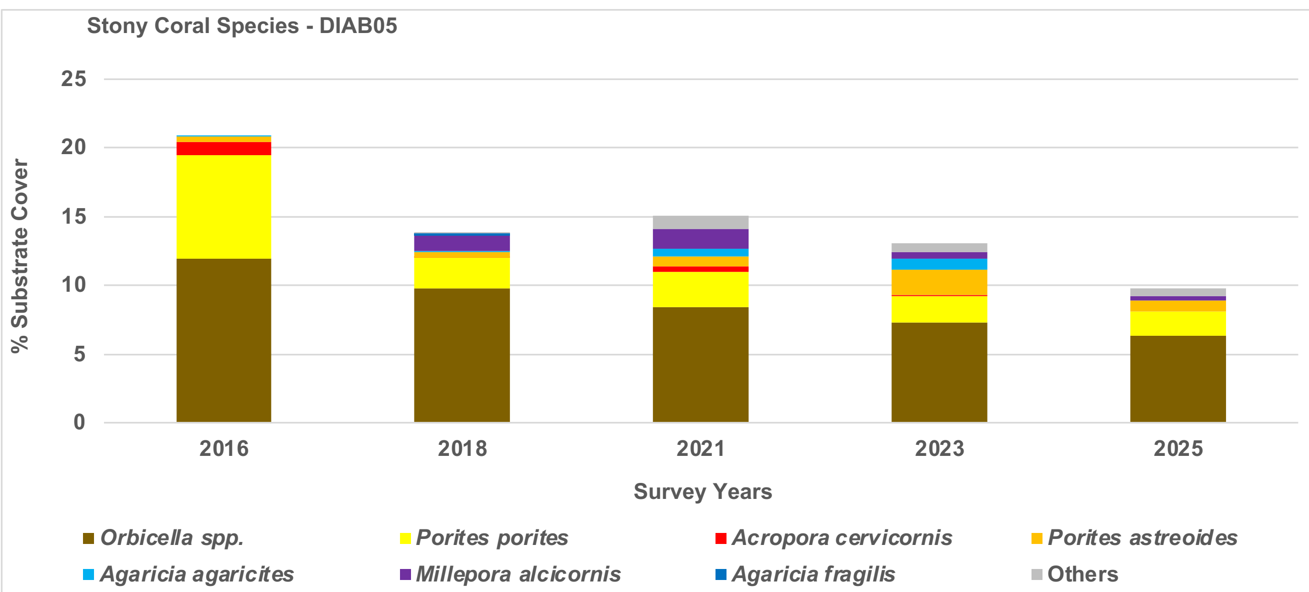


Figure 45. Monitoring trends (2016 - 2025) of mean substrate cover by the main coral species intercepted by transects at DIAB05, Fajardo. PRCRMP 2025 survey

13.3 Fishes and Motile Megabenthic Invertebrates

A total of 32 fish species were identified within belt-transects from a depth of 5 – 6m at DIAB05 during the 2025 monitoring survey with a mean density of 54.4 Ind/m^2 (range: 37– 76 Ind/30m^2) and a mean species richness of 13.6 Spp/30m^2 (Table 39). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 22.8 Ind/30m^2, representative of 41.9% of the total fish density. Five additional species were observed in at least four transects with a combined density of 19.4 Ind/30m^2, or 35.7% of the total individuals. The assemblage included the blue chromis (*C. cyanea*), bicolor and dusky damselfishes (*Stegastes partitu*s. S. adustus), sergeant major (*Abudefduf saxatilis*), and ocean surgeon (*Acanthurus tractus*). Motile megabenthic invertebrates were represented within belt-transects by seven individuals of the long-spined urchin (*Diadema antillarum*) (Table 39).

The fish trophic structure at DIAB05 was dominated in terms of mean density within belt-transects by small opportunistic carnivores (SOC) represented by 16 species and a mean density of 30.0 Ind/30m^2, representative of 55.1% of the total density. The SOC assemblage included wrasses (Labridae), grunts (Haemulidae), gobies (Gobiidae), goatfishes (Mullidae), squirrelfishes (Holocentridae), ha seabasses (Serranidae), and trumpetfishes (Aulostomidae). Zooplanktivores (ZPL) included four species with a combined density of 14.0 Ind/30m^2, or 25.7% of the total density. Three of the four zooplanktivore species (*Chromis cyanea, Stegastes partitus*, *Abudefduf saxatilis*) ranked among the top five in terms of mean density within belt-transects. Herbivores (HER) were represented by seven species with a combined density of 9.2 Ind/30m^2, or 16.9% of the total fish density. These included parrotfishes (Scaridae), damselfishes (Pomacentridae), and doctorfishes (Acanthuridae). Long-spined urchins (*Diadema antillarum*) were also present within belt-transects and contributed to the herbivorous trophic component at DIAB05 with a mean density of 1.4 Ind/30m^2. Corallivores and spongivores were represented by the four-eyed butterflyfish (*Chaetodon capistratus*) and the slender filefish (*Monacanthus tuckeri*) with a combined mean density of 0.6 Ind/30m^2.

Large and medium-sized piscivores included the yellowtail, schoolmaster and lane snappers (*Ocyurus chrysurus, Lutjanus apodus, L. synagris*) with a combined density of 0.6 Ind/60m^2 (Table 40). One great barracuda (*Sphyraena barracuda*), and cero mackerels (*Scomberomorus cavalla*) were observed outside transects foraging upon a school of anchovies (*Anchoa* spp.) at DIAB05 during the 2025 survey.

Table 39. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at DIAB05, Fajardo. PRCRMP 2025

DIAB05							
Survey Date: 6/21/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	12	39	9	28	26	**22.8**	SOC
Chromis cyanea	9	7	9	4	17	**9.2**	ZPL
Stegastes adustus	2	7	2	7	6	**4.8**	HER
Stegastes partitus	3	3	3	2	1	**2.4**	ZPL
Abudefduf saxatilis	2	4		2	1	**1.8**	ZPL
Acanthurus tractus	2	2	1		1	**1.2**	HER
Haemulon chrysargyreum		5			1	**1.2**	SOC
Haemulon flavolineatum	1	3			1	**1.0**	SOC
Gramma loreto	5					**1.0**	SOC
Halichoeres maculipinna			3		2	**1.0**	SOC
Acanthurus coeruleus	1	1	1		1	**0.8**	HER
Scarus taeniopterus			2		2	**0.8**	HER
Sparisoma aurofrenatum	1		2			**0.6**	HER
Chromis multilineata	2				1	**0.6**	ZPL
Sparisoma viride				2	1	**0.6**	HER
Elacatinus evelynae					3	**0.6**	SOC
Haemulon macrostomum	1				1	**0.4**	SOC
Chaetodon capistratus		2				**0.4**	COR
Haemulon aurolineatum		1			1	**0.4**	SOC
Acanthurus chirurgus		1	1			**0.4**	HER
Mulloidichthys martinicus	1					**0.2**	SOC
Anisotremus surinamensis	1					**0.2**	SOC
Bodianus rufus	1					**0.2**	SOC
Ocyurus chrysurus		1				**0.2**	LC
Caranx ruber					1	**0.2**	LC
Holocentrus rufus			1			**0.2**	SOC
Serranus tigrinus			1			**0.2**	SOC
Halichoeres poeyi			1			**0.2**	SOC
Anisotremus virginicus			1			**0.2**	SOC
Aulostomus maculatus				1		**0.2**	SOC
Lutjanus apodus				1		**0.2**	LC
Monacanthus tuckeri				1		**0.2**	SPO
Invertebrates							
Diadema antillarum		2			5	**1.4**	
Density (Ind/30m2)	**44**	**76**	**37**	**48**	**67**	**54.4**	
Richness (Species/30m2)	**15**	**13**	**14**	**9**	**17**	**13.6**	

The assemblage of large reef fish herbivores observed within belt-transects was comprised by parrotfishes (*Scarus* spp., *Sparisoma* spp.) and doctorfishes (*Acanthurus* spp.), with densities of 4.4 Ind/60m^2 and 6.2 Ind/60m^2, respectively (Table 40). Both doctorfishes and parrotfishes were observed as juveniles and adults, including recruitment stages (< 5cm) of doctorfish (*A. chirurgus*), blue tang (*A. coeruleus*), red-band, and princess parrotfishes (*Sparisoma aurofrenatum*, *Scarus taeniopterus*). This data is consistent with previous surveys indicative that DIAB05 serves as an important recruitment, grazing, and residential habitat for several doctorfish and parrotfish populations.

Table 40. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at DIAB05, Fajardo. PRCRMP 2025

DIAB05							
Survey Date: 6/21/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	2			1			Recruit
Acanthurus chirurgus c2	2-10		1		1		Juvenile
Acanthurus chirurgus c3	12			1			Juvenile
Acanthurus coeruleus c1	3			1			Recruit
Acanthurus coeruleus c2	10, 2-6, 7, 8	1	2	1	1		Juvenile
Acanthurus coeruleus c4	17					1	Adult
Acanthurus tractus c2	2-8, 10, 6		2	1		1	Juvenile
Acanthurus tractus c3	5-12, 15, 13	2	3	1		1	Adult
Lutjanus apodus c5	25			1			Adult
Lutjanus apodus c6	28				1		Adult
Lutjanus synagris c5	25				1		Adult
Ocyurus chrysurus c4	20		1				Adult
Scarus taeniopterus c1	2-3			2			Recruit
Scarus taeniopterus c2	2-10, 8-8, 4-6					14	Juvenile
Sparisoma aurofrenatum c1	2, 3			2			Recruit
Sparisoma aurofrenatum c4	18	1					Adult
Sparisoma aurofrenatum c5	22	1					Adult
Sparisoma rubripinne c6	30, 26	1		1			Adult
Sparisoma viride c2	10, 7		1			1	Juvenile
Sparisoma viride c3	15, 12		1			1	Juvenile
Sparisoma viride c4	20				1		Adult
Sparisoma viride c5	25				1		Adult
Sparisoma viride c6	26, 28	1			1		Adult
Sparisoma viride c7	33	1					Terminal
	Totals	8	11	12	7	19	

Variations of fish density and species richness between monitoring surveys at DIAB05 are presented in Figure 46. Both fish density and species richness evidenced increasing trends up to the 2021 survey. Differences between surveys were statistically significant for both density (ANOVA, $p = 0.026$; Appendix 5) and species richness (ANOVA, $p = 0.005$; Appendix 6). Fish density increased by 106.4%, from 49.8 Ind/30m^2 in 2016 to 102.8 Ind/30m^2 in 2021. Differences were driven by higher density of the numerically dominant bluehead wrasse (*Thalassoma bifasciatum*), but more importantly by a significantly higher number of species per transect, from 13.0 Spp/30m^2 in 2016 to 19.8 Spp/30m^2 in 2021, an increase of 52.3%. These fluctuations of fish density and species richness are common in shallow reefs and are mostly driven by physical conditions, such as the prevailing surge and water currents at the time of the survey (Garcia-Sais et al., 2017 and references therein).

During the 2025 survey both mean density and species richness declined relative to the previous 2023 survey but still fell within the range of previous assessments at DIAB05. Wave action and surge conditions were strong during the 2025 survey and may have influenced the relatively low fish density and species richness relative to previous surveys. Massive losses of live coral cover have been documented from DIAB05 since 2018, and such drastic changes of benthic community structure may have an effect upon the fish community. Future assessments are needed to evaluate the relative roles of physical disturbances and benthic habitat quality in regulation of fish community structure at DIAB05.

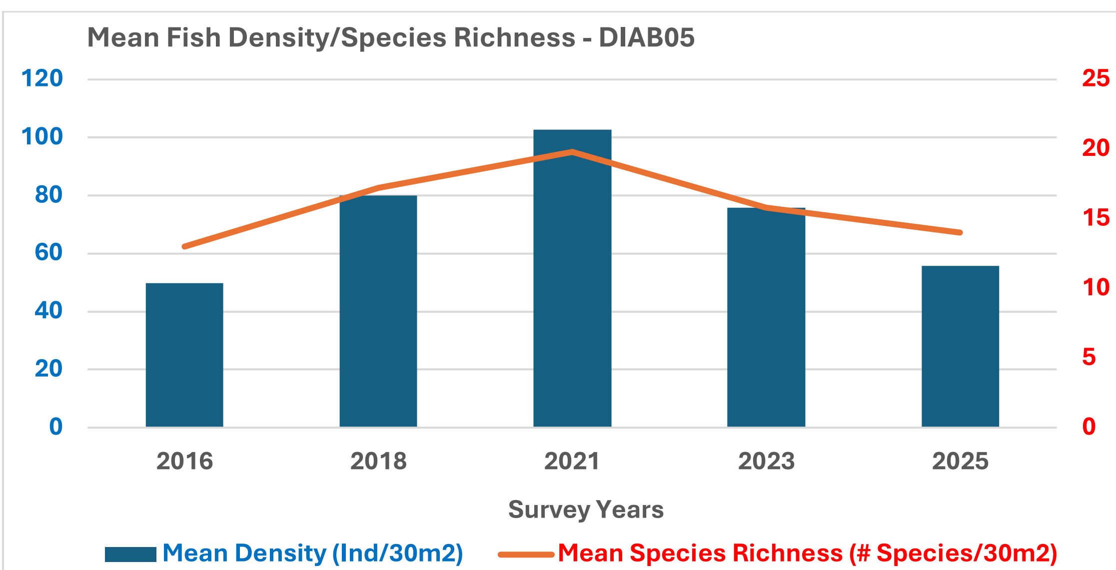
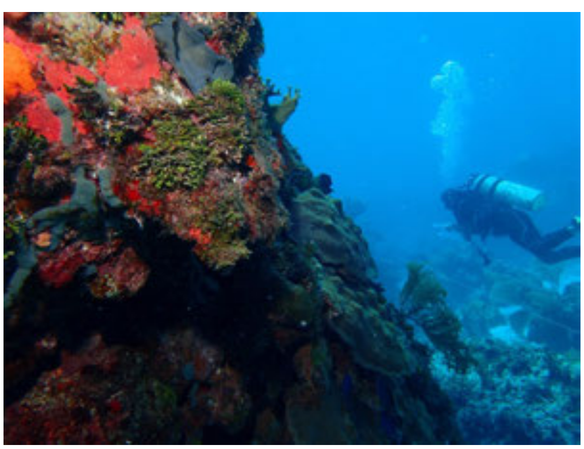


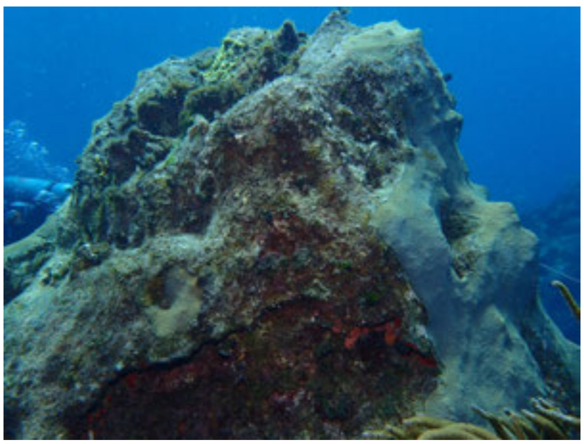
Figure 46. Monitoring trends (2016 – 2025) of mean fish density and species richness within 10 x 3m belt-transects at DIAB05, Fajardo. PRCRMP 2025 survey.

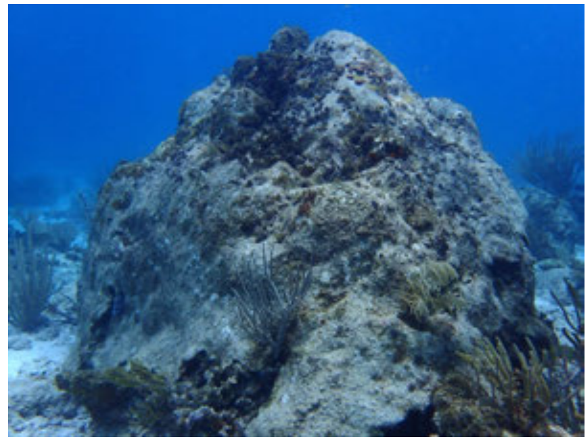
Photo Album 13. DIAB05









14.0 Palominito Reef 10m, Fajardo (PALT10)

14.1 Physical Description

Isla Palominito sits in the same reef platform with Palomino (Figure 40). A shallow sand channel separates both islands. Coral reefs occur to the northeast, east and south of Palominito. There is a large fringing reef that breaks down into a series of small, submerged patch reefs, particularly to the east and south of the island. The largest and best developed coral reef is located to the northeast, and it is the one included in our survey (PALT10). This is a fringing coral formation overlying the fore-reef slope with massive coral build-up. The reef structure is characterized by steep spurs and deep grooves with sandy sediments. The height of the spurs reaches six meters close to the base of the reef at a depth of 18 meters. It was not possible to corroborate how much of this structure is coral build-up. Massive stony corals grow on top and along the sides of the spurs providing high topographic relief and structural habitat to the reef community. Turtle seagrass occurs along the south coast in proximity with scattered patch reefs. The west section of the island presents scattered coral growth below depths of 5 - 6m and used to exhibit a small coralline sandy beach that was a recreational hotspot but has disappeared to coastal erosion. The baseline survey of PALT10 was performed in September 2016. Images of the reef community at PALT10 during the 2025 monitoring survey are shown in Photo Album 14.

14.2 Sessile Benthic Reef Community

A mixed assemblage of benthic algae comprised by brown fleshy, turf, red fleshy, and red crustose coralline macroalgae were the dominant benthic category covering reef substrate at PALT10 during the 2025 survey with a combined mean cover of 73.65% (range: 71.46 – 76.67%). Fleshy brown macroalgae, particularly y-twig alga (*Dictyota sp*.) and encrusting fan leaf alga (*Lobophora* sp.) were the dominant component of the benthic algae assemblage with a combined mean cover of 37.44%, representative of 50.8% of the total cover by benthic algae (Table 41). Fleshy algae were observed growing over uncolonized reef hard substrates and also growing over dead coral substrates colonized by *Ramicrusta sp.* Encrusting red crustose coralline algae, comprised by *Ramicrusta sp*. and Peyssonnelia sp. were intercepted by all five transects with a combined mean cover of 7.33%, representative of 9.95% of the total cover by benthic algae.
Red fleshy macroalgae (*Asparagopsis taxiformis*, *Galaxaura* spp.) were also intercepted by all transects with a combined mean cover of 11.74%, or 15.9% of the total cover by benthic algae. Cyanobacterial films were intercepted by four transects with a mean cover of 0.62% (Table 41).

Table 41. Percent reef substrate cover by sessile-benthic categories at PALT10, Fajardo. PRCRMP 2025

PALT10			**Transects**			
Survey date: 6/21/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**10.3**	**10.9**	**10.6**	**10.9**	**10.6**	**10.66**
Rugosity (m)	2.84	1.52	4.48	1.77	3.89	**2.90**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	6.22	7.90	10.25	7.25	10.48	**8.42**
Total Abiotic	**6.22**	**7.90**	**10.25**	**7.25**	**10.48**	**8.42**
Benthic Algae						
Dictyota spp.	13.20	17.74	30.17	35.32	23.89	**24.06**
Turf (mixed)	10.58	17.38	17.31	12.13	20.56	**15.59**
Lobophora spp.	46.24	20.66	0.00			**13.38**
Asparagopsis taxiformis	3.27	16.52	15.47	5.23	16.83	**11.47**
Ramicrusta spp.	1.42	3.04	7.83	12.84	9.17	**6.86**
Turf (mixed) with sediment				4.40		**0.88**
CCA (total)			1.06	0.36	1.92	**0.67**
Peyssonnelia spp.	0.87			1.19	0.30	**0.47**
Galaxaura spp.		1.34				**0.27**
Total Benthic Algae	**75.57**	**76.67**	**71.86**	**71.46**	**72.68**	**73.65**
Cyanobacteria	**0.00**	**0.00**	**0.97**	**1.43**	**0.71**	**0.62**
Stony Corals						
Orbicella faveolata	8.62	8.51	3.77	12.49	4.54	**7.58**
Porites astreoides	0.00	2.07	2.22	3.09	2.42	**1.96**
Orbicella franksi	5.67	0.85				**1.30**
Orbicella annularis			6.09			**1.22**
Millepora alcicornis				2.02	0.40	**0.48**
Porites porites				0.24	2.12	**0.47**
Siderastrea siderea	0.11					**0.02**
Total Stony Coral	**14.39**	**11.42**	**12.09**	**17.84**	**9.48**	**13.04**
# Coral Colonies/Transect	**6**	**9**	**14**	**14**	**9**	**10.40**
# Diseased Coral Colonies/Transect		**1**	**1**	**3**	**2**	**1.40**
# Erect Soft Coral Colonies/Transect	**21**	**25**	**17**	**18**	**36**	**23.40**
Soft Corals						
Erythropodium caribaeorum	0.76	0.73	0.29		1.81	**0.72**
Briareum asbestinum		1.58	0.58			**0.43**
Antillogorgia acerosa	0.44		0.19			**0.13**
Pseudoplexaura flagellosa					0.40	**0.08**
Plexaura kukenthali			0.39			**0.08**
Gorgonia ventalina		0.36				**0.07**
Total Soft Corals	**1.20**	**2.67**	**1.45**	**0.00**	**2.22**	**1.51**
# Erect Soft Coral Colonies/Transect	**16**	**19**	**13**	**12**	**25**	**17.00**
Ascidiacea						**0.00**
Ascidian spp.			0.29			**0.06**
Sponges						
Monanchora arbuscula			0.58	0.48	1.81	**0.57**
Amphimedon compressa			0.97	0.48	1.21	**0.53**
Chondrilla caribensis	1.42					**0.28**
Clathria spp.	0.44		0.29	0.59		**0.26**
Aplysina fistularis		1.09				**0.22**
Dysidea janiae			0.97			**0.19**
Verongula spp.					0.81	**0.16**
Sponge spp.				0.24	0.40	**0.13**
Agelas citrina	0.55					**0.11**
Aplysina fulva			0.29			**0.06**
Mycale laevis		0.24				**0.05**
Aplysina cauliformis				0.24		**0.05**
Niphates erecta	0.22					**0.04**
Niphates caribica					0.20	**0.04**
Total Sponges	**2.62**	**1.34**	**3.09**	**2.02**	**4.44**	**2.70**
Bleached Corals						
Orbicella faveolata		1		2	1	**0.80**
Orbicella annularis			1			**0.20**
Orbicella franksi				1	1	**0.40**
Diseased Corals						
Orbicella faveolata				1		**0.20**

Eight species of stony corals, including one hydrocoral (*Millepora alcicornis*) were intercepted by transects at PALT10 during the 2025 survey with a combined mean cover of 13.04% (range: 9.48 – 17.84%). Mountainous star coral (*Orbicella faveolata*) was the dominant species intercepted by transects with a mean substrate cover of 7.58%, representative of 58.1% of the total cover by stony corals (Table 41). Boulder star coral (*O. franksi*) was present in two transects with a mean cover of 1.30%. Large massive colonies of lobed star coral (*O. annularis*) were also present with a mean cover of 1.22%, for a total reef substrate cover by the *Orbicella* spp. complex of 10.1%, or 77.4% of the total cover by stony corals. Mustard-hill coral (*Porites astreoides*), and finger coral (*P. porites*) were present in five and two transects, respectively with a combined mean cover of 2.43%. A total of 52 stony coral colonies were intercepted from PALT10 during the 2025 monitoring survey, including one (1-*O. faveolata*) with an apparent coral disease infection (coral disease prevalence: 1.92%; Appendix 2).

Erect soft corals were prominent in all transects surveyed with a mean density of 17.0 Col/Transect (Table 41). Sea Rods (*Plexaura* spp., *Pseudoplexaura* spp.), sea plumes (*Antillogorgia spp*), and sea fans (*Gorgonia ventalina*) were the most abundant in transects. The encrusting gorgonian (*Erythropodium caribaeorum*), and the corky sea-finger (*Briareum asbestinum*) were intercepted by four and two transects, respectively with a mean combined cover of 1.15%. Sponges were represented by 14 species in transects with a combined mean cover of 2.70%. *Monachora arbuscula*, *Amphimedon compressa, Chondrilla caribensis, and Clathria* spp. were the most prominent in transects surveyed with a mean combined cover of 1.64%. In general, sponges were present as small and mostly encrusting colonies with minor contributions to the overall reef benthic habitat complexity and topographic relief. Reef overhangs, associated with massive coral buildups were the main component of the abiotic substrate categories cover with a mean cover of 8.42% and contributed to a mean reef rugosity of 2.90m (Table 41).

Variations of reef substrate cover by the major sessile-benthic categories between monitoring surveys at PALT10 are shown in Figure 47. The rank order of major benthic categories remained stable between surveys, but statistically significant differences of reef substrate cover by stony corals were measured (ANOVA, $p < 0.001$; Appendix 3). Reef substrate cover by live stony corals declined 13.1% between the 2016 baseline and the 2018 monitoring surveys. The change was statistically insignificant (ANOVA, $p < 0.05$) and attributed to physical stress associated with the pass of hurricanes Irma and Maria in September 2017. Continued degradation of stony coral cover has been documented from PALT10 in subsequent monitoring surveys until the most recent 2025 survey, resulting in an overall loss of 60.18% relative to the 2016 baseline survey (32.75%).

The largest reduction of reef substrate cover by stony corals was associated to a 29.1% reduction of cover by the *Orbicella* spp. complex between the 2018 and the 2021 surveys (Figure 48). Colonies of both *O. faveolata* and *O. annularis* were observed to be infected by coral diseases, including SCTLD (on *O. annularis*) at PALT10 during the 2021 survey (Garcia-Sais et al., 2022a). Given the high mortality associated with corals affected by SCTLD, such measured decline of cover by *Orbicella* spp. may be attributable to SCTLD. In addition, live colonies of boulder brain coral (*Colpophyllia natans*), and greater starlet coral (*Siderastrea siderea*) that contributed to stony coral cover in 2016 and 2018 were found dead and overgrown by benthic algae during 2021. It is possible that the severe coral bleaching event that affected coral reef communities around Puerto Rico between October 2019 and February 2020 may have triggered increased mortality rates of stony coral tissue due to pathogen infections, including SCTLD. Stony coral cover declined 14.89% in 2023 (relative to 2021) and declined again by 23.16% in 2025 (relative to 2023). The most recent reductions of substrate cover were largely driven by losses of cover by *Orbicella* spp. (-21.4%), *Porites astreoides* (-28.5%), and *P. porites* (-50.5%) probably associated with bleaching and disease infections triggered by heat stress.

The decline of reef substrate cover by stony corals has been mostly compensated by corresponding increments of cover by benthic algae (27.9%) and sponges (3.42-fold) (Figure 47). Colonization of reef hard ground by benthic algae at PALT10 has shown to be a highly dynamic process, including taxonomic phase shifts of alternating dominance by turf, brown fleshy, and crustose coralline algae, mostly *Ramicrusta* sp. (Garcia-Sais et al., 2022a). Fleshy algae typically increase in cover during the summer influenced by conditions of increased rainfall that bring nutrients and low wave energy. Y-twig alga (*Dictyota* sp.) has been observed overgrowing *Ramicrusta* sp. in what appears to be a temporary (seasonal) feature at PALT10 and other reefs of the east coast under the PRCRMP (e.g. DIAB05). It appears that *Ramicrusta* sp. is resilient to the seasonal overgrowth by *Dictyota* sp. as it has shown to regain its dominance as the main component of the benthic algal assemblage under conditions of strong wave action.

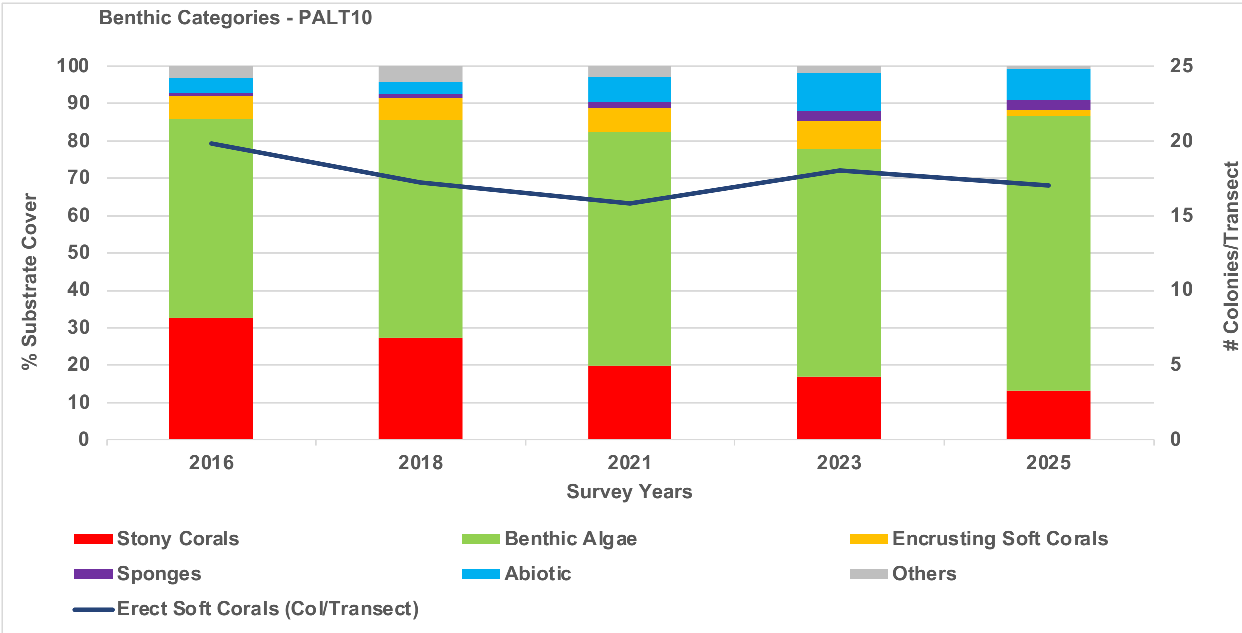


Figure 47. Monitoring trends (2016 - 2025) of mean substrate cover by sessile-benthic categories at PALT10, Fajardo. PRCRMP 2025

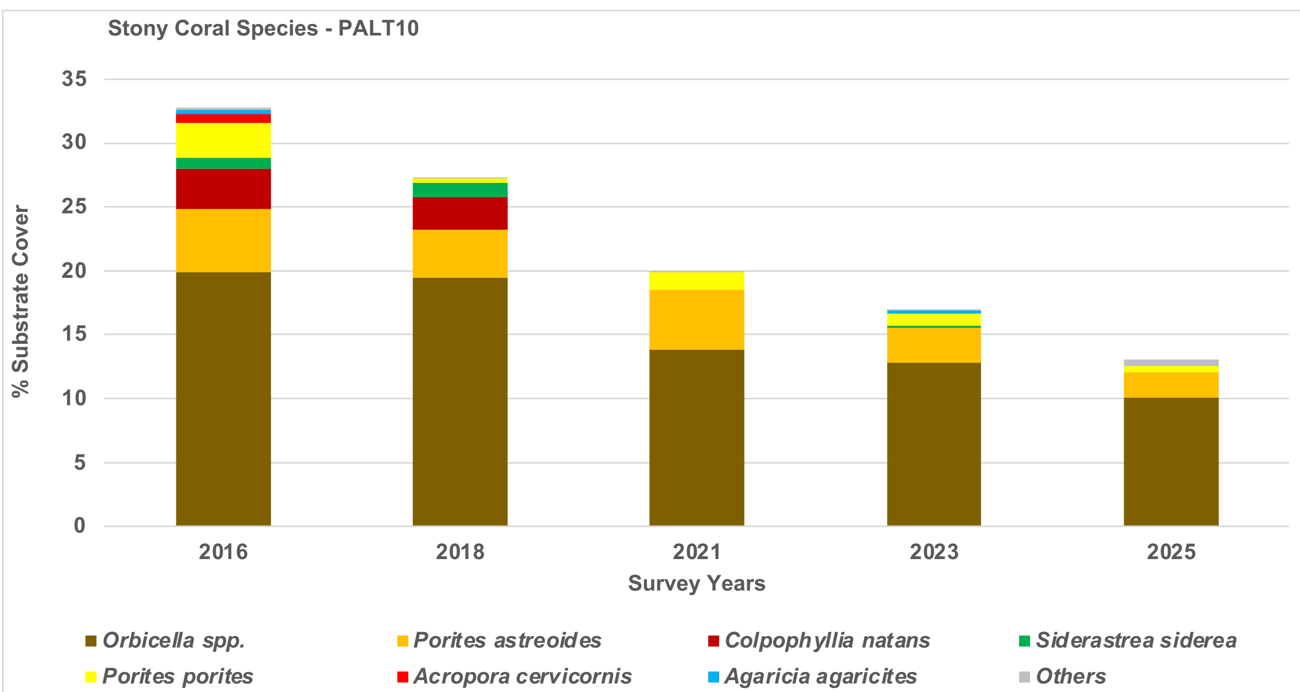


Figure 48. Monitoring trends (2016 - 2025 of mean substrate cover by coral species at PALT10, Fajardo. PRCRMP 2025

14.3 Fishes and Motile Megabenthic Invertebrates

A total of 33 fish species were identified within belt-transects from depths of 9 – 10m at PALT10 during the 2025 survey with a mean density of 55.2 Ind/30m^2 (range: 30 – 83 Ind/30m^2) and a mean species richness of 13.2 Spp/30m^2 (Table 42). Fish density was largely contributed by masked goby (*Coryphopterus personatus*), and recruitment juvenile parrotfishes (*Scarus* spp.) with a combined density of 32.8 Ind/30m^2, representative of 58.7% of the total individuals. Both of these species were observed in schooling aggregations. Masked goby were observed below ledges and protected sections of the reef, whereas *Scarus* spp. were observed in transit close to the reef substrate. One large streaming school of creole wrasse was observed in mid-water making frequent incursions to the reef and partially penetrating one transect contributing a mean density od 2.4 Ind/30m^2. Three species were present in at least four out of the five belt-transects surveyed with a combined mean density of 5.8 Ind/30m^2, representative of 10.1% of the total. The assemblage included the three-spot and beaugregory damselfishes (*Stegastes planifrons*, *S. leucostictus*), and the redband parrotfish (*Sparisoma aurofrenatum*). Motile megabenthic invertebrates were represented within belt-transects by one long-spined urchin (*Diadema antillarum*).

The fish trophic structure during the 2025 survey at PALT10 was evenly dominated in terms of their mean density within belt-transects by zooplanktivores (ZPL) and herbivorous (HER) assemblages. The ZPL assemblage was comprised of six species including three of the top five numerically dominant (*Coryphopterus personatus, Chromis cyanea, Clepticus parrae*) with a combined density of 24.8 Ind/30m^2, representative of 44.9% of the total fish density. The HER assemblage included four parrotfish species (Scaridae), two doctorfish species (Acanthuridae), and three territorial damselfishes (Pomacentridae) with a combined density of 24.6 Ind/30m^2, or 44.6% of the total individuals. One long spined urchin (*Diadema antillarum*) was observed within transects and was also an important component of the HER assemblage. Small opportunistic carnivores (SOC) included 13 species with a combined density of 4.4 Ind/30m^2. The SOC assemblage included wrasses (Labridae), squirrelfishes (Holocentridae), gobies (Gobiidae), hamlets (Serranidae), trunkfishes (Ostraciidae), seabasses (Serranidae), grunts (Haemulidae), and puffers (Tetraodontidae). Spongivores (Monacanthidae, Pomacanthidae) and corallivores (Chaetodontidae) were represented by three species with a combined density of 1.4 Ind/30m2, representative of 3.7% of the total fish density.

Table 42. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at PALT10, Fajardo. PRCRMP 2025

PALT10							
Survey Date: 6/21/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	25	30		39		**18.8**	ZPL
Scarus spp.	38	18	14			**14.0**	HER
Scarus taeniopterus	4	6	2	1		**2.6**	HER
Chromis cyanea		5		5	3	**2.6**	ZPL
Clepticus parrae					12	**2.4**	ZPL
Stegastes planifrons		2	2	4	3	**2.2**	HER
Stegastes leucostictus	2	2	3	1	2	**2.0**	HER
Sparisoma aurofrenatum	3	1	2	1	1	**1.6**	HER
Thalassoma bifasciatum	2	2	1			**1.0**	SOC
Sparisoma viride		2	1	1		**0.8**	HER
Acanthurus tractus	2			1		**0.6**	HER
Myripristis jacobus	1	1			1	**0.6**	SOC
Elacatinus evelynae		1		1	1	**0.6**	SOC
Acanthurus coeruleus				3		**0.6**	HER
Chaetodon capistratus	1	1				**0.4**	COR
Canthidermis sufflamen	2					**0.4**	ZPL
Abudefduf saxatilis				1	1	**0.4**	ZPL
Hypoplectrus puella				1	1	**0.4**	SOC
Caranx ruber				1	1	**0.4**	LC
Lactophrys triqueter	1					**0.2**	SOC
Cantherhines pullus	1					**0.2**	SPO
Hypoplectrus nigricans	1					**0.2**	SOC
Serranus tigrinus		1				**0.2**	SOC
Canthigaster rostrata			1			**0.2**	SOC
Stegastes variabilis			1			**0.2**	HER
Halichoeres garnoti			1			**0.2**	SOC
Haemulon sciurus			1			**0.2**	SOC
Pomacanthus paru			1			**0.2**	SPO
Chilomicterus sp.			1			**0.2**	SOC
Odontoscion dentex					1	**0.2**	SOC
Holocentrus rufus					1	**0.2**	SOC
Chromis multilineata					1	**0.2**	ZPL
Ocyurus chrysurus					1	**0.2**	LC
Invertebrates							
Diadema antillarum			1			**0.2**	
Density (Ind/30m2)	**83**	**72**	**31**	**60**	**30**	**55.2**	
Richness (Species/30m2)	**13**	**13**	**13**	**13**	**14**	**13.2**	

Mid-sized and large carnivores included the bar jack (*Caranx ruber*), yellowfin grouper (Mycteroperca venenosa), and the schoolmaster, dog, and yellowtail snappers (*Lutjanus apodus, L. jocu, Ocyurus chrysurus*) with a combined mean density of 1.8 Ind/60m^2 (Table 43). The larger reef fish herbivores were represented by two species of doctorfishes (Acanthurus spp.), and four species of parrotfishes (*Sparisoma* spp., *Scarus* spp.) with a combined density of 23.4 Ind/60m^2. Juveniles and adult stages (including recruitment juveniles and terminal stages) of parrotfishes (*Sparisoma* spp, *Scarus* spp.), and doctorfishes (*Acanthurus* spp.) were observed within belt-transects during the 2025 and previous monitoring surveys (Garcia-Sais et al., 2022a and references therein), indicative that PALT10 is a recruitment, nursery, and residential habitat for several parrotfish and doctorfish populations throughout their lifetimes. This reef is also a recruitment and foraging habitat for mid-sized and large carnivores, such as yellowtail, schoolmaster, and dog snappers (*Ocyurus chrysurus, Lutjanus apodus, L. jocu*), and the yellowfin and graysby groupers, among others.

Table 43. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at PALT10, Fajardo. PRCRMP 2025

PALT10							
Survey Date: 6/21/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c2	2-10, 2-7, 8, 9	1		1	2	2	Juvenile
Acanthurus coeruleus c3	14, 2-15, 11		2		2		Juvenile
Acanthurus coeruleus c4	16, 2-18					3	Adult
Acanthurus tractus c2	10				1		Juvenile
Acanthurus tractus c3	12, 13	2					Juvenile
Acanthurus tractus c4	17					1	Adult
Caranx ruber c7	30				1		Adult
Caranx ruber c8	36					1	Adult
Lutjanus apodus c4	18			1			Juvenile
Lutjanus apodus c8	36				1		Adult
Lutjanus jocu c8	40					1	Adult
Mycteroperca venenosa c10	50					1	Adult
Ocyurus chrysurus c7	35					1	Adult
Ocyurus chrysurus c9	2-45					2	Adult
Scarus spp. c1	70-2	38	18	14			Recruit
Scarus taeniopterus c1	5	1					Recruit
Scarus taeniopterus c2	3-10, 13-7, 7-8, 8-6,	4	8	9	11		Juvenile
Sparisoma aurofrenatum c2	3-10	2				1	Juvenile
Sparisoma aurofrenatum c3	3-15, 12	1	2		1		Juvenile
Sparisoma aurofrenatum c4	20			1			Adult
Sparisoma aurofrenatum c6	26			1			Terminal
Sparisoma viride c1	5, 3		1		1		Recruit
Sparisoma viride c2	10			1			Juvenile
Sparisoma viride c5	23, 25		1		1		Adult
	Totals	**49**	**32**	**28**	**21**	**13**	

The temporal variations of mean fish density and species richness between monitoring surveys at PALT10 are shown in Figure 49. Variations of fish density were pronounced, but not statistically significant (ANOVA, $p = 0.192$; Appendix 5) due to the high sampling variability within replicate transects. A marked density increment of 89.2% was measured during the 2021 survey, influenced in part by the relatively high density of pelagic species present and what appears to be a partial recuperation of the small demersal fishes after the marked density decline measured in 2018, after the pass of hurricane Maria in late 2017 (Garcia-Sais et al., 2018). The presence of these juvenile pelagic species was noted in the 2023 survey but the schooling aggregations remained mostly outside transect areas. During the 2025 survey mean fish density increased 46.8% relative to the previous 2023 survey in support of the partial recuperation hypothesis after the hurricane effects.

Variations of fish species richness were statistically significant (ANOVA, $p < 0.001$; Appendix 6) associated with the higher richness during the 2021 survey, as compared to the 2016 baseline and most recent 2023 and 2025 monitoring surveys. Again, the presence of various pelagic species in high schooling aggregations and the apparent recuperation trend of small territorial species after the pass of Hurricane Maria may have influenced the marked increase in species richness at PALT10 in the 2021 survey. The lower mean density measured in 2025 (13.2 Ind/30m^2) is similar to the baseline (13.4 Ind/30m^2) suggesting that such fluctuations may be occurring independently from factors associated with the massive live coral degradation measured after 2021.

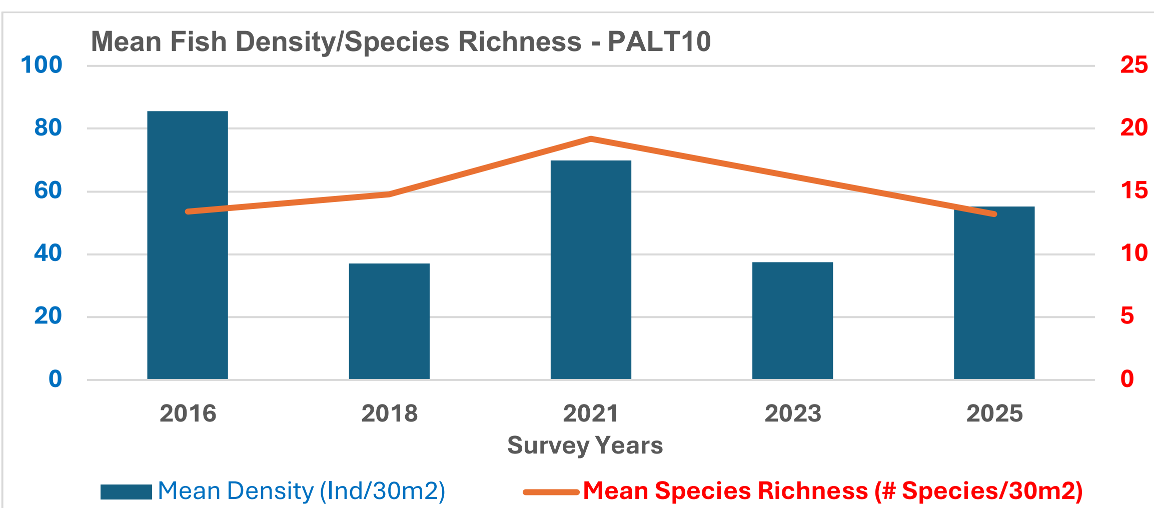
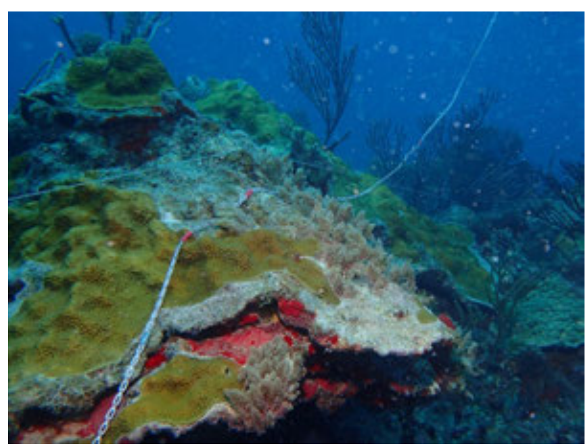
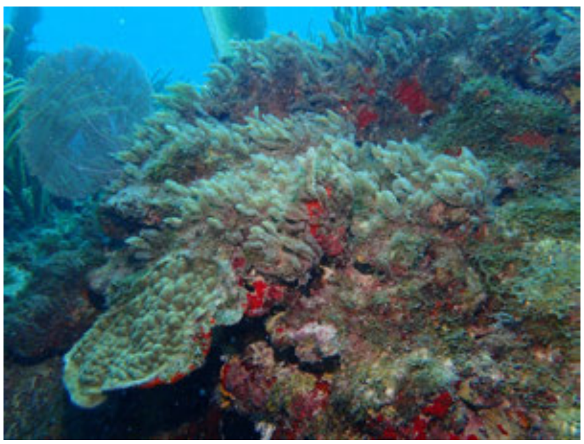
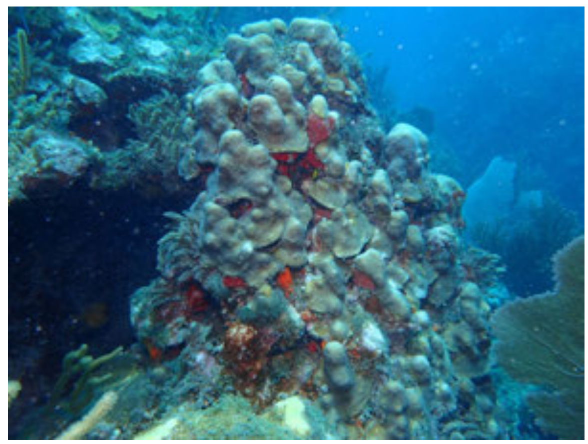


Figure 49. Monitoring trends (2016 – 2025) of mean fish density and species richness within 10 x 3m belt-transects at PALT10, Fajardo. PRCRMP 2025 survey.

Photo Album 14. PALT10










15.0 Palomino Reef 20m, Fajardo (PALN20)

15.1 Physical Description

Isla Palominos is located inside the chain of island reefs that form the "Cordillera Natural Reserve". The reef platform includes two emergent zones, the largest of which is Palomino, with the smaller sandy islet, Palominito located due south of Palominos (Figure 40). Fringing and patch coral reef formations are found along the north and eastern sections of the island. The baseline survey of Palominos Reef (PALN20) was in September 2016. Permanent transects were set on the northern section the island following a linear (contour) pattern at the base of the reef in the 14.8 – 17.0 m depth range. Panoramic views of the reef community at PALN20 during the 2025 monitoring survey are shown in Photo Album 15.

15.2 Sessile Benthic Reef Community

Benthic algae, comprised by a mixed assemblage of fleshy brown, turf, red fleshy, red crustose calcareous (mostly *Ramicrusta sp*), and red coralline (CCA mixed) macroalgae were the dominant category covering reef substrate at PALN20 with a combined mean cover of 65.23% (Table 44). Turf algae were the largest component with a mean cover of 41.92%, representative of 64.3% of the total cover by benthic algae. Almost one half of the turf algae were observed to be covered by fine sediments. Brown fleshy macroalgae (*Dictyota* sp.) was intercepted by all transects growing as dense tufts over hard substrates with a mean cover of 13.00%. Peyssonnelid crustose coralline algae, comprised by *Ramicrusta sp*., and *Peyssonnelia* sp. were present in all transects with a mean cover of 7.27%, representative of 11.1% of the total cover by benthic algae. Small patches of cyanobacteria were intercepted by three transects with a mean cover of 0.61% (Table 44).

A total of nine species of scleractinian corals and one hydrocoral (*Millepora alcicornis*) were intercepted by transects with a mean substrate cover of 6.28% (range: 1.79 – 8.53%). Mustard-hill coral (*Porites astreoides*) was the dominant species in terms of ref substrate cover with 2.33%, representative of 37.1% of the total cover by stony corals (Table 44). Small colonies of Madracis decactis, Siderastrea siderea, and Millepora alcicornis were intercepted by three transects with a combined mean cover of 2.43%, or 38.7% of the total. The previously large patches of live yellow-pencil coral (*Madracis auretenra*) were observed mostly dead and in advanced stages of deterioration with only very small live patches intercepted with a mean cover of 0.46%. Infectious coral diseases were not observed in any of the 37 stony coral colonies intercepted by transects from PALN20 during the 2025 monitoring survey (Appendix 2).

Table 44. Percent reef substrate cover by sessile-benthic categories at PALN20, Fajardo. PRCRMP 2025

PALN20			**Transects**			
Survey date: 6/22/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**17**	**14.9**	**15.2**	**15.4**	**16.1**	**15.72**
Rugosity (m)	3.45	3.03	3.99	1.30	4.90	**3.33**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	12.38	14.39	13.71	12.27	20.86	**14.72**
Sand		4.73	5.71		3.48	**2.78**
Rubble			1.50			**0.30**
Total Abiotic	**12.38**	**19.12**	**20.92**	**12.27**	**24.34**	**17.81**
Benthic Algae						
Turf (mixed)	43.81	19.66	16.32	16.48	16.07	**22.47**
Turf (mixed) with sediment	17.69	19.01	36.74	7.93	15.88	**19.45**
Dictyota spp.	10.09	16.11	6.61	5.20	26.97	**13.00**
Ramicrusta spp.	0.62	3.87	1.00	20.57	0.94	**5.40**
CCA (total)	0.62			11.52	1.79	**2.79**
Peyssonnelia spp.		3.33	1.00	2.85	2.16	**1.87**
Asparagopsis taxiformis	0.31	0.97				**0.26**
Total Benthic Algae	**73.15**	**62.94**	**61.66**	**64.56**	**63.82**	**65.23**
Cyanobacteria	**1.04**	**0.21**	**0.00**	**0.00**	**1.79**	**0.61**
Stony Corals						
Porites astreoides	6.76	0.97	0.80	2.73	0.38	**2.33**
Madracis decactis		2.90	1.20	2.11		**1.24**
Montastraea cavernosa			1.60	2.11		**0.74**
Siderastrea siderea	0.62	2.04			0.66	**0.66**
Millepora alcicornis	0.52		1.50	0.62		**0.53**
Madracis auretenra			1.80	0.50		**0.46**
Orbicella faveolata	0.21				0.75	**0.19**
Agaricia agaricites	0.21					**0.04**
Scolymia cubensis	0.21					**0.04**
Agaricia grahamae			0.20			**0.04**
Total Stony Coral	**8.53**	**5.91**	**7.11**	**8.05**	**1.79**	**6.28**
# Coral Colonies/Transect	**13**	**6**	**7**	**8**	**3**	**7.40**
# Diseased Coral Colonies/Transect	**1**					**0.20**
# Erect Soft Coral Colonies/Transect	**9**	**10**	**11**	**18**	**14**	**12.4**
Soft Corals						
Briareum asbestinum	0.94	5.05	4.90	7.31	3.38	**4.32**
Erythropodium caribaeorum		0.97	0.20		0.66	**0.36**
Eunicea flexuosa	0.21	0.21				**0.08**
Antillogorgia acerosa					0.38	**0.08**
Total Soft Corals	**1.14**	**6.23**	**5.11**	**7.31**	**4.42**	**4.84**
Sponges						
Monanchora arbuscula	1.46	1.72	1.00	1.61	0.56	**1.27**
Amphimedon compressa	1.14	0.32		1.61		**0.62**
Niphates caribica		0.32	1.70	0.37		**0.48**
Iotrochota birotulata	0.31	2.04				**0.47**
Aplysina cauliformis			0.80	1.12	0.19	**0.42**
Iotrochota arenosa			0.30	1.12		**0.28**
Niphates erecta	0.62	0.21	0.20	0.25		**0.26**
Verongula spp.				1.24		**0.25**
Agelas conifera					0.94	**0.19**
Plakortis spp.			0.80			**0.16**
Smenospongia conulosa					0.66	**0.13**
Scopalina ruetzleri			0.40	0.25		**0.13**
Sponge spp.		0.64				**0.13**
Callyspongia fallax		0.32			0.28	**0.12**
Ircinia spp. brown					0.38	**0.08**
Mycale laevis					0.38	**0.08**
Cinachyrella kuekenthali					0.28	**0.06**
Aplysina fulva				0.25		**0.05**
Aiolochroia crassa	0.21					**0.04**
Smenospongia aurea					0.19	**0.04**
Total Sponges	**3.75**	**5.59**	**5.21**	**7.81**	**3.85**	**5.24**
Bleached Corals						
Orbicella faveolata	1	0	0	0	0	**0.20**

Erect soft corals were prominent in all transects surveyed with a mean density of 12.4 Col/Transect. Erect soft coral species identifications were not produced but sea plumes (*Antillogorgia* spp.), sea rods (*Eunicea* spp., *Pseudopterogorgia* spp.), and the common sea fan (*Gorgonia ventalina*) were observed within and outside transects. The encrusting soft corals, *Briareum asbestinum* and *Erythropodium caribaeorum* were present with a combined mean cover of 4.68% (Table 44). Sponges were represented by 20 species in transects with a combined mean cover of 5.24%. Monachora arbuscula, *Amphimedon compressa, Niphates erecta,* and *Iotrochota birotulata* were the dominant species in terms of reef substrate cover with a combined mean cover of 2.84%, representative of 54.2% of the total cover by sponges. Sponges were present mostly as small encrusting colonies without any major contributions to the reef topographic relief or structural habitat complexity. Abiotic substrate categories were contributed by reef overhangs (14.72%), sand (2.78%), and coral rubble (0.30%). The mean reef rugosity of 3.33m was influenced by the irregular sedimentary features shaping bottom topography and by small to moderate sized coral colonies, most of them dead and overgrown by benthic algae and other encrusting biota.

Variations of the benthic community structure during monitoring surveys at PALN20 are shown in Figure 50. The rank order of reef substrate cover by benthic categories remained the same between surveys, but statistically significant variations of stony coral were measured (ANOVA, $p < 0.001$; Appendix 3). Degradation of the stony coral community at PALN20 was initially measured in 2018 when a 11.7% decline was measured relative to the mean cover measured in the 2016 baseline survey. Such decline was proposed to be potentially related to the physical disturbance caused by the pass of hurricanes Irma and Maria in 2017, but differences were statistically insignificant (Garcia-Sais et al., 2018). Several coral colonies intercepted by transects were observed to be affected by infectious coral diseases (disease prevalence = 8.0%), and such infections as causal drivers of the coral cover decline measured in 2018 cannot be discarded. Stony coral cover declined 28.4% between the 2018 survey (27.13%), and the 2021 survey (19.43%). Reductions of reef substrate cover were measured across a multi-species coral assemblage during the 2021 survey relative to the 2018 survey, including dominant coral species in terms of substrate cover such as *Agaricia grahamae* (-34.5%), *Madracis auretenra* (-46.4%), *Porites astreoides* (-34.5%), *Montastraea cavernosa* (-43.9%), *Orbicella* spp. (-53.8%), and *Siderastrea siderea* (-39.5%) (Figure 51). The largest degradation of the stony coral community at PALN20 was measured during the most recent 2025 survey when stony coral cover declined 62.88%, from 16.92% in 2023 to 6.28% in 2025. The difference of cover between the 2023 and

2025 surveys was statistically significant (ANOVA, p = 0.010; Appendix 3) and influenced by sharp declines of cover by the previously dominant dimpled sheet coral, *Agaricia grahamae* (-99.5%), yellow pencil coral, *Madracis auretenra* (-72.1%), star corals, *Orbicella* spp. (72.5%), and mustard-hill coral, *Porites astreoides* (-26.3%) (Figure 51). The generalized decline of cover by live stony corals at PALN20 appear to be related to the extreme heat stress experienced by Puertorrican reefs from mid-May until late October 2023 when 19 degree-heating weeks were measured (NESDIS, 2024).

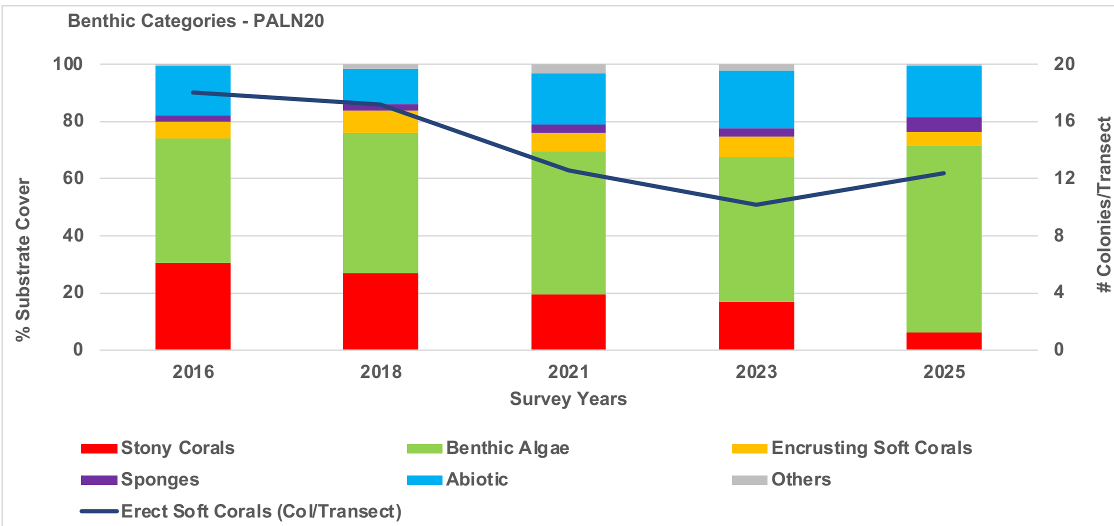


Figure 50. Monitoring trends (2016 - 2025) of mean substrate cover by sessile-benthic categories at PALN20, Fajardo. PRCRMP 2025

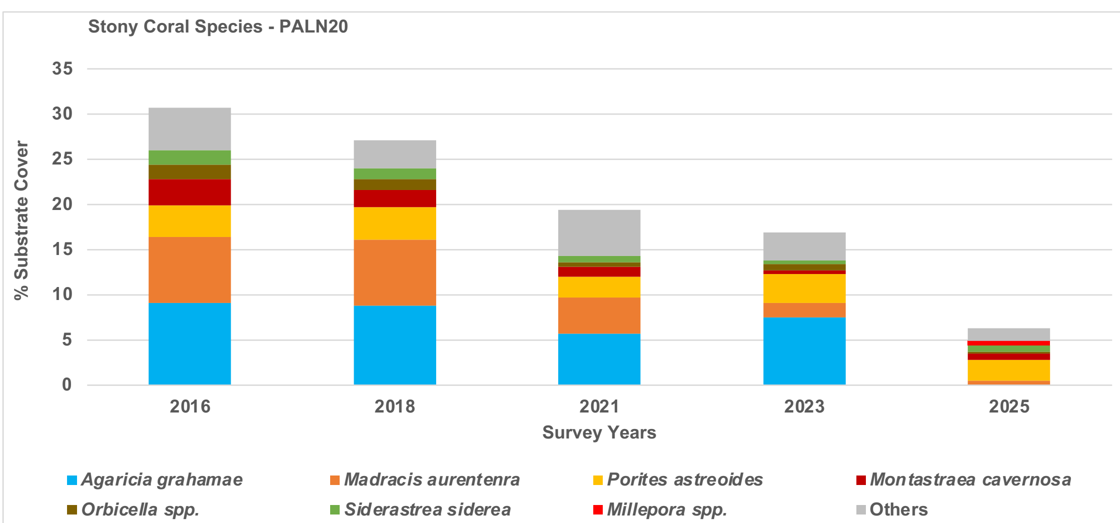


Figure 51. Monitoring trends (2016 - 2025) of mean substrate cover by the main coral species intercepted by transects at PALN20, Fajardo. PRCRMP 2025

15.3 Fishes and Motile Megabenthic Invertebrates

A total of 34 species of fish were identified within belt-transects from a depth of 15 - 17m at PALN20 during the 2025 survey with a mean density of 478.0 Ind/30m^2 (range: 191 – 845 Ind/30m^2), and a mean species richness of 16.8 Spp/30m^2 (Table 45). The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 428.6 Ind/30m^2, representing 89.7% of the total fish density. Large schooling aggregations of masked goby were observed below ledges and other protective habitats from all transects. Smaller schooling aggregations of blue chromis (*Chromis cyanea*) and recruitment juvenile parrotfishes (*Scarus* spp.) contributed to fish density in belt-transects. In addition to the masked goby, four species were present in all five transects with a combined density of 10.2 Ind/30m^2, contributing an additional 2.1% to the total fish density. The assemblage included the princess redband, and stoplight parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum, S. viride*), and the beaugregory (*Stegastes leucostictus*). Motile megabenthic invertebrates were not observed within belt-transects. One spiny lobster (*Panulirus argus*) was observed outside transects.

The trophic structure of fishes at PALN20 was strongly comprised by zooplanktivorous (ZPL) fishes due to the numerical dominance of the masked goby (*Coryphopterus personatus*) and to a lesser extent of the blue chromis (*Chromis cyanea*) which ranked second in mean density. The ZPL assemblage included five species with a combined mean density of 438.4 Ind/30m^2, representative of 91.8% of the total fish density. Herbivores (HER) were represented by parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with a total of 10 species and a combined density of 23.2 Ind/30m^2, or 4.9% of the total individuals. Small opportunistic carnivores (SOC) were represented by a specious assemblage that included 15 species with a combined density of 13.6 Ind/30m^2, or 2.8% of the total fish density. The assemblage included wrasses (Labridae), puffers (Tetraodontidae), goatfishes (Mullidae), gobies (Gobiidae), grunts (Haemulidae), hamlets and sea basses (Serranidae), squirrelfishes (Holocentridae), lizardfishes (Synodontidae), and trumpetfishes (Aulostomidae), Spongivores (Pomacanthidae) and corallivores (Chaetodontidae) were represented by two species and a combined density of 1.2 Ind/30m^2 (Table 45).

Table 45. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at PALN20, Fajardo. PRCRMP 2025

PALN20							
Survey Date: 6/21/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	273	350	160	800	560	**428.6**	ZPL
Chromis cyanea		32		16		**9.6**	ZPL
Scarus spp.	20		8		12	**8.0**	HER
Thalassoma bifasciatum	20	2	5			**5.4**	SOC
Scarus taeniopterus	2	3	4	2	6	**3.4**	HER
Stegastes leucostictus	4	2	1	3	3	**2.6**	HER
Sparisoma viride	3	3	2	2	1	**2.2**	HER
Sparisoma aurofrenatum	3	3	1	2	1	**2.0**	HER
Stegastes adustus		3	3	2		**1.6**	HER
Canthigaster rostrata	2	1	1		2	**1.2**	SOC
Gramma loreto				6		**1.2**	SOC
Acanthurus coeruleus				1	5	**1.2**	HER
Pseudupeneus maculatus	3		2			**1.0**	SOC
Halichoeres garnoti	1	1		2	1	**1.0**	SOC
Acanthurus chirurgus		1	1		3	**1.0**	HER
Stegastes variabilis	1	1		1	1	**0.8**	HER
Chaetodon capistratus	2				2	**0.8**	COR
Elacatinus evelynae		1			3	**0.8**	SOC
Haemulon aurolineatum		1	1	1	1	**0.8**	SOC
Caranx ruber					3	**0.6**	LC
Hypoplectrus puella	1			1		**0.4**	SOC
Ocyurus chrysurus	1				1	**0.4**	LC
Hypoplectrus unicolor		1			1	**0.4**	SOC
Pomacanthus arcuatus		2				**0.4**	SPO
Serranus tigrinus		1		1		**0.4**	SOC
Holocentrus rufus		1		1		**0.4**	SOC
Sparisoma atomarium				2		**0.4**	HER
Haemulon flavolineatum	1					**0.2**	SOC
Cephalopholis cruentata	1					**0.2**	LC
Stegastes partitus			1			**0.2**	ZPL
Hypoplectrus nigricans			1			**0.2**	SOC
Synodus intermedius				1		**0.2**	SOC
Aulostomus maculatus				1		**0.2**	SOC
Lutjanus apodus					1	**0.2**	LC
Density (Ind/30m2)	**338**	**409**	**191**	**845**	**607**	**478.0**	
Richness (Species/30m2)	**16**	**18**	**14**	**18**	**18**	**16.8**	

Medium and large-sized carnivores included the yellowtail and schoolmaster snappers (*Ocyurus chrysurus, Lutjanus apodus*), hogfish (*Lachnolaimus maximus*), bar jack (*Caranx ruber*), and graysbe (*Cephalopholis cruentata*) with a combined density of 2.4 Ind/60m^2 (Table 46). Adult great barracuda (*Sphyraena barracuda*), cero mackerel (*Scomberomorus regalis*), and Nassau, red hind and yellowfin grouper (*Epinephelus striatus, E. guttatus, Mycteroperca venenosa*), and lane snappers (*Lutjanus synagris*) were previously reported (Garcia-Sais et al 2023 and references therein). These data suggest that PALN 20 is a foraging habitat for demersal predators and that there is an active plankton-based food chain that supports the presence of pelagic predators, such as mackerels, barracudas, and jacks.

The larger reef fish herbivores were represented by parrotfishes (*Scarus taeniopterus, Scarus* spp.*, Sparisoma aurofrenatum, S. viride, S. atomarium*), and doctorfishes (*Acanthurus coeruleus, A. tractus, A. chirurgus*) with mean densities of 20.6 Ind/60m^2 and 2.6 Ind/60m^2, respectively. Doctorfishes and parrotfishes were observed throughout a wide size range at PALN20 during the 2025 and previous surveys including both juvenile and adult stages (Garcia-Sais et al 2022a and references therein). Recruitment juvenile stages (1 – 5cm) of stoplight, redband, and princess parrotfishes were present in the 2025 and previous surveys. The size range of doctorfishes and parrotfishes is indicative that PALN20 functions as a recruitment, grazing and residential habitat for these large herbivore populations.

Variations of fish density and species richness between monitoring surveys are presented in Figure 52. Differences of fish density were statistically significant (ANOVA; $p < 0.0001$; Appendix 5) associated with lower density during the 2023 survey relative to all other previous surveys since the 2016 baseline. The lower densities in 2023 were mostly related to a 75.0% reduction of density by masked goby (*Coryphopterus personatus*), the numerically dominant species in all previous surveys at PALN20. Fluctuations of this species are a recurrent aspect of the fish community structure of many reefs included in the PRCRMP and associated with physical disturbances and other fishery and/or density independent factors (Garcia-Sais et al., 2018, 2022a). During the 2025 survey peak fish density was measured at PALN20 driven by a population explosion of masked goby evidencing a full recovery of the population nine years after the hurricane debacle. Conversely, fish species richness reached a historical low at PALN20 perhaps associated with the strong wave and surge conditions experienced at the time of survey. The potential relationship of fish species richness decline associated with marked live coral losses at PALN20 appears to be contradicted by the fact that species richness peaked in 2023 preceding the largest drop of live coral measured at PALN20.

Table 46. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at PALN20, Fajardo. PRCRMP 2025

PALN20							
Survey Date: 6/21/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	8, 10					2	Juvenile
Acanthurus chirurgus c3	11, 15			1		1	Juvenile
Acanthurus coeruleus c1	2-3					2	Recruit
Acanthurus coeruleus c3	15, 14, 3-12			1	1	3	Adult
Acanthurus coeruleus c4	16, 18				2		Adult
Acanthurus tractus c1	5					1	Recruit
Acanthurus tractus c2	10			1			Juvenile
Acanthurus tractusc3	2-12			1	1		Juvenile
Acanthurus tractus c4	16		1				Adult
Caranx ruber c3	3-12					3	Juvenile
Cephalopholis cruentata c5	25	1					Adult
Lachnolaimus maximus c5	25		1				Adult
Lutjanus apodus c3	15					1	Juvenile
Ocyurus chrysurus c3	3-15	2				1	Adult
Ocyurus chrysurus c4	20, 18	2					Adult
Ocyurus chrysurus c5	22	1					Adult
Scarus spp. c1	40-5	20		8		12	Recruit
Scarus taeniopterus c1	3					1	Recruit
Scarus taeniopterus c2	3-7, 5-10, 16-8	2	2	13	2	5	Juvenile
Scarus taeniopterus c3	12, 15			2			Juvenile
Scarus taeniopterus c4	18, 20		1	1			Terminal
Sparisoma aurofrenatum c1	3, 2-5, 4-4	2	3		1	1	Recruit
Sparisoma aurofrenatum c2	2-9, 10		2		1		Juvenile
Sparisoma aurofrenatum c3	2-12		2				Juvenile
Sparisoma aurofrenatum c4	20, 16		1		1		Adult
Sparisoma aurofrenatum c5	3-25, 23	1	1	1			Terminal
S. atomarium c1	2-5				2		Recruit
Sparisoma viride c1	4-3, 3-4, 3-5	1	4	1	2	2	Recruit
Sparisoma viride c3	2-15	1		1			Juvenile
Sparisoma viride c6	28, 30	1				1	Adult
	Totals	**34**	**18**	**31**	**13**	**36**	

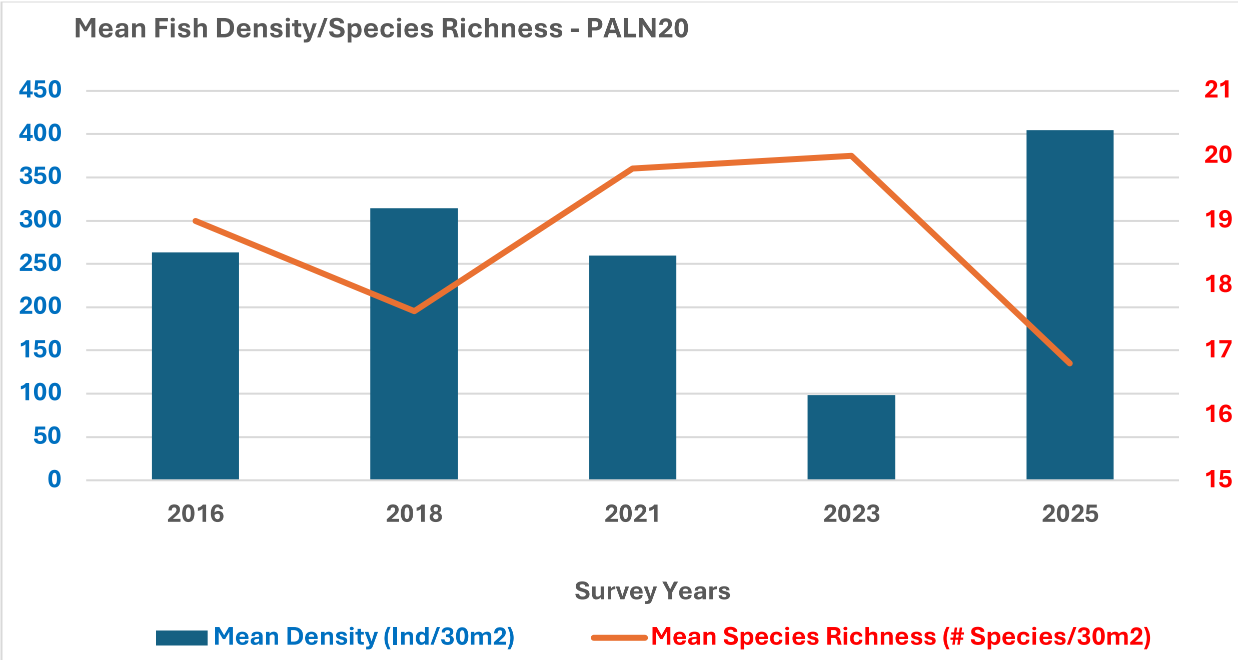
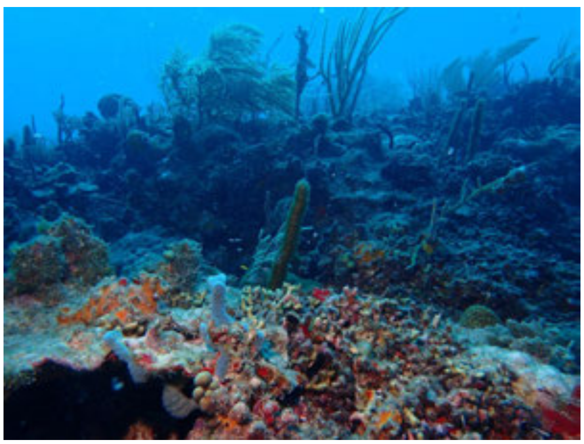
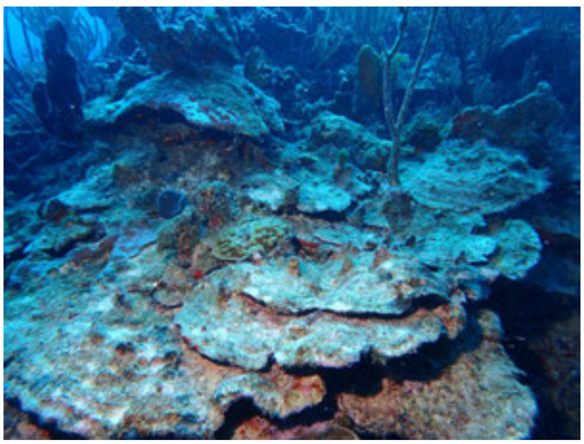
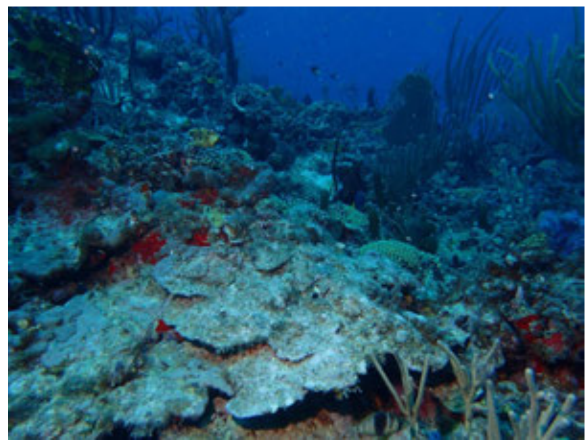


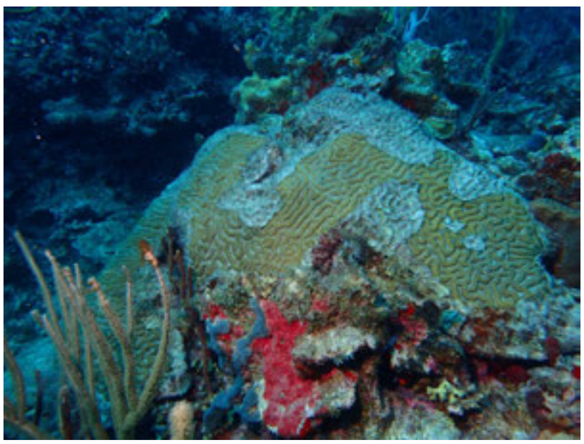
Figure 52. Monitoring trends (2016 – 2025) of mean fish density and species richness within 10 x 3m belt-transects at PALN20, Fajardo. PRCRMP 2025

Photo Album 15. PALN20









16.0 Luis Pena Reef 5m, Isla de Culebra

16.1 Physical Description

Luis Pena Island is located about 0.3 – 0.5 NM off the west coast of Isla de Culebra. Shallow water coral reefs fringe the eastern shoreline from the surface down to a depth of approximately 7.0m. The main coral formation is an irregular and patchy pillar growth of lobed star coral (*Orbicella annularis*) with areas dominated by thickets of finger coral (*Porites porites*). The baseline survey at LPEN05 was performed on the eastern central coastline of Cayo Luis Pena, within the LP Marine Reserve in September 2016 (Figure 53). Transects were run perpendicular to the shoreline over a set of discontinuous patches of *O. annularis* coral buildups. Panoramic views of the reef community at LPEN05 during the 2025 monitoring survey are shown in Photo Album 16.

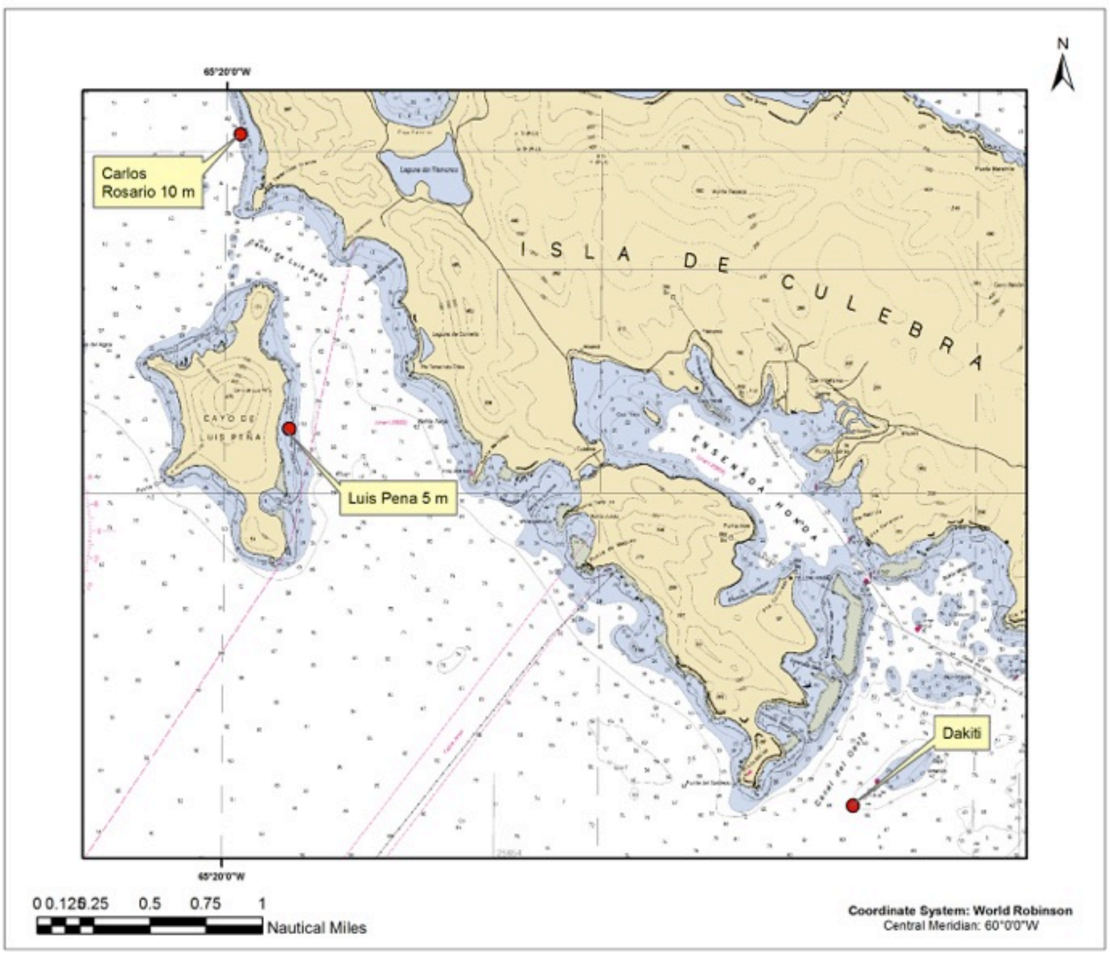


Figure 53. Location of coral reef monitoring stations in Isla de Culebra. PRCRMP 2025

16.2 Sessile Benthic Reef Community

Benthic algae, a mixed assemblage of encrusting red crustose calcareous alga (*Ramicrusta sp., Peyssonnelia sp.*), fleshy brown macroalgae (*Dictyota sp., Lobophora sp.*), turf algae (mixed assemblage), and green calcareous algae (*Halimeda spp. Caulerpa spp.*) were the dominant sessile-benthic category covering the reef substrate at LPEN05 during the 2025 survey with a combined mean cover of 73.09% (Table 47). *Ramicrusta sp*. was the dominant component with a mean cover of 34.03%, representing 46.8% of the total cover by benthic algae. *Ramicrusta sp*. was observed as a dark burgundy crust overgrowing available hard surfaces, but particularly over abundant dead standing lobed coral (*Orbicella annularis*) colonies. Fleshy brown (mostly *Dictyota* sp.) and turf algae (mixed brown and red algae) were intersected by all five transects with a combined mean cover of 37.02%, or 50.6% of the total cover by benthic algae. Cyanobacterial patches were present in three transects with a mean cover of 0.92%.

Stony corals were represented by five scleractinians in transects surveyed at LPEN05 with a combined mean substrate cover of 3.46% (range: 2.01 – 6.88%). Lobed star coral (*Orbicella annularis*), and mustard-hill coral (*Porites astreoides)* were the dominant corals intercepted by transects with a combined mean substrate cover of 2.67%, representative of 77.2% of the total cover by stony corals (Table 47). A total of 48 stony coral colonies were intercepted by transects, none of which were observed to be affected by coral diseases (Appendix 2).

Erect soft corals were prominent in all transects surveyed at LPEN05 with a mean density of 12.0 Colonies/Transect (Table 47). Sea Rods (*Plexaura spp., Pseudoplexaura spp.*), and the sea fan (*Gorgonia ventalina*) were the most abundant in transects. The encrusting gorgonian (*Erythropodium caribaeorum*) was present in four transects with a mean cover of 0.56%. Another encrusting species, the corky sea finger (*Briareum asbestinum*) was intersected by one transects with a mean cover of 0.04%. Sponges were represented by five species in transects with a combined mean cover of 0.85%. *Dictyonella funicularis* and *Chondrilla caribensis* were the most prominent in transects surveyed with a combined mean cover of 0.68%, representative of 80.0% of the total cover by sponges. Sponges were present as small and mostly encrusting colonies with minor contributions to the overall reef topographic relief and benthic habitat complexity. Abiotic substrate categories were contributed by reef overhangs (16.93%), and sections of sand (3.53%), and gaps/holes (0.22%). The mean reef rugosity of 4.73m was largely contributed by the irregular and vertically projected growth of live and relict stony corals (mostly *Orbicella annularis*).

Table 47. Percent reef substrate cover by sessile-benthic categories at LPEN05, Isla de Culebra. PRCRMP 2025

LPEN05			**Transects**			
Survey Date: 7/12/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**4.2**	**4.5**	**4.5**	**3.6**	**4.5**	**4.26**
Rugosity (m)	4.55	5.13	4.66	4.06	5.26	**4.73**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	16.17	15.36	21.20	15.04	16.88	**16.93**
Sand		7.31	1.34	8.47	0.55	**3.53**
Gaps/Holes		1.11				**0.22**
Total Abiotic	**16.17**	**23.77**	**22.54**	**23.51**	**17.43**	**20.68**
Benthic Algae						
Ramicrusta spp.	26.56	33.95	36.77	33.86	38.99	**34.03**
Dictyota spp.	27.43	21.46	21.68	20.22	22.02	**22.56**
Turf (mixed)	15.30	5.27	9.74	14.24	8.62	**10.64**
Turf (mixed) with sediment	0.67	8.88	2.58	4.28	1.47	**3.58**
Halimeda spp.	1.25		1.34		1.28	**0.77**
Jania spp.			2.67	0.30		**0.59**
Peyssonnelia spp.	2.41					**0.48**
Lobophora spp.	0.29				0.92	**0.24**
Caulerpa spp.				0.60		**0.12**
Padina spp.			0.38			**0.08**
Total Benthic Algae	**73.92**	**69.57**	**75.17**	**73.51**	**73.30**	**73.09**
Cyanobacteria	**3.85**	**0.46**	**0.00**	**0.00**	**0.28**	**0.92**
Stony Corals						
Orbicella annularis	0.77	1.48	0.38	0.30	4.86	**1.56**
Porites astreoides	1.54	1.11	1.43		1.47	**1.11**
Porites furcata				1.39	0.55	**0.39**
Porites porites		0.28	0.19	0.70		**0.23**
Orbicella faveolata	0.87					**0.17**
Total Stony Corals	**3.18**	**2.87**	**2.01**	**2.39**	**6.88**	**3.46**
# Coral Colonies /Transect	**7**	**7**	**8**	**11**	**15**	**9.6**
# Bleached Coral Colonies/Transect	**0**	**0**	**0**	**0**	**1**	**0.2**
# Erect Soft Coral Colonies/Transect	**11**	**15**	**7**	**13**	**14**	**12.0**
Soft Corals						
Erythropodium caribaeorum	0.67	0.65	0.29		1.19	**0.56**
Plexaura homomalla		0.65			0.46	**0.22**
Plexaura kukenthali					0.46	**0.09**
Pseudoplexaura flagellosa				0.40		**0.08**
Briareum asbestinum	0.19					**0.04**
Total Soft Corals	**0.87**	**1.30**	**0.29**	**0.40**	**2.11**	**0.99**
Sponges						
Dictyonella funicularis	1.35	1.39				**0.55**
Chondrilla caribensis		0.65				**0.13**
Mycale laevis	0.38					**0.08**
Plakortis spp.	0.29					**0.06**
Monanchora arbuscula				0.20		**0.04**
Total Sponges	**2.02**	**2.04**	**0.00**	**0.20**	**0.00**	**0.85**
Bleached Corals						
Orbicella annularis	0	0	0	0	1	**0.20**

Variations of reef substrate cover by the main sessile-benthic categories between monitoring surveys at LPEN05 are summarized in Figure 54. The most relevant change of sessile-benthic community structure was a marked, statistically significant decline of reef substrate cover by stony corals (ANOVA; $p < 0.001$; Appendix 3). Differences were associated with a 51.7% reduction of coral cover in 2018 relative to the 2016 baseline cover, and consecutive declines of cover measured in the 2021, 2023, and the most recent 2025 monitoring survey (Figure 54). The declining stony coral trend has resulted in an overall change of -79.62% relative to the 2016 baseline cover.

The initial decline of stony coral cover measured in 2018 relative to the 2016 baseline was contributed by several species, including *Orbicella annularis, Porites porites,* and *Colpophyllia natans* (Figure 55). These reductions were most probably driven by mechanical damage after the pass of hurricanes Irma and Maria in September 2017. Garcia-Sais et al. (2018) noted that after the pass of hurricanes Irma and Maria in late 2017 dozens of coral colonies in LPEN05 were detached from their base and overturned due to mechanical forces, including several large *O. annularis* colonies within transects and other branching (*Porites porites*) and massive corals (*Pseudodiploria strigosa, Colpophyllia natans*).

Declines of coral cover measured during the 2021 and 2023 surveys were mostly driven by cover losses of *Orbicella annularis* and *Porites astreoides* (Figure 55). Coral disease infections, perhaps triggered by the 2019 and 2023 coral beaching events may have acted as potential drivers of the coral decline measured from LPEN05 in 2021 and 2023. The most recent decline of -49.9% measured during the 2025 survey (relative to 2023) was contributed by substrate cover reductions of *P. porites* (-73.8%), *P. astreoides* (-40.3%), *Orbicella* spp. (-27.3%), and the loss from transects of *Colpophyllia natans* (-100%).

Another relevant change of the benthic community structure at LPEN05 relates to the loss of erect soft coral colonies. Mean density of soft corals declined 37.5% between the 2016 baseline (19.2 Col/Transect) and the 2023 survey (12.0 Col/Transect). The difference was statistically significant (ANOVA, $p = 0.002$; Appendix 4) and probably driven by conditions of extreme surge and abrasion that must have prevailed during the pass of hurricanes Irma and Maria in September 2017, perhaps with lingering effects posterior to 2018, and measured in the 2021 and 2023 monitoring surveys. During the 2025 survey the density of erect soft corals remained stable at 12.0 Col/Transect.

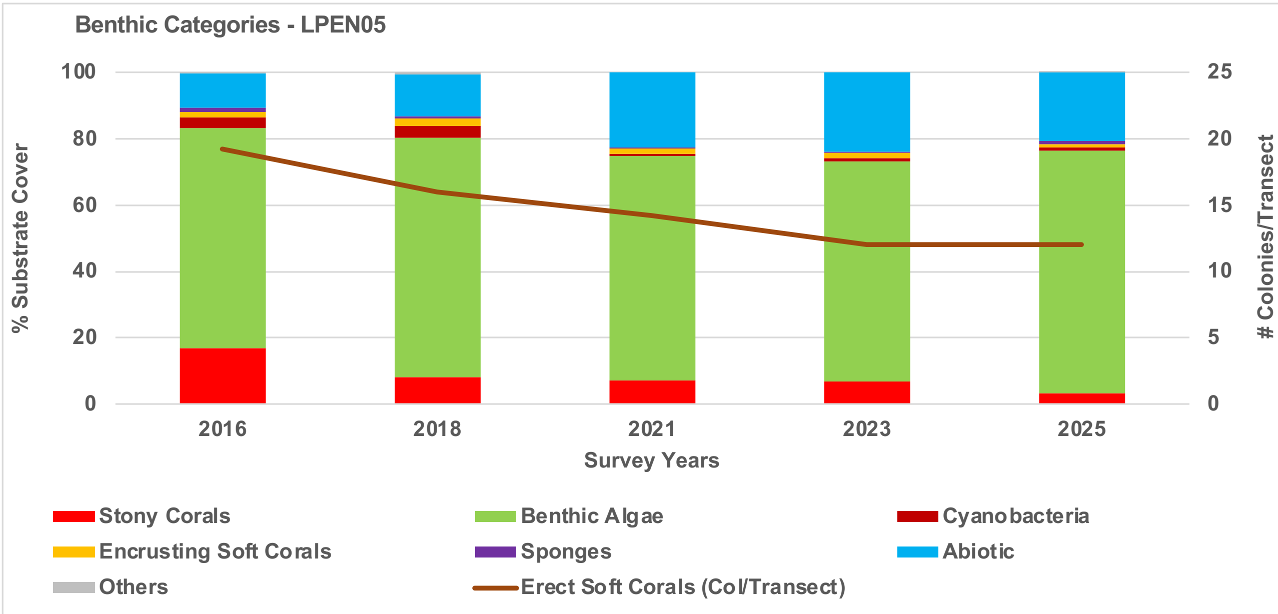


Figure 54. Monitoring trends (2016 - 25) of mean substrate cover by sessile-benthic categories at LPEN05, Isla de Culebra. PRCRMP 2025 survey

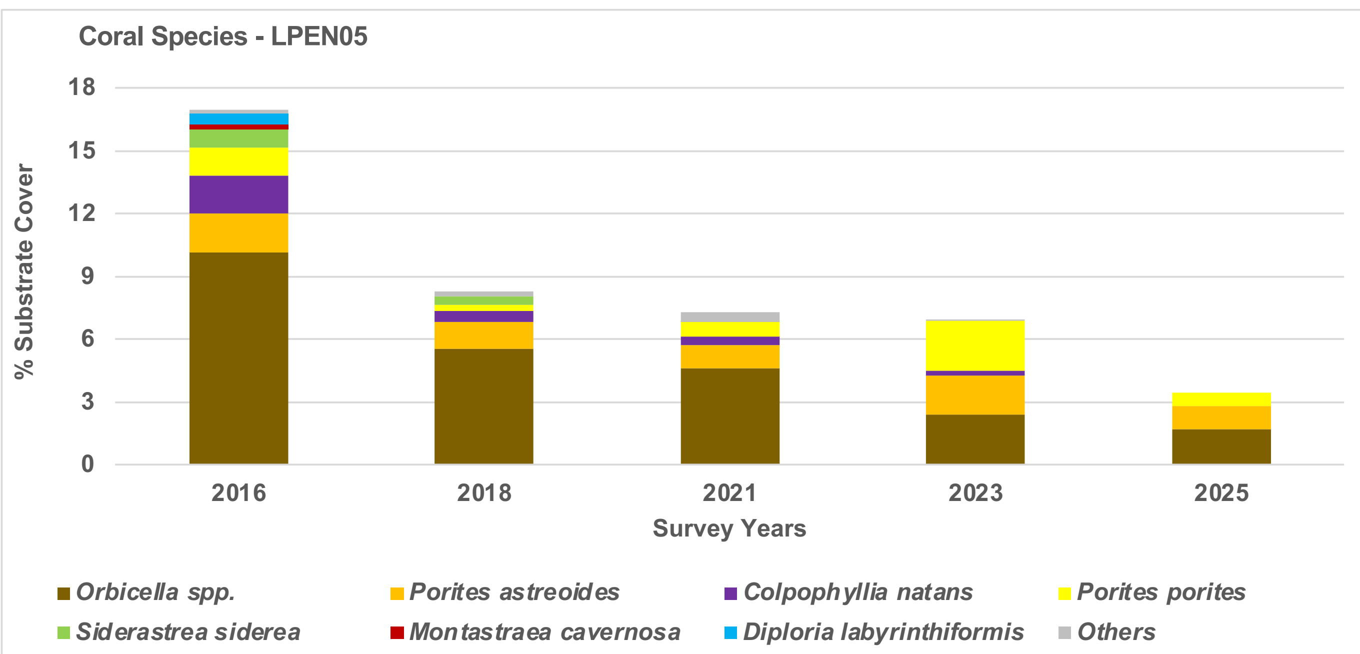


Figure 55. Monitoring trends (2016 - 25) of mean substrate cover by the main coral species intercepted by transects at LPEN05, Isla de Culebra. PRCRMP 2025 survey

16.3 Fishes and Motile Megabenthic Invertebrates

The taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3m x 10m belt-transects at LPEN05 during the 2025 monitoring survey are presented in Table 48. A total of 38 fish species were identified with a mean density of 194.8 Ind/30m^2 (range: 131 – 272 Ind/30m^2), and a mean species richness of 19.4 Spp/30m^2. The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 137.0 Ind/30m^2, representing 70.3% of the total fish density. In addition to *C. personatus*, an assemblage of five nine species were observed in at least four transects with a combined density of 38.8 Ind/30m^2, representing 19.9% of the total individuals (Table 48). These included the bluehead and yellowhead wrasses (*Thalassoma bifasciatum, Halichoeres garnoti*), doctorfish and blue tang (*Acanthurus chirurgus, A. coeruleus*), princess and stoplight parrotfishes (*Scarus taeniopterus*, *Sparisoma viride*), three-spot damselfish (*Stegastes planifrons)*, sergeant major (*Abudefduf saxatilis*), and french grunt (*Haemulon flavolineatum*). One large school of doctorfishes of over 100 individuals were transient over one transect. Motile megabenthic invertebrates observed within belt-transects included the long-spined urchin (*Diadema antillarum*), queen conch (*Lobatus gigas*), and the channel clinging crab (*Mithrax spinosissimus*) (Table 48).

The fish trophic structure at LPEN05 during the 2025 survey was dominated by zooplanktivores (ZPL) driven by the numerical dominance within belt-transects of masked goby (*Coryphopterus personatus*). Four additional species (*Abudefduf saxatilis, Chromis cyanea, Clepticus parrae,* and *Stegastes partitus*) contributed to the zooplanktivore trophic assemblage for a total density of 141.8 Ind/30m^2, representative of 72.8% of the total fish density (Table 48). The herbivore (HER) assemblage included 12 species with a combined density of 28.0 Ind/30m^2, or 14.4% of the total fish density. The assemblage included parrotfishes (Scaridae), damselfishes (Pomacentridae), and doctorfishes (Acanthuridae). Long-spined urchins (*Diadema antillarum*) with a men density of 0.4 Ind/30m^2 contributed to the herbivorous potential of LPEN10. Small opportunistic carnivores (SOC) were represented by 15 species with a combined density of 22.6 Ind/30m^2, representative of 11.6% of the total density. The assemblage included wrasses (Labridae), grunts (Haemulidae), squirrelfishes (Holocentridae), gobies (Gobiidae), puffers (Tetraodontidae), hamlets and seabasses (Serranidae). Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by two species with a combined density of 0.6 Ind/30m^2.

Table 48. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at LPEN05, Isla de Culebra. PRCRMP 2025

LPEN05							
Survey Date: 7/12/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	120	85	230	120	130	**137.0**	ZPL
Thalassoma bifasciatum	24	6	3	8	6	**9.4**	SOC
Acanthurus chirurgus	1	1		4	26	**6.4**	HER
Scarus taeniopterus	8	8	4	5	7	**6.4**	HER
Stegastes planifrons	6	5	3	1	5	**4.0**	HER
Haemulon flavolineatum	7	3	6	2	1	**3.8**	SOC
Sparisoma viride	5	2	2	5	3	**3.4**	HER
Scarus spp.					12	**2.4**	HER
Halichoeres garnoti	3	3	2		3	**2.2**	SOC
Abudefduf saxatilis	1	1	6		3	**2.2**	ZPL
Chromis cyanea	4	5			1	**2.0**	ZPL
Holocentrus rufus		2	6	1		**1.8**	SOC
Coryphopterus glaucofraenum	3		2	3		**1.6**	SOC
Sparisoma aurofrenatum	2	1		4		**1.4**	HER
Stegastes adustus		2		4		**1.2**	HER
Acanthurus coeruleus	2	1	1		1	**1.0**	HER
Chaetodon capistratus	2				2	**0.8**	COR
Canthigaster rostrata	2		1	1		**0.8**	SOC
Acanthurus tractus			2	1	1	**0.8**	HER
Hypoplectrus nigricans	1	1	1			**0.6**	SOC
Sparisoma atomarium					3	**0.6**	HER
Cephalopholis cruentata	1		1			**0.4**	LC
Pomacanthus arcuatus	2					**0.4**	SPO
Hypoplectrus chlorurus	1				1	**0.4**	SOC
Neoniphon marianus		1	1			**0.4**	SOC
Elacatinus evelynae		2				**0.4**	SOC
Clepticus parrae				1	1	**0.4**	ZPL
Hypoplectrus puella				1	1	**0.4**	SOC
Lutjanus apodus					2	**0.4**	LC
Stegastes leucostictus		1				**0.2**	HER
Stegastes partitus		1				**0.2**	ZPL
Microspathodon chrysurus			1			**0.2**	HER
Hypoplectrus indigo				1		**0.2**	SOC
Pterois volitans				1		**0.2**	LC
Hypoplectrus unicolor					1	**0.2**	SOC
Hypoplectrus sp. 1					1	**0.2**	SOC
Hypoplectrus sp. 2					1	**0.2**	SOC
Caranx ruber					1	**0.2**	LC
Invertebrates							
Mithrax spinnossissimus	1					**0.2**	
Diadema antillarum		1	1			**0.4**	
Lobatus gigas				1		**0.2**	
Density (Ind/30m2)	**195**	**131**	**272**	**163**	**213**	**194.8**	
Richness (Species/30m2)	**20**	**19**	**17**	**18**	**23**	**19.4**	

Medium and large-sized carnivores, the top predators at LPEN05 included the schoolmaster snapper (*Lutjanus apodus*), lionfish (*Pterois volitans*), graysbe (*Cephalopholis cruentata*), and bar jack (*Caranx ruber*) with a combined density of 1.4 Ind/60m^2 (Table 49). Other top predators previously reported from LPEN05 include the red hind (*Epinephelus guttatus*), yellowtail snapper (*Ocyurus chrysurus),* cero mackerel (*Scomberomorus regalis*), and southern sennet (*Sphyraena picudilla*) (Garcia-Sais et al., 2022a and references therein).

Parrotfishes, represented by four species (*Scarus* spp., *Sparisoma* spp.) were the most prominent reef herbivores at LPEN05 during the 2025 survey with a combined mean density of 21.0 Ind/60m^2 Doctorfishes (Acanthuridae) were also prominent with a combined density of 10.0 Ind/60m^2. Both doctorfishes and parrotfishes were observed across most of their size range, indicative that LPEN10 serves as a recruitment, grazing, and residential habitat for these reef herbivores. Juvenile and adult stages of graysby (*Cephalopholis cruentata*), yellowtail and schoolmaster snappers (*Ocyurus chrysurus, L. apodus*) were previously reported (Garcia-Sais et al., 2022a and references therein) indicative that LPEN serves as a recruitment, foraging, and residential habitat for these predator species.

Variations of mean fish density and species richness between monitoring surveys at LPEN05 are shown in Figure 56. Mean fish density declined 4-fold, from 179.0 Ind/30m^2 in 2016 to 43.0 Ind/30m^2 in 2018. Since then, consistent increments of mean density have been observed until the most recent 2025 survey when a peak mean density was reached (194.8 Ind/30m^2). This represents a full recuperation from the minimum densities measured in the 2018 survey after the pass of Hurricane Maria in September 2017, and winter storm Riley in March 2018. Fish density differences between monitoring surveys were statistically significant (ANOVA, $p < 0.001$; Appendix 5) and largely driven by density fluctuations of masked goby (*Coryphopterus personatus*). The population decline of *C. personatus* was consistent across most shallow reefs surveyed during 2018 and probably related to the surge and abrasive effects brought about by hurricanes and other extreme wave action events. The density increments noted since the 2021 survey may be indicative of a population recuperation trend for *C. personatus* and other small fish species that were negatively impacted by the hurricane effects at LPEN05. In the 2025 survey fish density was also influenced by peak fish species richness within belt-transects (19.4 Spp/30m^2). Differences of fish species richness between surveys were relatively small and not statistically significant (Figure 56), indicative of no major ecological impact on the fish community at LPEN05 despite the massive losses of live coral cover measured since 2018.

Table 49. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at LPEN05, Isla de Culebra. PRCRMP 2025

LPEN05							
Survey Date: 7/12/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	3, 2-4	1	2				Recruit
Acanthurus chirurgus c3	15		1				Juvenile
Acanthurus chirurgus c4	3-16, 26-17, 6-18			3	4	28	Adult
Acanthurus coeruleus c2	6, 8, 2-10	1	1		1	1	Juvenile
Acanthurus coeruleus c3	12, 14	1		1			Juvenile
Acanthurus tractus c2	8			1			Juvenile
Acanthurus tractus c3	14, 3-15	1		1	1	1	Juvenile
Caranx ruber c8	3-40			2		1	Adult
Cephalopholis cruentata c3	15			1			Juvenile
Cephalopholis cruentata c4	20				1		Adult
Cephalopholis cruentata c5	22	1					Adult
Lutjanus apodus c4	3-18, 20		2			2	Juvenile
Lutjanus apodus c6	28				1		Adult
Pterois spp. c4	17				1		Terminal
Scarus spp. c1	12-3					12	Recruit
Scarus taeniopterus c1	10-3, 3-5	4		3		6	Recruit
Scarus taeniopterus c2	24-6, 11-7, 7-8, 2-10	19	10	5	10		Juvenile
Scarus taeniopterus c3	12		1				Juvenile
Scarus taeniopterus c4	18					1	Adult
Sparisoma aurofrenatum c1	4, 5				2		Recruit
Sparisoma aurofrenatum c2	9	1					Juvenile
Sparisoma aurofrenatum c3	2-12, 14, 15	2				2	Juvenile
Sparisoma aurofrenatum c4	18, 20		1		1		Adult
Sparisoma aurofrenatum c5	2-23, 24, 25		1	1	1	1	Terminal
Sparisoma viride c1	2, 2-3, 4-4, 5	2	2	1	2	1	Recruit
Sparisoma viride c2	2-8, 2-10	2		1	1		Juvenile
Sparisoma viride c3	2-12, 15	2			1		Juvenile
Sparisoma viride c4	18, 2-20		2		1		Adult
Sparisoma viride c5	22, 25					2	Adult
Sparisoma viride c6	26					1	Adult
	Totals	**37**	**23**	**20**	**28**	**59**	

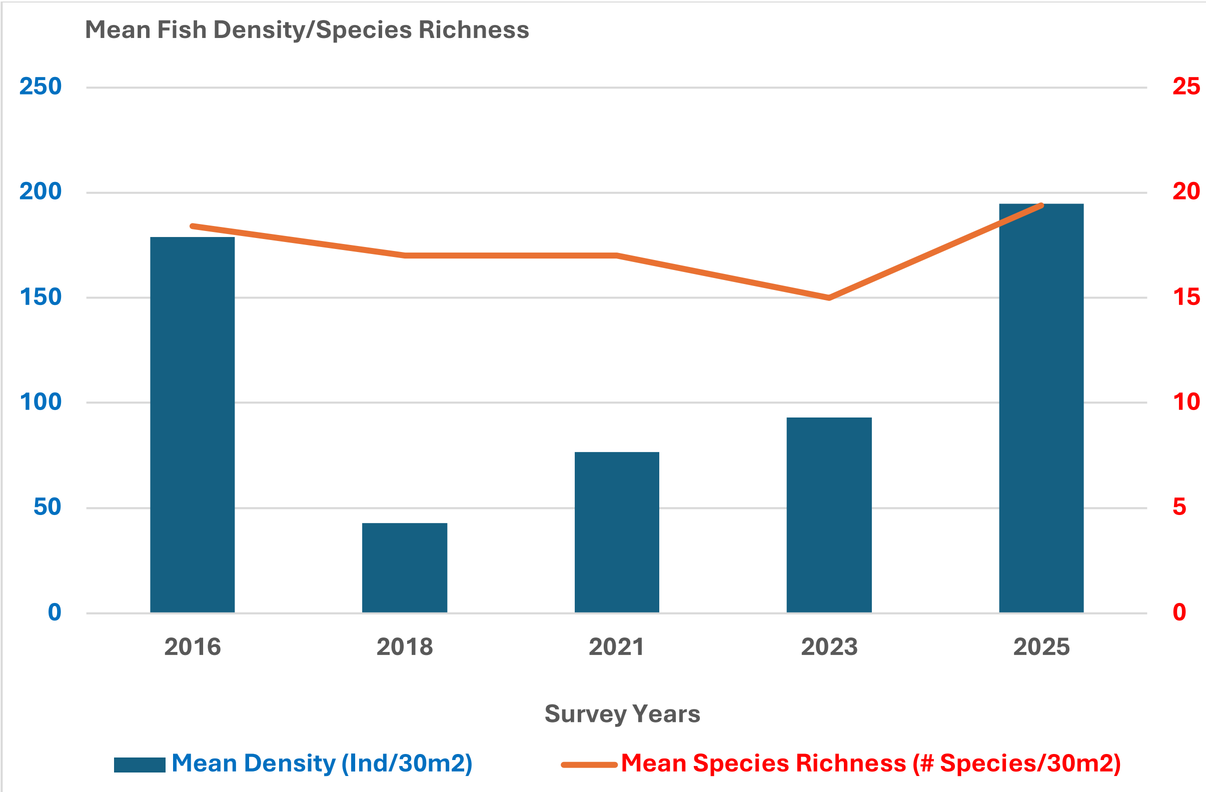
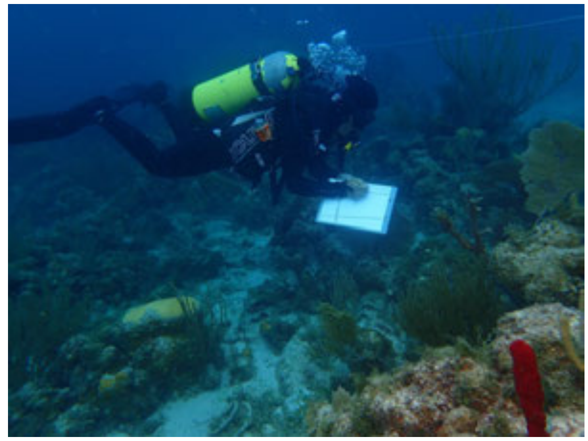


Figure 56. Monitoring trends (2016 – 25) of mean fish density and species richness within 10m x 3m belt-transects at LPEN05, Isla de Culebra. PRCRMP 2025 survey

Photo Album 16. LPEN05





17.0 Carlos Rosario Reef (CROS10), Isla de Culebra

17.1 Physical Description

Carlos Rosario Reef (CROS10) is a coastal fringing reef within the Luis Pena Natural Reserve. It is located about 0.2 NM north of Pta. Tamarindo in the main island of Culebra (Figure 53). The reef rises from a sandy bottom at a depth of 9.0m up to the surface across a steep fore-reef slope with several narrow terraces. The reef has significant structural buildup by scleractinian corals, particularly pillar growth of lobed star coral (*Orbicella annularis*). The reef is an important tourist attraction and several anchoring buoys support charter operations that bring divers to the reef. The baseline survey at CROS10 was performed in September 2016. Permanent transects were set very close to the reef base along the 8 - 10m depth contour. Images of the CROS10 reef community during the 2023 survey are presented in Photo Album 17.

17.2 Sessile Benthic Reef Community

Benthic algae comprised by an assemblage of fleshy brown, red crustose and encrusting coralline and turf algae were the dominant sessile-benthic category covering substrate at CROS during the 2025 monitoring survey with a combined mean cover of 55.23% (Table 50). Fleshy brown macroalgae comprised by the encrusting fan alga (*Lobophora* sp.) and y-twig alga (*Dictyota sp.*) were the main component of benthic algae with a combined mean cover of 28.60%, representative of 51.8% of the total benthic algae. The red crustose coralline algae (*Ramicrusta sp.*) was prominent in all transects with a mean cover of 13.11% and combined with other Peyssonnelid algae (3.42%) represented 29.9% of the total cover by benthic algae. Turf algae were also intercepted by all five transects with a mean cover of 9.84%. Patches of cyanobacteria were present in all transects with a mean cover of 6.32%.

Stony corals were represented by nine scleractinian species and one hydrocoral (*Millepora alcicornis*) intercepted by transects with a combined mean substrate cover of 5.16% (Table 50). Mustard-hill coral (*Porites astreoides)* was the dominant coral intercepted by transects with a mean substrate cover of 1.90%, representative of 36.8% of the total cover by stony corals. The *Orbicella* sibling species (*O. faveolata, O. franksi, and O. annularis*) were present in three transects each, with a combined cover of 1.89%, representative of 36.6% of the total cover by stony corals. A total of 42 coral colonies were intercepted by transects, including one (1- *O. faveolata*) apparently affected by an infectious coral disease, resulting in a coral disease prevalence of 2.38% (see Appendix 2).

Table 50. Percent reef substrate cover by sessile-benthic categories at CROS10, Isla de Culebra. PRCRMP 2025

17 - CROS10			**Transects**			
Survey Date: 7/12/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	8.8	9.1	9.7	8.5	9.4	**9.10**
Rugosity (m)	4.04	2.91	6.24	8.83	7.39	**5.88**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	16.25	32.65	21.21	36.28	23.91	**26.06**
Sand	1.69	1.63	4.31		2.42	**2.01**
Rubble	1.20				2.66	**0.77**
Total Abiotic	**19.14**	**34.27**	**25.52**	**36.28**	**28.99**	**28.84**
Benthic Algae						
Lobophora spp.	17.85	24.30	21.47	22.97	15.22	**20.36**
Ramicrusta spp.	9.07	8.68	6.98	20.30	20.53	**13.11**
Dictyota spp.	9.57	5.21	12.59	5.20	8.62	**8.24**
Turf (mixed)	12.56	8.13	6.90	3.27	4.75	**7.12**
Peyssonnelia spp.	4.09	3.69	3.79	2.23	3.30	**3.42**
Turf (mixed) with sediment	2.29	3.80	1.29		6.20	**2.72**
CCA (total)			0.34	0.15	0.81	**0.26**
Total Benthic Algae	**55.43**	**53.80**	**53.36**	**54.13**	**59.42**	**55.23**
Cyanobacteria	**6.68**	**5.31**	**9.14**	**5.95**	**4.51**	**6.32**
Stony Corals						
Porites astreoides	5.18	0.22	1.38	0.89	1.85	**1.90**
Orbicella faveolata	2.19	0.65	1.64			**0.90**
Montastraea cavernosa	1.60	2.28			0.56	**0.89**
Orbicella franksi	1.30		0.78	0.67		**0.55**
Orbicella annularis	0.80	0.65		0.74		**0.44**
Siderastrea siderea	0.40	0.33	0.69			**0.28**
Millepora alcicornis					0.48	**0.10**
Porites furcata	0.20					**0.04**
Favia fragum					0.16	**0.03**
Porites porites					0.16	**0.03**
Total Stoby Corals	**11.67**	**4.12**	**4.48**	**2.30**	**3.22**	**5.16**
# Coral Colonies /Transect	**17**	**5**	**9**	**4**	**7**	**8.4**
# Diseased Coral Colonies/Transect			**1**			**0.2**
# Bleached Coral Colonies/Transect		**1**				**0.2**
# Erect Soft Coral Colonies/Transect	**27**	**15**	**13**	**12**	**12**	**15.8**
Soft Corals						
Erythropodium caribaeorum	0.30	0.54	1.64		1.05	**0.71**
Gorgonia ventalina		0.22		0.74	0.32	**0.26**
Briareum asbestinum		0.33	0.34			**0.13**
Eunicea tourneforti		0.33				**0.07**
Plexaura homomalla	0.20					**0.04**
Total Soft Corals	**0.50**	**1.41**	**1.98**	**0.74**	**1.37**	**1.20**
Sponges						
Monanchora arbuscula	3.89	0.33	0.26			**0.89**
Dictyonella funicularis			2.33			**0.47**
Amphimedon compressa	0.30		1.55			**0.37**
Plakortis spp.	0.30			0.37	0.48	**0.23**
Clathria spp.		0.76		0.22		**0.20**
Sponge spp.	0.70		0.26			**0.19**
Ircinia strobilina			0.34		0.40	**0.15**
Verongula spp.	0.70					**0.14**
Mycale laevis			0.34		0.32	**0.13**
Aplysina fulva					0.56	**0.11**
Chondrilla caribensis					0.40	**0.08**
Aplysina cauliformis	0.20				0.16	**0.07**
Aplysina insularis	0.30					**0.06**
Ircinia felix			0.26			**0.05**
Aiolochroia crassa	0.20					**0.04**
Niphates erecta			0.17			**0.03**
Halisarca caerulea					0.16	**0.03**
Total Sponges	**6.58**	**1.08**	**5.52**	**0.59**	**2.50**	**3.25**
Diseased Corals						
Orbicella faveolata			1			**0.20**
Bleached Corals						
Orbicella annularis		1				**0.20**

Erect soft corals were prominent in all transects surveyed at CROS10 with a mean density of 15.8 Colonies/transect (Table 50). Taxonomic identifications of soft corals were not included in this survey, but it was noted that sea rods (*Eunicea spp, Plexaura sp*), and the sea fan (*Gorgonia ventalina*) were the most abundant in transects. The encrusting gorgonian (*Erythropodium caribaeorum*) and the corky sea finger (*Briareum asbestinum*) were present in four and two transects, respectively with a combined mean cover of 0.84%. Sponges were represented by 17 species with a combined mean cover of 3.25%. *Monachora arbuscula*, *Dictyonella funicularis,* and *Amphimedon compressa.* were the most prominent in transects with a combined cover of 1.73%, or 53.2% of the total cover by sponges. In general, sponges were present as small and mostly encrusting colonies with minor contributions to the overall reef topography and benthic habitat complexity. Abiotic substrate categories averaged a mean reef substrate cover of 28.84%, largely influenced by reef overhangs (mean= 26.06%). Sand and coral rubble were also present in some transects with a combined cover of 2.78% (Table 50). The mean rugosity of 5.88m was strongly influenced by the irregular topography produced by stony coral growth.

The most relevant change in the sessile-benthic community between monitoring surveys at CROS10 was a 56.86% decline of mean substrate cover by stony corals measured in 2025 relative to the mean cover measured in the previous 2023 survey (Figure 57). The difference was statistically significant (ANOVA, p= 0.045; Appendix 3) and associated with reductions of cover by some of the dominant stony coral species in terms of reef substrate over, such as the *Orbicella* spp. complex (-71.3%) and finger coral, *Porites porites* (-96.2%) (Figure 58). Previously, a 31.4% decline of reef substrate cover by stony corals decline was measured in 2021 relative to the mean cover in 2018 (Garcia-Sais et al. 2022).

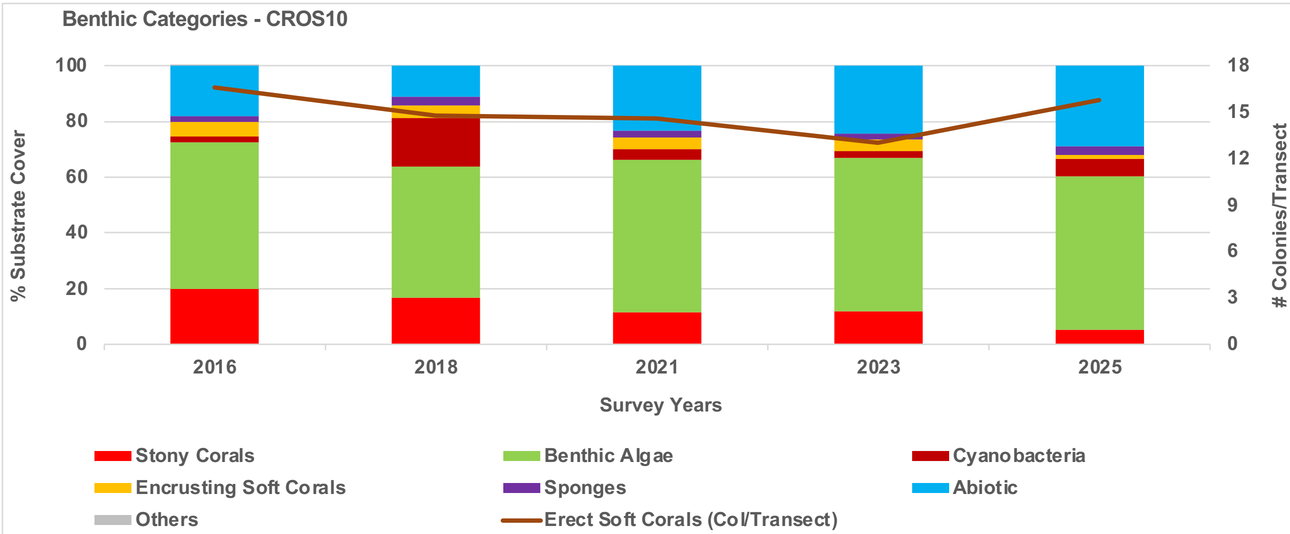


Figure 57. Monitoring trends (2016 - 2025) of mean substrate cover by sessile-benthic categories at CROS10, Isla de Culebra. PRCRMP 2025 survey

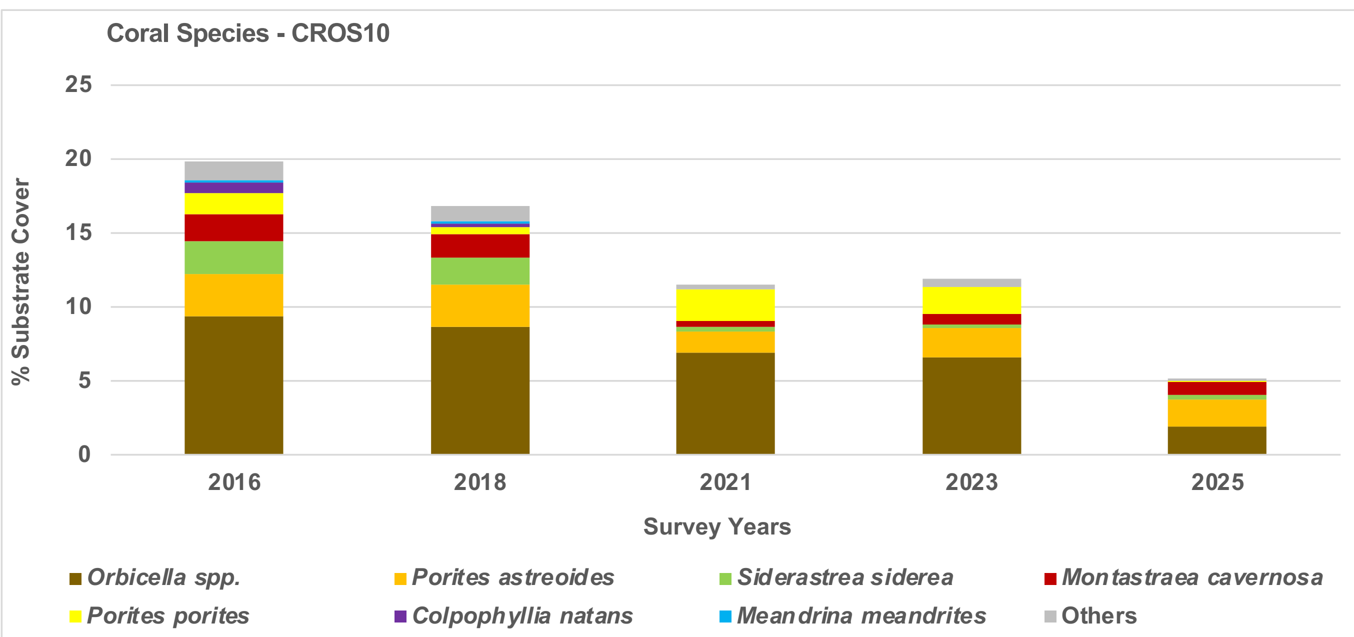


Figure 58. Monitoring trends (2016 - 2025) of mean substrate cover by coral species at CROS10, Isla de Culebra. PRCRMP 2025 survey

Fluctuations of reef substrate cover by cyanobacteria have been substantial at CROS10. An eight-fold increase in cover was measured in 2018, relative to the 2016 baseline (Figure 57). During 2021, cyanobacteria cover declined by 78.0% and then 33.0% furthermore in 2023 but increased by 134.9% in 2025. Such short-term variations may be related to conditions of wave and surge acting upon the reef substrate previous to the monitoring surveys, and/or variations of nutrient availability.

17.3 Fishes and Motile Megabenthic Invertebrates

A total of 41 fish species were identified within belt-transects during the 2025 survey at CROS10 (Table 51). Mean fish density peaked during the 2025 survey with 1,282 Ind/30m^2 (range: 1,028 – 1,485 Ind/30m^2). Mean fish species richness also peaked during the 2025 survey with 23.8 Spp/30m^2. The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 1,194.0 Ind/30m^2, representing 92.3% of the total fish density. Swarms of *C. personatus,* including many recruitment juveniles were observed in consecutive ledges and reef overhangs on all transects surveyed. Large schooling aggregations of creole wrasse (*Clepticus parrae*), tomtate (*Haemulon aurolineatum*), and recruitment juvenile parrotfishes (*Scarus* spp.) also contributed markedly to fish density with a combined mean of 36.8 Ind/30m^2, representative of 2.9%. In addition to masked goby, another six fish species were present in all five transects with a cumulative density of 11.2 Ind/30m^2. These included the three-spot and beaugregory damselfishes (*Stegastes planifrons, S. leucostictus*), squirrelfish (*Holocentrus rufus*), french grunt (*Haemulon flavolineatum*), redband parrotfish (*Sparisoma aurofrenatum*), and yellowhead wrasse (*Halichoeres garnoti*). Motile megabenthic invertebrates were not observed within belt-transects during the 2025 survey (Table 51). Spiny lobsters (*Panulirus argus*) were previously reported from CROS10 (Garcia-Sais et al., 2023 and references therein).

The fish trophic structure at CROS10 was strongly represented by zooplanktivorous (ZPL) fishes due to the numerical dominance of the masked goby (*Coryphopterus personatus*), and to a lesser extent of creole wrasse (*Clepticus parrae*), and blue chromis (*Chromis cyanea*), which combined with *C. personatus* for a mean density of 1210.8 Ind/30m^2, or 94.4% of the total fish density (Table 51). Small opportunistic carnivores were represented by 19 species with a combined density of 38.8 Ind/30m^2, representing 3.0% of the total.

Table 51. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CROS10, Isla de Culebra. PRCRMP 2025

CROS10							
Survey Date: 7/12/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	1300	1400	1100	1200	970	**1194.0**	ZPL
Clepticus parrae	14	45	13			**14.4**	ZPL
Haemulon aurolineatum			56	10		**13.2**	SOC
Scarus spp.	23		8		15	**9.2**	HER
Thalassoma bifasciatum	12	5	7	10		**6.8**	SOC
Gramma loreto	6		9	6	3	**4.8**	SOC
Scarus taeniopterus	10	4	2		1	**3.4**	HER
Stegastes planifrons	1	3	5	4	3	**3.2**	HER
Sparisoma viride	4	5		4	2	**3.0**	HER
Holocentrus rufus	5	1	4	2	1	**2.6**	SOC
Chromis cyanea	3		6	1	2	**2.4**	ZPL
Sparisoma aurofrenatum	1	3	2	2	3	**2.2**	HER
Halichoeres garnoti	1	1	3	1	5	**2.2**	SOC
Stegastes variabilis	4	1		3	2	**2.0**	HER
Stegastes leucostictus	1	2	3	1	1	**1.6**	HER
Haemulon flavolineatum	1	3	2	1	1	**1.6**	SOC
Lutjanus apodus				2	6	**1.6**	LC
Elacatinus evelynae	1		1		4	**1.2**	SOC
Neoniphon marianus	2		1	1	1	**1.0**	SOC
Coryphopterus glaucofraenum	4		1			**1.0**	SOC
Cephalopholis cruentata		1	3		1	**1.0**	LC
Acanthurus coeruleus	2			1	1	**0.8**	HER
Ocyurus chrysurus		1		3		**0.8**	LC
Caranx ruber				3	1	**0.8**	LC
Hypoplectrus chlorurus	1		1	1		**0.6**	SOC
Hypoplectrus puella	1		1		1	**0.6**	SOC
Hypoplectrus unicolor	1	1		1		**0.6**	SOC
Chaetodon capistratus	1	2				**0.6**	COR
Canthigaster rostrata		1	1	1		**0.6**	SOC
Pomacanthus arcuatus		3				**0.6**	SPO
Caranx bartholomaei			3			**0.6**	LC
Myripristis jacobus	2					**0.4**	SOC
Acanthurus tractus	1				1	**0.4**	HER
Aulostomus maculatus		1	1			**0.4**	SOC
Acanthurus chirurgus		1		1		**0.4**	HER
Pseudupeneus maculatus			1		1	**0.4**	SOC
Hypoplectrus nigricans			1		1	**0.4**	SOC
Epinephelus guttatus		1				**0.2**	LC
Synodus intermedius			1			**0.2**	SOC
Hypoplectrus spp.				1		**0.2**	SOC
Sparisoma atomarium					1	**0.2**	HER
Density (Ind/30m2)	**1402**	**1485**	**1236**	**1260**	**1028**	**1282.2**	
Richness (Species/30m2)	**25**	**21**	**26**	**23**	**24**	**23.8**	

The (SOC) assemblage included grunts (Haemulidae), wrasses (Labridae), basslets (Grammatidae), squirrelfishes (Holocentridae), gobies (Gobiidae), hamlets (Serranidae), puffers (Tetraodontidae), trumpetfishes (Aulostomidae), goatfishes (Mullidae), and lizardfishes (Synodontidae). Herbivores (HER) were represented by 11 species, including parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with a combined density of 26.4 Ind/30m^2, or 2.1% of the total fish density. Corallivores (COR) and spongivores (SPO) were represented by two species and a combined density of 1.2 Ind/30m^2).

Medium and large-sized fish carnivores were represented by blue runners and bar jacks (*Caranx crysos, C. ruber*), red hind and graysbe groupers (*Epinephelus guttatus, Cephalopholis cruentata*), and the schoolmaster, lane, and yellowtail snappers (*Lutjanus apodus, L. synagris, Ocyurus chrysurus*) with a combined density of 5.2 Ind/60m^2 (Table 52). Parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum, S. viride*) and doctorfishes (*Acanthurus chirurgus, A. coeruleus, A. tractus*) were the most prominent reef herbivores with densities of 20.0 Ind/60m^2 and 2.2 Ind/60m^2, respectively. Parrotfishes and doctorfishes were present throughout most of their size range, including early recruitment juveniles and terminal phase adults, indicative that CROS10 functions as a recruitment, grazing, and residential habitat for these species. The yellowtail snapper (*Ocyurus chrysurus*), and bar jack (*Caranx ruber*) populations previously observed out of transects in schools of more than 200 individuals were not observed in such quantities during the 2025 survey. The difference may be related to the removal of the anchoring buoy that was previously installed close to our monitoring station CROS10 where tourist used to feed these fishes with the consequences of artificially increasing the density as well as the organic inputs to the reef.

Variations of fish density and species richness between monitoring surveys at CROS10 are presented in Figure 59. Both mean fish density and species richness peaked during the 2025 monitoring survey. The peak of fish density (1282.2 Ind/30m2) was driven by a massive recruitment of masked goby (Coryphopterus personatus) but also influenced by schooling aggregations of several species (*Clepticus parrae, Haemulon aurolineatum, Scarus* spp.), and an overall increase of species richness within belt-transects. Density differences between monitoring surveys were statistically significant (ANOVA, $p < 0.001$; Appendix 5) associated with the lower densities in 2023 compared to other monitoring surveys. The lower densities of 2023 were associated with a decline of masked goby densities, and these were also accompanied with an overall decline of fish species richness, suggesting that masked goby may function as an important forage species that drives fish community structure at CROS by adding complexity to the food web. Differences of fish species richness between the previous 2023 and the 2025 monitoring surveys were statistically significant (ANOVA, p = 0.011; Appendix 6) associated with the 22.7% increase of species richness during 2025. Such increase was associated with a 2.36-fold increase in the density of carnivore fish species, including hamlets and groupers (Serranidae), snappers (Lutjanidae), squirrelfishes (Holocentridae), grunts (Haemulidae), and jacks (Carangidae).

Table 52. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CROS10, Isla de Culebra. PRCRMP 2025

CROS10							
Survey Date: 7/12/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	5			1			Recruit
Acanthurus chirurgus c3	15				1		Juvenile
Acanthurus coeruleus c1	3-5	3					Recruit
Acanthurus coeruleus c2	2-8, 10		1		1	1	Juvenile
Acanthurus coeruleus c3	12		1				Juvenile
Acanthurus coeruleus c4	16	1					Adult
Acanthurus tractus c3	12	1					Juvenile
Caranx crysos c8	3-40			3			Juvenile
Caranx ruber c5	2-25					2	Juvenile
Cephalopholis cruentata c4	2-16			1		1	Adult
Cephalopholis cruentata c5	25			1			Adult
Cephalopholis cruentata c6	28, 30		1	1			Adult
Epinephelus guttatus c9	43		1				Adult
Lutjanus apodus c5	24, 25				2		Adult
Lutjanus synagris c4	20			1			Adult
Ocyurus chrysurus c1	4			1			Recruit
Ocyurus chrysurus c4	3-16				3		Adult
Ocyurus chrysurus c5	8-25			8			Adult
Scarus spp. c1	46-3	23		8		15	Recruit
Scarus taeniopterus c1	5-3, 2-4, 5	5	2	1			Recruit
Scarus taeniopterus c2	6-6, 9-7, 8	6	9	1			Juvenile
Scarus taeniopterus c3	12	1					Juvenile
Sparisoma aurofrenatum c1	3, 3-4, 2-5	1	2			3	Recruit
Sparisoma aurofrenatum c2	2-6, 10		2			1	Juvenile
Sparisoma aurofrenatum c5	25			1			Terminal
Sparisoma viride c1	2, 2-3, 3-4, 5	1	4		2		Recruit
Sparisoma viride c2	6, 7, 3-8, 10	3	1		2		Juvenile
Sparisoma viride c3	13, 15	1			1		Juvenile
Sparisoma viride c4	16			1			Juvenile
Sparisoma viride c6	30	1					Adult
Sparisoma viride c7	32, 35		2				Terminal
	Totals	**47**	**26**	**29**	**12**	**23**	

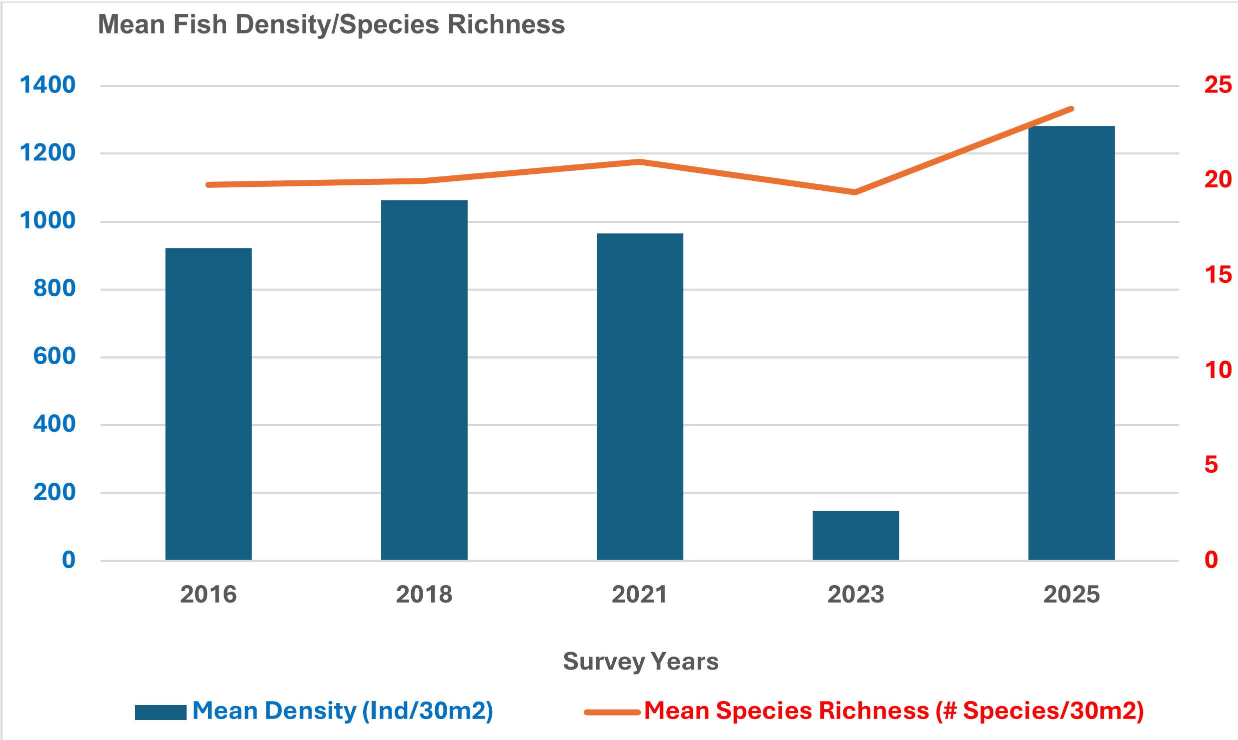
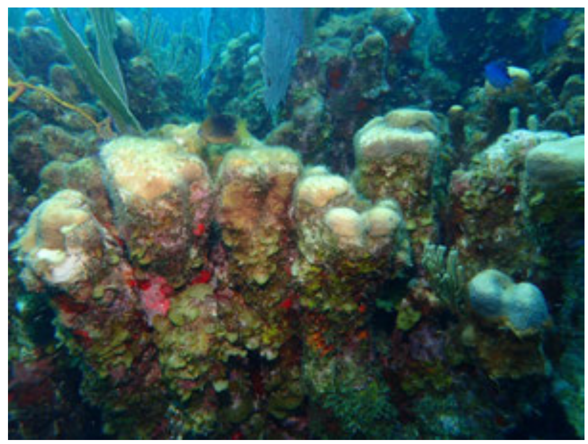
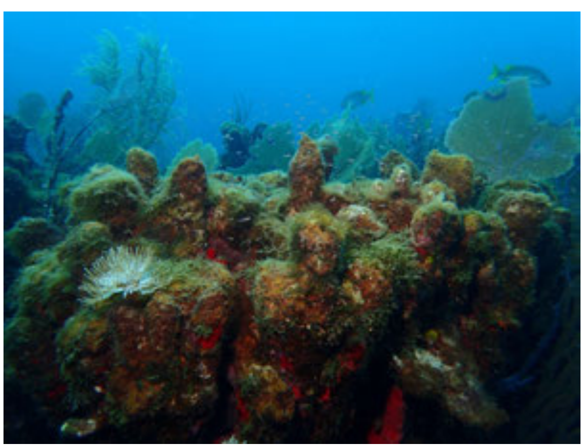
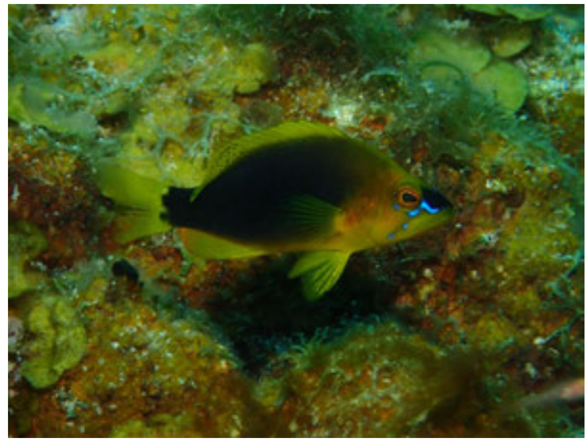


Figure 59. Monitoring trends (2016 – 25) of mean fish density and species richness within 10 x 3m belt-transects at CROS10, Isla de Culebra. PRCRMP 2025 survey

Photo Album 17. CROS10







18.0 Dakiti Reef, Isla de Culebra (DAKI20)

18.1 Physical Description

Dakiti Reef (DAKI20) is a submerged coral reef formation located about 0.9 NM southwest of the entrance channel to Ensenada Honda, on the south coast of Isla de Culebra (Figure 53). The reef rises from a soft sediment bottom at a depth of 25 – 27m and rises to a depth of about 3m. There is a navigation buoy anchored at the reef to mark a pass through "Canal del Oeste". The coral reef formation is continuous down to depths of at least 25m. The reef appears to be of sedimentary origin, but massive coral buildup is substantial and still represents an important contribution to the overall reef rugosity and habitat complexity. The baseline survey was performed in September 2016. Transects were placed down the reef slope on top of irregular spurs at depths between 17 – 19m. Images of the reef community at DAKI20 taken during the 2025 monitoring survey are shown in Photo Album 18.

18.2 Sessile-Benthic Reef Community

A mixed assemblage of benthic algae comprised by fleshy brown, red crustose calcareous and coralline, and turf algae were the dominant sessile-benthic category covering reef substrate at DAKI20 during the 2023 survey with a mean cover of 68.31% (Table 53). The encrusting fan-leaf alga (*Lobophora* sp.) was the main taxonomic component with a mean cover of 50.08%, representative of 73.3% of the total cover by benthic algae. Fleshy brown y-twig alga (*Dictyota* sp.) was intercepted by all five transects with a mean cover of 7.22%. Encrusting red crustose coralline algae (*Ramicrusta* sp., *Peyssonnelia* spp.) were also intercepted by all five transects with a mean combined cover of 6.82%, or 10.0% of the total benthic algae. Turf algae, a mixed assemblage of short brown and red algae were also present in all five transects with a mean substrate cover of 4.07%, or 5.9% of the total benthic algae. Small cyanobacterial patches were present with a mean cover 0.18% (Table 53).

A total of seven stony coral species and one hydrocoral (*Millepora alcicornis*) were intercepted by transects with a combined mean substrate cover of 6.62% (range: 4.48 – 8.30%). Mountainous star coral (*Orbicella faveolata*), and mustard-hill coral (*Porites astreoides*) were the dominant species in terms of reef substrate cover with a combined mean of 5.36%, representative of 81.0% of the total cover by corals (Table 53). A total of 45 stony coral colonies were intercepted by transects, including four (2- *O. faveolata*, 2- *S. siderea*) with apparent infectious disease(s) (disease prevalence = 8.89%; Appendix 2).

Table 53. Percent reef substrate cover by sessile-benthic categories at DAKI20, Isla de Culebra. PRCRMP 2025

18 - DAKI20			**Transects**			
Survey Date: 7/12/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**17.6**	**18.5**	**19.1**	**18.8**	**18.2**	**18.44**
Rugosity (m)	5.96	6.20	5.99	3.57	5.62	**5.47**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	27.81	20.57	24.52	19.09	20.34	**22.47**
Sand		0.86				**0.17**
Total Abiotic	**27.81**	**21.43**	**24.52**	**19.09**	**20.34**	**22.64**
Benthic Algae						
Lobophora spp.	45.26	47.19	45.88	60.27	51.79	**50.08**
Dictyota spp.	5.53	10.37	11.56	3.72	4.93	**7.22**
Ramicrusta spp.	8.77	3.72	2.63	0.31	12.72	**5.63**
Turf (mixed)	2.63	5.45	3.33	3.10	1.16	**3.13**
Peyssonnelia spp.	1.75	0.52	1.49	0.83	1.34	**1.19**
Turf (mixed) with sediment	0.70	1.38	0.44	2.17		**0.94**
CCA (total)	0.61					**0.12**
Total Benthic Algae	**65.26**	**68.63**	**65.32**	**70.38**	**71.95**	**68.31**
Cyanobacteria	**0.00**	**0.17**	**0.00**	**0.72**	**0.00**	**0.18**
Stony Corals						
Orbicella faveolata	3.77	2.85	4.73	3.92	1.08	**3.27**
Porites astreoides	1.67	3.89	0.44	2.68	1.79	**2.09**
Orbicella franksi			1.58		0.90	**0.49**
Siderastrea siderea		1.30		0.00	0.18	**0.30**
Millepora alcicornis				1.14	0.27	**0.28**
Orbicella annularis	0.18				0.27	**0.09**
Agaricia lamarcki		0.26				**0.05**
Stephanocoenia intersepta				0.21		**0.04**
Total Stony Corals	**5.61**	**8.30**	**6.74**	**7.95**	**4.48**	**6.62**
# Coral Colonies /Transect	**11**	**9**	**8**	**9**	**8**	**9.0**
# Diseased Coral Colonies/Transect	**2**	**1**			**1**	**0.8**
# Bleached Coral Colonies/Transect					**2**	**0.4**
# Erect Soft Coral Colonies/Transect	**0**	**2**	**3**	**2**	**2**	**1.8**
Soft Corals						
Erythropodium caribaeorum		0.69				**0.14**
Briareum asbestinum					0.18	**0.04**
Total Soft Corals		**0.69**			**0.18**	**0.17**
Sponges						
Aiolochroia crassa		0.61	0.35		0.63	**0.32**
Amphimedon compressa	1.32				0.18	**0.30**
Plakortis spp.				1.24		**0.25**
Aplysina cauliformis		0.17	0.26	0.31	0.27	**0.20**
Svenzea zeai					0.90	**0.18**
Aplysina fistularis					0.72	**0.14**
Monanchora arbuscula			0.35	0.31		**0.13**
Agelas spp.			0.61			**0.12**
Iotrochota arenosa			0.53			**0.11**
Verongula spp.			0.44			**0.09**
Neopetrosia spp. smooth					0.36	**0.07**
Cinachyrella kuekenthali			0.35			**0.07**
Mycale laevis			0.35			**0.07**
Niphates erecta			0.18			**0.04**
Total Sponges	**1.32**	**0.78**	**3.42**	**1.86**	**3.05**	**2.08**
Diseased Corals						
Siderastrea sidera		1			1	**0.40**
Orbicella faveolata	2					
Bleached Corals						
Orbicella annularis					1	**0.20**
Orbicella faveolata					1	**0.20**

Erect soft corals were present in four transects at DAKI20 with a mean density of 1.8 Colonies/transect. Although taxonomic identifications were not included in the survey it was noted that the sea fan (*Gorgonia ventalina*), and sea plumes (*Antillogorgia sp*., *Pseudopterogorgia spp*) were the most abundant in transects. The encrusting species, *Erythropodium caribaeorum* and *Briareum asbestinum* were present in one transect each, with a combined mean cover of 0.18% (Table 53). Sponges were represented by 14 species with a combined mean cover of 2.08%. *Aiolochoria crassa, Amphimedon compressa,* and *Plakortis spp.* were the most prominent with a combined cover of 0.87%. In general, sponges were present as small and mostly encrusting colonies with minor contributions to the overall reef topographic relief and benthic habitat complexity. Abiotic substrates, mostly contributed by reef overhangs (22.47%) presented a mean cover of 22.64%. The mean reef rugosity of 5.47m was influenced by the irregular reef bottom topography and growth of massive coral colonies.

The major change of benthic community structure at DAKI20 documented since the 2016 baseline survey was a 34.5% decline of reef substrate cover by stony corals measured during the 2021 survey relative to the previous 2018 survey (Figure 60). The marked decline of stony coral cover was mostly related to a decline of cover by *Orbicella spp*., from a combined mean of 9.23% in 2018, to a combined mean of 4.18% in 2021 (Figure 61). Other coral species that were present with relatively low cover at DAKI20 during the 2016 baseline survey have disappeared from transects. These include maze coral (*Meandrina meandrites*), and symmetrical brain coral (*Pseudodiploria strigosa*). Given the high coral disease prevalence documented at DAKI20 during the 2021 survey (13.89%) and the apparent infections of *O. faveolata* and *O. franksi* with SCTLD it is possible that the drastic decline of stony coral cover at DAKI20 may be related to coral disease(s), including SCTLD. Such disease infections may have been triggered or enhanced by the coral bleaching event of October 2019 that continued until (at least) February 2020 in waters around Puerto Rico. During the 2025 survey a 25.6% decline of reef substrate cover by stony corals was measured from DAKI20 resulting in an overall change of -56.16% relative to the 2016 baseline survey. Differences of reef substrate cover between monitoring surveys were statistically significant (ANOVA, p= 0.008; Appendix 3).

Differences of erect soft corals densities between monitoring surveys were statistically significant (ANOVA, p= 0.001; Appendix 4), associated with a 56.5% decline during the 2018 survey driven by physical damages imposed by hurricanes Irma and/or Maria in 2017.

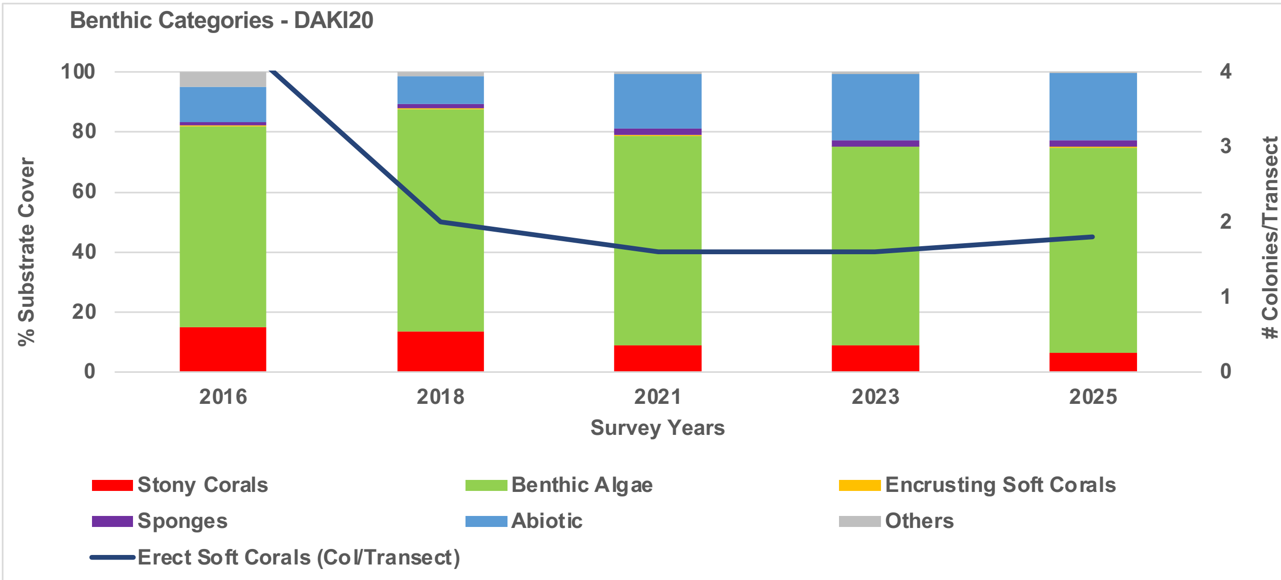


Figure 60. Monitoring trends (2016 - 25 of mean substrate cover by sessile-benthic categories at DAKI20, Isla de Culebra. PRCRMP 2025

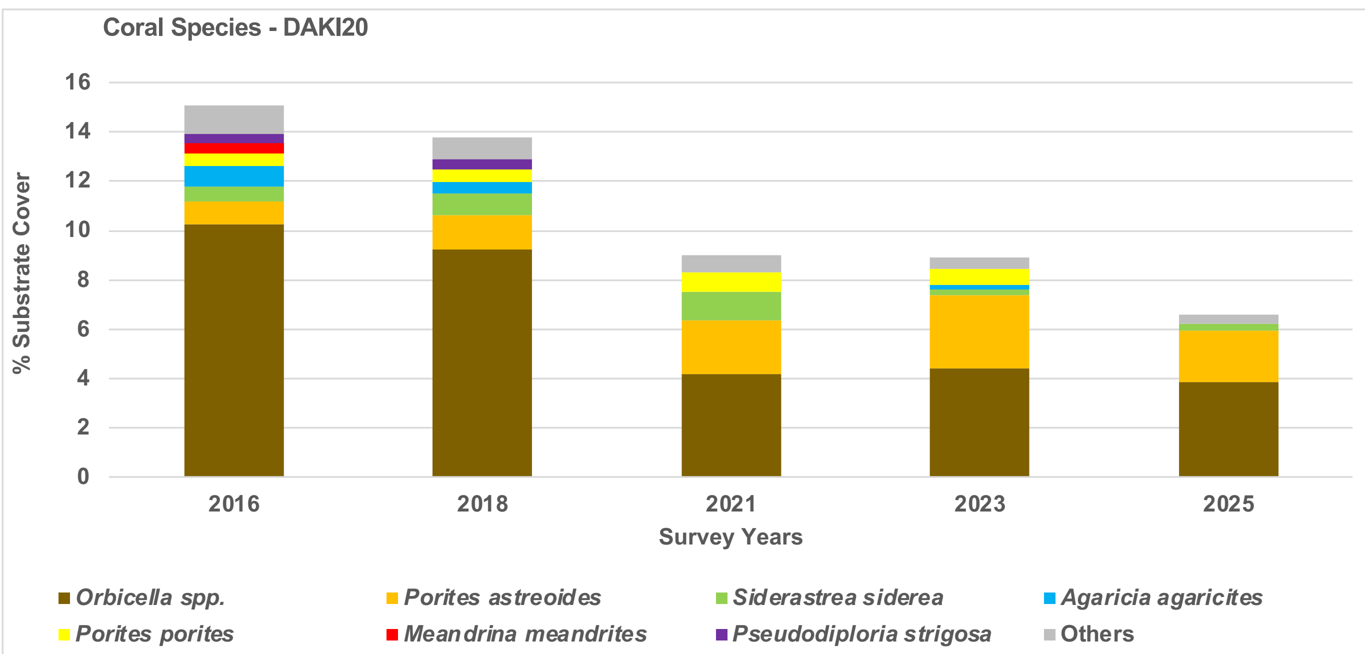


Figure 61. Monitoring trends (2016 - 25) of mean substrate cover by the main coral species intercepted by transects at DAKI20, Isla de Culebra. PRCRMP 2025

18.3 Fishes and Motile Megabenthic Invertebrates

A total of 34 fish species were identified within belt-transects at DAKI20 during the 2025 survey with a mean density of 555.4 Ind/30m^2 (range: 392 – 703 Ind/30m^2), and a mean species richness of 17.4 Spp/30m^2 (Table 54). The masked goby (*Coryphopterus personatus*) was the numerically dominant species with a mean density of 508.0 Ind/30m^2, representing 91.5% of the total fish density. Schooling aggregations of creole wrasse (*Clepticus parrae*) were observed in one transect, contributing with a mean density of 8.0 Ind/30m^2. An assemblage of eight species (in addition to *C. personatus*) were present in at least four transects with a combined density of 28.8 Ind/30m^2, or 5.2 % of the total fish density. The assemblage included the princess, stoplight, and redband parrotfishes (*Scarus taeniopterus, Sparisoma viride, S. aurofrenatum),* bluehead wrasse (*Thalassoma bifasciatum*), Caribbean puffer (*Canthigaster rostrata*), three-spot, beaugregory, cocoa and sergeant major damselfishes (*Stegastes planifrons, S. leucostictus, S. variabilis, Abudefduf saxatilis*) and the sharknose goby (*Elacatinus evelynae*). Motile megabenthic invertebrates were represented within belt-transects by one large spiny lobster (*Panulirus argus*) and one adult long-spined urchin (*Diadema antillarum*). Two additional spiny lobsters were observed outside transects.

The trophic structure of fishes at DAKI20 during the 2025 survey was strongly dominated by zooplanktivorous (ZPL) species due to the numerical dominance of the masked goby and, to a lesser extent of creole wrasse (*Clepticus parrae*), chub (*Kyphosus* sp.), and sergeant major (*Abudefduf saxatilis*) with a combined density of 520.2 Ind/30m^2, representative of 93.7% of the total fish density within belt-transects. Herbivores (HER) were represented by eight species, including parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with a combined density of 19.2 Ind/30m^2, or 3.5% of the total fish density. Small opportunistic carnivores (SOC) were represented by an assemblage of 17 species with a combined density of 14.8 Ind/30m^2, representative of 2.7% of the total fishes within belt-transects. The (SOC) assemblage included wrasses (Labridae), gobies (Gobiidae), puffers (Tetraodontidae), squirrelfishes (Holocentridae), hamlets (Serranidae), basslets (Grammatidae), trumpetfishes (Aulostomidae), and trunkfishes (Ostraciidae). Corallivores (COR) and spongivores (SPO) were represented within bel-transects by the four-eye butterflyfish (*Chaetodon capistratus*), and the white-spotted filefish (*Cantherhines pul*lus) with a combined mean density of 0.6 Ind/30m^2 (Table 54).

Table 54. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at DAKI20, Isla de Culebra. PRCRMP 2025

DAKI20							
Survey Date: 7/12/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	550	430	670	580	310	**508.0**	ZPL
Scarus taeniopterus	13	6	6	10	5	**8.0**	HER
Clepticus parrae					40	**8.0**	ZPL
Thalassoma bifasciatum	11	1	2		12	**5.2**	SOC
Stegastes planifrons	4	3	5	2	6	**4.0**	HER
Kyphosus sp.	4	6	3			**2.6**	ZPL
Stegastes leucostictus	3	2	1	4	2	**2.4**	HER
Elacatinus evelynae		4	3	2	3	**2.4**	SOC
Abudefduf saxatilis	1	3		2	2	**1.6**	ZPL
Sparisoma aurofrenatum	1	2		2	2	**1.4**	HER
Canthigaster rostrata	2	1	1	2	1	**1.4**	SOC
Sparisoma viride		1	1	3	2	**1.4**	HER
Holocentrus rufus	1	2	2			**1.0**	SOC
Stegastes variabilis	1		1	1	1	**0.8**	HER
Hypoplectrus nigricans		1	2		1	**0.8**	SOC
Acanthurus tractus	1	1			1	**0.6**	HER
Sparisoma atomarium			3			**0.6**	HER
Coryphopterus glaucofraenum			3			**0.6**	SOC
Halichoeres garnoti					3	**0.6**	SOC
Hypoplectrus puella	1	1				**0.4**	SOC
Gramma loreto	1			1		**0.4**	SOC
Hypoplectrus chlorurus	1			1		**0.4**	SOC
Chaetodon capistratus		1		1		**0.4**	COR
Hypoplectrus puella		1			1	**0.4**	SOC
Cephalopholis cruentata	1					**0.2**	LC
Epinephelus guttatus		1				**0.2**	LC
Neoniphon marianus		1				**0.2**	SOC
Hypoplectrus indigo		1				**0.2**	SOC
Hypoplectrus spp.		1				**0.2**	SOC
Aulostomus maculatus				1		**0.2**	SOC
Lactophrys triqueter				1		**0.2**	SOC
Ocyurus chrysurus				1		**0.2**	LC
Hypoplectrus unicolor				1		**0.2**	SOC
Cantherhines pullus				1		**0.2**	SPO
Invertebrates							
Panulirus argus	1					**0.2**	
Diadema antillarum					1	**0.2**	
Density (Ind/30m2)	**596**	**470**	**703**	**616**	**392**	**555.4**	
Richness (Species/30m2)	**17**	**21**	**14**	**18**	**17**	**17.4**	

Medium and large fish carnivores included the red hind, Nassau and graysby groupers (*Epinephelus guttatus, E. striatus, Cephalopholis cruentata), yellowtail snapper (Ocyurus chrysurus),* and bar jack (*Caranx ruber)* with a combined density of 0.8 Ind/60m^2 (Table 55). The lionfish *(Pterois volitans),* hogfish (*Lachnolaimus maximus*), and the schoolmaster and mutton snappers (*Lutjanus apodus, L. analis*) were previously reported from DAKI20 (Garcia-Sais et al., 2023 and references therein). Parrotfishes, represented by at least five species (*Sparisoma viride, S. rubripinne, S. aurofrenatum, Scarus taeniopterus, Scarus spp.*) were the main larger herbivore assemblage with a combined density of 14.4 Ind/60m^2. Doctorfishes were represented by two species (*Acanthurus coeruleus, A, tractus*) with a combined density of 1.0 Ind/60m^2 (Table 55).

Juvenile (including recruitment 1-5cm) and adult stages of princess, redband, and stoplight parrotfishes (*Scarus taeniopterus, Sparisoma aurofrenatum, S. viride*), and doctorfishes (*Acanthurus* spp.) were observed during the 2025 monitoring survey. These data is consistent with previous observations and is indicative that DAKI20 functions as a recruitment, grazing, and residential habitat for these parrotfish and doctorfish species throughout their life cycle. Red hinds and Nassau (*Epinephelus guttatus, E. striatus*), hogfish (*Lachnolaimus maximus*), and the schoolmaster and mutton snappers (*Lutjanus apodus, L. analis*) were observed as adults in previous surveys and appear to be some of the main demersal predators of the reef system (Table 55). Great barracudas (*Sphyraena barracuda*) have been previously reported (Garcia-Sais et al., 2022a) and represent top pelagic predators from DAKI20.

Variations of fish density and species richness between monitoring surveys at DAKI20 are presented in Figure 62. Statistically significant differences of fish density were found (ANOVA, $p < 0.001$; Appendix 5) associated with higher densities during 2018 and 2025, relative to the densities in all other surveys, including the previous 2023 survey. Differences were largely associated with density fluctuations of masked goby (*Coryphopterus personatus*) which peaked during 2025. Such density fluctuations of masked goby may be related to both density dependent and density independent factors, such as food availability, predation, and/or recruitment dynamic aspects. In 2025 fish density was also influenced by the 20.8% increase of fish species richness relative to the previous 2023 survey, indicative of no major degradation of the fish community structure at DAKI20 despite the massive decline of live coral cover since 2018. Differences of fish species richness between monitoring surveys were statistically insignificant (ANOVA, $p = 0.696$; Appendix 6).

Table 55. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at DAKI20, Isla de Culebra. PRCRMP 2025

DAKI20							
Survey Date: 7/12/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c2	10				1		Juvenile
Acanthurus tractus c2	10, 8	1				1	Juvenile
Acanthurus tractus c3	15, 12	1	1				Juvenile
Cephalopholis cruentata c3	12	1					Juvenile
Epinephelus guttatus c7	33		1				Adult
Epinephelus striatus c8	40					1	Juvenile
Ocyurus chrysurus c3	15				1		Adult
Scarus spp. c1	4-3		4				Recruit
Scarus taeniopterus c1	8-4, 5-5, 4-3	8		4	5		Recruit
Scarus taeniopterus c2	9-6, 3-7, 7-8, 2-9, 7-10	4	6	4	7	7	Juvenile
Scarus taeniopterus c3	5-12, 13, 3-15	2	2	2	1	2	Juvenile
Scarus taeniopterus c5	24					1	Terminal
Sparisoma aurofrenatum c2	6		1				Juvenile
Sparisoma aurofrenatum c3	14, 13		1			1	Juvenile
Sparisoma aurofrenatum c4	17, 2-20	1		1	1		Adult
Sparisoma aurofrenatum c5	24, 2-25				1	21	Terminal
Sparisoma rubripinne c6	30					1	Adult
Sparisoma viride c1	3				1		Recruit
Sparisoma viride c2	2-6, 7		1	1	1		Juvenile
Sparisoma viride c5	25			1			Adult
Sparisoma viride c7	33, 35		1	1			Terminal
	Totals	**18**	**18**	**14**	**19**	**35**	

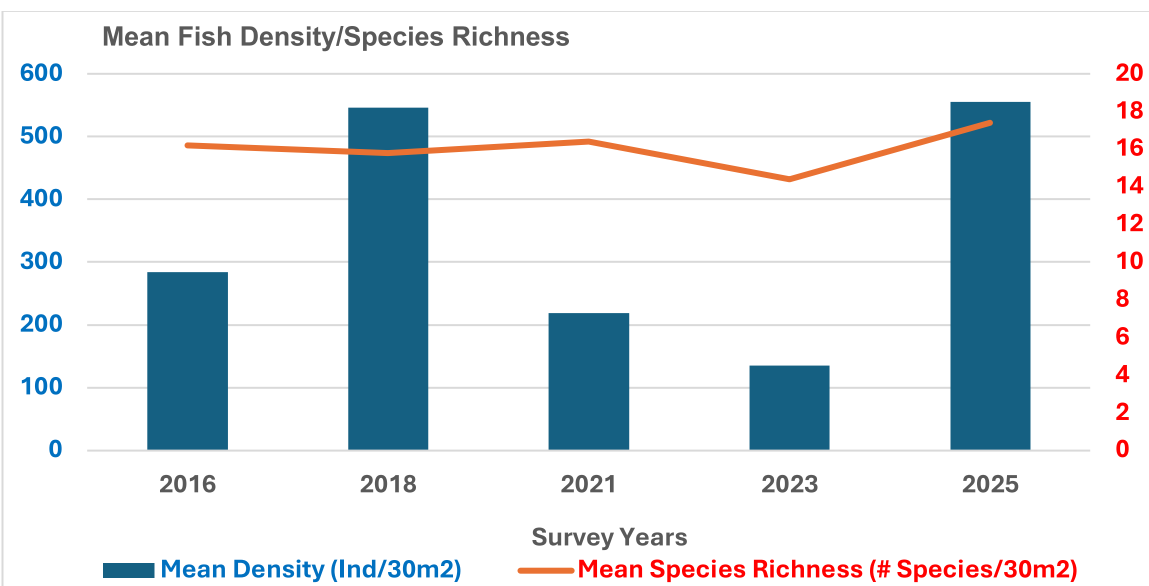
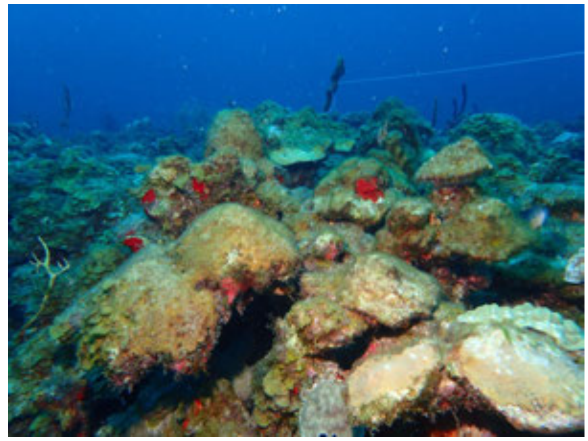


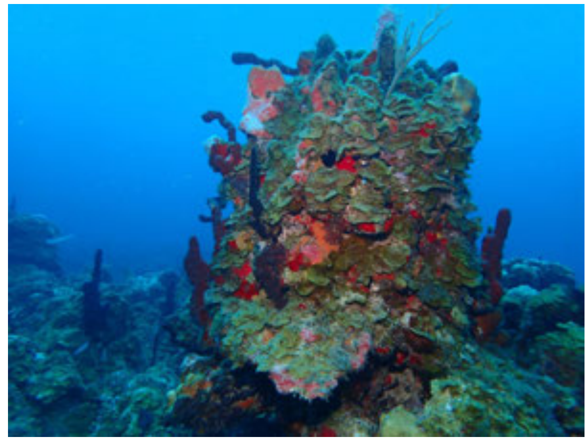
Figure 62. Monitoring trends (2016 – 25) of mean fish density and species richness within 10 x 3m belt-transects at DAKI20, Isla de Culebra. PRCRMP 2025

Photo Album 18. DAKI20







19.0 Boya Esperanza Reef – Isla de Vieques (ESPE10)

19.1 Physical Description

Boya Esperanza Reef (ESPE10) is a submerged patch reef sitting at the edge of a hard-ground platform located about 0.8 nautical miles off Puerto Esperanza, on the south coast of Vieques (Figure 63). A green navigation buoy used to mark the eastern boundary of the reef and the entrance channel to Puerto Esperanza, but after Hurricane Maria in September 2017, the buoy disappeared. The reef has a highly irregular bathymetry, with large coral outcrops rising more than three meters from the base of the reef platform and reaching to about 3 - 4m from the surface. Extensive coralline sand pools are found at the base of the reef on its northern boundary. Large crevices are found at the interface of the sandy bottom and the rock/coral outcrops. Transects were established on top of large coral outcrops of mountainous star coral (*Orbicella faveolata*) at a mean depth of 7.9m. The baseline survey of ESPE10 was performed in February 2001. Panoramic images of the reef community at ESPE10 during the 2025 survey are included as Photo Album 19.

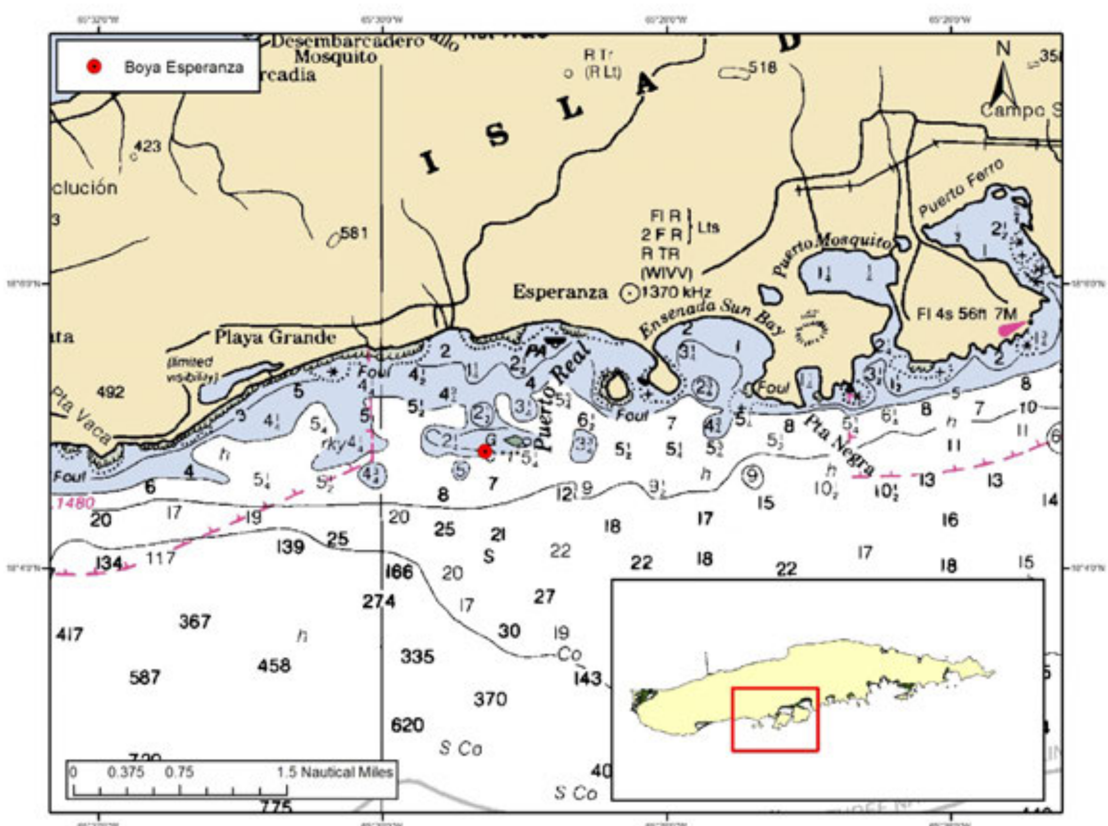


Figure 63. Location of the coral reef monitoring station at ESPE10, Isla de Vieques. PRCRMP 2025

19.2 Sessile-Benthic Reef Community

Reef substrate cover at ESPE10 was dominated by an assemblage of benthic algae that included fleshy brown, green calcareous red crustose calcareous and turf algae, with a combined mean cover of 83.81% (range: 72.42 – 87.77%). Fleshy brown algae, mostly y-twig alga (*Dictyota sp.*), with minor contributions from the encrusting fan-leaf alga (*Lobophora* sp.) were the dominant taxon with a combined mean cover of 35.84%, representing 42.8% of the total cover by benthic algae (Table 56). Crustose calcareous algae (*Ramicrusta sp.,* Peyssonnelia), and green calcareous alga (*Halimeda* sp.) were both intercepted by all five transects with substrate cover means of 27.94% and 3.35%, respectively. Turf algae, the dominant algal component in surveys before 2018 was present in all transects with a mean cover of 16.67%, or 19.9% of the total cover by benthic algae. Small cyanobacterial patches were present with a mean cover of 0.65%.

Stony corals were represented by six scleractinian species and one hydrocoral (*Millepora alcicornis*) during the 2025 survey at ESPE10 with a combined mean cover of 2.58% (range 1.36 – 4.16%). Mountainous star coral (*Orbicella faveolata*) was the dominant species with a mean reef substrate cover of 1.00%, representative of 38.8% of the total cover by stony corals (Table 56). Mustard-hill and finger corals (*Porites astreoides, P. porites*), and greater starlet coral (*Siderastrea siderea*) were intercepted by four and three transects, respectively with substrate cover means of 0.50%, 0.35%, and 0.48%. Standing dead colonies of staghorn and elkhorn corals (*Acropora palmata*, *A. cervicornis*) were observed outside transects. A total of 19 stony coral colonies were intercepted by transects at ESPE10 during the 2025 survey, including one (1-*Siderastrea siderea*,) apparently affected by infectious coral disease(s), resulting in a coral disease prevalence of 5.26% (Appendix 2).

Erect soft corals were moderately abundant at ESPE10 with a mean density of 9.6 Colonies/Transect (Table 56). Taxonomic identifications of erect soft corals were not performed in the 2025 survey, but sea rods (*Eunicea spp*, *Plexaura spp, Pseudoplexaura spp*.), and sea fans (*Gorgonia ventalina*) were prominent in transects. The encrusting gorgonians (*Erythropodium caribaeorum*, *Briareum asbestinum*) were intercepted by one transect each with a combined mean cover of 0.23%. Erect and encrusting sponges were represented in transects by 20 species with a combined mean cover of 1.62%. *Mycaele levis* and *Agelas citrina*, were the most prominent along transects with a combined cover of 0.84%. The encrusting colonial zoanthid (*Palythoa caribaeorum*) was present in two transects with a mean cover of 0.20%.

Table 56. Percent reef substrate cover by sessile-benthic categories at ESPE10, Isla de Vieques. PRCRMP 2025

ESPE10			**Transects**			
Survey Date: 7/13/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**7.9**	**6.7**	**8.5**	**7.9**	**8.5**	**7.90**
Rugosity (m)	2.49	2.38	2.94	2.12	1.93	**2.37**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	4.82	7.35	7.79	6.35	12.21	**7.70**
Sand	1.57		2.06		5.28	**1.78**
Total Abiotic	**6.39**	**7.35**	**9.85**	**6.35**	**17.49**	**9.49**
Benthic Algae						
Dictyota spp.	43.72	36.09	27.81	41.92	28.52	**35.61**
Halimeda spp.	7.06	1.58	0.97	1.96	5.16	**3.35**
Lobophora spp.					1.17	**0.23**
Peyssonnelia spp.	0.22	1.13	2.92	0.35		**0.92**
Ramicrusta spp.	11.10	28.51	42.86	25.52	27.11	**27.02**
Turf (mixed)	5.94	11.20	1.84	6.93	4.23	**6.03**
Turf (mixed) with sediment	18.72	8.71	11.36	8.20	6.22	**10.64**
Total Benthic Algae	**86.77**	**87.22**	**87.77**	**84.87**	**72.42**	**83.81**
Cyanobacteria	**2.58**	**0.68**	**0.00**	**0.00**	**0.00**	**0.65**
Stony Corals						
Orbicella faveolata	0.90			1.39	2.70	**1.00**
Porites astreoides	1.12		0.43	0.58	0.35	**0.50**
Siderastrea siderea		0.45		1.73	0.23	**0.48**
Porites porites		0.34	1.41			**0.35**
Orbicella annularis		0.57				**0.11**
Millepora alcicornis				0.46		**0.09**
Stephanocoenia intersepta	0.22					**0.04**
Total Stony Corals	**2.24**	**1.36**	**1.84**	**4.16**	**3.29**	**2.58**
# Coral Colonies/Transect	**4**	**4**	**3**	**4**	**4**	**3.80**
# Diseased Coral Colonies/Transect				**1**		**0.20**
# Erect Soft Coral Colonies/Transect	**12**	**8**	**9**	**11**	**8**	**9.60**
Soft Corals						
Erythropodium caribaeorum					0.70	**0.14**
Eunicea flexuosa	0.34			0.23		**0.11**
Briareum asbestinum				0.46		**0.09**
Pseudoplexaura flagellosa		0.23				**0.05**
Total Soft Corals	**0.34**	**0.23**	**0.00**	**0.69**	**0.70**	**0.39**
Zoanthids						
Palythoa caribaeorum	0.00	0.45	0.00	0	0.82	**0.35**
Sponges						
Mycale laevis	1.68	0.23		0.58	0.23	**0.54**
Agelas citrina		0.79		0.69		**0.30**
Niphates erecta		0.34			0.47	**0.16**
Cinachyrella kuekenthali				0.81		**0.16**
Verongula spp.			0.32		0.23	**0.11**
Neopetrosia spp. smooth					0.47	**0.09**
Sponge spp.				0.46		**0.09**
Aplysina cauliformis		0.23	0.22			**0.09**
Amphimedon compressa		0.34				**0.07**
Total Sponges	**1.68**	**1.92**	**0.54**	**2.54**	**1.41**	**1.62**
Diseased Corals						
Siderastrea sidera				1		**0.20**

The most relevant change of benthic community structure was a drastic, statistically significant decline of substrate cover by live stony corals (ANOVA, $p < 0.001$; Appendix 3). Mean substrate cover declined 69.1%, from 33.1% in 2004 to 10.4% in 2013 (Figure 64). Both the magnitude of the total cover loss and the coral species affected (*Orbicella spp* complex) pointed out to the 2005 regional coral bleaching event as the probable cause of the stony coral degradation (Garcia-Sais et al., 2018 and references therein). Coral cover stabilized during the period between 2013 and 2018 but suffered another drastic substrate cover loss of 72.3% measured during the 2021 survey. Mean substrate cover by stony corals declined again 27.7% during the most recent 2025 survey relative to the previous 2023 survey, but this difference was within sampling variability error (ANOVA; $p= 0.442$; Appendix 3). At present (2025 survey), the overall change of cover by stony corals at ESPE10 is a reduction of 92.84% relative to the 2001 baseline survey.

The major declines of stony coral losses measured during the 2013 and 2021 surveys were strongly related to losses of cover by the dominant coral species *Orbicella faveolata*. *Orbicella spp.* declined 83.1% in 2013, and 89.9% in 2021 (Figure 65). In addition to *Orbicella* spp., massive starlet coral (*Siderastrea siderea)*, symmetrical brain coral (*Pseudodiploria strigosa)*, and grooved brain coral (*Diploria labyrinthiformis*) also evidenced drastic reductions of reef substrate cover (>75%) in 2025 relative to their mean cover in 2018.

Densities of erect soft corals also show a declining trend since the 2016 survey when a decline of 9.6% was measured (Figure 64). The largest decline (-23.9%) was measured in 2018 associated with the mechanical damage and stress imposed by the pass of hurricanes Irma and Maria in September 2017. Further density reductions were documented in the three most recent 2021, 2023, and 2025 surveys, resulting in an overall decline of 54.7% relative to the 2001 baseline survey. Density differences between surveys are statistically significant (ANOVA, $p < 0.001$; Appendix 4).

Statistically significant variations of reef substrate cover by benthic categories have been also related to the benthic algal community (Garcia-Sais et al., 2016). Turf algae was the dominant component of reef substrate cover at ESPE10 in the 2001 baseline and the 2004 monitoring surveys. In the 2013 monitoring survey the red crustose coralline alga (*Ramicrusta sp*.) displaced turf algae as the dominant category of reef substrate cover at ESPE10 (Garcia-Sais et al., 2014) and prevailed as the main taxonomic algal component until the most recent 2023 survey. During the most recent 2025 survey Y-twig alga (Dictyota sp.) was the dominant benthic algae taxon.

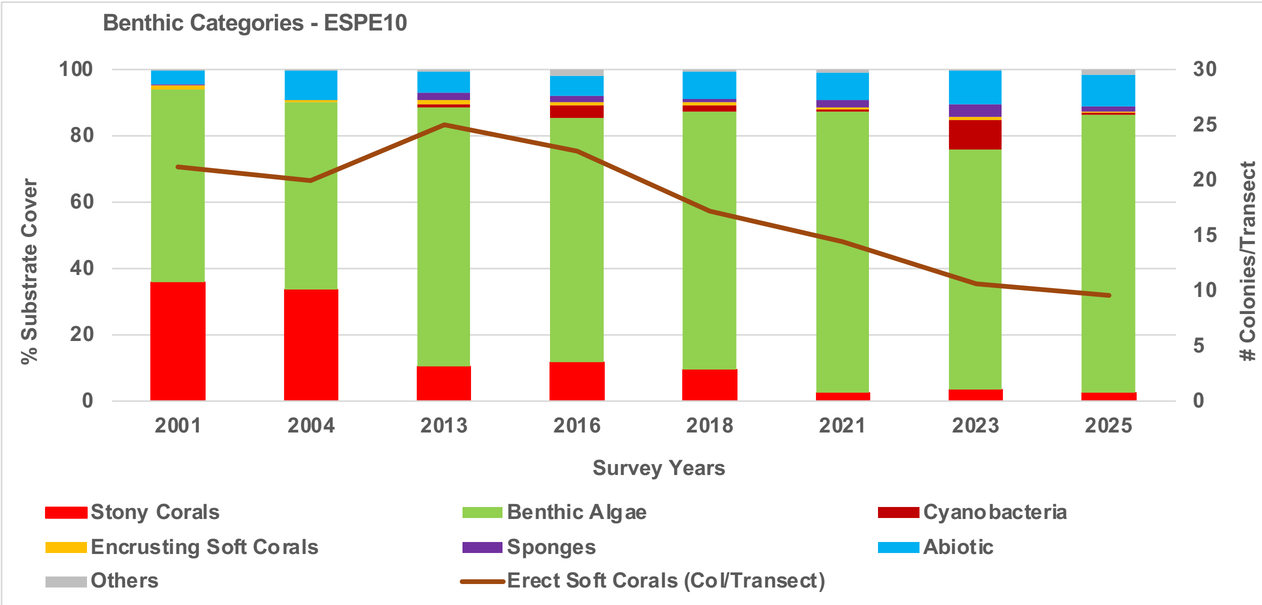


Figure 64 Monitoring trends (2001 - 25) of mean substrate cover by sessile-benthic categories at ESPE10, Isla de Vieques. PRCRMP 2025

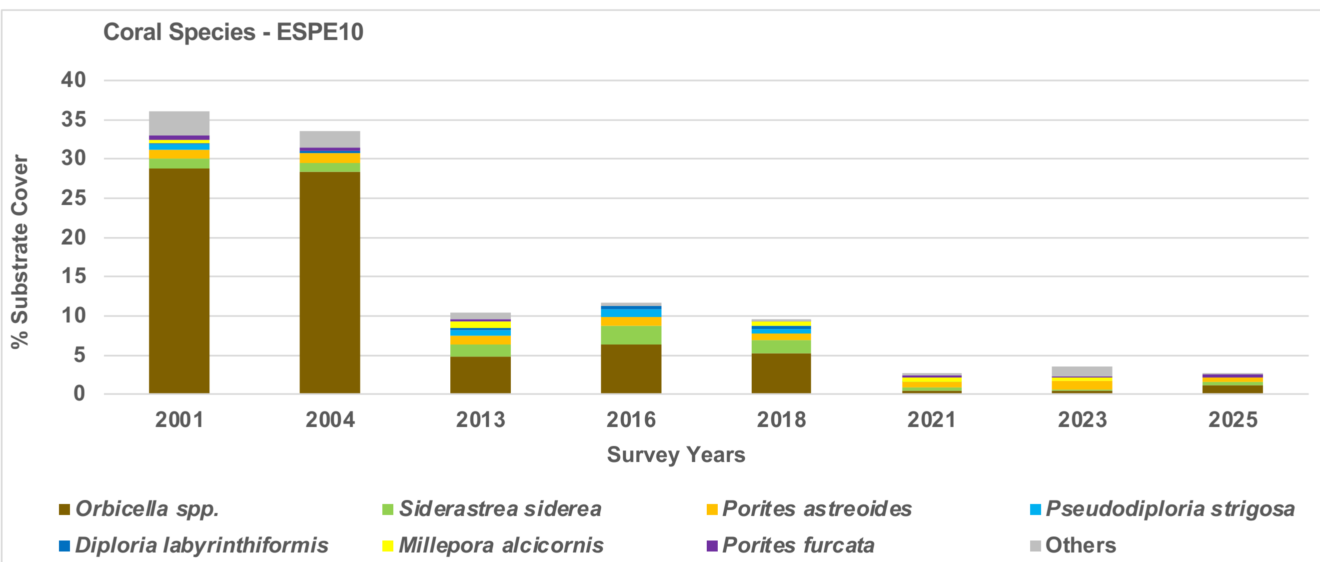


Figure 65. Monitoring trends (2001 -25) of mean substrate cover by the main coral species intercepted by transects at ESPE10, Isla de Vieques. PRCRMP 2025

20.3 Fishes and Motile Megabenthic invertebrates

A total of 42 fish species were observed within belt-transect at ESPE10 during the 2025 survey with a mean density of 60.4 Ind/30m^2 and a mean richness of 18.6 Spp/30m^2 (Table 57). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 28.6 Ind/30m^2, representative of 47.4% of the total fish density. Another nine species were observed in at least four belt-transects with a combined density of 17.6 Ind/30m^2, or 29.1% of the total individuals. These included the bicolor damselfish (*Stegastes partitus),* french grunt (*Haemulon flavolineatum*), stoplight and redband parrotfishes (*Sparisoma viride, S. aurofrenatum*), yellowhead wrasse (*Halichoeres garnoti*), doctorfish and blue tang (*Acanthurus chirurgus, A. coeruleus*), squirrelfish (*Holocentrus rufus*), and bar jack (*Caranx ruber*). Motile megabenthic invertebrates not observed within belt-transects during the 2025 survey at ESPE10.

The fish trophic structure of ESPE10 was numerically dominated during the 2025 survey by small opportunistic carnivores (SOC) represented by 21 species with a combined density of 39.4 Ind/30m^2, representative of 65.2% of the total individuals within belt-transects. The assemblage included wrasses (Labridae), grunts (Haemulidae), squirrelfishes (Holocentridae), goatfishes (Mullidae), hamlets and small seabasses (Serranidae), basslets (Grammatidae), hawkfishes (Cirrhitidae), puffers (Tetraodontidae), trumpetfishes (Aulostomidae), and glasseyes (Priacanthidae). The herbivore (HER) assemblage was represented by 10 species including parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae) with a combined density of 10.0 Ind/30m^2, representative of 16.6% of the total fish density. Zooplanktivores (ZPL) were represented by three damselfish species (Pomacentridae) with a cumulative density of 6.4 Ind/30m^2, representative of 10.6% of the total fish density. Corallivores (COR) were represented by two butterflyfish species (Chaetodontidae) with a combined density of 3.0 Ind/30m^2 (Table 57).

Mid-size and large demersal and pelagic carnivores included the red hind, Nassau and graysby groupers (*Epinephelus guttatus, E. striatus*, *Cephalopholis cruentata*), yellowtail, schoolmaster and mutton snappers (*Ocyurus chrysurus, Lutjanus apodus, L. analis*), nurse shark (*Ginglymostoma cirratum*) and bar jack (*Caranx ruber*) with a combined density of 3.6 Ind/60m^2 (Table 58). The larger fish herbivores were comprised by parrotfishes (*Scarus taeniopterus, Sparisoma viride, S. aurofrenatum*), and doctorfishes (*Acanthurus chirurgus, A, tractus, A. coeruleus)* with mean densities of 5.6 Ind/60m^2 and 6.4 Ind/60m^2, respectively.

Table 57. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at ESPE10, Isla de Vieques. PRCRMP 2025

ESPE10							
Survey Date: 7/13/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	8	45	46	19	25	**28.6**	SOC
Stegastes partitus	1	2	3	7	7	**4.0**	ZPL
Haemulon flavolineatum	2	5	2	3	1	**2.6**	SOC
Sparisoma viride		2	3	3	4	**2.4**	HER
Halichoeres garnoti	1		4	1	4	**2.0**	SOC
Chromis multilineata		5	3			**1.6**	ZPL
Acanthurus chirurgus	2	2	1	2		**1.4**	HER
Holocentrus rufus	1		2	2	2	**1.4**	SOC
Sparisoma aurofrenatum	1		3	2	1	**1.4**	HER
Stegastes adustus	3				3	**1.2**	HER
Caranx ruber	1	2	2	1		**1.2**	LC
Acanthurus coeruleus	1		2	2	1	**1.2**	HER
Acanthurus tractus	1		2		1	**0.8**	HER
Abudefduf saxatilis		2	2			**0.8**	ZPL
Cephalopholis cruentata	1		1		1	**0.6**	LC
Stegastes leucostictus	2				1	**0.6**	HER
Pseudupeneus maculatus	1		1		1	**0.6**	SOC
Myripristis jacobus		1	1	1		**0.6**	SOC
Halichoeres maculipinna		1		2		**0.6**	SOC
Microspathodon chrysurus			1	1	1	**0.6**	HER
Serranus tigrinus			2		1	**0.6**	SOC
Bodianus rufus		1	1			**0.4**	SOC
Mulloidichthys martinicus		2				**0.4**	SOC
Gramma loreto		2				**0.4**	SOC
Chaetodon ocellatus		2				**0.4**	COR
Lutjanus apodus		2				**0.4**	LC
Amblycirrhitus pinos			2			**0.4**	SOC
Ocyurus chrysurus				1	1	**0.4**	LC
Canthigaster rostrata	1					**0.2**	SOC
Chaetodon striatus	1					**0.2**	COR
Aulostomus maculatus	1					**0.2**	SOC
Ginglymostoma cirratum	1					**0.2**	LC
Anisotremus surinamensis		1				**0.2**	SOC
Haemulon chrysargyreum		1				**0.2**	SOC
Haemulon carbonarium		1				**0.2**	SOC
Stegastes variabilis		1				**0.2**	HER
Priacanthus arenatus			1			**0.2**	SOC
Sparisoma rubripinne					1	**0.2**	HER
Haemulon sciurus					1	**0.2**	SOC
Haemulon macrostomum					1	**0.2**	SOC
Sargocentron coruscum					1	**0.2**	SOC
Epinephelus guttatus					1	**0.2**	LC
Density (Ind/30m2)	**30**	**80**	**85**	**47**	**60**	**60.4**	
Richness (Species/30m2)	**18**	**19**	**21**	**14**	**21**	**18.6**	

The size-frequency distributions of commercially important reef fishes and the larger reef fish herbivores are shown in Table 58. Recruitment, juvenile, and adult stages of doctorfishes (*Acanthurus* spp.), and parrotfishes (*Scarus* spp., *Sparisoma* spp.) were observed, indicative that ESPE10 functions as a recruitment and residential habitat for these taxa. Medium and large carnivores, such red hinds (*Epinephelus guttatus*), graysby *(Cephalopholis cruentata*) schoolmaster, mutton, and yellowtail snappers (*Lutjanus apodus, L. analis, Ocyurus chrysurus*) were observed as adults, indicative that ESPE10 may also function as a residential and/or foraging habitat for these species. One juvenile Nassau grouper (*E. striatus*) was observed in support of the high recruitment observed from many other reefs in the PRCRMP for this endangered and protected species since last year (Garcia-Sais et al., 2024).

Variations of mean fish density and species richness between monitoring surveys at ESPE10 are shown in Figure 66. Statistically significant differences of both fish density and species richness were found (ANOVA, $p < 0.05$; Appendices 5 and 6). Differences were associated with lower densities and richness during the 2018 survey relative to the peak values of 2004, 2016, 2021 and 2023. It is possible that many small fishes were unable to withstand the mechanical stress associated with the pass of Hurricanes Irma and Maria in September 2017, or other wave storm events and suffered significant population mortality. The sharp increase of fish densities during the 2021 and 2023 surveys suggest a replenishment of these populations. During the 2025 survey mean fish density declined 44.4% relative to the previous 2023 survey largely associated with a density reduction of bluehead wrasse (*Thalassoma bifasciatum*) the numerically dominant species. This species is distributed in schooling aggregations, and such density fluctuations are common and do not imply any significant change of fish community structure. Mean fish density during 2025 (60.4 Ind/30m^2) was within the range of previous surveys at ESPE10.

Fish species richness has shown wide fluctuations throughout the monitoring program at ESPE10. Aside from the sharp and statistically significant decline during the 2018 survey (ANOVA, $p = 0.009$; Appendix 6) all other assessments of fish species richness are within 95% confidence intervals. It is interesting that despite the drastic loss of live coral cover (> 90%) at ESPE10 the mean fish species richness during the 2025 survey remains almost identical to the species richness measure in the 2001 baseline survey, 24 years ago.

Table 58. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at ESPE10, Isla de Vieques. PRCRMP 2025

ESPE10							
Survey Date: 7/13/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	4				1		Recruit
Acanthurus chirurgus c2	10			1			Juvenile
Acanthurus chirurgus c3	11, 3-12, 13, 14, 15	2	2	1	2		Adult
Acanthurus coeruleus c2	7, 4-8, 9, 2-10	2	2	1	2	1	Juvenile
Acanthurus coeruleus c3	2-12, 13, 15		1	1	1	1	Adult
Acanthurus coeruleus c4	16					1	Adult
Acanthurus tractus c1	2-2			2			Recruit
Acanthurus tractus c2	8, 9, 2-10	1	1	2			Juvenile
Acanthurus tractus c3	2-12, 14, 15	1				3	Juvenile
Caranx ruber c3	5-15		2	2	1		Juvenile
Caranx ruber c5	25	1					Juvenile
Cephalopholis cruentata c5	24, 2-25	1		1		1	Adult
Epinephelus guttatus c7	34					1	Adult
Epinephelus striatus c7	35				1		Juvenile
Ginglymostoma cirratum c18	90	1					Juvenile
Lutjanus analis c10	50	1					Adult
Lutjanus apodus c6	28, 2-30	1	2				Adult
Ocyurus chrysurus c4	16, 18				1	1	Adult
Scarus taeniopterus c2	9				1		Juvenile
Scarus taeniopterus c4	20			1			Adult
Scarus taeniopterus c5	25				1		Terminal
Sparisoma aurofrenatum c1	4, 5			1	1		Recruit
Sparisoma aurofrenatum c2	6			1			Juvenile
Sparisoma aurofrenatum c3	15					1	Adult
Sparisoma aurofrenatum c4	17, 2-18, 20	1		1	2		Adult
Sparisoma rubripinne c6	26, 30					2	Adult
Sparisoma viride c1	4-2, 2-3		1	3		2	Recruit
Sparisoma viride c2	6, 7, 9, 10			1	2	1	Juvenile
Sparisoma viride c5	25		1				Adult
Sparisoma viride c6	26, 30				2		Adult
Sparisoma viride c7	33, 35		1			1	Terminal
	Totals	**12**	**13**	**19**	**18**	**16**	

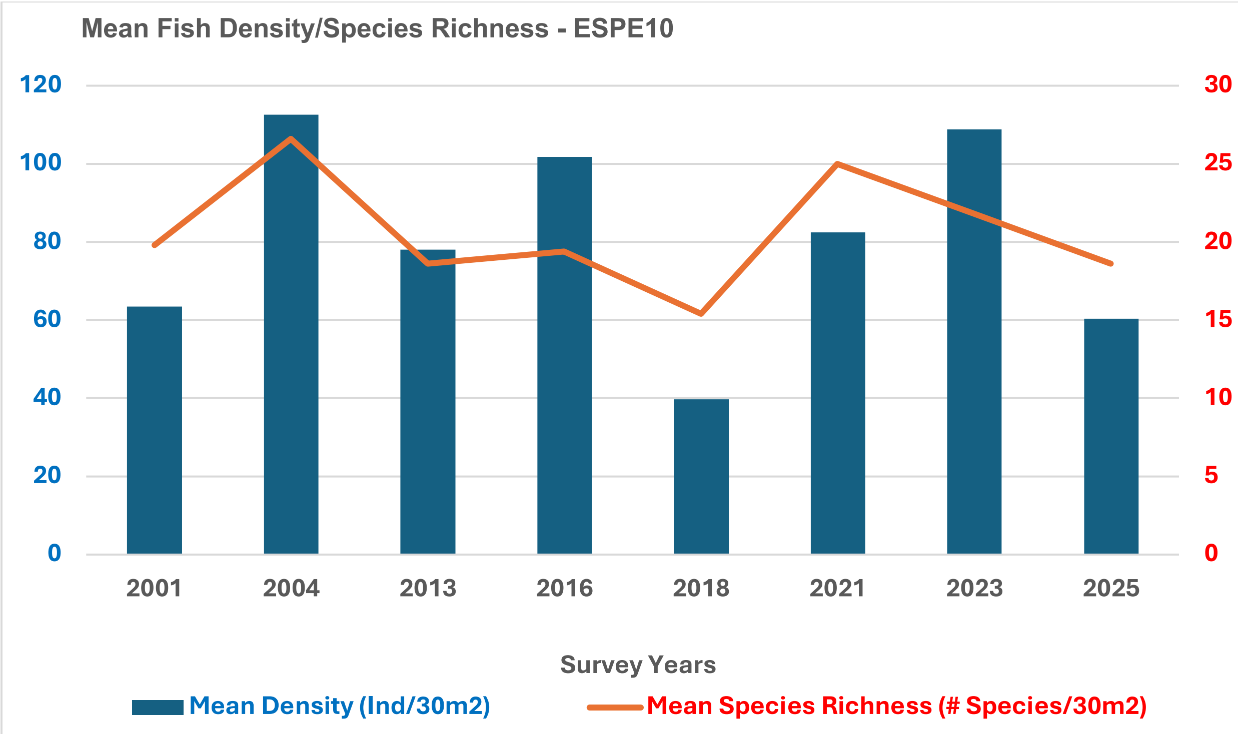
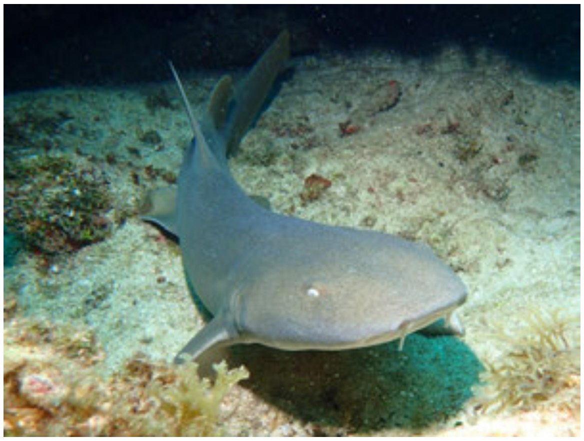
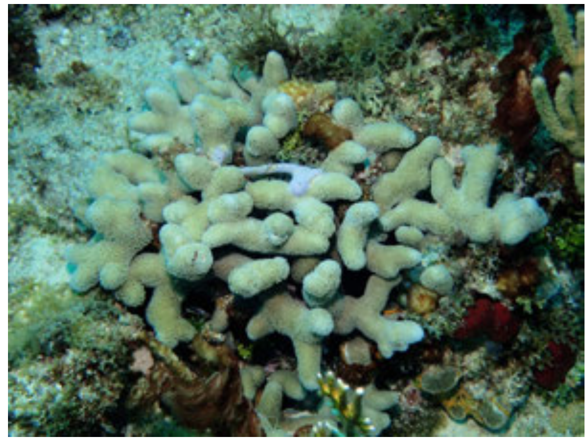
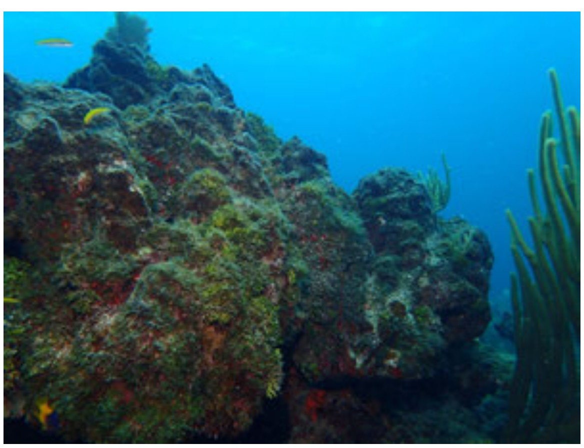
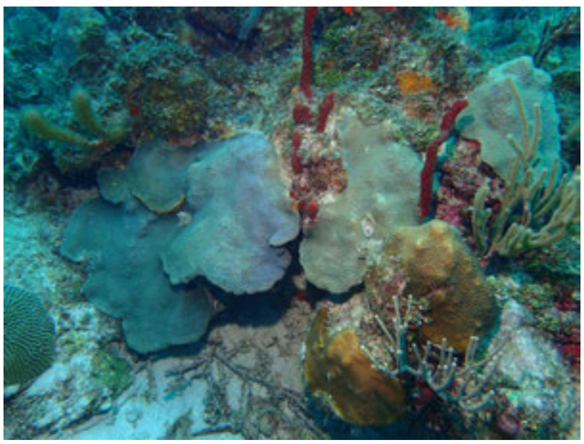


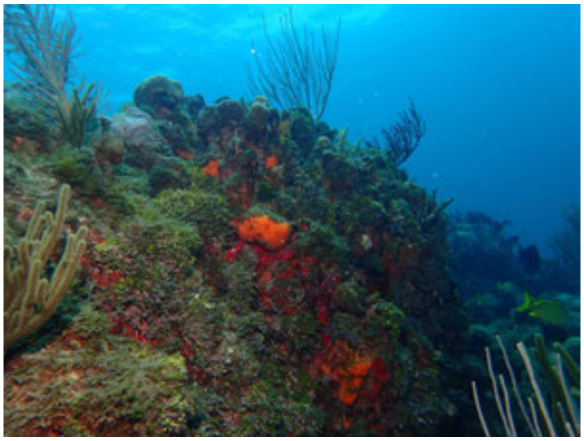
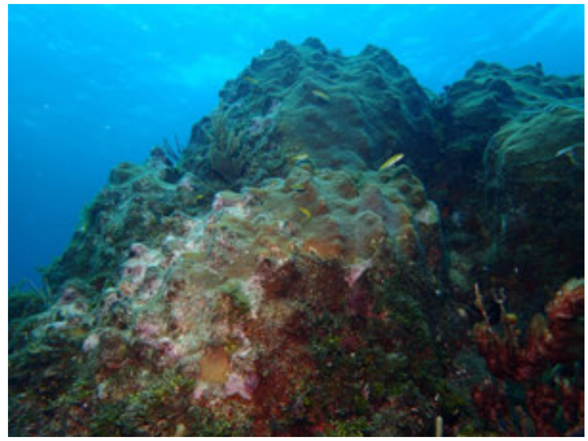
Figure 66. Monitoring trends (2001 – 25) of mean fish density and species richness within 10 x 3m belt-transects at ESPE10, Isla de Vieques. PRCRMP 2025

Photo Album 19. ESPE10



20.0 Canjilones Reef 20m, Isla de Vieques (CANJ20)

20.1 Physical Description

Canjilones Reef (CANJ20) is a diffuse "spur-and-groove" coral reef system located at the base of the southern edge of a rather long and narrow rocky ridge that runs along an east-west axis off Punta Arenas, on the southwest coast of Vieques (Figure 67). The ridge presents an almost flat, hard-ground terrace with sparse soft corals and coral heads at depths of 9 -11m and slopes down to a depth of 15 - 16m where the spur-and-groove coral reef formation has developed. The spurs rise about 2 - 3m from the narrow sandy channels that separate them at the base. The baseline survey at CANJ20 was performed in February 2001. Permanent transects were established along five consecutive spurs at a mean depth of 15.2m. During 2018, rebar markers at transect 5 were not found and new markers were set on a nearby location adjacent to transect #1. Images of CANJ20 reef community during the 2025 survey are included as Photo Album 20.

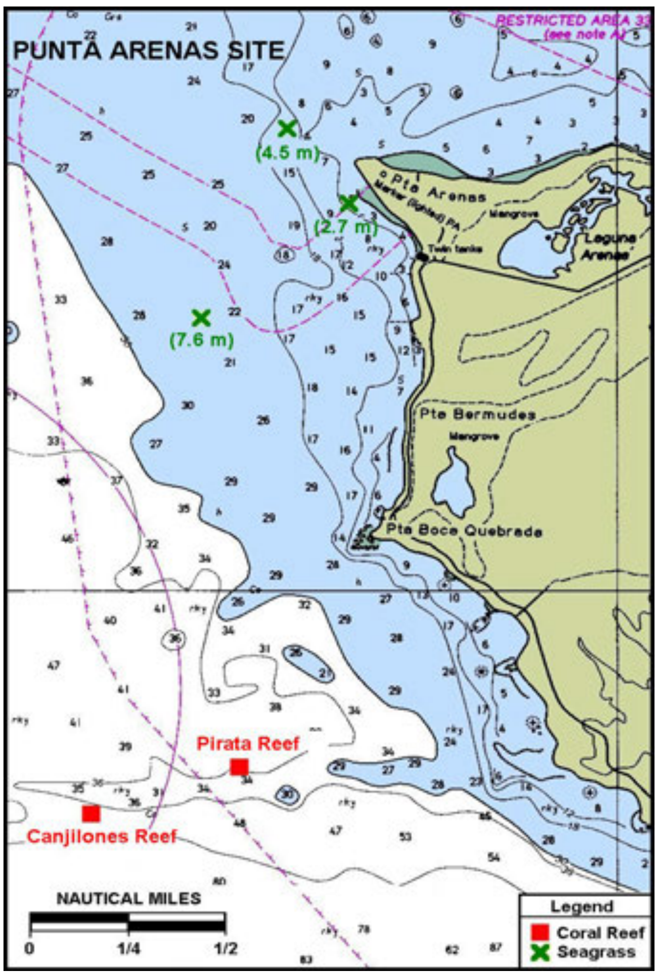


Figure 67. Location of CANJ20 along the western coast of Isla de Vieques. PRCRMP 2025

20.2 Sessile Benthic Reef Community

Reef substrate cover at CANJ20 was dominated by an assemblage of benthic algae that included fleshy brown, red crustose calcareous, turf algae, and red coralline algae with a combined mean cover of 76.21% (range: 74.16 – 81.16%). Fleshy brown algae, comprised by y-twig alga (*Dictyota sp.*), and the encrusting fan-leaf alga (*Lobophora* sp.) were the dominant taxon in terms of reef substrate cover with a combined mean of 52.32%, representative of 23.2% of the total.

The encrusting crustose calcareous red alga (*Ramicrusta sp.*) was the dominant alga in all transects with a mean cover of 26.16%, representative of 68.6% of the total cover by benthic algae (Table 59). Red crustose (*Ramicrusta* sp., *Peyssonnelia* sp.) and coralline algae (CCA mixed) were intercepted by all five transects with a combined mean cover of 17.08%, or 22.4% of the total benthic algae. Turf algae (mixed assemblage), was also present in all transects with a mean cover of 6.82%. Small cyanobacterial patches were intercepted by three transects with a mean substrate cover of 0.54% (Table 59).

The sessile-benthic community at CANJ20 was characterized by a high density and specious assemblage of erect soft corals with a mean density of 11.6 Colonies/transect. Sea Fans (*Gorgonia ventalina*), sea plumes (*Plexaura* spp.) and sea rods (*Eunicea spp*) were the most prominent in transects. The encrusting gorgonian (*Erythropodium caribaeorum*) was intercepted by one transect with a mean density of 0.27%. Sponges were represented by an assemblage of six species with a mean cover of 0.90%. *Aplysina fistularis* and *Neopetrosia sp.,* were the most prominent along transects with a combined mean cover of 0.49% (Table 59).

Stony corals were represented by eight scleractinian species in transects with a combined mean cover of 3.32% (range: 2.54% – 4.24%). Mountainous star coral (*Orbicella faveolata*) was the main coral species with a mean cover of 1.38%, representing 41.6% of the total reef substrate cover by stony corals (Table 59). The sibling species, *O. annularis* was intercepted by three transects with a mean cover of 0.84% for a total Orbicella spp. cover of 2.22%, representative of 66.9% of the total cover by stony corals. A total of 26 stony coral colonies were intercepted by transects at CANJ20 during the 2025 monitoring survey, none of which were observed to be affected by coral diseases (see Appendix 2). Total or partial bleaching was noted on three coral colonies intercepted by transects (2- *O. annularis*; 1- *O. faveolata*).

Table 59. Percent reef substrate cover by sessile-benthic categories at CANJ20, Isla de Vieques. PRCRMP 2025

CANJ20			**Transects**			
Survey Date: 7/13/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**15.2**	**15.2**	**14.8**	**15.2**	**15.2**	**15.12**
Rugosity (m)	4.20	5.44	3.44	3.61	6.55	**4.65**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	13.21	18.50	13.23	20.47	19.37	**16.96**
Sand			4.69			**0.94**
Rubble			3.02			**0.60**
Total Abiotic	**13.21**	**18.50**	**20.94**	**20.47**	**19.37**	**18.50**
Benthic Algae						
Lobophora spp.	36.29	42.79	43.75	29.32	17.43	**33.92**
Dictyota spp.	25.44	11.88	10.94	20.88	22.84	**18.40**
Ramicrusta spp.	9.17	10.34	8.85	15.84	26.23	**14.09**
Turf (mixed)	7.89	5.08	4.79	3.19	6.35	**5.46**
Peyssonnelia spp.	1.68	1.09	4.69	1.95	0.51	**1.98**
Turf (mixed) with sediment		1.63		3.91	1.27	**1.36**
CCA (total)	0.69	1.36	1.46	0.62	0.93	**1.01**
Total Benthic Algae	**81.16**	**74.16**	**74.48**	**75.72**	**75.55**	**76.21**
Cyanobacteria	**0.00**	**1.54**	**0.73**	**0.41**	**0.00**	**0.54**
Stony Corals						
Orbicella faveolata	2.27	1.09	2.08	0.72	0.76	**1.38**
Orbicella annularis		0.54		2.37	1.27	**0.84**
Montastraea cavernosa			0.31		1.61	**0.38**
Porites astreoides	1.48					**0.30**
Siderastrea siderea	0.49		0.31		0.17	**0.19**
Agaricia lamarcki		0.45				**0.09**
Madracis decactis		0.45				**0.09**
Porites porites			0.21			**0.04**
Total Stony Corals	**4.24**	**2.54**	**2.92**	**3.09**	**3.81**	**3.32**
# Coral Colonies/Transect	**6**	**6**	**5**	**4**	**5**	**5.2**
# Bleached Coral Colonies/Transect		**2**		**1**		**0.6**
Soft Corals						
Erythropodium caribaeorum	0.30	0.54	0.52			**0.27**
Eunicea spp.	0.59					**0.12**
Plexaura homomalla	0.20			0.31		**0.10**
Eunicea succinea			0.21			**0.04**
Total Soft Corals	**1.08**	**0.54**	**0.73**	**0.31**		**0.53**
# Erect Soft Coral Colonies/Transect	**7**	**10**	**14**	**12**	**15**	**11.6**
Sponges						
Aplysina fistularis		1.45				**0.29**
Neopetrosia spp. smooth		1.00				**0.20**
Ectyoplasia ferox			0.21		0.51	**0.14**
Amphimedon compressa	0.20	0.27			0.17	**0.13**
Mycale laevis	0.10				0.34	**0.09**
Chondrilla caribensis					0.25	**0.05**
Total Sponges	**0.30**	**2.72**	**0.21**		**1.27**	**0.90**
Bleached Corals						
Orbicella faveoalta				1		**0.20**
Orbicella annularis		2				**0.40**

The temporal variations of reef substrate cover by the main sessile-benthic categories between monitoring surveys at CANJ20 are presented in Figure 68. The most relevant change of benthic community structure at CANJ20 is related to the drastic decline of reef substrate cover by live stony corals. Differences of total live coral cover between surveys were statistically significant and related to higher cover during the 2001 and 2004 surveys, relative to all other subsequent monitoring surveys, and lower cover in 2025 relative to all other surveys (ANOVA, $p < 0.001$; Appendix 3). Reef substrate cover by live stony corals declined 33.9% between the 2004 and 2013 surveys. As for several other reefs stations included in the PRCRMP monitoring program, such decline was largely associated with the regional 2005 coral bleaching event (Garcia-Sais et al. 2015 and references therein). The main coral species associated with the marked decline of live coral cover at CANJ20 was the *Orbicella spp* complex (Figure 69), which declined 87.1%, from a maximum mean cover of 17.88% measured in 2004 to a minimum of 2.22% (combined cover by *Orbicella* spp.) measured during the most recent 2025 survey. Coral disease infections triggered by heat stress and coral bleaching appear to be the main drivers of coral degradation at CANJ20.

Soft corals have shown a declining trend of density since their peak mean of 23.6 Colonies/Transect in 2013 to a minimum density of 11.6 Colonies/Transect in 2025 (ANOVA, $p = 0.029$; Appendix 4). Such declining trend may have been initially related to the mechanical detachment of colonies forced by hurricanes Irma and Maria in 2017. The appearance of dead standing colonies during the most recent 2023 and 2025 surveys suggest that other environmental factors, perhaps related to heat stress is the driver of such continued loss of soft coral colonies at CANJ20.

Statistically significant temporal variations of the taxonomic composition and reef substrate cover by benthic algae were previously reported for CANJ20 (Garcia-Sais et al., 2016). The main factor contributing to the variability between surveys was the phase shift of turf algal dominance towards the red encrusting alga (*Ramicrusta sp.*) measured in 2016. Another shift of algal dominance was measured during the 2025 survey as brown fleshy algae growing over red crustose calcareous Ramicrusta sp. is now the dominant taxa. It is uncertain at this point if the cover by brown fleshy algae (largely *Dictyota* sp.) is a seasonal (summer) condition influenced by low wave action.

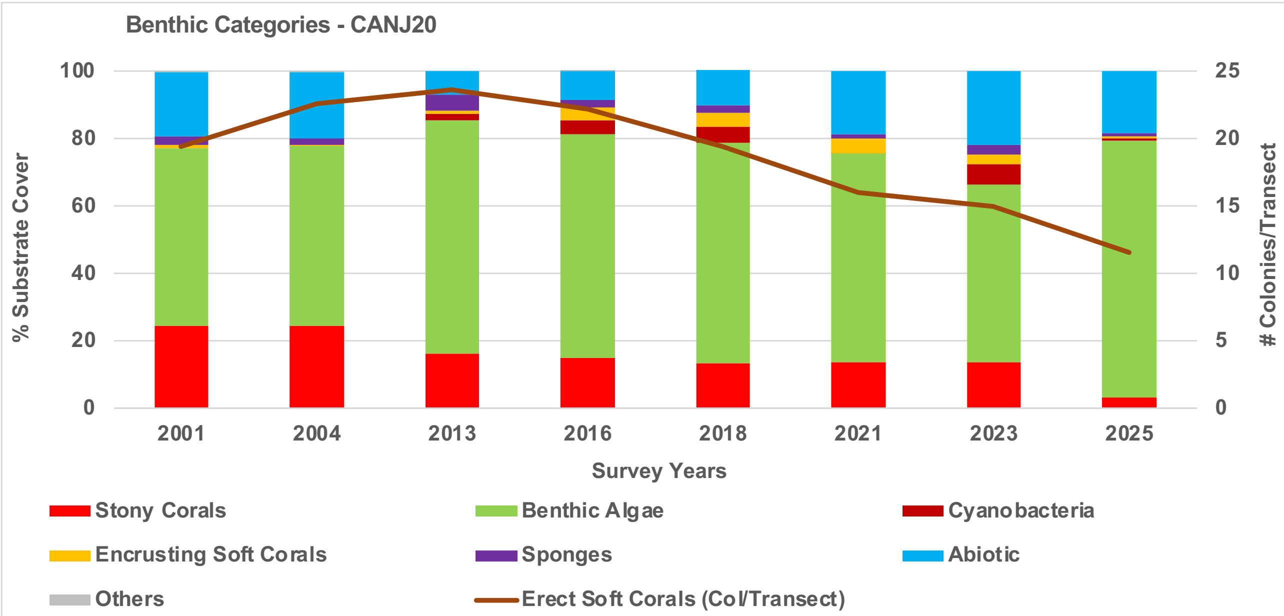


Figure 68. Monitoring trends (2001 - 25) of mean substrate cover by sessile-benthic categories at CANJ20, Isla de Vieques. PRCRMP 2025

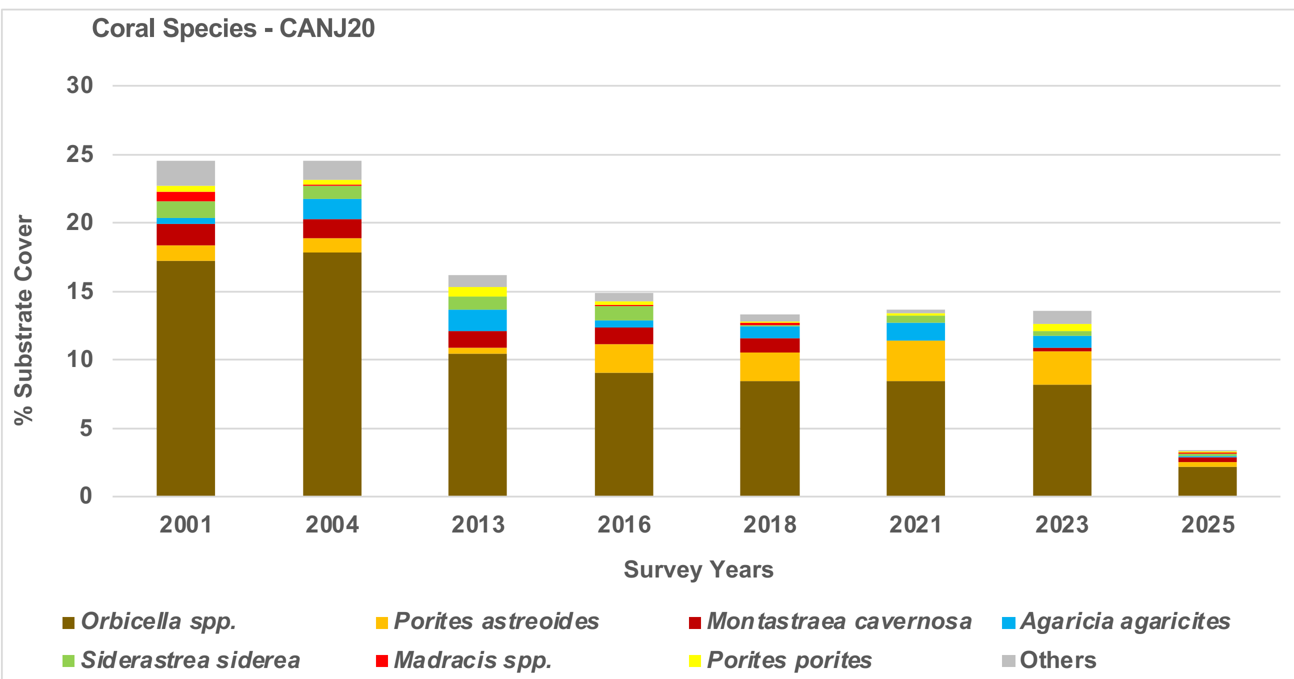


Figure 69. Monitoring trends (2001 - 25) of mean substrate cover by coral species at CANJ20, Isla de Vieques. PRCRMP 2025

20.3 Fishes and Motile Megabenthic Invertebrates

A total of 38 fish species were identified within belt-transects at CANJ20 during the 2025 monitoring survey with a mean density of 52.8 Ind/30m^2, and a mean species richness of 17.4 Spp/30m^2 (Table 60). The masked goby (*Coryphopterus personatus*), blue chromis (*Chromis cyanea*), and bluehead wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with a combined mean density of 24.6 Ind/30m^2, representative of 46.6% of the total fish density within belt-transects. An assemblage of six species were observed in at least four transects with a combined density of 14.8 Ind/30m^{2,} or 28.0% of the total fish density. The assemblage included the bicolor and beaugregory damselfishes (*Stegastes partitus, S. leucostictus*), princess and redband parrotfishes (Scarus taeniopterus, *Sparisoma aurofrenatum*), yellowhead wrasse (*Halichoeres garnoti*), and ocean surgeon (*Acanthurus tractus*). Motile megabenthic invertebrates were represented within belt-transects by an arrow crab (*Stenorhinchus seticornis*) (Table 60).

The fish trophic structure at CANJ20 during the 2023 survey was dominated by zooplanktivores (ZPL), represented by three species and a combined density of 20.6 Ind/30m^2, representative of 39.0% of the total fish density. The assemblage included three of the top five more abundant species including the masked goby (*Coryphopterus personatus),* blue chromis (*Chromis cyanea*), and the bicolor damselfish (*Stegastes partitus*). Small opportunistic carnivores (SOC) were represented by 15 species including wrasses (Labridae), gobies (Gobiidae), grunts (Haemulidae), squirrelfishes (Holocentridae), hamlets and seabasses (Serranidae), porgies (Sparidae), goatfishes (Mullidae), and puffers (Tetraodontidae) with a combined abundance of 15.8 Ind/30m^2, or 29.9% of the total fish individuals. The herbivore (HER) assemblage included 11 species with a combined density of 12.0 Ind/30m^2, or 22.7% of the total. The assemblage included parrotfishes (Scaridae), doctorfishes (Acanthuridae), and damselfishes (Pomacentridae). Spongivores (Pomacanthidae), and corallivores (Chaetodontidae) were represented by three species with a combined density of 1.8 Ind/30m^2 (Table 60).

Medium and large carnivores included adult mutton and yellowtail snappers (*Lutjanus analis, Ocyurus chrysurus*), adult red hind and graysby groupers (*Epinephelus guttatus, Cephalopholis cruentata*), and one large adult hogfish (*Lachnolaimus maximus*). Juvenile Nassau grouper (*E. striatus*), graysby (*C. cruentata*), mahogany snapper (*L. mahogoni*), and bar jacks (*Caranx ruber*) were also observed with a combined density of 4.0 Ind/60m^2 (Table 61). The larger reef herbivores were represented by parrotfishes (*Scarus* spp., *Sparisoma* spp.), and doctorfishes (*Acanthurus* spp.) with combined densities of 10.8 Ind/60m^2 and 3.8 Ind/60m^2, respectively.

Table 60. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CANJ20, Isla de Vieques. PRCRMP 2025

CANJ20							
Survey Date: 7/13/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	27			11	5	**8.6**	ZPL
Chromis cyanea	33	1	4		2	**8.0**	ZPL
Thalassoma bifasciatum	18		16	6		**8.0**	SOC
Stegastes partitus	5	5	6	1	3	**4.0**	ZPL
Scarus taeniopterus	3	4	4	4	2	**3.4**	HER
Sparisoma aurofrenatum	4	4		6	2	**3.2**	HER
Halichoeres garnoti	3	3	1	3		**2.0**	SOC
Coryphopterus glaucofraenum		6	2			**1.6**	SOC
Stegastes leucostictus	1	1	1	1	2	**1.2**	HER
Chaetodon capistratus	2	2		2		**1.2**	COR
Sparisoma viride		1		5		**1.2**	HER
Acanthurus tractus	1	1	2	1		**1.0**	HER
Haemulon flavolineatum	2		1		1	**0.8**	SOC
Elacatinus evelynae	2			1	1	**0.8**	SOC
Stegastes adustus	2				2	**0.8**	HER
Cephalopholis cruentata		1	2	1		**0.8**	LC
Holocentrus rufus	1	2				**0.6**	SOC
Lutjanus apodus	1		1	1		**0.6**	LC
Epinephelus guttatus		1	1	1		**0.6**	LC
Holacanthus tricolor	1			1		**0.4**	SPO
Hypoplectrus chlorurus	1			1		**0.4**	SOC
Scarus iseri			1		1	**0.4**	HER
Lutjanus analis	1					**0.2**	LC
Lachnolaimus maximus	1					**0.2**	LC
Ocyurus chrysurus	1					**0.2**	LC
Stegastes planifrons	1					**0.2**	HER
Haemulon sciurus	1					**0.2**	SOC
Haemulon macrostomum	1					**0.2**	SOC
Calamus pennatula	1					**0.2**	SOC
Hypoplectrus unicolor	1					**0.2**	SOC
Pomacanthus arcuatus		1				**0.2**	SPO
Serranus tigrinus		1				**0.2**	SOC
Mulloidichthys martinicus		1				**0.2**	SOC
Sparisoma rubripinne			1			**0.2**	HER
Acanthurus coeruleus			1			**0.2**	HER
Acanthurus chirurgus					1	**0.2**	HER
Canthigaster rostrata					1	**0.2**	SOC
Myripristis jacobus					1	**0.2**	SOC
Invertebrates							
Stenorhynchus seticornis				1		**0.2**	
Density (Ind/30m2)	**115**	**35**	**44**	**46**	**24**	**52.8**	
Richness (Species/30m2)	**26**	**16**	**15**	**17**	**13**	**17.4**	

Stoplight, redband, and princess parrotfishes (*Sparisoma viride S. aurofrenatum, Scarus taeniopterus*) were observed as both adults and juveniles, including recruitment juveniles (1 – 5 cm) (Table 61). These data are indicative that CANJ20 serves as a recruitment, grazing and residential habitat for these parrotfishes. Likewise, doctorfishes (*Acanthurus* spp.) have also been reported across the entire range of size classes (Garcia-Sais et al., 2018 and references therein), indicative that they spend their entire lifetime in this reef. Large demersal and pelagic predators were observed as adults and juveniles at CANJ20 during the 2025 survey indicative that CANJ20 serves as a residential and nursery habitat for these species.

Table 61. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CANJ20, Isla de Vieques. PRCRMP 2025

CANJ20							
Survey Date: 7/13/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	10					1	Juvenile
Acanthurus coeruleus c2	8	1					Juvenile
Acanthurus coeruleus c3	3-12, 13, 15			3		2	Adult
Acanthurus tractus c2	2-8, 9, 3-10	1	1	3	1		Juvenile
Acanthurus tractus c3	2-11, 3-12, 13	1		2	1	2	Juvenile
Caranx ruber c5	2-25	2					Juvenile
Cephalopholis cruentata c2	6, 9		1		1		Juvenile
Cephalopholis cruentata c4	16, 20			2			Adult
Epinephelus guttatus c5	25		1				Adult
Epinephelus guttatus c6	30			1			Adult
Epinephelus guttatus c9	42, 45				1	1	Adult
Epinephelus striatus c7	35				1		Juvenile
Lachnolaimus maximus c10	50	1					Adult
Lutjanus analis c10	50	1					Adult
Lutjanus apodus c4	18, 20	1		1			Juvenile
Lutjanus apodus c5	22, 23		1		1		Juvenile
Lutjanus mahogoni c3	15			1			Juvenile
Ocyurus chrysurus c4	18, 20	1	1				Adult
Scarus iseri c3	11, 12, 14, 15			1		3	Juvenile
Scarus taeniopterus c1	2-5	2					Recruit
Scarus taeniopterus c3	3-12, 14		1		1	2	Recruit
Scarus taeniopterus c2	2-6, 6-7, 7-8, 3-10	1	3	4	10		Juvenile
Sparisoma aurofrenatum c1	2-4, 3-5		3		2		Recruit
Sparisoma aurofrenatum c2	2-7, 8, 10	2	1		1		Juvenile
Sparisoma aurofrenatum c3	14, 15				2		Adult
Sparisoma aurofrenatum c5	22, 2-23, 2-25	2			1	2	Terminal
Sparisoma rubripinne c5	25			1			Adult
Sparisoma rubripinne c6	27		1				Adult
Sparisoma viride c1	3-3				3		Recruit
Sparisoma viride c2	6, 7				2		Juvenile
Sparisoma viride c4	20		1				Adult
Sparisoma viride c6	30					1	Adult
Sparisoma viride c7	34	1					Terminal

Figure 70 presents the variations of mean fish density and species richness between monitoring surveys at CANJ20. Mean densities have fluctuated between 36.8 – 88.0 Ind/30m^2 since the 2001 baseline survey, but differences between monitoring surveys were not statistically significant (ANOVA, p= 0.105; Appendix 5). During 2021, mean fish density increased by 73.8% relative to the previous 2018 survey, largely driven by what appears to be a partial recuperation of numerically dominant species, such as the masked goby (*Coryphopterus personatus*), and the blue chromis (*Chromis cyanea*) which may have been negatively impacted by harsh conditions during the pass of Hurricanes Irma and/or Maria in 2017 (Garcia-Sais et al., 2018). During the 2025 survey mean fish densities were well within previous assessment at CANJ20 (Figure 70).

Variations of species richness between monitoring surveys were statistically significant at CANJ20 (ANOVA, p = 0.003; Appendix 6) and associated to higher richness during the 2004 survey relative to all other surveys. Such fluctuations appear to be real phenomena of the inter-annual variability dynamics of fish community structure in Caribbean reefs (Esteves 2013) and have shown to be highly sensitive to physical climatological/oceanographical conditions at the time of surveys. Mean species richness during 2025 (17.4 Spp/30m^2) was not significantly different from the previous 2023 survey and fell within previous assessments at CANJ20.

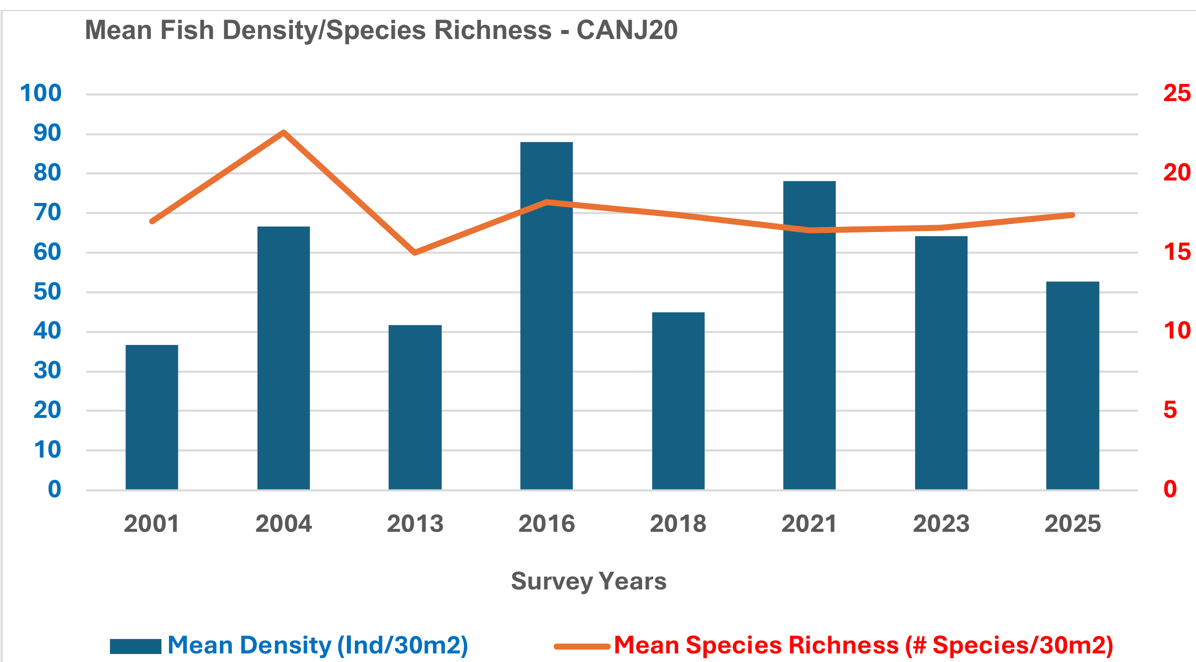
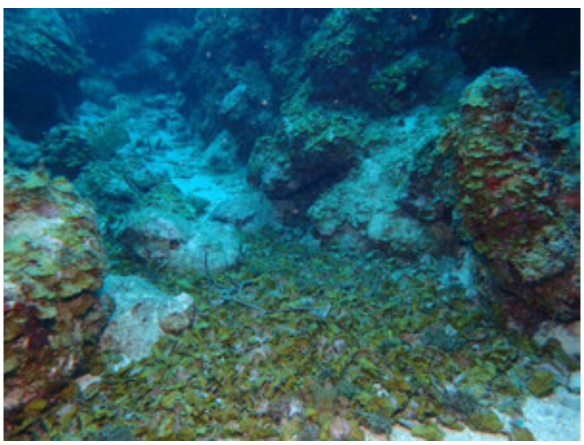
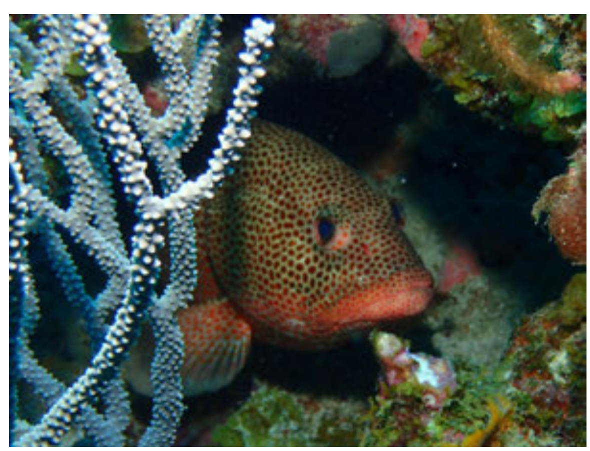


Figure 70. Monitoring trends (2011 – 25) of mean fish density and species richness within 10 x 3 m belt-transects at CANJ20, Isla de Vieques. PRCRMP 2025

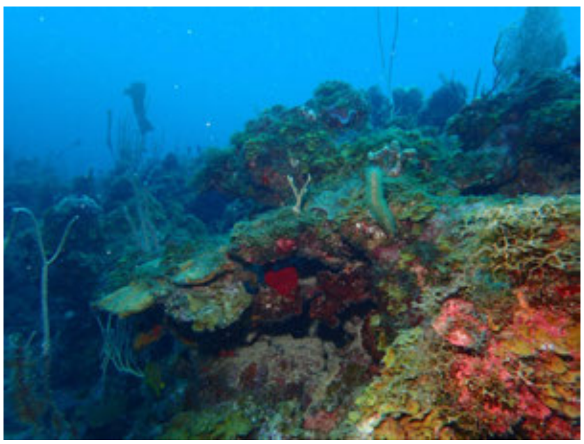
Photo Album 20. CANJ20










21.0 El Seco Reef 30m (SECO30) - Isla de Vieques

21.1 Physical Description

"El Seco" is a submerged promontory, or ridge that rises from a deep outer shelf basin at the southeastern tip of the Vieques shelf, approximately 6 km from Punta del Este (Figure 71). The promontory with an elliptical shape runs along a north-south axis and rises from the basin at depths of 33 – 36 m to a mostly flat hard ground reef top at depths of 23 – 28 m. Depth increases towards the shelf-edge to the east and south of the ridge, and decreases towards the north, where an extensive mesophotic coral reef system consisting of several benthic habitats was discovered (Garcia-Sais et al., 2011). The coral reef system ends as patch reef spurs separated by coralline sand pools at depths between 40–45 m. Clear waters prevail at "El Seco" with underwater visibility exceeding the 30 - 40m range.

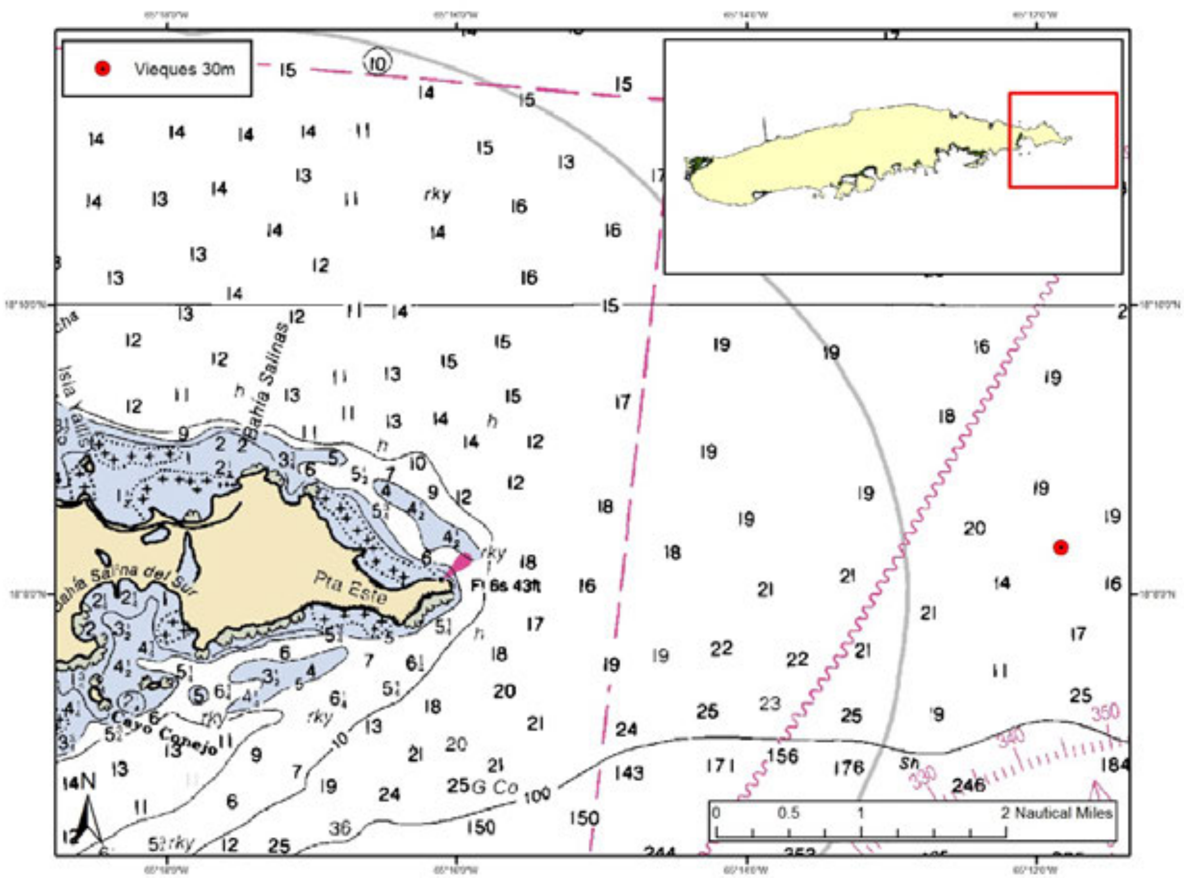


Figure 71. Location of coral reef monitoring station at El Seco Reef (SECO30), Isla de Vieques. PRCRMP 2025

The coral bank reef habitat at El Seco (SECO30) is an impressive continuous formation of scleractinian corals growing at depths of 33–41m throughout the northern and northeastern sections of the study area. The coral reef is largely a biotope of star corals, *Orbicella franksi/faveolata* growing as laminar planks of up to 1m of diameter, supported by pedestals of unknown origin and variable heights. Even though its entire areal extension has not been mapped, the coral reef formation off southeast Vieques represents the largest continuous coral reef benthic habitat reported for Puerto Rico (Garcia-Sais et al. 2011). The baseline characterization survey of SECO30 was performed in October 2011. Images of the coral reef community at SECO30 during the 2025 survey are presented as Photo Album 21.

18.2 Sessile-Benthic Reef Community

Substrate cover by sessile-benthic categories from transects surveyed at SECO30 during the 2025 monitoring survey are presented in Table 62. The combined assemblage of benthic algae, comprised by fleshy brown, turf, red crustose calcareous and coralline algae (CCA) were the dominant sessile-benthic category in terms of reef substrate cover with a combined mean of 78.51% (range: 73.82 – 84.25%). Fleshy brown macroalgae, mostly represented in transects by the encrusting fan-leaf alga (*Lobophora sp.*) with minor contributions by y-twig alga (*Dictyota* sp.) were the main component of the benthic algae with a combined mean cover of 50.82%, representative of 64.7% of the total cover by benthic algae. Red crustose calcareous algae, *Ramicrusta sp*. and other Peyssonnelid algae were observed in all transects with a combined mean cover of 13.09%, or 16.7% of the total cover by benthic algae. Turf algae, a mixed assemblage of short filamentous red and brown algae were observed overgrowing relict and/or recently dead coral sections with a mean cover of 11.76%. Cyanobacterial patches were present in all five transects with a mean cover of 2.18% (Table 62).

Stony corals were represented in transects by five scleractinians with a combined mean substrate cover of 15.68% (range: 12.48 – 22.47%). The boulder/mountainous star coral complex, (*Orbicella franksi/faveolata*) was the dominant stony coral taxa with a mean substrate cover of 12.03%, representative of 75.3% of the total cover by stony corals (Table 62). Whitestar sheet and grahamae lettuce corals (*Agaricia lamarki*, *A. grahamae*) were present in two and four transects, respectively with a combined mean cover of 3.50%. A total of 68 stony coral colonies were observed within photo-transects during the 2025 monitoring survey, including one (1- *O. franksi/faveolata)* apparently affected by infectious coral diseases (coral disease prevalence = 1.47%; Appendix 2).

Table 62. Percent reef substrate cover by sessile-benthic categories at SECO30, Isla de Vieques. PRCRMP 2025

SECO30			**Transects**			
Survey Date: 7/13/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**35.8**	**33.6**	**35.8**	**35.4**	**35.4**	**35.20**
BENTHIC CATEGORIES						
Abiotic						
Sand				4.72	4.92	**1.93**
Recently dead coral				1.07	0.29	**0.27**
Total Abiotic	**0.00**	**0.00**	**0.00**	**5.79**	**5.21**	**2.20**
Benthic Algae						
Lobophora spp.	56.39	53.94	49.46	42.97	50.74	**50.70**
Turf (mixed species)	9.88	11.69	16.29	13.32	7.64	**11.76**
Peysonnalia	4.03	8.44	9.87	7.56	7.67	**7.51**
Ramicrusta spp.	4.84	6.50	4.77	7.00	4.81	**5.58**
Crustose coralline algae	1.98	3.39	2.78	2.97	3.04	**2.83**
Dictyota spp.		0.29			0.30	**0.12**
Total Benthic Algae	**77.12**	**84.25**	**83.17**	**73.82**	**74.20**	**78.51**
Cyanobacteria	**0.40**	**2.19**	**0.81**	**5.23**	**2.28**	**2.18**
Stony Corals						
Montastrea franksi/faveolata	20.78	11.35	12.48		15.56	**12.03**
Agaricia lamarcki	0.40			14.07		**2.89**
Agaricia grahamae	0.87	1.34		0.56	0.29	**0.61**
Porites porites	0.43					**0.09**
Siderastrea sidera				0.27		**0.05**
Total Stony Corals	**22.47**	**12.69**	**12.48**	**14.90**	**15.85**	**15.68**
# Coral Colonies/Transect	**18**	**12**	**7**	**14**	**17**	**13.6**
# Diseased Coral Colonies/Transect	**0**	**1**	**0**	**0**	**1**	**0.4**
Soft Corals						
Erythropodium caribeaorum		0.32	0.28		0.54	**0.23**
Total Soft Corals	**0.00**	**0.32**	**0.28**	**0.00**	**0.54**	**0.23**
# Erect Soft Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.00**
Sponges						
Dictyonella funicularis				0.27	1.91	**0.44**
Svenzea zeai		0.36				**0.07**
Agelas dispar		0.18				**0.04**
Total Sponges		**0.54**		**0.27**	**1.91**	**0.54**
Diseased Corals						
O. franksi		1			1	**0.4**

Soft corals were not observed in photo-transects at SECO30 during the 2025 survey. Sponges were represented by three small encrusting species (*Dictyonella funicularis, Svenzea zeai, and Agelas dispar*) with a mean combined cover of 0.54%. Abiotic substrates were contributed by sand (1.93%), and recently dead coral (0.27%) (Table 62).

Variations of reef substrate cover by the main sessile-benthic categories between monitoring surveys at SECO30 are presented in Figure 72. The main change of benthic community structure at SECO30 was a marked, statistically significant decline of cover by stony corals (ANOVA, $p < 0.001$; Appendix 3), and a corresponding increase of cover by benthic algae. A consistent pattern of stony coral cover decline was measured since the 2018 survey until the most recent 2025 survey. Live stony cover declined 17.8% in 2018, and again 21.5% in 2021. During the 2023 survey, another smaller reduction of 9.6% was measured. The largest reduction of live stony coral cover was measured during the most recent 2025 survey (-34.75%) relative to the previous 2023 survey (ANOVA, $p= 0.010$; Appendix 3), resulting in an overall substrate cover decline of 64.10% relative to the 2011 mean baseline cover.

The reductions of coral cover were largely driven by losses of cover by the dominant coral assemblage, the *Orbicella franksi/faveolata* complex (Figure 73). Including the most recent reductions measured in 2025, the overall decline of cover by the *O. faveolata/franksi* complex stands at -68.86% relative to the 2011 baseline. Intraspecific variations within the benthic algae community were reported by Garcia-Sais et al. (2016) related to a shift of dominance in terms of reef substrate cover from turf algae in 2011 and 2013, to a brown fleshy/red crustose macroalgae (*Lobophora*/*Ramicrusta* sp) dominance that has prevailed until the most recent 2025 survey.

The sharp decline of stony coral cover at SECO30 appears to be strongly related to coral disease infections. Williams et al., (2021) reported SCTLD infections on *Orbicella franksi/faveolata* colonies from a locality in the close vicinity of SECO30 during a July 2020 survey (Garcia-Sais et al., 2020). A total of 13 out of the 99 coral colonies present within photo-transects during the 2021 survey were apparently affected by coral diseases (unknown pathogens) but none considered to be SCTLD infections. Substantial amount of necrotic tissue, discoloration, and bleached patches were noted in stony coral colonies within the images analyzed in the 2018 survey (Garcia-Sais et al., 2018). Such anomalies may have resulted in further tissue losses and/or mortality of colonies influencing the coral cover decline measured in the 2021 survey at SECO30. The losses measured in the most recent 2025 survey may be related to additional outbursts of coral diseases triggered by heat stress induced bleaching perhaps initiated after our 2023 survey when 19 degree-heating weeks were accumulated by late October (NESDIS, 2024).

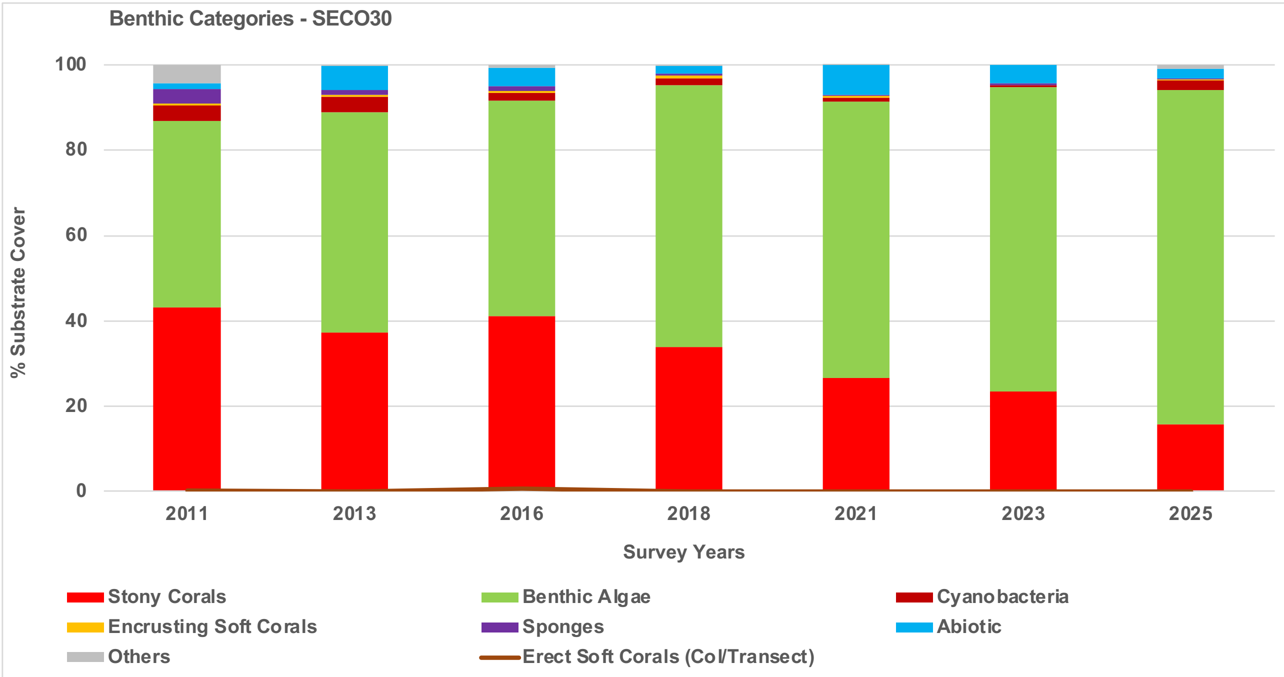


Figure 72. Monitoring trends (2011 - 25) of mean substrate cover by sessile-benthic categories at SECO30, Isla de Vieques. PRCRMP 2025

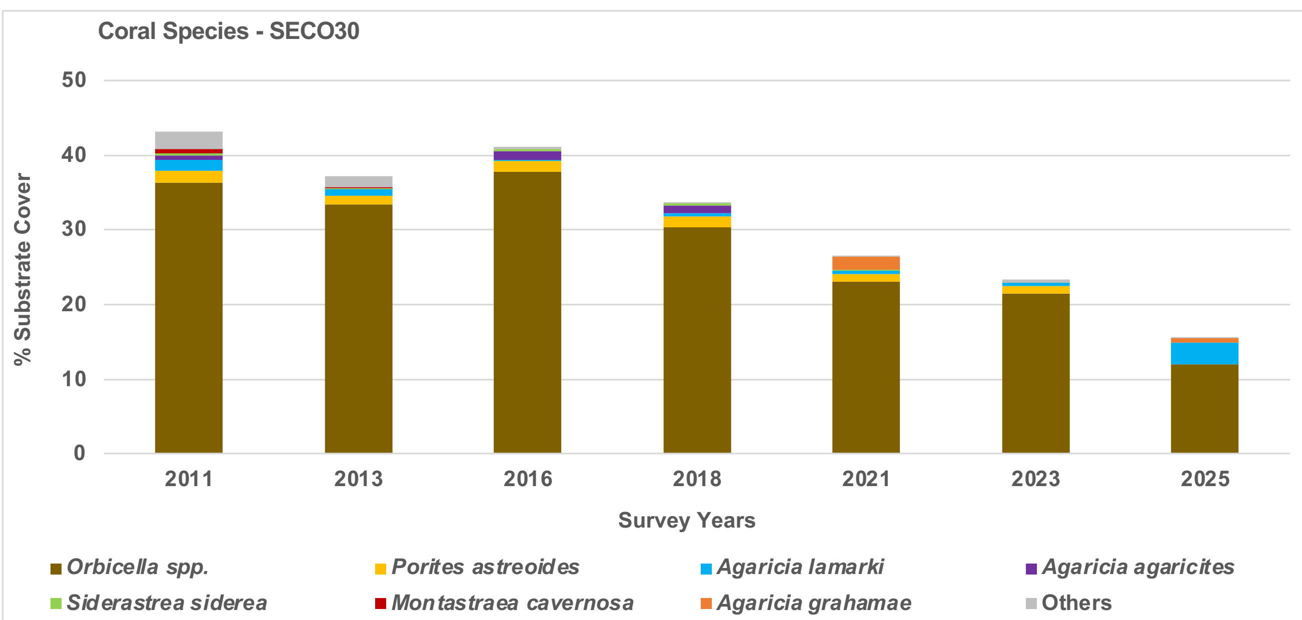


Figure 73. Monitoring trends (2011 - 25) of mean substrate cover by the main coral species intercepted by transects at SECO30, Isla de Vieques. PRCRMP 2025

18.3 Fishes and Motile Megabenthic Invertebrates

A total of 18 fish species were identified within belt-transects at SECO30 during the 2025 monitoring survey with a mean abundance of 21.2 Ind/30m^2 (range: 11 - 36 Ind/30m^2), and a mean species richness of 8.2 Spp/30m^2 (range: 5 – 10 Spp/30m^2) (Table 63). The combined density within belt-transects of five species represented 78.3% of the total fish density. These included the masked goby (*Coryphopterus personatus*), bicolor damselfish (*Stegastes partitus*), blue chromis (*Chromis cyanea*), bluehead wrasse (*Thalassoma bifasciatum*), and princess parrotfish (*Scarus taeniopterus*). Motile megabenthic invertebrates were not observed within belt-transects (Table 63).

Table 63. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at SECO30, Isla de Vieques. PRCRMP 2025

SECO30							
Survey Date: 7/13/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Coryphopterus personatus	1	1	15	3	3	**4.6**	ZPL
Stegastes partitus	6	2	3	4	3	**3.6**	ZPL
Chromis cyanea				5	13	**3.6**	ZPL
Thalassoma bifasciatum	2	1	1	3	7	**2.8**	SOC
Scarus taeniopterus	2	1	4		3	**2.0**	HER
Acanthurus tractus	1	1			2	**0.8**	HER
Halichoeres garnoti	1	1	1			**0.6**	SOC
Elacatinus evelynae	2					**0.4**	SOC
Chaetodon capistratus	1				1	**0.4**	COR
Lutjanus apodus		1			1	**0.4**	LC
Scarus iseri					2	**0.4**	HER
Hypoplectrus unicolor	1					**0.2**	SOC
Caranx ruber		1				**0.2**	LC
Liopropoma mowbrayi		1				**0.2**	SOC
Hypoplectrus chlorurus		1				**0.2**	SOC
Chromis insolata				1		**0.2**	ZPL
Coryphopterus lipernes				1		**0.2**	SOC
Holacanthus tricolor				1		**0.2**	SPO
Myripristis jacobus					1	**0.2**	SOC
Density (Ind/30m2)	**17**	**11**	**24**	**18**	**36**	**21.2**	
Richness (Species/30m2)	**9**	**10**	**5**	**7**	**10**	**8.2**	

Zooplanktivorous (ZPL) fishes dominated the trophic community structure at SECO30 during the 2025 survey with four species and a combined density of 12.0 Ind/30m^2, representative of 56.6% of the total fish density within belt-transects. The ZPL assemblage included the numerically dominant masked goby (*Coryphopterus personatus*), and three damselfishes (*Chromis cyanea, C. insolata, Stegastes partitus*). Small opportunistic carnivores (SOC) included seven species with a combined density of 4.8 Ind/30m^2, representative of 22.6% of the total fish density. These included wrasses (Labridae), gobies (Gobiidae), hamlets (Serranidae), and squirrelfishes (Holocentridae). Herbivores (HER) were represented by three species, including parrotfishes (Scaridae) and doctorfishes (Acanthuridae) with a combined density of 3.2 Ind/30m^2, or 15.1% of the total fishes. Spongivores (*Holacanthus* tricolor), and corallivores (*Chaetodon capistratus*) had a combined density of 0.6 Ind/30m^2 (Table 63).

A pair of small adult schoolmaster snappers (*Lutjanus apodus*) were the only large/medium size carnivores observed within extended belt-transects at SECO30 during the 2025 survey. Previous assessments have shown that SECO30 functions as the residential habitat of several commercially important medium and large demersal reef fish predators, such as the hogfish (*Lachnolaimus maximus),* queen triggerfish (*Balistes vetula*), schoolmaster, mutton, dog, and cubera, snappers (*Lutjanus apodus, L. analis, L. jocu, L. cyanopterus*), red hind, Nassau and tiger groupers (*Epinephelus guttatus, E. striatus*, *Mycteroperca tigris*), and nurse shark (*Ginglymostoma cirratum*). Schools of mackerel scad (*Decapterus macarelus*) and creole wrasse (*Clepticus parrae*) were observed in mid-water outside transects during 2021 and previous surveys. These serve as potential forage species for the larger pelagic predators, such as almaco jacks (*Seriola rivoliana*), great barracuda (*Sphyraena barracuda*), and cero mackerel (*Scomberomorus regalis*) previously reported (Garcia-Sais et al., 2022a, and references therein). Several large adult hawksbill turtles (*Eretmochelys imbricata*) were observed at SECO30 during the 2011 baseline survey (Garcia-Sais et al., 2012).

The larger reef fish herbivores were represented by parrotfishes (*Scarus taeniopterus, S. vetula, S. iseri*), and doctorfishes (*Acanthurus tractus, A. coeruleus*) with mean densities of 3.6 Ind/60m^2 and 0.4 Ind/60m^2, respectively. Both juveniles and/or adults were present but in relatively lower densities than in shallower reefs (Table 64).

Table 64. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at SECO30, Isla de Vieques. PRCRMP 2025

SECO30							
Survey Date: 7/13/25							
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c3	14			1			Adult
Acanthurus tractus c3	15		1				Juvenile
Caranx ruber c5	22		1				Juvenile
Lutjanus apodus c6	28, 30		1			1	Adult
Scarus iseri c3	12					1	Juvenile
Scarus iseri c4	16					1	Adult
Scarus taeniopterus c1	2-18	1	1				Recruit
Scarus taeniopterus c2	3-8					3	Juvenile
Scarus taeniopterus c3	7-12, 13, 14, 15	1	3	4		2	Juvenile
Scarus vetula c4	20		1				Adult
	Totals	**2**	**8**	**5**	**0**	**8**	

Figure 74 shows the variations of mean fish density and species richness between monitoring surveys at SECO30. A pattern of declining fish density and species richness was observed in successive monitoring surveys since the baseline characterization in 2011 until 2023 when a marked increment of fish density was measured. Differences of both fish density and species richness were statistically significant, associated with lower densities during the 2021 and 2025 surveys compared to the 2011, 2013, and 2023 surveys (ANOVA, $p = 0.015$; Appendix 5), and lower species richness in 2018, 2021, 2023, and 2025 compared to the 2011 baseline (ANOVA, $p < 0.001$; Appendix 6). Density reductions have been related with abundance fluctuations of numerically dominant species, such as the masked goby (*Coryphopterus personatus*), but were also related to an overall decline of species richness. It is possible that the recruitment dynamics of short-lived reef fish species may have been affected by the extreme physical/climatological events that impacted coral reef systems around Puerto Rico during the period between September 2017 and March 2018. A sharp density increase of 159.1% was noted in the previous 2023 survey suggesting a partial recuperation of the small, numerically dominant residential fish populations after the hurricane impacts.

A marked -88.0% density decline of masked goby (*Coryphopterus personatus*) was measured in 2025 relative to the previous 2023 survey. It is possible that the abundance fluctuations of this forage species has relevant implications for the fish community structure at SECO30 by regulating the occurrence and density of small fish predators and the larger piscivores up the food web.

Fish species richness in 2025 (8.2 Spp/30m^2) represents an overall decline of 48.1% relative to the peak richness measured in the 2011 baseline survey. Given the bold deterioration of the benthic habitat at SECO30 associated with the loss of live stony coral cover potential direct and indirect effects upon the fish community may be expected and should be carefully monitored.

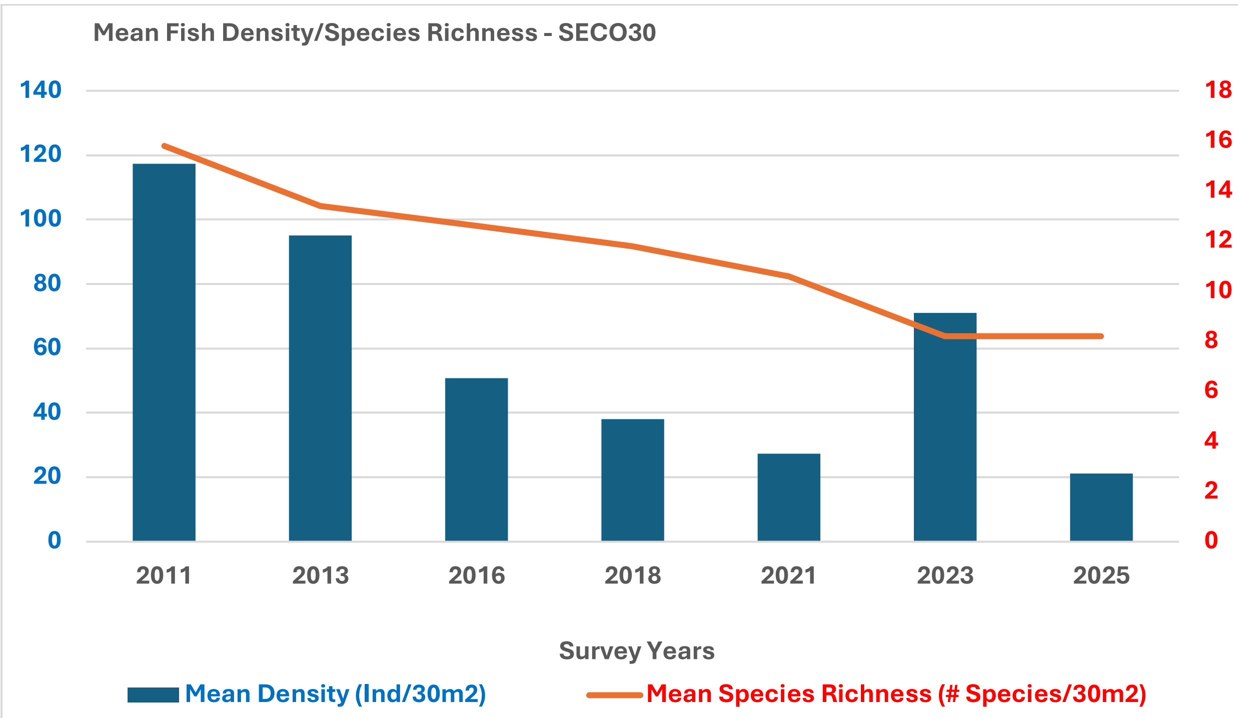
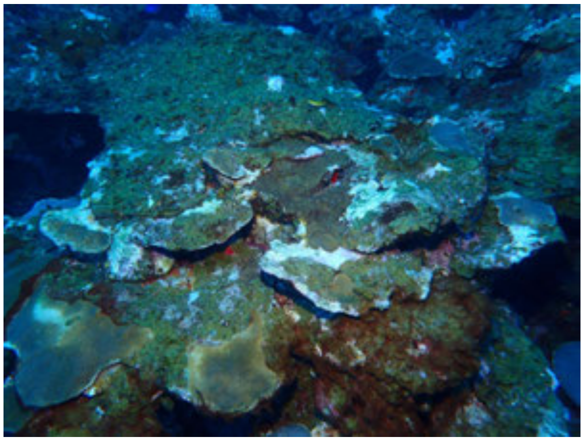
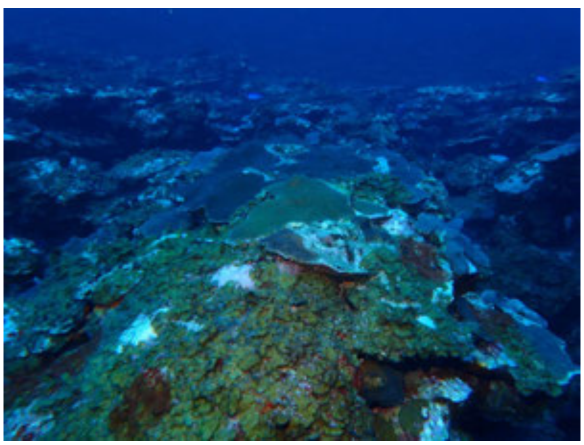
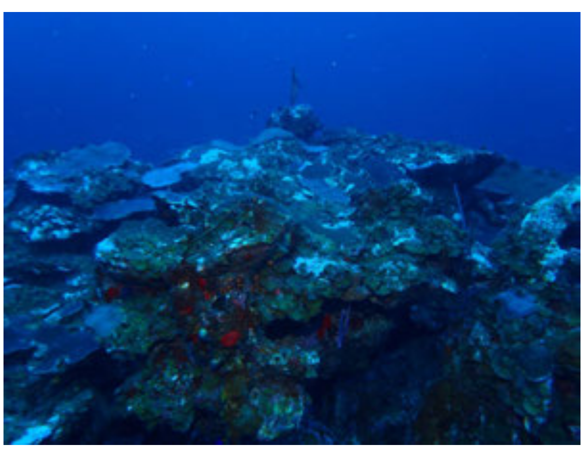


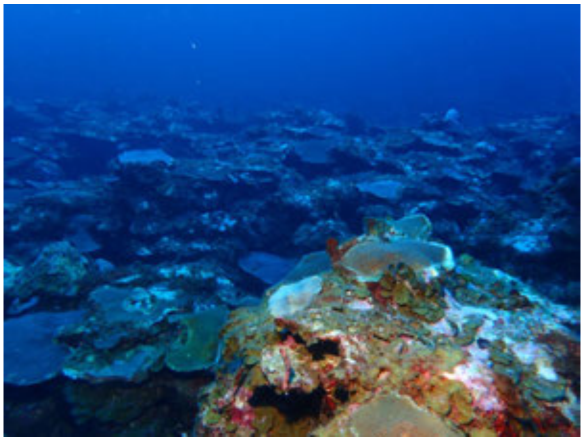
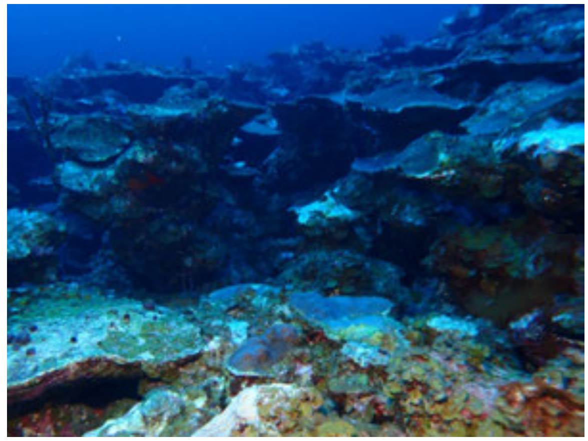
Figure 74. Monitoring trends (2011 – 25) of mean fish density and species richness within 10 x 3m belt-transects at SECO30, Isla de Vieques. PRCRMP 2025

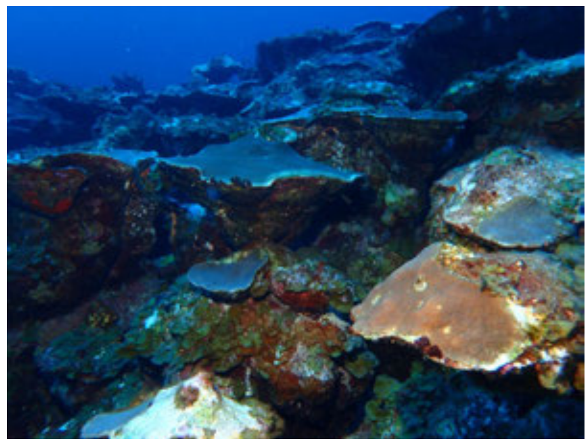
Photo Album 21. SECO30

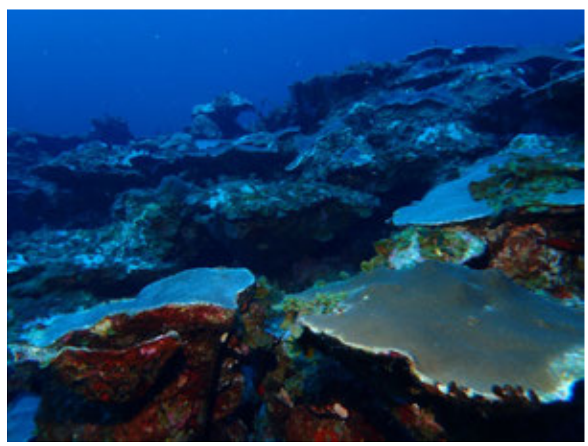










IX. Baseline Characterizations of San Juan/Carolina Reefs

1.0 Maria Grande 10m (MARI10)

1.1 Physical Description

Maria Grande is an emergent rock reef of eolianite (sedimentary) origin located approximately 1.75 km off Punta Las Marias in Carolina, on the northeast coast. The reef is part of a chain of submerged and emergent promontories that run essentially parallel to the coastline. The north cost of Puerto Rico experiences seasonally high wave action from winter swells from the North Atlantic Ocean, therefore coral reef communities are exposed to high waves and strong surge during the October thru March period. Reef communities off Punta Las Marias are also exposed to up current inputs of brackish water tidal/storm runoff from the Boca de Cangrejos mangrove estuarine inlet, and of freshwater inputs from stormwater discharges inland. MARI10 is located at approximately 1.6 Km off the coastline and approximately 0.8 km west of Punta Las Marias (Figure 75). The baseline characterization of MARI10 was performed on August 14, 2025. Transects were positioned at depths of 9.7 – 12.7m along a string running roughly perpendicular to the shoreline. The seafloor at MARI10 is moderately irregular with a series of grooves and crevices that cut across an otherwise pavement seascape colonized by benthic algae and encrusting biota, including sponges and live stony corals. Views of the reef communities and benthic habitat at MARI10 during the 2025 baseline survey are shown in Photo Album 22.

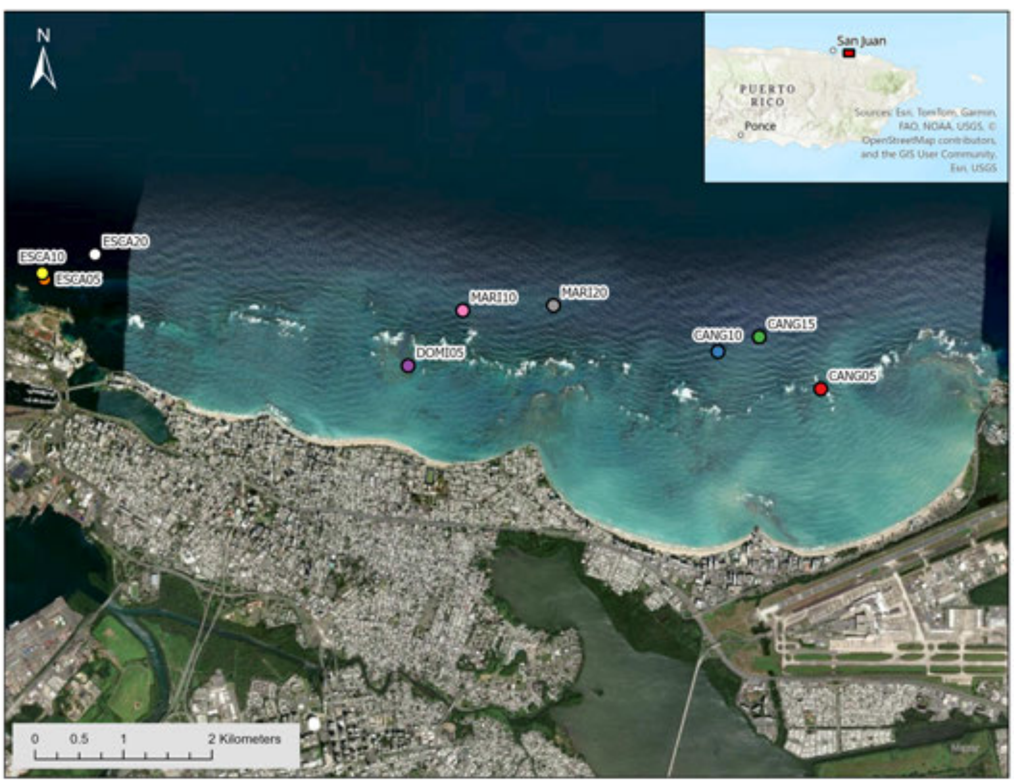


Figure 75. Location of reef stations for baseline characterizations off the San Juan – Carolina coastlines. PRCRMP 2025.

1.2 Sessile-Benthic Communities

Reef substrate cover at MARI10 was dominated by an assemblage of benthic algae comprised by turf, fleshy brown, and red crustose calcareous macroalgae with a combined mean cover of 64.01% (Figure 76). Turf algae, a mixed assemblage of short articulated red and brown algae was the dominant algal component with a mean cover of 35.61%, representative of 55.6% of the total reef substrate cover by benthic algae (Table 65). Fleshy brown, y-twig alga (*Dictyota sp.*) was intercepted by all five transects with a mean cover of 23.60%, or 36.9% of the total cover by benthic algae. Small scattered patches of crustose calcareous red algae (*Peyssonnelia* sp., *Ramicrusta sp.*) were present in all transects with a combined cover of 3.90%. Cyanobacteria (blue-green algae) were prominent growing as a reddish slimy mat over algal turf and also covering tufts of *Dictyota* sp. It was intercepted by all transects with a mean substrate cover of 21.90% (Table 65).

Stony corals were represented by six scleractinian species and one hydrocoral (*Millepora alcicornis*) during the 2025 survey at MARI10 with a combined mean cover of 6.59% (range 3.59 – 11.88%; Table 65). Mustard-hill coral (*Porites astreoides*), great star coral (*Montastraea cavernosa*), and symmetrical brain coral (*Pseudodiploria strigosa*) were the dominant coral species with a combined reef substrate cover of 4.87%, representative of 73.9% of the total cover by stony corals (Figure 77). Stony corals were mostly present as encrusting colonies growing over pavement with only minor contributions to the ref topographic relief and habitat complexity. A total of 30 stony coral colonies were intercepted by transects at MARI10 during the 2025 survey, none of which were observed to be affected by coral disease infections (Appendix 2).

Erect soft corals were moderately abundant at MARI10 with a mean density of 5.2 Colonies/Transect (Table 65). Taxonomic identifications of erect soft corals were not performed in the 2025 survey, but sea rods (*Eunicea flexuosa, Pseudoplexaura spp.*), and sea fans (*Gorgonia ventalina*) were prominent in transects. The encrusting zoanthid (*Palythoa caribaeorum*) was intercepted by four transects with a mean cover of 1.17%. Erect and encrusting sponges were represented in transects by 11 species with a combined mean cover of 3.77%. *Mycaele levis* was the most prominent along transects with a mean cover of 1.70%, representative of 45.1% of the total cover by sponges. Reef overhangs, mostly of sedimentary origin contributed 2.47 to the abiotic cover at MARI10.

Table 65. Percent reef substrate cover by sessile-benthic categories at MARI10, Carolina. PRCRMP 2025

MARI10			Transects			
Survey Date: 8/14/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	12.7	12.7	12.1	11.5	9.7	**11.74**
Rugosity (m)	0.49	1.31	1.16	0.58	0.95	**0.90**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	0.93	1.49	4.52	0.79	4.60	**2.47**
Total Abiotic	**0.93**	**1.49**	**4.52**	**0.79**	**4.60**	**2.47**
Benthic Algae						
Turf (mixed) with sediment	13.48	23.39	35.51	62.57	34.27	**33.84**
Dictyota spp.	24.84	26.49	29.86	7.80	29.03	**23.60**
Peyssonnelia spp.	1.74	4.21	4.52	0.40	3.84	**2.94**
Turf (mixed)	1.20	0.99	1.63	0.79	4.22	**1.77**
Ramicrusta spp.		1.73		0.53	2.56	**0.96**
CCA (total)		0.50	0.38		3.58	**0.89**
Total Benthic Algae	**41.26**	**57.30**	**71.89**	**72.09**	**77.49**	**64.01**
Cyanobacteria	**44.46**	**29.58**	**13.30**	**16.14**	**6.01**	**21.90**
Stony Corals						
Porites astreoides	1.07		1.76	2.65	3.84	**1.86**
Montastraea cavernosa	8.68					**1.74**
Pseudodiploria strigosa		0.99	0.50	0.66	4.22	**1.27**
Stephanocoenia intersepta	0.93	1.61			0.77	**0.66**
Millepora alcicornis	1.20		1.88			**0.62**
Siderastrea siderea				1.19		**0.24**
Orbicella faveolata		0.99				**0.20**
Total Stony Corals	**11.88**	**3.59**	**4.14**	**4.50**	**8.82**	**6.59**
# Coral Colonies/Transect	**6**	**3**	**4**	**7**	**10**	**6.0**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Zoanthids						
Palythoa caribaeorum		**1.73**	**1.88**	**2**	**0.26**	**1.17**
Soft Corals						
Eunicea flexuosa			0.50			**0.10**
Total Soft Corals	**0.00**	**0.00**	**0.50**	**0.00**	**0.00**	**0.10**
# Erect Soft Corals/Transect	**6**	**3**	**3**	**6**	**8**	**5.2**
Sponges						
Mycale laevis	0.67	0.74	2.26	3.44	1.41	**1.70**
Halisarca caerulea		0.87	0.75			**0.32**
Neopetrosia spp. smooth		1.36				**0.27**
Aplysina insularis			0.75	0.53		**0.26**
Dictyonella funicularis		0.74			0.38	**0.23**
Verongula reiswigi					1.02	**0.20**
Neopetrosia proxima		0.99				**0.20**
Niphates caribica		0.99				**0.20**
Niphates erecta	0.27			0.53		**0.16**
Callyspongia vaginalis		0.62				**0.12**
Agelas dispar	0.53					**0.11**
Total Sponges	**1.47**	**6.31**	**3.76**	**4.50**	**2.81**	**3.77**

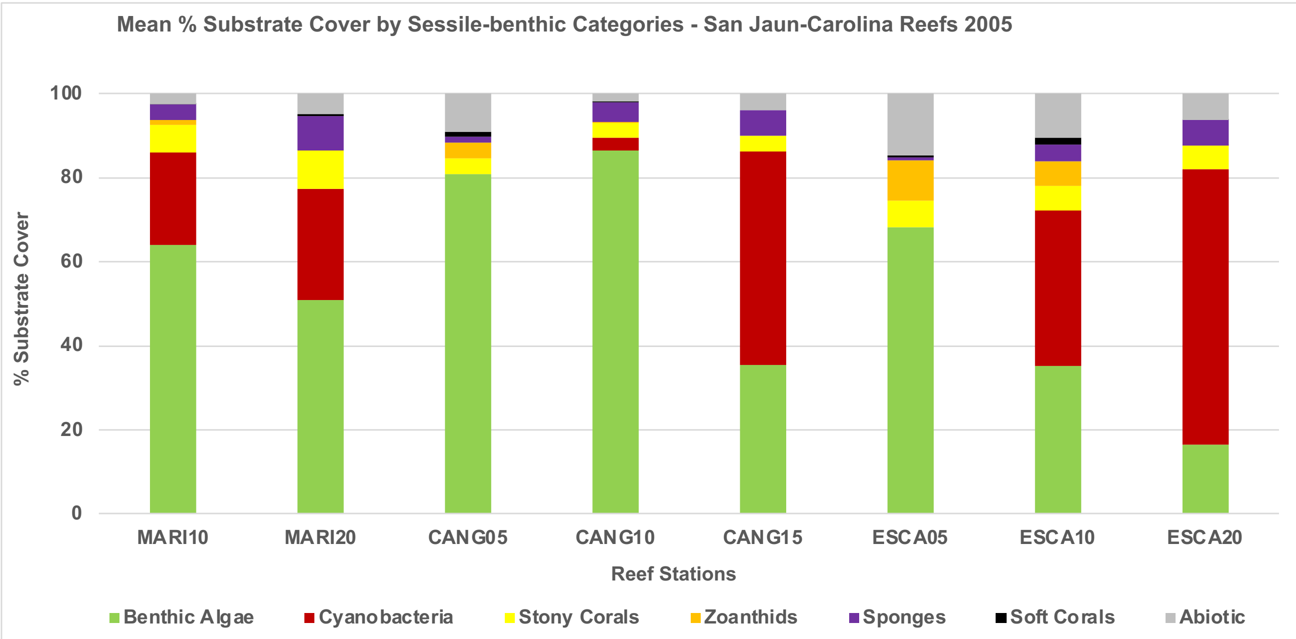


Figure 2. Mean % substrate cover by sessile-benthic categories from reef stations surveyed off the San Juan and Carolina coastlines. PRCRMP 2025.

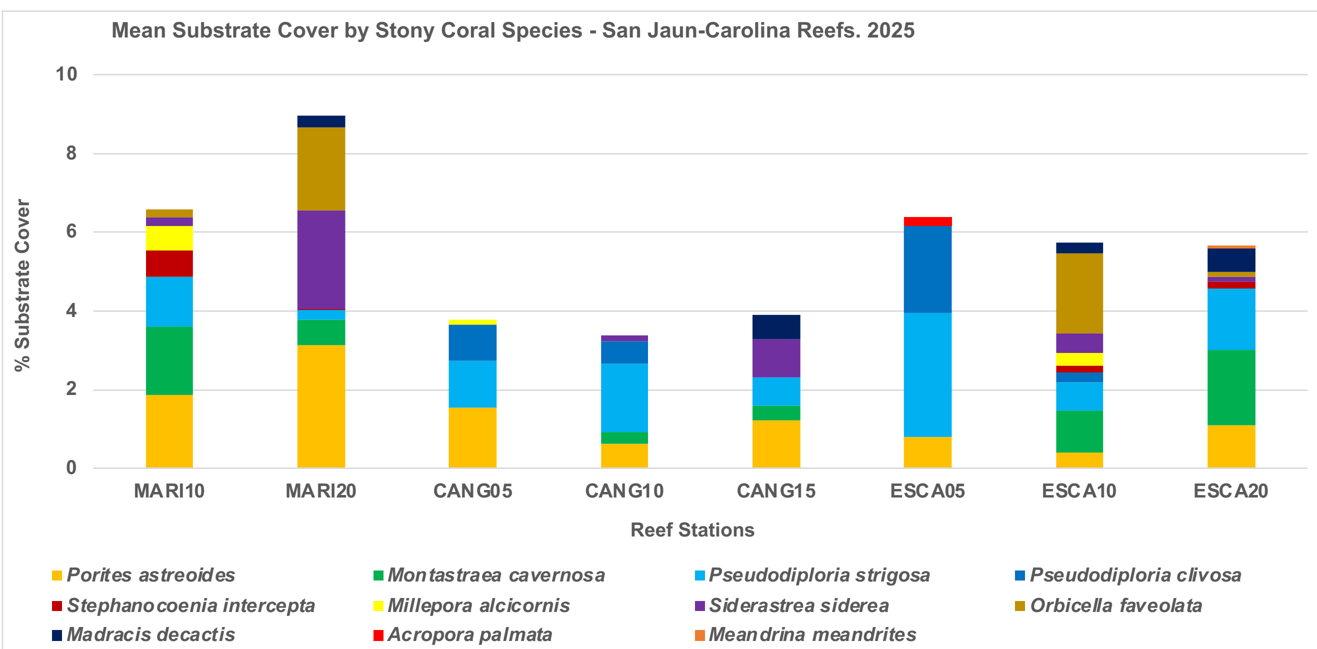


Figure 3. Mean substrate cover by stony coral species from reef stations surveyed off the San Juan and Carolina coastlines. PRCRMP 2025.

1.3 Fishes and Motile Megabenthic Invertebrates

A total of 30 fish species were identified within belt-transects at MARI10 during the 2025 baseline survey with a mean density of 52.2 Ind/30m^2, and a mean species richness of 11.4 Spp/30m^2 (Table 66). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 32.4 Ind/30m^2, representative of 62.1% of the total fish density. Bluehead wrasse were observed in schooling aggregations of adults in the water column close to the substrate, and as very small (<2cm) recruitment juveniles associated with sponges and other protective microhabitats. The bicolor damselfish (*Stegastes partitus*) and the coney (*Cephalopholis fulva*) were observed within all five belt-transects with mean densities of 7.0 Ind/30m^2 and 1.8 Ind/30m^2, respectively. Motile megabenthic invertebrates were represented within belt-transects by three long spined urchins (*Diadema antillarum*).

The fish trophic structure at MARI10 was dominated by small opportunistic carnivores (SOC) with a combined abundance of 36.4 Ind/30m^2, representative of 69.7% of the total fish individuals within belt-transects. The assemblage was comprised by 13 species including wrasses (Labridae), gobies (Gobiidae), trunkfishes (Ostraciidae), squirrelfishes (Holocentridae), seabasses (Serranidae), mojarras (Gerreidae), and grunts (Haemulidae). Zooplanktivores (ZPL), were represented by two species (*Stegastes partitus, Melichthys niger*) with a combined density of 7.4 Ind/30m^2, representative of 14.2% of the total fish density. The herbivore (HER) assemblage included nine species with a combined density of 5.8 Ind/30m^2, or 11.1% of the total individuals. The assemblage included three species of doctorfishes (Acanthuridae), four species of parrotfishes (Scaridae), and two species of damselfishes (Pomacentridae). Spongivores (Pomacanthidae), and corallivores (Chaetodontidae) were represented by two species, each with a combined density of 1.0 Ind/30m^2 (Table 66).

Medium and large carnivores included adult yellowtail and schoolmaster snappers (*Ocyurus chrysurus, Lutjanus apodus,*), one adult red hind (*Epinephelus guttatus*), and both juvenile and adult coney groupers (*Cephalopholis cruentata*) with a combined density of 3.0 Ind/60m^2 (Table 67). The larger reef herbivores were represented by three species of doctorfishes (*Acanthurus* spp.), and four species of parrotfishes (*Scarus* spp., *Sparisoma* spp.) with combined densities of 4.8 Ind/60m^2 and 1.4 Ind/60m^2, respectively. Doctorfishes were present as both juvenile and adults, including recruitment juvenile stages of blue tangs (*A. coeruleus*) and ocean surgeons (*A. tractus*). Parrotfishes were mostly observed as adults.

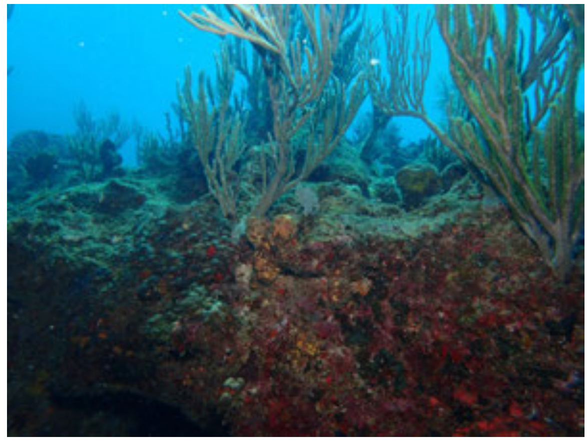
Table 66. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at MARI10, Carolina. PRCRMP 2025

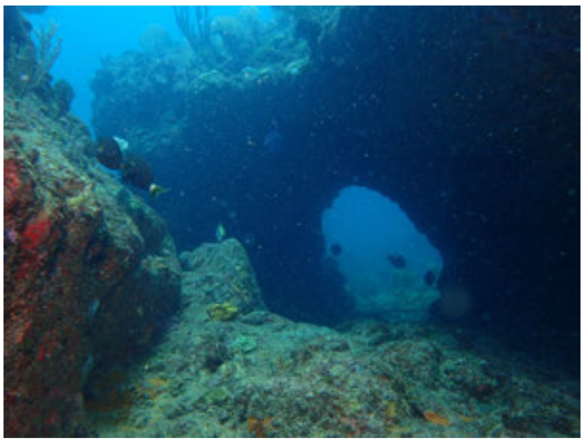
MARI10							
Survey Date: 8/14/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	27	37	32	45	21	**32.4**	SOC
Stegastes partitus	9	9	4	5	8	**7.0**	ZPL
Acanthurus chirurgus		8	1			**1.8**	HER
Cephalopholis fulva	1	1	1	1	2	**1.2**	LC
Acanthurus tractus	1		2	2		**1.0**	HER
Halichoeres bivittatus	3		1	1		**1.0**	SOC
Acanthurus coeruleus		2	1	1	1	**1.0**	HER
Malacoctenus triangulatus	2		1			**0.6**	SOC
Stegastes variabilis		1	2			**0.6**	HER
Acanthostracion polygonius	1				1	**0.4**	SOC
Halichoeres maculipinna	1			1		**0.4**	SOC
Chaetodon striatus		1			1	**0.4**	COR
Sparisoma aurofrenatum			1	1		**0.4**	HER
Ocyurus chrysurus				1	1	**0.4**	LC
Scarus iseri				2		**0.4**	HER
Melichthys niger				2		**0.4**	ZPL
Halichoeres poeyi	1					**0.2**	SOC
Holocentrus adscensionis		1				**0.2**	SOC
Holacanthus tricolor		1				**0.2**	SPO
Serranus tigrinus		1				**0.2**	SOC
Gerres cinereus			1			**0.2**	SOC
Stegastes adustus				1		**0.2**	HER
Sparisoma rubripinne				1		**0.2**	HER
Chaetodon capistratus					1	**0.2**	COR
Sparisoma chrysopterum					1	**0.2**	HER
Anisotremus virginicus					1	**0.2**	SOC
Holocentrus rufus					1	**0.2**	SOC
Lactophrys triqueter					1	**0.2**	SOC
Haemulon aurolineatum					1	**0.2**	SOC
Pomacanthus arcuatus					1	**0.2**	SPO
Invertebrates							
Diadema antillarum	3					**0.6**	HER
Density (Ind/30m2)	46	62	47	64	42	**52.2**	
Richness (Species/30m2)	9	10	11	13	14	**11.4**	

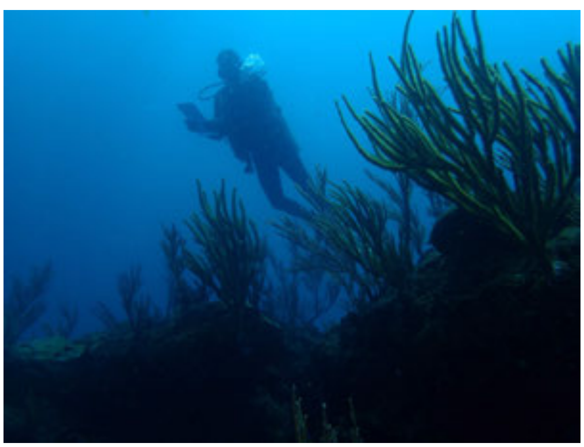
Table 67. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at MARI10, Carolina. PRCRMP 2025

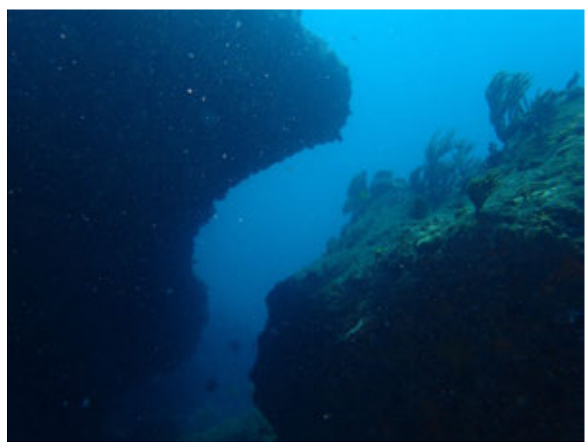
MARI10							
Survey Date: 8/14/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	15	0	0	1	0	0	Juvenile
Acanthurus chirurgus c4	4-18, 4-20	0	8	0	0	0	Adult
Acanthurus coeruleus c1	3	0	1	0	0	0	Recruit
Acanthurus coeruleus c3	3-12	0	1	0	1	1	Juvenile
Acanthurus coeruleus c4	17	0	0	1	0	0	Adult
Acanthurus tractus c1	2-5	2	0	0	0	0	Recruit
Acanthurus tractus c2	3-8, 10	2	0	2	0	0	Juvenile
Acanthurus tractus c3	11, 13, 15	0	0	2	1	0	Juvenile
Acanthurus tractus c4	16	0	0	0	1	0	Adult
Cephalopholis fulva c2	10	0	0	0	0	1	Juvenile
Cephalopholis fulva c3	15, 12	0	1	1	0	0	Juvenile
Cephalopholis fulva c4	2-20	0	2	0	0	0	Adult
Cephalopholis fulva c5	22	0	0	0	0	1	Adult
Cephalopholis fulva c6	26, 30, 2-28	1	0	0	2	1	Adult
Epinephelus guttatus c8	38	0	0	0	1	0	Adult
Lutjanus apodus c5	25	0	0	0	0	1	Adult
Lutjanus apodus c7	33	0	0	0	0	1	Adult
Ocyurus chrysurus c6	2-30	0	0	0	1	1	Adult
Scarus iseri c5	25	0	0	0	0	1	Adult
Scarus iseri c6	28, 30	0	0	0	2	0	Adult
Sparisoma aurofrenatum c2	6	0	0	0	1	0	Juvenile
Sparisoma aurofrenatum c5	24	0	0	1	0	0	Adult
Sparisoma chrysopterum c6	30	0	0	0	0	1	Adult
Sparisoma rubripinne c6	29	0	0	0	1	0	Adult
	Totals	5	13	8	11	9	

Photo Album 22. MARI10









2.0 Maria Grande 20m (MARI20)

2.1 Physical Description

MARI20 sits in the same shelf section as MARI10 roughly 1.6 km off Punta Las Marias and directly due north of the emergent rock reef known as Maria Grande (Figure 75). The seafloor is a mostly flat pavement with grooves and crevices filled with sand. Pavement was mostly colonized by benthic algae, sponges, erect soft corals, and encrusting biota, including zoanthids and live stony corals. MARI20 is essentially a mid-shelf reef located between the shoreline and the shelf-edge approximately 1.5 km further offshore. Transects were positioned along a string at depths in the 17.9m – 18.5m range. The baseline characterization of MARI20 was performed on August 14, 2025. Panoramic view of the MARI10 reef community are shown as Photo Album 23.

2.2 Sessile-Benthic Community

Reef substrate cover at MARI20 was dominated by an assemblage of benthic algae that included fleshy brown, turf, red coralline, crustose calcareous and fleshy macroalgae, with a combined mean cover of 50.90% (range: 32.26 – 66.46%; Table 68). Fleshy brown, y-twig alga (*Dictyota sp.*) were the dominant taxon with a mean cover of 43.56, representative of 85.6% of the total reef substrate cover by benthic algae. Red coralline algae (CCA, mixed assemblage) were intercepted by four transects with a mean cover of 1.01%. Red crustose calcareous (*Peyssonnelia* sp.), and fleshy macroalgae (*Gracilaria* sp.) were observed in small patches with a combined cover of 0.82%. Large patches of cyanobacterial (blue-green algae) growing over pavement, turf and fleshy brown algae were prominent in all transects with a mean cover of 26.48% (Figure 76).

Stony corals were represented by seven scleractinian species during the 2025 baseline survey at MARI20 with a combined mean cover of 9.12% (range 3.53 – 14.63%). Mustard-hill coral (*Porites astreoides*), greater starlet coral (*Siderastrea siderea*), and mountainous star coral (*Orbicella faveolata*) were the main coral species intercepted by transects with a combined reef substrate cover of 7.74%, representative of 84.9% of the total cover by stony corals (Table 68; Figure 77). A total of 23 stony coral colonies were intercepted by transects at MARI20 during the 2025 survey, none of which were observed to be affected by coral disease infections (Appendix 2).

Erect soft corals were present in low density at MARI20 (mean: 9.6 Colonies/Transect). Sea rods (*Eunicea flexuosa*, *Eunicea spp*.), and sea fans (*Gorgonia ventalina*) were prominent in transects. The encrusting gorgonian (*Erythropodium caribaeorum*) was intercepted by one transect with a mean cover of 0.18%. Sponges were represented in transects by 14 species with a combined mean cover of 8.27%. The giant barrel sponge (*Xestospongia muta*) was the most prominent with a mean cover of 6.32%, representative of 76.4% of the total sponge cover. Giant barrel sponges (*X. muta*) were observed growing in relatively large sizes with major contributions to the reef topographic relief and benthic habitat complexity.

Table 68. Percent reef substrate cover by sessile-benthic categories at MARI20, Carolina. PRCRMP 2025

MARI20			**Transects**			
Survey Date: 8/14/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	18.5	18.2	17.9	18.5	18.2	**18.26**
Rugosity (m)	1.24	2.12	1.10	1.28	1.77	**1.51**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	6.72	6.93	4.54	1.99	4.28	**4.89**
Total Abiotic	**6.72**	**6.93**	**4.54**	**1.99**	**4.28**	**4.89**
Benthic Algae						
Dictyota spp.	47.07	44.11	61.79	28.66	36.15	**43.56**
Turf (mixed) with sediment	10.46	2.66	2.65	2.48	4.04	**4.46**
Turf (mixed)	1.87	3.46				**1.07**
CCA (total)		1.15	1.13	0.74	2.02	**1.01**
Peyssonnelia spp.	1.62		0.25	0.37	1.19	**0.69**
Gracilaria spp.			0.63			**0.13**
Total Benthic Algae	**61.02**	**51.39**	**66.46**	**32.26**	**43.40**	**50.90**
Cyanobacteria	**19.18**	**20.09**	**17.28**	**50.87**	**24.97**	**26.48**
Stony Corals						
Porites astreoides		1.85		2.23	11.53	**3.12**
Siderastrea siderea	4.73	3.23		2.11	2.50	**2.51**
Orbicella faveolata	4.23			6.33		**2.11**
Montastraea cavernosa			3.28			**0.66**
Madracis decactis	0.62		0.25		0.59	**0.29**
Pseudodiploria strigosa				1.24		**0.25**
Stephanocoenia intersepta	0.75			0.12		**0.17**
Total Stony Corals	**10.34**	**5.08**	**3.53**	**12.03**	**14.63**	**9.12**
# Coral Colonies/Transect	**4**	**3**	**3**	**7**	**6**	**4.6**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Soft Corals						
Erythropodium caribaeorum		0.92				**0.18**
Eunicea spp.			0.50			**0.10**
Eunicea flexuosa					0.24	**0.05**
Total Soft Corals	**0.00**	**0.92**	**0.50**	**0.00**	**0.24**	**0.33**
# Erect Soft Corals/Transect	**4**	**1**	**5**	**2**	**2**	**2.8**
Sponges						
Xestospongia muta		13.39	5.04	2.48	10.70	**6.32**
Neopetrosia spp. smooth			1.39			**0.28**
Niphates caribica	1.25					**0.25**
Agelas dispar	0.37	0.23	0.50			**0.22**
Agelas clathrodes					1.07	**0.21**
Aplysina cauliformis	0.87					**0.17**
Sponge spp.	0.25			0.37		**0.12**
Clathria spp.		0.58				**0.12**
Verongula spp.			0.50			**0.10**
Niphates erecta			0.25		0.24	**0.10**
Neopetrosia proxima					0.48	**0.10**
Agelas spp.		0.46				**0.09**
Amphimedon compressa		0.46				**0.09**
Verongula reiswigi		0.46				**0.09**
Total Sponges	**2.74**	**15.59**	**7.69**	**2.85**	**12.49**	**8.27**

2.3 Fishes and Motile Megabenthic Invertebrates

A total of 30 fish species were identified within belt-transects at MARI20 during the 2025 baseline survey with a mean density of 64.6 Ind/30m^2, and a mean species richness of 17.4 Spp/30m^2 (Table 69). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 24.0 Ind/30m^2, representative of 37.2% of the total fish density. The blue chromis (*Chromis cyanea*), and the bicolor damselfish (*Stegastes partitus*) were observed in all five transects with mean densities of 10.2 Ind/30m^2 and 9.4 Ind/30m^2, representative of 15.8% and 14.6% of the total fish density, respectively. Motile megabenthic invertebrates were not observed within belt-transects.

The fish trophic structure at MARI20 was dominated by small opportunistic carnivores (SOC) with a combined abundance of 33.0 Ind/30m^2, representative of 51.1% of the total fish individuals within belt-transects. The assemblage was comprised by 19 species including wrasses (Labridae), grunts (Haemulidae), squirrelfishes (Holocentridae), seabasses (Serranidae), hawkfishes (Cirrhitidae), gobies (Gobiidae), goatfishes (Mullidae), and puffers (Tetraodontidae). Zooplanktivores (ZPL), were represented by two of the top three species in terms of mean density within belt-transects (*Chromis cyanea*, *Stegastes partitus*) with a combined density of 19.6 Ind/30m^2, representative of 30.3% of the total fish density. The herbivore (HER) assemblage included 11 species with a combined density of 7.4 Ind/30m^2, or 11.4% of the total individuals. The assemblage included three species of doctorfishes (Acanthuridae), five species of parrotfishes (Scaridae), and three species of damselfishes (Pomacentridae). Spongivores (Pomacanthidae), and corallivores (Chaetodontidae) were represented by two and one species, respectively with a combined density of 1.2 Ind/30m^2 (Table 69).

Medium and large carnivores included adult yellowtail snappers (*Ocyurus chrysurus*), one juvenile and two adult red hinds (*Epinephelus guttatus*), and both juvenile and adult coney groupers (*Cephalopholis cruentata*), juvenile bar jacks (*Caranx ruber*), one lionfish (*Pterois* sp), and one adult hogfish (*Lachnolaimus maximus*) with a combined density of 6.6 Ind/60m^2 (Table 70). The larger reef herbivores were represented by three species of doctorfishes (*Acanthurus* spp.), and four species of parrotfishes (*Scarus* spp., *Sparisoma* spp.) with combined densities of 3.2 Ind/60m^2 and 1.4 Ind/60m^2, respectively. Doctorfishes were present as both juvenile and adults, including recruitment juvenile stages of blue tangs (*A. coeruleus*). Parrotfishes were observed as both juvenile and adults, including terminal phase males of stoplight and princess parrotfishes (*Sparisoma viride, Scarus taeniopterus*).

Table 69. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at MARI20, Carolina. PRCRMP 2025

MARI20							
Survey Date: 8/14/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	25	18	27	39	11	**24.0**	SOC
Chromis cyanea	10	15	4	10	12	**10.2**	ZPL
Stegastes partitus	10	9	13	7	8	**9.4**	ZPL
Stegastes adustus	4	3				**1.4**	HER
Halichoeres maculipinna	2	1	3	1		**1.4**	SOC
Sparisoma aurofrenatum	2	1		1	2	**1.2**	HER
Halichoeres garnoti	4		2			**1.2**	SOC
Cephalopholis fulva		2	1	2	1	**1.2**	LC
Caranx ruber	2			2	1	**1.0**	LC
Acanthurus coeruleus	1	1	1		2	**1.0**	HER
Acanthurus tractus		1	1	3		**1.0**	HER
Stegastes leucostictus			2	2	1	**1.0**	HER
Ocyurus chrysurus	2				2	**0.8**	LC
Chaetodon capistratus		1	1	2		**0.8**	COR
Haemulon aurolineatum			1		2	**0.6**	SOC
Myripristis jacobus	2				1	**0.6**	SOC
Haemulon carbonarium	1		2			**0.6**	SOC
Bodianus rufus		1		1	1	**0.6**	SOC
Scarus iseri		3				**0.6**	HER
Haemulon flavolineatum			1	1	1	**0.6**	SOC
Serranus tigrinus			2	1		**0.6**	SOC
Amblycirrhitus pinos	1		1			**0.4**	SOC
Anisotremus virginicus	1			1		**0.4**	SOC
Elacatinus evelynae	1	1				**0.4**	SOC
Holocentrus rufus		1		1		**0.4**	SOC
Stegastes variabilis			2			**0.4**	HER
Scarus taeniopterus				1		**0.2**	HER
Acanthurus chirurgus				1		**0.2**	HER
Sparisoma rubripinne				1		**0.2**	HER
Pseudupeneus maculatus					1	**0.2**	SOC
Pterois volitans					1	**0.2**	LC
Haemulon plumierii	1					**0.2**	SOC
Halichoeres radiatus	1					**0.2**	SOC
Haemulon sciurus		1				**0.2**	SOC
Holacanthus tricolor		1				**0.2**	SPO
Pomacanthus arcuatus		1				**0.2**	SPO
Canthigaster rostrata		1				**0.2**	SOC
Sparisoma viride			1			**0.2**	HER
Epinephelus guttatus			1			**0.2**	LC
Holocentrus adscensionis			1			**0.2**	SOC
Density (Ind/30m2)	70	62	67	77	47	**64.6**	
Richness (Species/30m2)	17	18	19	18	15	**17.4**	

Table 70. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at MARI20, Carolina. PRCRMP 2025

MARI20							
Survey Date: 8/14/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c3	2-15	0	1	0	1	0	Juvenile
Acanthurus chirurgus c4	18	0	0	0	1	0	Adult
Acanthurus coeruleus c1	4	0	0	0	0	1	Recruit
Acanthurus coeruleus c2	10	0	0	0	0	1	Juvenile
Acanthurus coeruleus c3	15, 14, 12	1	1	1	0	0	Adult
Acanthurus tractus c2	2-9, 7, 2-10	0	1	2	2	0	Juvenile
Acanthurus tractus c3	5-15	2	0	1	0	2	Juvenile
Acanthurus tractus c4	4-16	0	3	0	1	0	Adult
Caranx ruber c2	10	0	0	0	0	1	Juvenile
Caranx ruber c4	2-18	2	0	0	0	0	Juvenile
Caranx ruber c3	2-15	0	0	0	2	0	Juvenile
Cephalopholis fulva c2	2-10, 8	0	1	0	2	0	Juvenile
Cephalopholis fulva c3	12, 15	0	1	1	0	0	Juvenile
Cephalopholis fulva c4	18, 20	0	1	0	0	1	Adult
Cephalopholis fulva c5	25	0	0	1	0	0	Adult
Cephalopholis fulva c6	28	1	0	0	0	0	Adult
Epinephelus guttatus c2	10	0	0	1	0	0	Juvenile
Epinephelus guttatus c6	28	0	0	0	1	0	Adult
Epinephelus guttatus c7	35	0	0	0	0	1	Adult
Lachnolaimus maximus c9	45	1	0	0	0	0	Adult
Ocyurus chrysurus c5	23, 25	0	0	0	0	2	Adult
Ocyurus chrysurus c6	2-30, 28	2	0	1	0	0	Adult
Pterois spp. c5	25	0	0	0	0	1	Adult
Scarus iseri c2	3-9	0	3	0	0	0	Juvenile
Scarus taeniopterus c2	10	0	0	0	1	0	Juvenile
Scarus taeniopterus c4	18	0	0	1	0	0	Adult
Scarus taeniopterus c5	25	1	0	0	0	0	Terminal
Sparisoma aurofrenatum c2	6, 2- 8, 7	1	1	0	1	1	Juvenile
Sparisoma aurofrenatum c3	14	0	0	0	0	1	Juvenile
Sparisoma aurofrenatum c5	22	1	0	0	0	0	Adult
Sparisoma rubripinne c5	25	0	0	0	1	0	Adult
Sparisoma rubripinne c7	32	1	0	0	0	0	Adult
Sparisoma viride c7	32, 33	0	0	1	0	1	Terminal
	Totals	**13**	**13**	**10**	**13**	**13**	

Photo Album 23. MARI20






3.0 Boca de Cangrejos 5m (CANG05)

3.1 Physical Description

Boca de Cangrejos is an estuarine mangrove inlet connected to the Isla Verde (Carolina) shelf that serves as a marina for yachts and fishermen boats. An intermittent ridge of emergent and submerged eolianite rock reefs run east – west roughly parallel to the coastline. Approximately 0.8 km off the Boca de Cangrejos inlet mouth there is a gap or "pasa" that allows boats to navigate from the marina and inshore waters to and from offshore waters. Breaker reefs at both ends of the gap are known as "El Jardin" on the West end, and "El Caballo" on the East end. Station CANG05 was established at "El Jardin" (Figure 75) in a colonized pavement habitat featuring an essentially flat reef top with large holes or gaps filled with sand. Transects were arranged in linear fashion over the pavement at depth in the 3.3m – 3.6m range. The baseline characterization of reef communities at CANG05 was performed on August 14, 2025. Panoramic views of the CANG05 reef community are included as Photo Album 24.

3.2 Sessile-Benthic Reef Community

Reef substrate cover at CANG05 was dominated by an assemblage of benthic algae that included turf algae, red crustose calcareous and coralline, and fleshy brown macroalgae with a combined mean cover of 80.87% (Figure 76). Turf algae, a mixed assemblage of short red and brown algae was the dominant algal component with a mean cover of 70.04%, representative of 86.6% of the total cover by benthic algae (Table 71). Crustose calcareous algae (mostly *Ramicrusta sp.*) were intercepted by all five transects with a mean cover of 9.57%, or 11.8% of the total benthic algae. Small tufts of fleshy brown algae (*Dictyota sp*.), and patches of red coralline algae (CCA) were present with a combined mean cover of 0.80%.

Stony corals were represented by three scleractinian species and one hydrocoral (*Millepora alcicornis*) during the 2025 baseline survey at CANG05 with a combined mean cover of 3.76% (range 2.04 – 4.85%). Mustard-hill coral (*Porites astreoides*) and symmetrical brain coral (*Pseudodiploria strigosa*) were the dominant species in terms of reef substrate cover with means of 1.55% and 1.18% (Table 71; Figure 77). Colonies of the aforementioned species were intercepted by all five transects. Knobby brain coral (*P. clivosa*) was intercepted by four transects with a mean cover of 0.93%. A total of 25 stony coral colonies were intercepted by transects at CANG05 during the 2025 baseline survey, none of which were observed to be affected by coral disease infections (Appendix 2).

Erect soft corals were the most prominent benthic assemblage at CANG05 with a mean density of 36.4 Colonies/Transect, which is the highest in the PRCRMP (Table 71). Although soft coral colonies were not quantified by species, it was visually evident that the wide-mesh sea fan (*Gorgonia mariae*) was the overwhelming dominant species with minor contributions of the common sea fan (*G. ventalina*), and sea rods (*Eunicea* spp.). The encrusting zoanthid (*Palythoa caribaeorum*) was intercepted by all five transects with a mean cover of 3.75%. Sponges were represented by four species with a combined mean cover of 1.47%. *Niphates amorpha* and *Ircinia spp.*, were the most prominent along transects with a combined cover of 1.02%.

Table 71. Percent reef substrate cover by sessile-benthic categories at CANG05, Carolina. PRCRMP 2025

CANG05			**Transects**			
Survey Date: 8/14/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	**3.6**	**3.6**	**3.3**	**3.3**	**3.3**	**3.42**
Rugosity (m)	0.58	0.67	2.42	2.35	1.94	**1.59**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	2.91	2.23	14.99	10.54	14.54	**9.04**
Total Abiotic	**2.91**	**2.23**	**14.99**	**10.54**	**14.54**	**9.04**
Benthic Algae						
Turf (mixed)	79.23	80.97	68.77	68.14	53.11	**70.04**
Ramicrusta spp.	8.47	4.86	5.07	9.41	17.47	**9.05**
Dictyota spp.	0.66	1.97	0.23	0.68		**0.71**
Peyssonnelia spp.	0.93	0.52		0.34	0.82	**0.52**
Turf (mixed) with sediment			2.25			**0.45**
CCA (total)			0.00	0.45		**0.09**
Total Benthic Algae	**89.29**	**88.32**	**76.32**	**79.02**	**71.40**	**80.87**
Stony Corals						
Porites astreoides	1.46	2.62	1.13	1.25	1.29	**1.55**
Pseudodiploria strigosa	1.98	0.00	1.80	0.34	1.76	**1.18**
Pseudodiploria clivosa		1.57	1.92	0.45	0.70	**0.93**
Millepora alcicornis	0.53					**0.11**
Total Stony Corals	**3.97**	**4.20**	**4.85**	**2.04**	**3.75**	**3.76**
# Coral Colonies/Transect	**4**	**7**	**6**	**4**	**4**	**5.0**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Zoanthids						
Palythoa caribaeorum	1.72	1.18	2.71	6	6.92	3.75
Soft Corals						
Gorgonia mariae	0.93	0.26	0.23	1.25	0.59	**0.65**
Gorgonia ventalina		1.05	0.23			**0.26**
Eunicea flexuosa		0.39			0.59	**0.20**
Total Soft Corals	**0.93**	**1.71**	**0.45**	**1.25**	**1.17**	**1.10**
# Erect Soft Coral Colonies/Transect	**32**	**40**	**45**	**35**	**30**	**36.4**
Sponges						
Niphates amorpha	1.19	0.52	0.45		0.59	**0.55**
Ircinia spp. brown		1.44		0.91		**0.47**
Neopetrosia spp. smooth					1.64	**0.33**
Sponge spp.		0.39	0.23			**0.12**
Total Sponges	**1.19**	**2.36**	**0.68**	**0.91**	**2.23**	**1.47**
Diseased Coral Colonies						
Porites astreoides	1					**0.20**
Siderastrea siderea					1	**0.20**

3.3 Fishes and Motile Megabenthic Invertebrates

A total of 29 fish species were identified within belt-transects at CANG05 during the 2025 baseline survey with a mean density of 47.0 Ind/30m^2, and a mean species richness of 14.4 Spp/30m^2 (Table 72). The bluehead wrasse (*Thalassoma bifasciatum*) and the dusky damselfish (Stegastes adustus) were the numerically dominant species with a combined mean density of 24.8 Ind/30m^2, representative of 52.8% of the total fish density. Slippery dick (*Halichoeres bivittatus*), yellowtail damselfish (*Microspathodon chrysurus*), and blue tang (*Acanthurus coeruleus*) were observed in all five transects with combined mean densities of 6.0 Ind/30m^2, representative of 12.8% of the total fish density, respectively. Motile megabenthic invertebrates were not observed within belt-transects during the 2025 baseline survey at CANG05.

The fish trophic structure at CANG05 was dominated by small opportunistic carnivores (SOC) and herbivores (HER). SOC presented a combined density of 22.6 Ind/30m^2, representative of 48.1% of the total fish individuals within belt-transects. The assemblage was comprised by 14 species including wrasses (Labridae), gobies (Gobiidae), grunts (Haemulidae), seabasses (Serranidae), puffers (Tetraodontidae), blennies (Blenniidae), and goatfishes (Mullidae). The herbivore (HER) assemblage included seven species with a combined density of 21.0 Ind/30m^2, or 44.7% of the total individuals. The assemblage included three species of doctorfishes (Acanthuridae), one parrotfish species (*Sparisoma rubripinne*), and three species of damselfishes (Pomacentridae). Zooplanktivores (ZPL), were represented by one species (*Abudefduf saxatilis*) with a mean density of 0.8 Ind/30m^2, representative of 1.7% of the total fish density. Spongivores (Pomacanthidae), and corallivores (Chaetodontidae) were represented by one and three species, respectively with a combined density of 1.6 Ind/30m^2 (Table 72).

Medium and large carnivores included juvenile bar jacks (*Caranx ruber*), adult coney groupers (*Cephalopholis cruentata*), and one adult schoolmaster snapper (*Lutjanus apodus*) with a combined density of 1.4 Ind/60m^2 (Table 73). The larger reef herbivores were largely represented by three species of doctorfishes (*Acanthurus* spp.) with combined densities of 9.0 Ind/60m^2, representative of 88.2% of the large herbivore assemblage. Doctorfishes density was strongly influenced by a large school of adult ocean surgeon (*A. tractus*). Parrotfishes were represented by one species (*Sparisoma rubripinne*) with a mean density of 1.2 Ind/60m^2. Doctorfishes were present as both juvenile and adults, including recruitment juvenile stages of blue tangs (*A. coeruleus*). Yellowtail parrotfishes (*S. rubripinne*) were observed as both juvenile and adults.

Table 72. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CANG05, Carolina. PRCRMP 2025

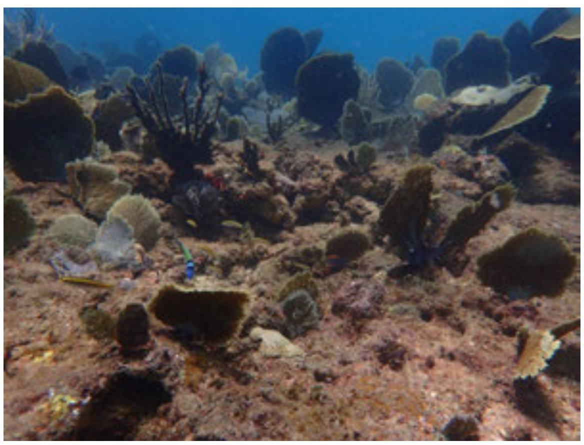
CANG05							
Survey Date: 8/14/25	Belt-Transects (3x10m)						Trophic
Species	T1	T2	T3	T4	T5	Mean	Level
Thalassoma bifasciatum	16	6	17	14	15	13.6	SOC
Stegastes adustus	13	11	10	9	13	11.2	HER
Acanthurus tractus	3	7	9		3	4.4	HER
Halichoeres bivittatus	1	2	1	3	4	2.2	SOC
Microspathodon chrysurus	1	1	2	3	4	2.2	HER
Acanthurus coeruleus	1	1	1	3	2	1.6	HER
Halichoeres maculipinna	2		3		2	1.4	SOC
Malacoctenus triangulatus	2		1	2	1	1.2	SOC
Haemulon chrysargyreum			1	4		1.0	SOC
Sparisoma rubripinne	1	1	1	1		0.8	HER
Abudefduf saxatilis			1	3		0.8	ZPL
Bodianus rufus		1		2		0.6	SOC
Canthigaster rostrata		1		1	1	0.6	SOC
Chaetodon capistratus		2			1	0.6	COR
Acanthurus chirurgus			1	1	1	0.6	HER
Haemulon flavolineatum			1	1	1	0.6	SOC
Chaetodon ocellatus	2					0.4	COR
Caranx ruber	2					0.4	LC
Halichoeres radiatus	1	1				0.4	SOC
Cephalopholis fulva			1	1		0.4	LC
Chaetodon striatus					2	0.4	COR
Ophioblennius atlanticus	1					0.2	SOC
Anisotremus virginicus	1					0.2	SOC
Pomacanthus paru	1					0.2	SPO
Haemulon plumierii	1					0.2	SOC
Labrisomus spp		1				0.2	SOC
Lutjanus apodus			1			0.2	LC
Stegastes variabilis			1			0.2	HER
Pseudupeneus maculatus					1	0.2	SOC
Density (Ind/30m2)	49	35	52	48	51	47.0	
Richness (Species/30m2)	16	12	16	14	14	14.4	

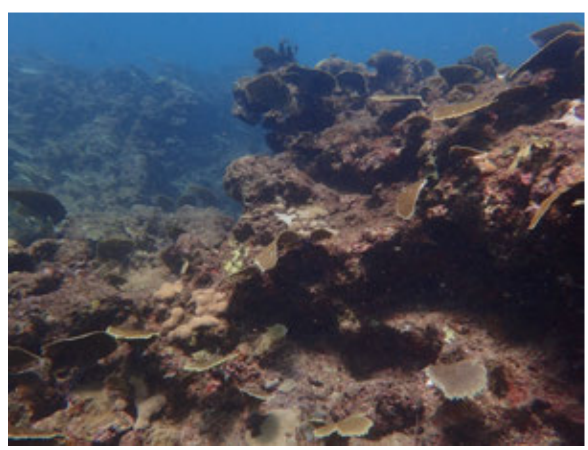
Table 73. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CANG05, Carolina. PRCRMP 2025

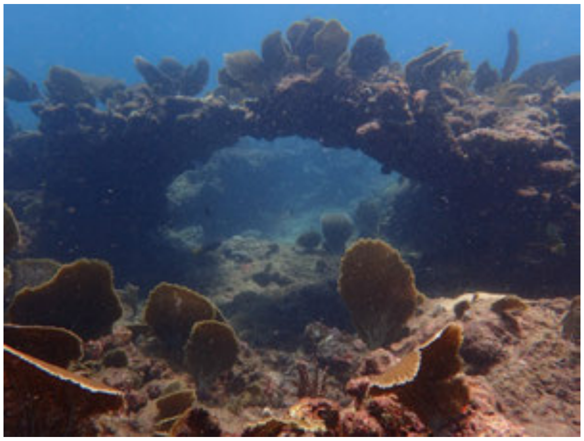
CANG05							
Survey Date: 8/14/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	10, 8	0	0	0	1	1	Juvenile
Acanthurus chirurgus c3	12	0	0	1	0	0	Juvenile
Acanthurus coeruleus c1	5	0	0	0	0	1	Recruit
Acanthurus coeruleus c2	4-8, 10, 7	1	1	0	3	1	Juvenile
Acanthurus coeruleus c3	15, 12	1	0	1	0	0	Juvenile
Acanthurus coeruleus c4	18	0	0	1	0	0	Adult
Acanthurus tractus c4	3-16, 2-18	0	0	0	1	2	Adult
Acanthurus tractus c2	6, 7, 7-10	3	3	3	0	0	Juvenile
Acanthurus tractus c3	14-12, 13, 3-15	3	7	7	0	1	Juvenile
Caranx ruber c3	2-12	2	0	0	0	0	Juvenile
Cephalopholis fulva c5	25	0	0	1	0	0	Adult
Cephalopholis fulva c6	2-30, 26	0	0	1	1	1	Adult
Lutjanus apodus c5	25	0	0	1	0	0	Adult
Sparisoma rubripinne c2	6, 7	0	1	0	1	0	Juvenile
Sparisoma rubripinne c3	15	0	0	0	1	0	Juvenile
Sparisoma rubripinne c4	20	0	0	1	0	0	Adult
Sparisoma rubripinne c6	30, 26	0	0	1	0	1	Adult
	Totals	**10**	**12**	**18**	**8**	**8**	

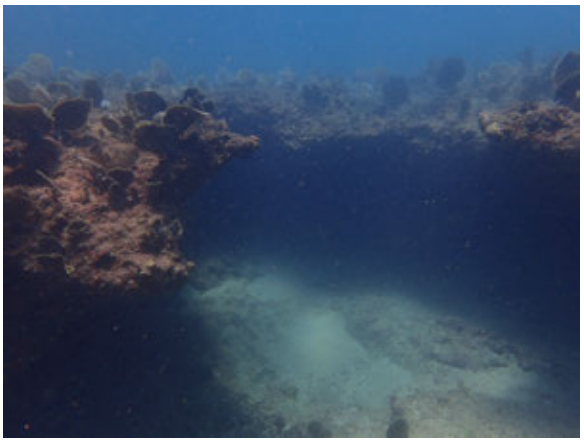
Photo Album 24. CANG05

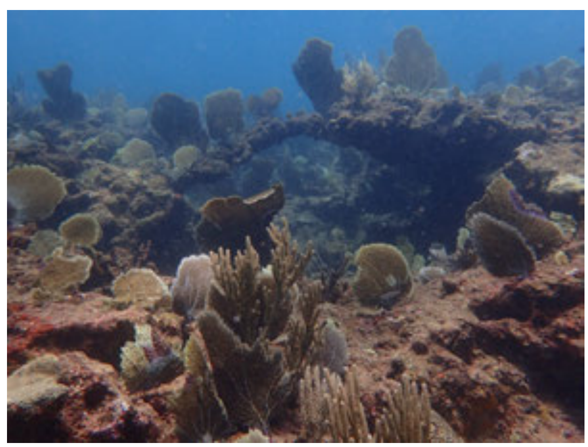










4.0 Boca de Cangrejos 10m (CANG10)

4.1 Physical Description

CANG10 is located approximately 1.75 km northwest off the Boca de Cangrejos inlet mouth, about 0.2 km north of CANG05 (Figure 75). The benthic habitat was characterized by a low relief pavement mostly colonized by benthic algae packed with fine sediments, with minor contributions of sponges and live stony corals growing mostly as encrusting colonies. Interspersed within the mostly flat seascape there were a series of small low relief (<1.5m) rocky outcrops that served for attachment of corals and sponges, and it is around these structures where most of the fish community was concentrated. The baseline characterization of CANG10 was performed on August 15, 2025. A string of five 10m long transects were established within a 9.7m – 12.7m depth range. Panoramic views of the reef community at CANG10 are shown as Photo Album 25.

4.2 Sessile-Benthic Reef Community

Reef substrate cover at CANG10 was dominated by an assemblage of benthic algae that included turf algae, fleshy brown, and red crustose calcareous algae with a combined mean cover of 86.51% (Figure 76). Turf algae, a mixed assemblage of short red and brown algae was the dominant algal component with a mean cover of 70.62%, representative of 81.6% of the total cover by benthic algae (Table 74). Tufts of fleshy brown y-twig alga (*Dictyota sp.*) were intercepted by all five transects with a mean cover of 15.12%, or 17.5% of the total benthic algae. Small patches of crustose calcareous algae (*Peyssonnelia* sp., *Ramicrusta sp.*) were present with a combined mean cover of 0.77%. Patches of cyanobacteria were intercepted by all five transects with a mean cover of 3.00% (Table 74).

Stony corals were represented by five scleractinian species during the 2025 baseline survey at CANG10 with a combined mean cover of 3.40% (range 1.99 – 5.63%). Symmetrical brain coral (*Pseudodiploria strigosa*) was the dominant species in terms of reef substrate cover with a mean of 1.75% (Table 74; Figure 77). Colonies of mustard-hill coral (*Porites astreoides*) were intercepted by four transects with a mean cover of 0.63%. Small encrusting colonies of knobby brain coral (*P. clivosa*), great star coral (*Montastraea cavernosa*), and greater starlet coral (*Siderastrea siderea*) were also intercepted with a combined cover of 1.01%. A total of 14 stony coral colonies were intercepted by transects at CANG10 during the 2025 baseline survey, none of which were observed to be affected by coral disease infections (Appendix 2).

A total of five erect soft corals were intercepted by transects at CANG10 with a mean density of 1.0 Colonies/Transect (Table 74). Erect and encrusting sponges were represented in transects by six species with a combined mean cover of 4.70%. The giant barrel sponge *(Xestospongia muta)* was the dominant species in terms of reef substrate cover with a mean of 2.02%, representative of 43.0% of the total cover by sponges and was the main sessile-benthic component contributing reef topographic relief and protective microhabitat for fishes. The encrusting colonial zoanthid (*Palythoa caribaeorum*) was present in two transects with a mean cover of 0.20%.

Table 74. Percent reef substrate cover by sessile-benthic categories at CANG10, Carolina. PRCRMP 2025

CANG10			**Transects**			
Survey Date: 8/15/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	8.8	9.1	9.1	8.5	8.5	**8.80**
Rugosity (m)	0.33	0.70	0.54	0.44	0.78	**0.56**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	0.68	5.63	1.99		0.78	**1.82**
Sand			0.66			**0.13**
Total Abiotic	**0.68**	**5.63**	**2.66**		**0.78**	**1.95**
Benthic Algae						
Turf (mixed) with sediment	59.62	63.87	75.17	79.89	74.55	**70.62**
Dictyota spp.	28.86	15.58	10.76	8.18	12.21	**15.12**
Peyssonnelia spp.	1.63	1.05				**0.53**
Ramicrusta spp.	0.41				0.78	**0.24**
Total Benthic Algae	**90.51**	**80.50**	**85.92**	**88.07**	**87.53**	**86.51**
Cyanobacteria	**3.39**	**2.49**	**5.71**	**0.67**	**2.73**	**3.00**
Stony Corals						
Pseudodiploria strigosa	1.36	0.92	1.46	2.28	2.73	**1.75**
Porites astreoides	0.54	1.18	0.53		0.91	**0.63**
Pseudodiploria clivosa				2.82		**0.56**
Montastraea cavernosa	1.08				0.39	**0.29**
Siderastrea siderea				0.54	0.26	**0.16**
Total Stony Corals	**2.98**	**2.09**	**1.99**	**5.63**	**4.29**	**3.40**
# Coral Colonies/Transect	**3**	**2**	**2**	**3**	**4**	**2.8**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Zoanthids						
Palythoa caribaeorum			1.46			**0.29**
Soft Corals						
Eunicea tourneforti	0.41	0.39				**0.16**
Total Soft Corals	**0.41**	**0.39**	**0.00**	**0.00**	**0.00**	**0.16**
# Erect Soft Coral Colonies/Transect	**1**	**1**	**2**	**0**	**1**	**1.0**
Sponges						
Xestospongia muta		6.02		2.41	1.69	**2.02**
Neopetrosia proxima	1.49	0.92	1.33	0.67	1.82	**1.24**
Sponge spp.	0.54	1.96	0.93	1.61	0.91	**1.19**
Ptilocaulis walpersii				0.54		**0.11**
Spirastrella coccinea				0.40		**0.08**
Scopalina ruetzleri					0.26	**0.05**
Total Sponges	**2.03**	**8.90**	**2.26**	**5.63**	**4.68**	**4.70**

4.3 Fishes and Motile Megabenthic Invertebrates

A total of 19 fish species were identified within belt-transects at CANG10 during the 2025 baseline survey with a mean density of 40.6 Ind/30m^2, and a mean species richness of 10.2 Spp/30m^2 (Table 75). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 18.0 Ind/30m^2, representative of 44.3% of the total fish density. The slippery dick and clown wrasses (*Halichoeres bivittatus, H. maculipinna*), bicolor damselfish (*Stegastes partitus*), and the coney (*Cephalopholis fulva*) were observed in all five belt-transects with a combined mean density of 11.8 Ind/30m^2, or 29.1% of the total fish density. One streaming school of blue runners (*Caranx crysos*) was observed over one belt-transect. Motile megabenthic invertebrates were represented within transects by one long spined urchin (*Diadema antillarum*) and one common octopus (*Octopus vulgaris*).

The fish trophic structure at CANG10 was strongly dominated by small opportunistic carnivores (SOC) comprised by nine species and a combined density of 25.8 Ind/30m^2, representative of 63.6% of the total fish individuals within belt-transects. The SOC assemblage included wrasses (Labridae), seabasses (Serranidae), squirrelfishes (Holocentridae), grunts (Haemulidae),and hawkfishes (Cirrhitidae). The herbivore (HER) assemblage included four species with a combined density of 5.2 Ind/30m^2, or 12.8% of the total individuals. The assemblage included two species of doctorfishes (*Acanthurus tractus, A, chirurgus*), and two species of damselfishes (*Stegastes adustus, S. variabilis*). In addition, one herbivore urchin (*Diadema antillarum*) was observed within belt-transects. Zooplanktivores (ZPL), were represented by one species (*S. partitus*) with a mean density of 3.6 Ind/30m^2, representative of 8.9% of the total fish density. Spongivores were represented by one species (*Holacanthus tricolor*), with a mean density of 0.2 Ind/30m^2 (Table 75).

Medium and large carnivores included a school of adult blue runners (*Caranx crysos*), one juvenile bar jack (*Caranx ruber*), a couple of adult cero mackerels (*Scomberomorus regalis*), juvenile and adult coneys (*Cephalopholis fulva*), one juvenile graysby (*C. cruentata*), and two adult yellowtail snappers (*Ocyurus chrysurus*) with a combined density of 8.0 Ind/60m^2, of which 62.5% were coastal pelagic, and 37.5% were demersal reef species (Table 76). The larger reef herbivores were only represented by doctorfishes (*Acanthurus* tractus, *A. chirurgus*) with a combined density of 5.2 Ind/60m^2. Doctorfishes were present as both juvenile and adults, including recruitment juvenile stages both *A. tractus* and *A. chirurgus*.

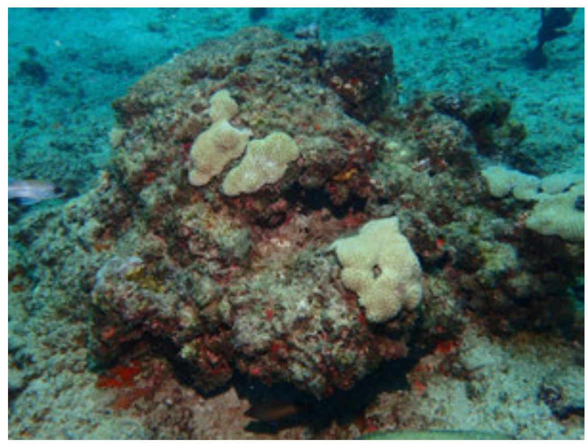
Table 75. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CANG10, Carolina. PRCRMP 2025

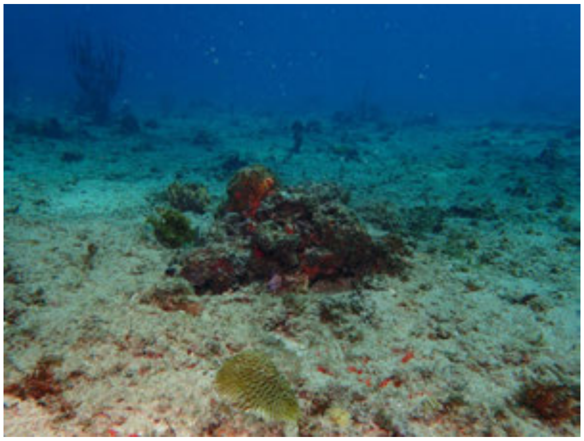
CANG10							
Survey Date: 8/15/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	14	28	15	12	21	**18.0**	SOC
Halichoeres bivittatus	5	2	4	3	6	**4.0**	SOC
Stegastes partitus	7	5	3	1	2	**3.6**	ZPL
Acanthurus tractus	3	6			3	**2.4**	HER
Caranx crysos	12					**2.4**	LC
Cephalopholis fulva	2	3	1	3	2	**2.2**	LC
Halichoeres maculipinna	2	1	2	3	2	**2.0**	SOC
Stegastes adustus	4			1	3	**1.6**	HER
Caranx ruber		4				**0.8**	LC
Acanthurus chirurgus		2	1		1	**0.8**	HER
Serranus baldwini			2	1		**0.6**	SOC
Scomberomorus regalis	1				1	**0.4**	LC
Holocentrus adscensionis		1			1	**0.4**	SOC
Stegastes variabilis		1	1			**0.4**	HER
Haemulon flavolineatum		1				**0.2**	SOC
Holacanthus tricolor		1				**0.2**	SPO
Holocentrus rufus			1			**0.2**	SOC
Serranus tigrinus				1		**0.2**	SOC
Amblycirrhitus pinos					1	**0.2**	SOC
Invertebrates							
Diadema antillarum		1				**0.2**	HER
Octopus vulgaris				1		**0.2**	SOC
Density (Ind/30m2)	50	55	30	25	43	**40.6**	
Richness (Species/30m2)	9	13	9	9	11	**10.2**	

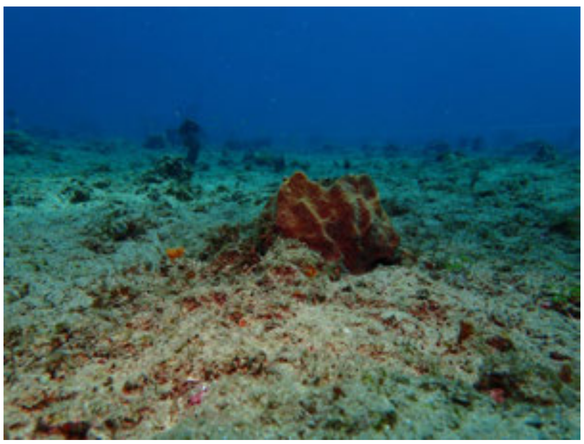
Table 76. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CANG10, Carolina. PRCRMP 2025

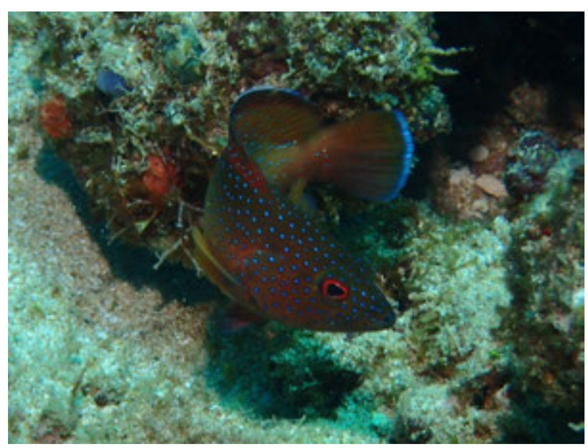
CANG10							
Survey Date: 8/15/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c1	2-5	0	0	2	0	0	Recruit
Acanthurus chirurgus c2	7, 10	0	0	1	0	1	Juvenile
Acanthurus chirurgus c4	2-18, 17	0	3	0	0	0	Adult
Acanthurus tractus c1	3-5	1	0	0	0	2	Recruit
Acanthurus tractus c2	6, 9-8, 7, 10	3	8	0	0	1	Juvenile
Acanthurus tractus c3	3-15, 12	0	0	3	1	0	Juvenile
Caranx crysos c6	22-30	22	0	0	0	0	Adult
Caranx ruber c3	12	0	4	0	0	0	Juvenile
Cephalopholis cruentata c3	12	1	0	0	0	0	Juvenile
Cephalopholis fulva c1	5	0	0	0	1	0	Recruit
Cephalopholis fulva c2	2-8, 6, 2-10	1	0	1	2	1	Juvenile
Cephalopholis fulva c3	2-12, 15	0	1	0	1	1	Juvenile
Cephalopholis fulva c4	20	1	0	0	0	0	Adult
Cephalopholis fulva c5	25	0	1	0	0	0	Adult
Cephalopholis fulva c6	30	0	1	0	0	0	Adult
Ocyurus chrysurus c7	35	0	0	1	0	0	Adult
Ocyurus chrysurus c8	38	0	0	1	0	0	Adult
Scomberomorus regalis c10	46, 50	1	0	0	0	1	Adult
	Totals	**30**	**18**	**9**	**5**	**7**	

Photo Album 25. CANG10









5.0 Boca de Cangrejos 15m (CANG15)

5.1 Physical Description

CANG15 was surveyed on the outer shelf off Boca de Cangrejos approximately 2.3 km off the shoreline, and about 0.7 km offshore from the emergent rock reef ridge marked by breakers mid-shelf. The benthic habitat was characterized by a flat pavement colonized by benthic algae packed with fine sediments. Topographic relief was mostly contributed by scattered rock outcrops and giant barrel sponges (*Xestospongia muta*). Cracks and crevices interspaced in the pavement contributed to the substrate heterogeneity. Transects were set over the pavement habitat along a string in the 15.8m – 17.3m depth range. The baseline characterization of CANG15 was performed on August 14, 2025. Panoramic views of the reef community at CANG15 is shown in Photo Album 26.

5.2 Sessile-Benthic Reef Community

Reddish cyanobacterial mats growing over pavement (and perhaps turf algae) were the dominant component of reef substrate cover at CANG15 during the 2025 baseline survey with a mean cover of 50.60% (Figure 76). Cyanobacterial patches are typically of short duration and seasonally associated to summer periods of low wave and surge energy and also observed to colonize recently dead stony corals. Benthic algae, comprised by an assemblage of fleshy brown, turf, and crustose calcareous algae were intercepted by all five transects with a combined mean cover of 35.53%. Fleshy brown y-twig alga (*Dictyota* sp.) was the main component with a mean cover of 20.42%, representative of 57.5% of the total benthic algae (Table 77). Turf algae (mixed assemblage) was intercepted by all five transects with a mean cover of 12.62%, or 35.5% of the total benthic algae. Small patches of crustose calcareous algae (*Peyssonnelia* sp., *Ramicrusta sp.*) were present with a combined mean cover of 0.52%.

Stony corals were represented by five scleractinian species during the 2025 baseline survey at CANG15 with a combined mean cover of 3.89% (range 2.42 – 6.11%). Mustard-hill coral (*Porites astreoides*) and greater starlet coral (*Siderastrea siderea*) were the most prominent species intercepted by three transects each, with mean substrate cover of 1.23% and 0.95%, respectively (Table 74; Figure 77). Small encrusting colonies of symmetrical brain coral (*Pseudodiploria strigosa*) and tufts of ten-ray star coral (*Madracis decactis*) were present with a combined cover of 1.37%. A total of 21 stony coral colonies were intercepted by transects at CANG15 during the 2025 baseline survey, including two (1-*P. astreoides*, 1-*S. siderea*) affected by coral disease infections (coral disease prevalence: 9.52%; see Appendix 2).

Erect soft corals were very sparsely distributed at CANG15 with a mean density of 0.2 Colonies/Transect (Table 77). Erect and encrusting sponges were represented in transects by eight species with a combined mean cover of 6.12%. The giant barrel sponge *(Xestospongia muta)* was the dominant species in terms of reef substrate cover with a mean of 4.64%, representative of 75.8% of the total cover by sponges and was the main sessile-benthic component contributing reef topographic relief and protective microhabitat for fishes at CANG15.

Table 77. Percent reef substrate cover by sessile-benthic categories at CANG15, Carolina. PRCRMP 2025

CANG15			**Transects**			
Survey Date: 8/14/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	17.3	15.8	16.4	16.4	16.1	**16.40**
Rugosity (m)	0.42	1.00	0.40	0.75	0.96	**0.71**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	7.26	2.67		1.56	3.96	**3.09**
Sand					3.83	**0.77**
Total Abiotic	**7.26**	**2.67**	**0.00**	**1.56**	**7.79**	**3.86**
Benthic Algae						
Dictyota spp.	5.65	18.32	4.31	47.40	26.44	**20.42**
Turf (mixed) with sediment	8.06	18.58	17.63	10.94	7.41	**12.52**
Macroalgae spp.					8.81	**1.76**
CCA (total)		0.51			0.51	**0.20**
Ramicrusta spp.				0.78		**0.16**
Turf (mixed)		0.51				**0.10**
Peyssonnelia spp.			0.54		1.28	**0.36**
Total Benthic Algae	**13.71**	**37.91**	**22.48**	**59.11**	**44.44**	**35.53**
Cyanobacteria	**72.04**	**46.56**	**66.89**	**30.21**	**37.29**	**50.60**
Stony Corals						
Porites astreoides	1.61	1.40		3.13		**1.23**
Siderastrea siderea		2.67	0.27		1.79	**0.95**
Pseudodiploria strigosa	1.48		2.15			**0.73**
Madracis decactis		2.04			1.15	**0.64**
Montastraea cavernosa					1.79	**0.36**
Total Stony Corals	**3.09**	**6.11**	**2.42**	**3.13**	**4.73**	**3.89**
# Coral Colonies/Transect	3	5	3	5	5	**4.20**
# Diseased Coral Colonies/Transect	1	0	0	0	1	**0.40**
# Erect Soft Coral Colonies/Transect	1	0	0	0	0	**0.20**
Sponges						
Xestospongia muta	3.90	6.36	7.54	2.08	3.32	**4.64**
Neopetrosia proxima				1.43	1.79	**0.64**
Clathria spp.				0.78	0.64	**0.28**
Sponge spp.		0.38	0.13	0.52		**0.21**
Mycale laevis			0.54			**0.11**
Niphates digitalis				0.52		**0.10**
Aplysina cauliformis				0.39		**0.08**
Niphates erecta				0.26		**0.05**
Total Sponges	**3.90**	**6.74**	**8.21**	**5.99**	**5.75**	**6.12**

5.3 Fishes and Motile Megabenthic Invertebrates

A total of 27 fish species were identified within belt-transects at CANG20 during the 2025 baseline survey with a mean density of 49.0 Ind/30m^2, and a mean species richness of 11.6 Spp/30m^2 (Table 78). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 22.0 Ind/30m^2, representative of 44.9% of the total fish density. The bicolor damselfish (*Stegastes partitus*), and the coney (*Cephalopholis fulva*) were observed in all five belt-transects with a combined mean density of 12.8 Ind/30m^2, or 26.1% of the total fish density. One streaming school of bar jacks (*Caranx ruber*) was observed over two belt-transects with a mean density of 2.4 Ind/30m^2. Motile megabenthic invertebrates were not observed within belt-transects at CANG20.

The fish trophic structure at CANG20 was strongly dominated by small opportunistic carnivores (SOC) comprised by 14 species and a combined density of 29.0 Ind/30m^2, representative of 59.2% of the total fish individuals within belt-transects. The SOC assemblage included wrasses (Labridae), seabasses (Serranidae), squirrelfishes (Holocentridae), puffers (Tetraodontidae), gobies (Gobiidae), hawkfishes (Cirrhitidae), and grunts (Haemulidae). Zooplanktivores (ZPL), were represented by two species (*S. partitus, M. niger*) with a mean density of 10.4 Ind/30m^2, representative of 21.2% of the total fish density. The herbivore (HER) assemblage included five species with a combined density of 3.2 Ind/30m^2, or 6.5% of the total individuals. The assemblage included two species of doctorfishes (*Acanthurus tractus, A, chirurgus*), one damselfish (*Stegastes adustus*), and two parrotfish species (*Sparisoma aurofrenatum, S. chrysopterum*) Spongivores were represented by three species (*Holacanthus tricolor, Cantherhines pullus, Pomacanthus paru*), with a mean density of 0.6 Ind/30m^2 (Table 78).

Medium and large carnivores included a school of juvenile bar jacks (*Caranx ruber*), one juvenile bar jack (*Caranx ruber*), a couple of adult cero mackerels (*Scomberomorus regalis*), juvenile and adult coneys (*Cephalopholis fulva*), two adult red hinds (*Epinephelus guttatus*) and two adult yellowtail snappers (*Ocyurus chrysurus*) with a combined density of 6.6 Ind/60m^2, of which 36.4% were coastal pelagic (bar jacks), and 63.6% were demersal reef species (Table 78). The larger reef herbivores were represented by doctorfishes (*Acanthurus* tractus, *A. chirurgus*) with a combined density of 3.6 Ind/60m^2, and parrotfishes (Sparisoma aurofrenatum, S. chrysopterum) with a combined density of 1.0 Ind/60m^2. Doctorfishes and parrotfishes were observed as both juvenile and adults.

Table 78. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at CANG20, Carolina. PRCRMP 2025

CANG20							
Survey Date: 8/14/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	22	35	22	11	20	**22.0**	SOC
Stegastes partitus	20	15	8	6	3	**10.4**	ZPL
Cephalopholis fulva	2	5	1	2	2	**2.4**	LC
Caranx ruber	8	4				**2.4**	LC
Halichoeres bivittatus	1		4	3		**1.6**	SOC
Serranus baldwini			3	3	2	**1.6**	SOC
Acanthurus tractus		2		4	1	**1.4**	HER
Holocentrus rufus	1	1			2	**0.8**	SOC
Serranus tigrinus	1	1	1			**0.6**	SOC
Canthigaster rostrata	1	1			1	**0.6**	SOC
Sparisoma aurofrenatum	1	2				**0.6**	HER
Acanthurus chirurgus	1		1	1		**0.6**	HER
Ocyurus chrysurus	2					**0.4**	LC
Sparisoma chrysopterum		1	1			**0.4**	HER
Halichoeres maculipinna			1	1		**0.4**	SOC
Melichthys niger	1				2	**0.6**	ZPL
Halichoeres garnoti	1					**0.2**	SOC
Elacatinus evelynae	1					**0.2**	SOC
Holacanthus tricolor		1				**0.2**	SPO
Amblycirrhitus pinos		1				**0.2**	SOC
Bodianus rufus		1				**0.2**	SOC
Holocentrus adscensionis		1				**0.2**	SOC
Stegastes adustus			1			**0.2**	HER
Cantherhines pullus				1		**0.2**	SPO
Anisotremus virginicus					1	**0.2**	SOC
Pomacanthus paru					1	**0.2**	SPO
Halichoeres bivittatus					1	**0.2**	SOC
Density (Ind/30m2)	63	71	43	32	36	**49.0**	
Richness (Species/30m2)	14	14	10	9	11	**11.6**	

Table 79. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at CANG20, Carolina. PRCRMP 2025

CANG20							
Survey Date: 8/14/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	7, 8	0	0	1	1	0	Juvenile
Acanthurus chirurgus c3	13, 12	1	0	0	1	0	Juvenile
Acanthurus coeruleus c4	18, 17	1	0	0	1	0	Adult
Acanthurus tractus c2	10, 3-9	0	0	1	3	0	Juvenile
Acanthurus tractus c3	3-12, 2-13, 14	0	2	0	1	3	Juvenile
Acanthurus tractus c4	2-16	0	2	0	0	0	Adult
Caranx ruber c3	12-15	8	4	0	0	0	Juvenile
Cephalopholis fulva c2	2-8, 10	0	2	0	0	1	Juvenile
Cephalopholis fulva c3	2-14, 3-12, 2-15, 13	1	3	1	2	1	Juvenile
Cephalopholis fulva c5	23, 22, 24	1	0	0	0	2	Adult
Cephalopholis fulva c6	30	0	0	0	0	1	Adult
Cephalopholis fulva c7	32	1	0	0	0	0	Adult
Epinephelus guttatus c7	35	1	0	0	0	0	Adult
Epinephelus guttatus c9	45	0	1	0	0	0	Adult
Ocyurus chrysurus c6	28, 30	2	0	0	0	0	Adult
Ocyurus chrysurus c8	40	1	0	0	0	0	Adult
Sparisoma aurofrenatum c2	8, 7, 6	1	2	0	0	0	Juvenile
Sparisoma chrysopterum c6	2-26	0	1	1	0	0	Adult
	Totals	**18**	**17**	**4**	**9**	**8**	

Photo Album 26. CANG15






6.0 El Escambrón 5m (ESCA05)

6.1 Physical Description

The San Juan coastline is characterized by an intermittent ridge of emergent and submerged rock reefs that run essentially parallel to the shoreline. The reefs are of sedimentary origin (aeolianites), mostly cemented sand dunes drowned by sea level increments after a previous glaciation event. El Escambrón is a section of the coastline off the east end of the San Juan islet. ESCA05 is located at approximately 0.6 km off the shoreline due north of Piedra La Ocho a well-known local surf spot (Figure 75). The seafloor is characterized by a series of large rocks separated by sand pools. Transects were set on top of these rocks at depths in the 3.9 – 5.8m range. The baseline characterization of ESCA05 was performed on August 15, 2025. Panoramic views of the reef community at ESCA05 is included as Photo Album 27.

6.2 Sessile-Benthic Reef Community

Reef substrate cover at ESCA05 was dominated by an assemblage of benthic algae that included turf, fleshy brown, red crustose calcareous and coralline algae, with a combined mean cover of 68.19% (Figure 76). Turf algae, a mixed assemblage of short red and brown algae was the dominant component of benthic algae with a mean cover of 56.08%, representative of 82.2% of the total cover by benthic algae (Table 80). Fleshy brown algae, mostly y-twig alga (*Dictyota sp.*), with minor contributions from unidentified brown macroalgae were intercepted by all five transects with a combined mean cover of 10.31%, or 15.1% of the total benthic algae. Y-twig algae was observed growing over turf algae in many sections, perhaps as a transitory (seasonal) condition associated with the relatively low summer wave action. Crustose calcareous algae (*Peyssonnelia* sp.), and coralline algae (CCA, mixed) were intercepted with low substrate cover (combined mean: 0.93%).

Stony corals were represented by four scleractinian species during the 2025 baseline survey at ESCA05 with a combined mean cover of 6.39% (range 5.07 – 7.52%). Symmetrical brain and knobby brain corals (Pseudodiploria strigosa, P. clivosa) were the most prominent stony corals intercepted by five and four transects, respectively with a combined mean reef substrate cover of 5.38%, representative of 84.2% of the total cover by stony corals (Table 80; Figure 77). One small encrusting colony of elkhorn coral (*Acropora palmata*) was intercepted by one transect with a mean cover of 0.22%. Standing dead colonies of staghorn and elkhorn corals (*A. palmata*, *A. cervicornis*) were observed outside transects. A total of 33 stony coral colonies were intercepted by transects at ESCA05 during the 2025 survey, none of which were observed to be affected by coral disease infections (Appendix 2).

Erect soft corals were moderately abundant at ESCA05 with a mean density of 8.2 Colonies/Transect (Table 80). Taxonomic identifications of erect soft corals were not performed in the 2025 survey, but sea rods (*Eunicea spp*.), and wide-mesh sea fans (*Gorgonia mariae*) were prominent in transects. Relatively large patches of the encrusting zoanthid (*Palythoa caribaeorum*) were intercepted by all five transects with a mean substrate cover of 9.45%. Sponges were not prominent at ESCA05 represented in transects by only two species (*Verongula reiswigi, Xestospongia muta*) with a combined mean cover of 0.80%. Reef overhangs, largely of sedimentary origin associated with substrate gaps created by rock promontories were the main contributor of abiotic cover with a mean of 14.53% (table 80).

Table 80. Percent reef substrate cover by sessile-benthic categories at ESCA05, San Juan. PRCRMP 2025

ESCA05			Transects			
Survey Date: 8/15/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	5.8	5.2	4.5	4.5	3.9	**4.78**
Rugosity (m)	3.76	1.17	1.93	4.15	1.61	**2.52**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	11.29	6.89	8.80	20.08	25.57	**14.53**
Gaps/Holes					0.97	**0.19**
Total Abiotic	**11.29**	**6.89**	**8.80**	**20.08**	**26.54**	**14.72**
Benthic Algae						
Turf (mixed) with sediment	60.94	54.01	56.22	45.40	27.74	**48.86**
Dictyota spp.	5.60	12.78	21.36	7.82	3.98	**10.31**
Turf (mixed)	1.02				35.10	**7.22**
Peyssonnelia spp.	2.75		0.94		0.60	**0.86**
Macroalgae spp.		4.26				**0.85**
CCA (total)	0.41					**0.08**
Total Benthic Algae	**70.70**	**71.05**	**78.52**	**53.22**	**67.43**	**68.19**
Stony Corals						
Pseudodiploria strigosa	1.93	5.26	2.11	4.65	1.81	**3.15**
Pseudodiploria clivosa	1.32		3.99	2.57	3.26	**2.23**
Porites astreoides	2.64	1.00		0.30		**0.79**
Acropora palmata	1.12					**0.22**
Total Stony Corals	**7.02**	**6.27**	**6.10**	**7.52**	**5.07**	**6.39**
# Coral Colonies/Transect	**8**	**7**	**7**	**7**	**4**	**6.6**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Zoanthids						
Palythoa caribaeorum	**10.38**	**13.41**	**3.52**	**19**	**0.97**	**9.45**
Soft Corals						
Eunicea flexuosa		0.50	1.29			**0.36**
Gorgonia mariae			0.23	0.20		**0.09**
Total Soft Corals		**0.50**	**1.53**	**0.20**		**0.44**
# Erect Soft Coral Colonies/Transect	**9**	**11**	**7**	**6**	**8**	**8.2**
Sponges						
Verongula reiswigi	0.61	0.63	1.53			**0.55**
Xestospongia muta		1.25				**0.25**
Total Sponges	**0.61**	**1.88**	**1.53**	**0.00**	**0.00**	**0.80**

6.3 Fishes and Motile Megabenthic Invertebrates

A total of 38 fish species were identified within belt-transects at ESCA05 during the 2025 baseline survey with a mean density of 84.8 Ind/30m^2, and a mean species richness of 19.0 Spp/30m^2 (Table 81). The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 31.0 Ind/30m^2, representative of 36.6% of the total fish density. Streaming schools of bar jacks (*Caranx ruber*) were observed in four transects with a mean density of 11.8 Ind/30m^2, or 13.9% of the total individuals. Dusky damselfish (*Stegastes adustus*), ocean surgeon (*Acanthurus tractus*), coney (*Cephalopholis fulva*), and yellowtail parrotfish (*Sparisoma rubripinne*) were observed in all five transects with a combined density of 15.4 Ind/30m^2, representative of 18.2% of the total fish density. Schools of blue tangs (*A. coeruleus*) were also present with a mean density of 3.6 Ind/30m^2. Motile megabenthic invertebrates were not observed within belt-transects.

The fish trophic structure at ESCA05 was strongly dominated by small opportunistic carnivores (SOC) comprised by 18 species and a combined density of 42.8 Ind/30m^2, representative of 50.5% of the total fish individuals within belt-transects. The SOC assemblage included wrasses (Labridae), grunts (Haemulidae), goatfishes (Mullidae), blennies (Blenniidae), squirrelfishes (Holocentridae), puffers (Tetraodontidae), Trumpetfishes (Aulostomidae), and croakers (Sciaenidae). The herbivore (HER) assemblage included six species with a combined density of 18.4 Ind/30m^2, or 21.7% of the total individuals. The assemblage included two species of doctorfishes (*Acanthurus tractus, A, chirurgus*), one damselfish (*Stegastes adustus*), and three species of parrotfishes (*Sparisoma rubripinne, S. viride, Scarus taeniopterus*). Zooplanktivores (ZPL), were represented by five species with a mean density of 5.8 Ind/30m^2, representative of 6.8% of the total fish density. The ZPL assemblage included three damselfishes (Pomacentridae), one triggerfish (Balistidae), and one chub (Kyphosidae). Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by three and one species, respectively with a combined density of 1.8 Ind/30m^2 (Table 81).

Medium and large coastal pelagic carnivores included a large school of juvenile and adult bar jacks (*Caranx ruber*) with a mean density of 12.0 Ind/60m^2. Reef demersal species included juvenile and adult coneys (*Cephalopholis fulva*), and adult schoolmaster, grey, and yellowtail snappers (*Lutjanus apodus, L. griseus, Ocyurus chrysurus*) with a combined density of 5.8 Ind/60m^2 (Table 82). The larger reef herbivores were represented by juvenile and adult doctorfishes (*Acanthurus* tractus, *A. chirurgus*), including recruitment stages of *A. coeruleus* and

A. tractus with a combined density of 8.8 Ind/60m^2. Parrotfishes were represented by juvenile and adults of *Sparisoma viride, S. rubripinne*, and *Scarus taeniopterus* with a combined density of 4.6 Ind/60m^2.

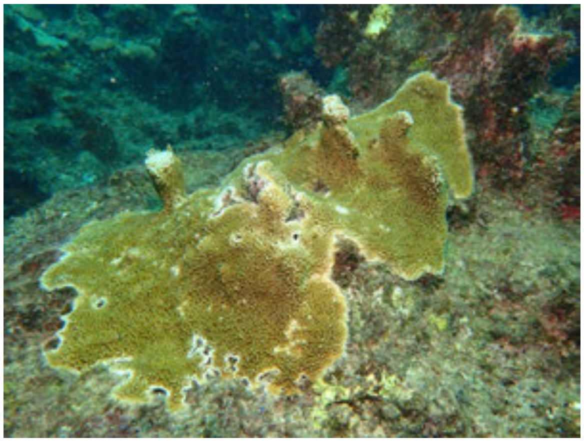
Table 81. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at ESCA05, San Juan. PRCRMP 2025

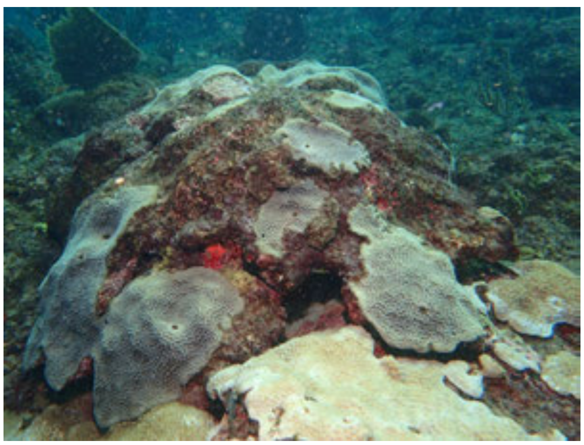
ESCA05							
Survey Date: 8/15/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	26	43	35	19	32	**31.0**	SOC
Caranx ruber	12		2	15	30	**11.8**	LC
Stegastes adustus	7	10	11	9	7	**8.8**	HER
Acanthurus coeruleus	2		1	3	12	**3.6**	HER
Acanthurus tractus	4	5	2	1	3	**3.0**	HER
Abudefduf saxatilis	2		6	1	2	**2.2**	ZPL
Cephalopholis fulva	3	2	3	1	1	**2.0**	LC
Anisotremus virginicus		2	7		1	**2.0**	SOC
Kyphosus bermudensis	1		2		6	**1.8**	ZPL
Sparisoma rubripinne	1	1	2	1	3	**1.6**	HER
Haemulon carbonarium		3	2		2	**1.4**	SOC
Bodianus rufus	2	1		1	2	**1.2**	SOC
Haemulon flavolineatum			4		2	**1.2**	SOC
Melichthys niger		1		1	3	**1.0**	ZPL
Mulloidichthys martinicus				3	2	**1.0**	SOC
Ocyurus chrysurus	2	1			2	**1.0**	LC
Lutjanus apodus			2	1	2	**1.0**	LC
Sparisoma viride	1		1	2		**0.8**	HER
Chaetodon capistratus	2				2	**0.8**	COR
Ophioblennius atlanticus				1	3	**0.8**	SOC
Holocentrus adsencionis	1			2	1	**0.8**	SOC
Scarus taeniopterus		2			1	**0.6**	HER
Myripristis jacobus		1		2		**0.6**	SOC
Canthigaster rostrata		1		2		**0.6**	SOC
Stegastes partitus	2	1				**0.6**	ZPL
Chaetodon striatus			2			**0.4**	COR
Chaetodon ocellatus				2		**0.4**	COR
Pseudopeneus maculatus	1				1	**0.4**	SOC
Aulostomus maculatus			2			**0.4**	SOC
Anisotremus surinamensis				2		**0.4**	SOC
Chromis cyanea				1		**0.2**	ZPL
Halichoeres bivittatus				1		**0.2**	SOC
Haemulon macrostomum				1		**0.2**	SOC
Haemulon plumieri				1		**0.2**	SOC
Lutjanus griseus		1				**0.2**	LC
Halichoeres garnoti			1			**0.2**	SOC
Cantherhines macrocerus				1		**0.2**	SPO
Odontoscion denyex		1				**0.2**	SOC
Density (Ind/30m2)	69	76	85	74	120	**84.8**	
Richness (Species/30m2)	16	16	17	24	22	**19.0**	

Table 82. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at ESCA05, San Juan. PRCRMP 2025

ESCA05							
Survey Date: 8/15/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c1	5	0	0	1	0	0	Recruit
Acanthurus coeruleus c2	2-8, 10	1	0	0	2	0	Juvenile
Acanthurus coeruleus c3	9-12, 10-15	0	0	0	7	12	Adult
Acanthurus coeruleus c4	2-16, 17	1	0	2	0	0	Adult
Acanthurus tractus c1	2-5	2	0	0	0	0	Recruit
Acanthurus tractus c2	7, 9, 4-10	1	2	2	1		Juvenile
Acanthurus tractus c3	3-12, 14, 2-15	1	2	0	0	3	Adult
Acanthurus tractus c4	3-16	0	1	0	2	0	Adult
Caranx ruber c3	57-12	12	0	0	15	30	Juvenile
Caranx ruber c5	28, 30	0	0	2	0	0	Adult
Caranx ruber c8	38	0	1	0	0	0	Adult
Cephalopholis fulva c1	5	0	0	0	0	1	Recruit
Cephalopholis fulva c2	8, 2-10	1	1	0	1	0	Juvenile
Cephalopholis fulva c3	2-12, 15	1	1	0	1	0	Juvenile
Cephalopholis fulva c6	2-28, 3-30	1	0	1	2	1	Adult
Lutjanus apodus c4	18, 20	0	0	1	1	0	Juvenile
Lutjanus apodus c5	4-25	1	0	1	0	2	Adult
Lutjanus apodus c7	35	0	1	0	0	0	Adult
Lutjanus griseus c6	28	0	1	0	0	0	Adult
Ocyurus chrysurus c4	3-18, 2-20	2	1	0	2	0	Adult
Ocyurus chrysurus c5	2-25	0	0	0	0	2	Adult
Ocyurus chrysurus c7	33, 35	0	0	1	1	0	Adult
Scarus taeniopterus c2	2-10	0	2	0	0	0	Juvenile
Scarus taeniopterus c5	20	0	0	0	0	1	Adult
Sparisoma rubripinne c2	8, 10	0	0	2	0	0	Juvenile
Sparisoma rubripinne c4	18, 20	1	0	0	1	0	Adult
Sparisoma rubripinne c5	24	0	1	0	0	0	Adult
Sparisoma rubripinne c6	26, 2-28, 3-30	0	1	2	1	2	Adult
Sparisoma rubripinne c7	3-32, 33, 35	0	2	0	2	1	Adult
Sparisoma viride c3	2-15	1	0	1	0	0	Juvenile
Sparisoma viride c5	24	0	0	0	1	0	Adult
Sparisoma viride c6	30	0	0	0	1	0	Adult
	Totals	**26**	**17**	**16**	**41**	**55**	

Photo Album 27. ESCA05





7.0 El Escambrón 10m (ESCA10)

7.1 Physical Description

ESCA10 is located approximately 0.7 km due north of Piedra La Ocho on the eastern corner of the San Juan islet and offshore contiguous to ESCA05 (Figure 75). The seafloor has a section where large rocks rise from a sandy bottom at depths of 12 - 13m with a reef top at 8 - 9m, and a section of a mostly flat pavement densely colonized by soft corals (gorgonians) and sponges at a depth of 8 - 9m. Transects were set along that transition with transects 1 - 2 on the flat pavement, and transects 3 - 5 over the top of the large aggregated rocks. The baseline characterization of ESCA10 was performed on August 15, 2025. Panoramic views of the reef community at ESCA10 are shown as Appendix 28.

7.2 Sessile-Benthic Reef Community

Reef substrate cover at ESCA10 was dominated by large patches of cyanobacteria (blue-green algae), intermixed with an assemblage of benthic algae that included turf algae, fleshy brown, and red crustose calcareous and coralline algae (Figure 76). Cover by cyanobacterial mats averaged 37.15% along transects, whereas the combined benthic algal assemblage averaged a reef substrate cover of 35.10% (Table 83). Turf algae, a mixed assemblage of short red and brown algae growing as a carpet over hard ground was the main component of the benthic algal assemblage with a mean cover of 25.99%, representative of 74.0% of the total benthic algae. Fleshy brown, y-twig alga (*Dictyota sp.*) were intercepted by all five transects with a mean cover of 8.27%, or 23.6% of the total benthic algae. Red crustose calcareous and coralline algae (*Peyssonnelia* sp., CCA mixed) were present with relatively lower reef substrate cover (< 1%).

Stony corals were represented by eight scleractinian species and one hydrocoral (*Millepora alcicornis*) during the 2025 baseline survey at ESCA10 with a combined mean cover of 5.75% (range 2.57 – 7.26%). Mountainous star coral (*Orbicella faveolata*) was the dominant species with a mean reef substrate cover of 2.03%, representative of 35.3% of the total cover by stony corals (Table 83; Figure 77). Great star coral (*Montastraea cavernosa*) and symmetrical brain coral (*Pseudodiploria strigosa*) were intercepted by two and four transects, respectively with substrate cover means of 1.05%, and 0.72%, respectively. Standing dead colonies of elkhorn coral (*Acropora palmata*), and other brain corals (*Pseudodiploria* spp.) were observed outside transects. A total of 23 stony coral colonies were intercepted by transects at ESCA10 during the 2025 survey, including one (1-*Siderastrea siderea*,) apparently affected by infectious coral disease(s), resulting in a coral disease prevalence of 4.35% (Appendix 2).

Table 83. Percent reef substrate cover by sessile-benthic categories at ESCA10, San Juan. PRCRMP 2025

ESCA10			Transects			
Survey Date: 8/15/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	9.1	9.1	9.7	9.4	8.5	**9.16**
Rugosity (m)	0.21	0.88	2.15	4.10	3.83	**2.23**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	3.29	1.29	8.64	20.95	17.81	**10.40**
Total Abiotic	**3.29**	**1.29**	**8.64**	**20.95**	**17.81**	**10.40**
Benthic Algae						
Turf (mixed) with sediment	8.64	35.14	32.83	32.87	13.46	**24.59**
Dictyota spp.	4.12	1.29	1.73	16.19	18.02	**8.27**
Turf (mixed)				3.48	3.54	**1.40**
Peyssonnelia spp.	0.27	0.39	0.81	0.20	1.21	**0.58**
CCA (total)	0.41	0.90				**0.26**
Total Benthic Algae	**13.44**	**37.71**	**35.37**	**52.73**	**36.23**	**35.10**
Cyanobacteria	**62.69**	**48.26**	**42.51**	**11.02**	**21.26**	**37.15**
Stony Corals						
Orbicella faveolata	2.74		4.61	2.78		**2.03**
Montastraea cavernosa				1.19	4.05	**1.05**
Pseudodiploria strigosa		1.29	0.81	0.60	0.91	**0.72**
Siderastrea siderea	1.51			0.99		**0.50**
Porites astreoides		0.39	0.58	0.40	0.71	**0.41**
Millepora alcicornis	1.65					**0.33**
Madracis decactis					1.42	**0.28**
Pseudodiploria clivosa			1.27			**0.25**
Stephanocoenia intersepta		0.90				**0.18**
Total Stony Corals	**5.90**	**2.57**	**7.26**	**5.96**	**7.09**	**5.75**
# Coral Colonies/Transect	**2**	**4**	**5**	**7**	**5**	**4.60**
# Diseased Corals/Transect	**1**	**0**	**0**	**0**	**0**	**0.20**
Zoanthids						
Palythoa caribaeorum	**6.04**	**2.32**	**5.41**	**4**	**11.64**	**5.92**
Soft Corals						
Erythropodium caribaeorum	5.76		0.58		0.40	**1.35**
Eunicea flexuosa	0.82				0.20	**0.21**
Eunicea spp.		0.51				**0.10**
Total Soft Corals	**6.58**	**0.51**	**0.58**		**0.61**	**1.66**
# Erect Soft Coral Colonies/Transect	**15**	**17**	**10**	**8**	**11**	**12.2**
Sponges						
Xestospongia muta		3.35		0.70	1.21	**1.05**
Neopetrosia proxima			0.23	0.99	2.02	**0.65**
Neopetrosia spp. smooth		2.19			1.01	**0.64**
Sponge spp.	0.69			0.50	0.61	**0.36**
Verongula reiswigi				1.69		**0.34**
Aplysina insularis	0.82	0.51				**0.27**
Verongula spp.		1.29				**0.26**
Spirastrella coccinea				0.99		**0.20**
Callyspongia vaginalis	0.55					**0.11**
Niphates erecta					0.30	**0.06**
Agelas citrina				0.30		**0.06**
Aplysina cauliformis					0.20	**0.04**
Total Sponges	**2.06**	**7.34**	**0.23**	**5.16**	**5.36**	**4.03**
Diseased Coral Colonies						
Siderastrea siderea	1					**0.20**

Erect soft corals were moderately abundant at ESCA10 with a mean density of 12.2 Colonies/Transect (Table 83). Taxonomic identifications of erect soft corals were not performed in the 2025 survey, but sea rods (*Eunicea flexuosa, Eunicea spp*.), and sea fans (*Gorgonia mariae, G. ventalina*) were prominent within and outside transects (particularly in the flat pavement benthic habitat (transects 1 and 2). The encrusting gorgonian (*Erythropodium caribaeorum*) was intercepted by three transects with a mean cover of 1.35%. The encrusting zoanthid (*Palythoa caribaeorum*) was intersected by all five transects with a mean cover of 5.92%. Erect and encrusting sponges were represented in transects by 12 species with a combined mean cover of 4.03%. The giant barrel sponge *(Xestospongia muta)* was the most prominent along transects with a mean cover of 1.05%.

Abiotic cover averaged 10.40% along transects at ESCA10 associated with reef overhangs of sedimentary origin produced by discontinuities of rock formations that appear to be broken sections of drowned eolianite rocks.

7.3 Fishes and Motile Megabenthic Invertebrates

A total of 40 fish species were identified within belt-transects at ESCA10 during the 2025 baseline survey with a mean density of 106.4 Ind/30m^2, and a mean species richness of 17.2 Spp/30m^2 (Table 84). The most specious fish assemblage was observed from the rock reef habitat where fish species richness ranged from 19 – 21 Spp/30m^2, as compared to the pavement section where richness was 12 Spp/30m^2. The bar jack (*Caranx ruber*) and the bluehead wrasse (*Thalassoma bifasciatum*) were the numerically dominant species with mean densities of 35.2 Ind/30m^2 and 34.2 Ind/30m^2, respectively. Their combined density represented 65.2% of the total individuals within belt-transects. The density of *C. ruber* was influenced by a large school of 140 individuals that penetrated T-4, and a smaller school that transitioned mid-water over T-2. Bluehead wrasses (*T. bifasciatum*) were also observed in several schooling aggregations but close to the reef substrate. One school of 22 porgies (*Anisotremus virginicus*) was observed streaming over T-3 with a mean density of 5.4 Ind/30m^2. Another schooling aggregation of chubs (*Kyphosus sectatrix*) was observed mid-water over the rock reef habitat. The dusky damselfish (*Stegastes adustus*) and the ocean surgeon (*Acanthurus tractus*) were observed in all five transects with a combined density of 4.2 Ind/30m^2. Motile megabenthic invertebrates were not observed within belt-transects.

Table 84. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at ESCA10, San Juan. PRCRMP 2025

ESCA10							
Survey Date: 8/15/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Caranx ruber	1	28	4	140	3	**35.2**	LC
Thalassoma bifasciatum	42	49	15	9	56	**34.2**	SOC
Anisotremus virginicus		1	22	4		**5.4**	SOC
Kyphosus sectatrix			14	1		**3.0**	ZPL
Acanthurus tractus	3	1	1	3	3	**2.2**	HER
Stegastes partitus		5		5	1	**2.2**	ZPL
Stegastes adustus	2	3	2	1	2	**2.0**	HER
Sparisoma rubripinne	2		2		4	**1.6**	HER
Cephalopholis fulva	2	2	1		2	**1.4**	LC
Ocyurus chrysurus	3	3		1		**1.4**	LC
Haemulon flavolineatum			3	4		**1.4**	SOC
Acanthurus coeruleus			3	1	2	**1.2**	HER
Lutjanus apodus			5	1		**1.2**	LC
Haemulon carbonarium			6			**1.2**	SOC
Scarus taeniopterus				6		**1.2**	HER
Elacatinus evelynae				6		**1.2**	SOC
Abudefduf saxatilis			1	2	2	**1.0**	ZPL
Bodianus rufus	1		2	1		**0.8**	SOC
Canthigaster rostrata	1	2			1	**0.8**	SOC
Haemulon plumierii			2	2		**0.8**	SOC
Halichoeres bivittatus	1	1		1		**0.6**	SOC
Chaetodon capistratus	2				1	**0.6**	COR
Pomacanthus paru			3			**0.6**	SPO
Sparisoma viride			2		1	**0.6**	HER
Mulloidichthys martinicus				3		**0.6**	SOC
Sparisoma aurofrenatum	2					**0.4**	HER
Pomacanthus arcuatus			1	1		**0.4**	SPO
Melichthys niger			1		1	**0.4**	ZPL
Holocentrus adscensionis			1		1	**0.4**	SOC
Chaetodon ocellatus					2	**0.4**	COR
Aulostomus maculatus		1				**0.2**	SOC
Stegastes variabilis		1				**0.2**	HER
Haemulon macrostomum			1			**0.2**	SOC
Holocentrus rufus				1		**0.2**	SOC
Odontoscion dentex				1		**0.2**	SOC
Myripristis jacobus				1		**0.2**	SOC
Abudefduf taurus					1	**0.2**	ZPL
Chromis cyanea					1	**0.2**	ZPL
Gerres cinereus					1	**0.2**	SOC
Haemulon aurolineatum					1	**0.2**	SOC
Density (Ind/30m2)	62	97	92	195	86	**106.4**	
Richness (Species/30m2)	12	12	21	22	19	**17.2**	

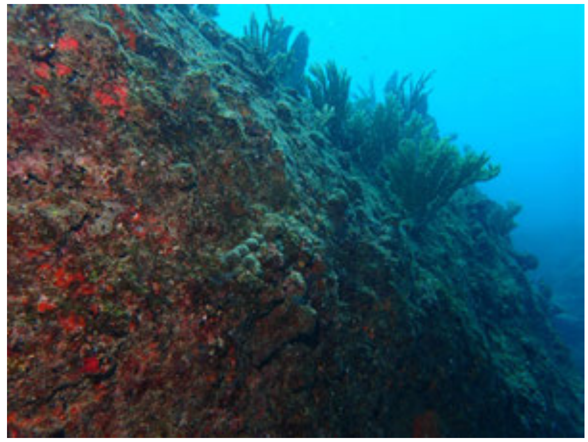
The fish trophic structure at ESCA10 was strongly dominated by small opportunistic carnivores (SOC) comprised by 18 species and a combined density of 48.8 Ind/30m^2, representative of 45.9% of the total fish individuals within belt-transects. The SOC assemblage included wrasses (Labridae), grunts (Haemulidae), gobies (Gobiidae), puffers (Tetraodontidae), goatfishes (Mullidae), squirrelfishes (Holocentridae), Trumpetfishes (Aulostomidae), croakers (Sciaenidae), and mojarras (Gerreidae). The herbivore (HER) assemblage included eight species with a combined density of 9.4 Ind/30m^2, representative of 8.8% of the total individuals. The assemblage included two species of doctorfishes (*Acanthurus tractus, A, chirurgus*), two damselfishes (*Stegastes adustus, S. variabilis*), and four species of parrotfishes (*Sparisoma rubripinne, S. viride, S. aurofrenatum, Scarus taeniopterus*). Zooplanktivores (ZPL), were represented by six species with a mean density of 7.0 Ind/30m^2, representative of 6.6% of the total fish density. The ZPL assemblage included four damselfishes (Pomacentridae), one triggerfish (Balistidae), and one chub (Kyphosidae). Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by two species, each with a combined density of 2.0 Ind/30m^2 (Table 84).

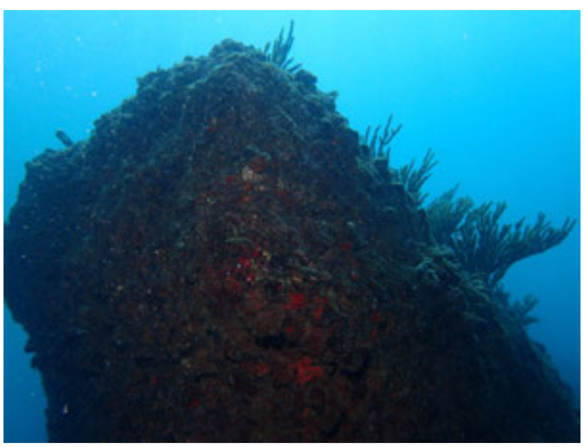
Medium and large coastal pelagic carnivores included a large school of juvenile bar jacks (*Caranx ruber*) in the 12 – 15cm total length range with a mean density of 35.8 Ind/60m^2. Demersal reef species included juvenile and adult coneys (*Cephalopholis fulva*), juvenile and adult schoolmaster snappers (*Lutjanus apodus*), adult yellowtail and grey snappers (*Ocyurus chrysurus, L. griseus*), and adult lionfish (*Pterois* sp.) with a combined density of 6.0 Ind/60m^2 (Table 85). The larger reef herbivores were represented by juvenile and adult doctorfishes (*Acanthurus* tractus, *A. chirurgus*), with a combined density of 4.0 Ind/60m^2. Parrotfishes were represented by juvenile and adults of stoplight parrotfish (*Sparisoma viride*), adult stages of yellowtail parrotfish (*S. rubripinne*), and juvenile stages of princess and redband parrotfishes (*Scarus taeniopterus, s. aurofrenatum)* with a combined density of 4.2 Ind/60m^2.

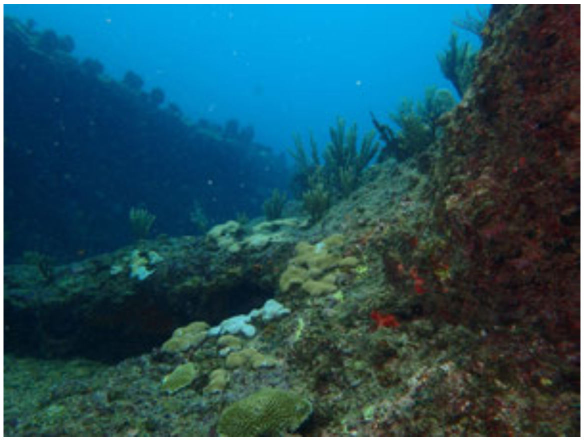
Table 85. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at ESCA10, San Juan. PRCRMP 2025

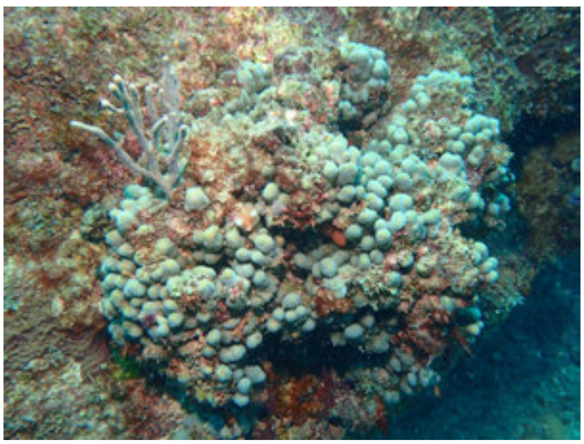
ESCA10							
Survey Date: 8/15/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus coeruleus c2	10	0	0	0	0	1	Juvenile
Acanthurus coeruleus c3	3-15, 13	0	0	2	1	1	Adult
Acanthurus coeruleus c4	16, 18	0	0	2	0	0	Adult
Acanthurus tractus c2	3-10, 3-8	1	1	0	2	2	Juvenile
Acanthurus tractus c3	2-13, 11, 2-12, 14, 15	4	0	0	2	1	Juvenile
Caranx ruber c3	151-12, 28-15	1	28	4	143	3	Juvenile
Cephalopholis fulva c2	8, 7	1	1	0	0	0	Juvenile
Cephalopholis fulva c3	15	1	0	0	0	0	Adult
Cephalopholis fulva c4	20, 18	0	0	0	0	2	Adult
Cephalopholis fulva c5	3-23	0	1	2	0	0	Adult
Cephalopholis fulva c6	29, 30	0	0	0	0	2	Adult
Lutjanus apodus c3	3-15	0	0	3	0	0	Juvenile
Lutjanus apodus c4	16	0	0	1	0	0	Juvenile
Lutjanus apodus c5	4-25	0	2	2	0	0	Adult
Lutjanus apodus c6	26	0	0	0	1	0	Adult
Lutjanus griseus c5	25	0	1	0	0	0	Adult
Ocyurus chrysurus c4	18, 20	0	1	0	0	1	Adult
Ocyurus chrysurus c5	25	0	1	0	0	0	Adult
Ocyurus chrysurus c6	30, 27	0	1	0	1	0	Adult
Ocyurus chrysurus c7	4-35	3	0	0	0	1	Adult
Pterois spp. c6	28	0	0	1	0	0	Adult
Scarus taeniopterus c2	4-6, 9, 10	0	0	0	6	0	Juvenile
Sparisoma aurofrenatum c1	2-5	2	0	0	0	0	Recruit
Sparisoma rubripinne c5	22, 23	0	0	0	0	2	Adult
Sparisoma rubripinne c6	3-30, 26	1	1	1	0	1	Adult
Sparisoma rubripinne c7	32, 33, 34, 35	1	1	0	1	1	Adult
Sparisoma viride c3	13	0	0	1	0	0	Juvenile
Sparisoma viride c5	25	0	0	0	0	1	Adult
Sparisoma viride c6	26	0	0	1	0	0	Adult
	Totals	**15**	**39**	**20**	**157**	**19**	

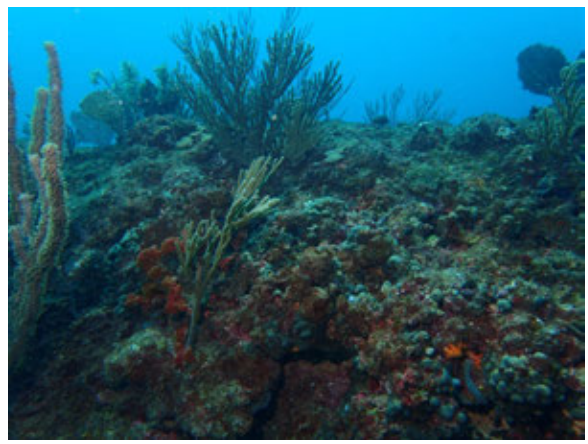
Photo Album 28. ESCA10











8.0 El Escambrón 20m (ESCA20)

8.1 Physical Description

ESCA20 is located at approximately 2.3 km offshore from the shoreline due north of Piedra La Ocho on the eastern section of the San Juan islet. The benthic habitat was characterized by a mostly flat sloping pavement largely colonized by benthic algae and few encrusting corals and sponges. Highly irregular rock outcrops with holes and crevices were observed interspersed within the pavement habitat where most of the fish were concentrated. Two of the transects (T 1 - 2) were set over the rock outcrops at depths of 17.6 – 17.9m, and three transects (T 3 - 5) were set over the pavement habitat at depths of 15.8 – 17.6m. The baseline characterization of ESCA20 was performed on August 15, 2025. Panoramic views of the reef community at ESCA20 are shown in Photo Album 29.

8.2 Sessile-Benthic Reef Community

Reef substrate cover at ESCA20 was largely dominated by large patches of reddish slimy cyanobacteria (blue-green algae) growing over turf and other benthic algae colonizing the pavement hard ground (Figure 76). Cyanobacterial patches prevailed as the dominant benthic cover on all five transects with a mean cover of 65.58% (range: 55.22% - 82.38%) (Table 86). Turf algae, a mixed assemblage of short red and brown algae growing as a carpet over hard ground was the main component of the benthic algae with a mean cover of 12.53%, representative of 76.4% of the total reef substrate cover by benthic algae. Fleshy brown, y-twig alga (*Dictyota sp.*), and red crustose calcareous algae (*Peyssonnelia* sp.) were intercepted by five and four transects, respectively with a combined cover of 3.87%.

Stony corals were represented by eight scleractinian species during the 2025 baseline survey at ESCA20 with a combined mean cover of 5.65% (range 1.04 – 14.23%). Great star coral (*Montastraea cavernosa*), symmetrical brain coral (*Pseudodiploria strigosa*), and mustard-hill coral (*Porites astreoides*) were the dominant species with a combined mean reef substrate cover of 4.58%, representative of 81.1% of the total cover by stony corals (Table 86; Figure 77). Stony corals were observed growing encrusted over the pavement and rocky outcrops with minor contributions to the reef topographic relief. A total of 24 stony coral colonies were intercepted by transects at ESCA20 during the 2025 baseline survey, none of which were observed to be affected by coral disease infections (Appendix 2).

Table 86. Percent reef substrate cover by sessile-benthic categories at ESCA20, San Juan. PRCRMP 2025

ESCA20			**Transects**			
Survey Date: 8/15/25	**1**	**2**	**3**	**4**	**5**	**Mean**
Depth (m)	17.9	17.6	17.6	16.4	15.8	**17.06**
Rugosity (m)	3.82	1.19	0.81	0.43	1.00	**1.45**
BENTHIC CATEGORIES						
Abiotic						
Reef overhang	14.89	9.14	2.46		4.20	**6.14**
Gaps/Holes	0.30					**0.06**
Total Abiotic	**15.20**	**9.14**	**2.46**		**4.20**	**6.20**
Benthic Algae						
Turf (mixed) with sediment	2.84	11.89	6.99	7.79	13.99	**8.70**
Turf (mixed)	3.95	8.01		3.62	3.56	**3.83**
Dictyota spp.	2.43	2.00	6.61	1.34	2.80	**3.04**
Peyssonnelia spp.	1.01	0.88		1.61	0.64	**0.83**
Total Benthic Algae	**10.23**	**22.78**	**13.60**	**14.36**	**20.99**	**16.39**
Cyanobacteria	**59.27**	**62.95**	**82.38**	**68.05**	**55.22**	**65.58**
Stony Corals						
Montastraea cavernosa	0.41	2.25	0.26	2.68	3.94	**1.91**
Pseudodiploria strigosa				7.92		**1.58**
Porites astreoides	0.30			3.62	1.53	**1.09**
Madracis decactis	2.43	0.50				**0.59**
Stephanocoenia intersepta			0.78			**0.16**
Siderastrea siderea					0.64	**0.13**
Orbicella faveolata	0.61					**0.12**
Meandrina meandrites		0.38				**0.08**
Total Stony Corals	**3.75**	**3.13**	**1.04**	**14.23**	**6.11**	**5.65**
# Coral Colonies/Transect	**5**	**3**	**2**	**7**	**7**	**4.8**
# Diseased Coral Colonies/Transect	**0**	**0**	**0**	**0**	**0**	**0.0**
Zoanthids						
Palythoa caribaeorum	**0.00**	**0.50**	**0.00**	**0.00**	**0.00**	**0.10**
Soft Corals						
Erythropodium caribaeorum	0.51					**0.10**
Total Soft Corals	**0.51**	**0.00**	**0.00**	**0.00**	**0.00**	**0.1**
# Erect Soft Coral Colonies/Transect	**0**	**0**	**0**	**4**	**1**	**1.0**
Sponges						
Xestospongia muta	7.90				6.74	**2.93**
Halisarca caerulea		1.50			2.80	**0.86**
Sponge spp.	0.71			2.15	1.02	**0.77**
Neopetrosia proxima				0.94	1.65	**0.52**
Niphates erecta	1.72					**0.34**
Niphates caribica			0.26		0.76	**0.20**
Smenospongia aurea	0.71					**0.14**
Spirastrella coccinea					0.51	**0.10**
Scopalina ruetzleri				0.27		**0.05**
Spheciospongia vesparium			0.26			**0.05**
Total Sponges	**11.04**	**1.50**	**0.52**	**3.36**	**13.49**	**5.98**

Erect and encrusting sponges were represented in transects by 10 species with a combined mean cover of 5.98%. The giant barrel sponge (*Xestospongia muta*) was the most prominent with a mean reef substrate cover of 2.93%, representative of 49.0% of the total cover by sponges. Giant barrel sponges were the main biotic component contributing to the reef topographic relief and benthic habitat complexity at ESCA20, particularly in the flat pavement habitat mostly colonized by cyanobacteria and benthic algae. The encrusting colonial zoanthid (*Palythoa caribaeorum*), and the encrusting gorgonian (*Erythropodium caribaeorum*) were intercepted by one transect each, with a combined mean cover of 0.20%. Erect soft corals (gorgonians) were present in low densities at ESCA20 (mean: of 1.0 Colonies/Transect). Abiotic cover was largely associated with substrate discontinuities, such as reef overhangs and gaps on rocky outcrops of sedimentary origin with a mean cover of 6.20% (Table 86).

8.3 Fishes and Motile Megabenthic Invertebrates

A total of 41 fish species were identified within belt-transects at ESCA20 during the 2025 baseline survey with a mean density of 61.4 Ind/30m^2, and a mean species richness of 15.8 Spp/30m^2 (Table 87). The most specious fish assemblage was observed from the rocky outcrop habitat (T 1-2) where fish species richness averaged 22.0 Spp/30m^2, as compared to the pavement section (T 3-5) where richness averaged 11.7 Spp/30m^2. The bluehead wrasse (*Thalassoma bifasciatum*) was the numerically dominant species with a mean density of 25.0 Ind/30m^2, representative of 40.7% of the total fish density. Bluehead wrasse was observed in all five transects forming schooling aggregations close to the reef substrate. Schooling aggregations of blue chromis (*Chromis cyanea*) were observed as swarms of juvenile and adults swarming over the rock outcrop transects 1-2, resulting in a mean density of 6.8 Ind/30m^2, representative of 11.1% of the total individuals. The bicolor damselfish (*Stegastes partitus*) was observed more evenly distributed across all five belt transects with a mean density of 6.0 Ind/30m^2. Five species of grunts (Haemulidae) were observed associated with the rock outcrop habitats with a combined density of 4.4 Ind/30m^2. Motile megabenthic invertebrates were represented by one long spine urchin (*Diadema antillarum*) within belt-transects.

The fish trophic structure at ESCA20 was strongly dominated by small opportunistic carnivores (SOC) comprised by 21 species and a combined density of 37.4 Ind/30m^2, representative of 60.9% of the total fish individuals within belt-transects. The SOC assemblage included wrasses (Labridae), grunts (Haemulidae), squirrelfishes (Holocentridae), puffers (Tetraodontidae), goatfishes (Mullidae), seabasses (Serranidae), hawkfishes (Cirrhitidae), glasseyes (Priacanthidae), and blennies (Blenniidae). Zooplanktivores (ZPL), were represented by three species with a combined mean density of 13.4 Ind/30m^2, representative of 21.8% of the total fish density. The ZPL assemblage included two species of damselfishes (*Chromis cyanea, Stegastes partitus*), and one triggerfish (*Melichthys niger*). The herbivore (HER) assemblage included six species with a combined density of 5.2 Ind/30m^2, representative of 8.5% of the total individuals. The HER assemblage included three species of doctorfishes (*Acanthurus tractus, A, chirurgus, A. coeruleus*), two damselfishes (*Stegastes adustus, S. leucostictus*), and one parrotfish (*Sparisoma aurofrenatum*). One long-spined urchin (*Diadema antillarum*) also contributed to the HER assemblage. Corallivores (Chaetodontidae) and spongivores (Pomacanthidae) were represented by two and three species, respectively with a combined density of 1.6 Ind/30m^2 (Table 87).

Medium and large coastal pelagic carnivores included a large school of juvenile bar jacks (*Caranx ruber*) in the 12 – 15cm total length range with a mean density of 35.8 Ind/60m^2. Demersal reef species included juvenile and adult coneys (*Cephalopholis fulva*), juvenile and adult schoolmaster snappers (*Lutjanus apodus*), adult yellowtail and grey snappers (*Ocyurus chrysurus, L. griseus*), and adult lionfish (*Pterois* sp.) with a combined density of 6.0 Ind/60m^2 (Table 88). The larger reef herbivores were represented by juvenile and adult doctorfishes (*Acanthurus* tractus, *A. chirurgus*), with a combined density of 4.0 Ind/60m^2. Parrotfishes were represented by juvenile and adults of stoplight parrotfish (*Sparisoma viride*), adult stages of yellowtail parrotfish (*S. rubripinne*), and juvenile stages of princess and redband parrotfishes (*Scarus taeniopterus, s. aurofrenatum)* with a combined density of 4.2 Ind/60m^2.

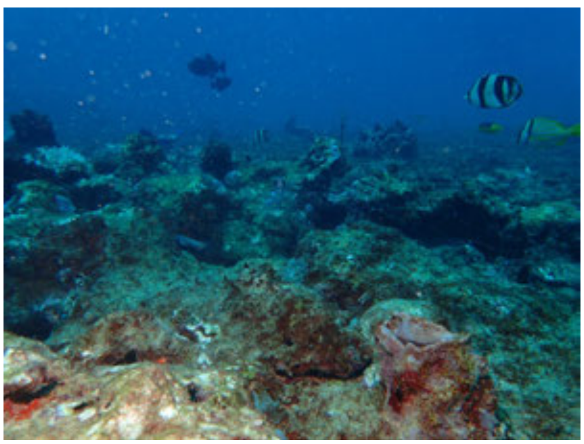
Table 87. Taxonomic composition and density of fishes and motile megabenthic invertebrates surveyed within 3x10m belt-transects at ESCA20, San Juan. PRCRMP 2025

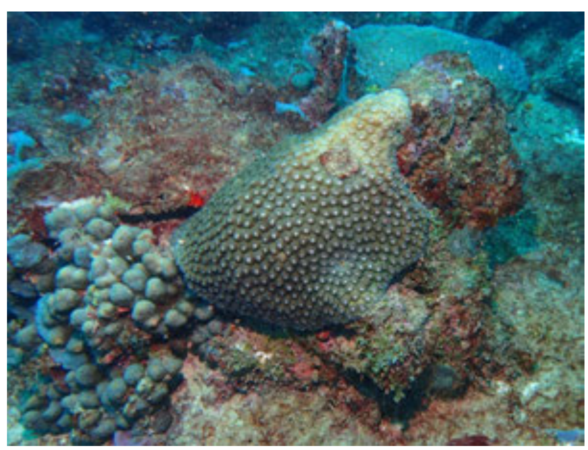
ESCA20							
Survey Date: 8/15/25	**Belt-Transects (3x10m)**						**Trophic**
Species	**T1**	**T2**	**T3**	**T4**	**T5**	**Mean**	**Level**
Thalassoma bifasciatum	14	33	16	37	25	**25.0**	SOC
Chromis cyanea	19	15				**6.8**	ZPL
Stegastes partitus	5	7	3	7	8	**6.0**	ZPL
Cephalopholis fulva	2	1		2	3	**1.6**	LC
Haemulon flavolineatum	8					**1.6**	SOC
Haemulon aurolineatum	2	5				**1.4**	SOC
Halichoeres bivittatus			3		4	**1.4**	SOC
Acanthurus tractus				5	2	**1.4**	HER
Sparisoma aurofrenatum	1	1	1	3		**1.2**	HER
Myripristis jacobus	3	2				**1.0**	SOC
Scomberomorus regalis			5			**1.0**	LC
Stegastes adustus	3	1				**0.8**	HER
Holocentrus rufus	2				2	**0.8**	SOC
Acanthurus chirurgus		1			3	**0.8**	HER
Anisotremus virginicus	2	1				**0.6**	SOC
Melichthys niger	1	2				**0.6**	ZPL
Canthigaster rostrata	1	1	1			**0.6**	SOC
Acanthurus coeruleus	2	1				**0.6**	HER
Pseudupeneus maculatus	2	1				**0.6**	SOC
Holocentrus adscensionis		1		1	1	**0.6**	SOC
Ocyurus chrysurus				1	2	**0.6**	LC
Serranus tigrinus				1	2	**0.6**	SOC
Chaetodon striatus	2					**0.4**	COR
Stegastes leucostictus	1	1				**0.4**	HER
Haemulon plumierii	1	1				**0.4**	SOC
Holacanthus tricolor	1				1	**0.4**	SPO
Haemulon carbonarium		2				**0.4**	SOC
Serranus baldwini			1		1	**0.4**	SOC
Amblycirrhitus pinos			1		1	**0.4**	SOC
Chaetodon capistratus				2		**0.4**	COR
Halichoeres garnoti				1	1	**0.4**	SOC
Halichoeres maculipinna					2	**0.4**	SOC
Bodianus rufus	1					**0.2**	SOC
Priacanthus arenatus	1					**0.2**	SOC
Cephalopholis cruentata	1					**0.2**	LC
Lutjanus apodus		1				**0.2**	LC
Epinephelus guttatus		1				**0.2**	LC
Pomacanthus paru		1				**0.2**	SPO
Halichoeres poeyi		1				**0.2**	SOC
Malacoctenus triangulatus			1			**0.2**	SOC
Cantherhines pullus				1		**0.2**	SPO
Invertebrates							
Diadema antillarum	0	1	0	0	0	**0.2**	
Density (Ind/30m2)	**75**	**81**	**32**	**61**	**58**	**61.4**	
Richness (Species/30m2)	**22**	**22**	**9**	**11**	**15**	**15.8**	

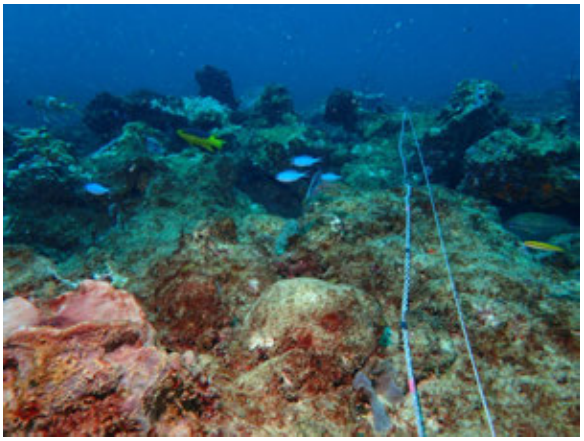
Table 88. Size distributions of commercially important fishes observed within 20m x 3m belt-transects at ESCA20, San Juan. PRCRMP 2025

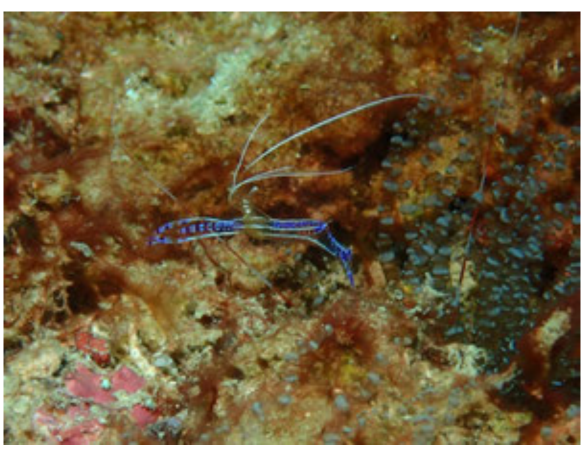
ESCA20							
Survey Date: 8/15/25		**Belt-Transects (3m x 20m)**					
Fish Species	**Observed Size**	**T1**	**T2**	**T3**	**T4**	**T5**	**Life Stage**
Acanthurus chirurgus c2	3-10	0	0	0	0	3	Juvenile
Acanthurus chirurgus c4	16	0	1	0	0	0	Juvenile
Acanthurus coeruleus c1	5	1	0	0	0	0	Recruit
Acanthurus coeruleus c2	10	0	0	0	1	0	Juvenile
Acanthurus coeruleus c3	15	0	1	0	0	0	Adult
Acanthurus coeruleus c4	16	1	0	0	0	0	Adult
Acanthurus tractus c1	5-5	0	0	0	5	0	Recruit
Acanthurus tractus c2	4-10, 9, 6, 8	0	3	1	0	3	Juvenile
Acanthurus tractus c3	8-12	0	5	1	1	1	Juvenile
Cephalopholis fulva c1	2-5	1	0	0	0	1	Recruit
Cephalopholis fulva c2	2-6, 2-7, 8, 3-10	1	2	0	2	3	Juvenile
Cephalopholis fulva c3	2-15	1	0	0	1	0	Adult
Cephalopholis fulva c5	23, 25	1	0	0	0	1	Adult
Cephalopholis fulva c6	27	0	0	1	0	0	Adult
Epinephelus guttatus c6	28	0	1	0	0	0	Adult
Lutjanus apodus c3	15	0	1	0	0	0	Juvenile
Ocyurus chrysurus c4	18, 20	0	0	0	0	2	Adult
Ocyurus chrysurus c5	2-25	0	0	0	1	1	Adult
Scomberomorus regalis c8	5-40	0	0	5	0	0	Adult
Sparisoma aurofrenatum c1	2-4, 5	0	0	0	3	0	Recruit
Sparisoma aurofrenatum c2	8, 7	2	0	0	0	0	Juvenile
Sparisoma aurofrenatum c5	25, 22	0	1	1	0	0	Terminal
	Totals	**8**	**15**	**9**	**14**	**15**	

Photo Album 29. ESCA20









IX. Conclusions

1- The most relevant change of benthic community structure from reef stations surveyed during the 2025 PRCRMP event relative to the previous 2023 survey for the same set of reef monitoring stations was a massive -45.72% decline of reef substrate cover by stony corals. Mean cover by stony corals declined in 20 out of the 21 reef stations surveyed (except CIBU05) with the major losses measured from TRES05 (-94.34%), BOTE20 (-86.39%), TOUR30 (-78.295), CANJ20 (-75.53%), and CANO30 (-72.47%).

2- The drastic decline of substrate cover by stony corals measured in 2025 relative to the previous 2023 survey was not species specific, but rather evident across most intercepted stony coral species in transects, with major species contributions to the overall loss of cover from *Acropora palmata* (-98.5%), *Porites porites* (-82.6%), *Orbicella* spp. (-48.6%), and *P. astreoides* (-38.1%).

3- Taxonomic phase shifts of stony coral dominance from massive and branching reef building species (mostly *Orbicella* spp. and *Acropora* spp.) to fast growing opportunistic species (*Porites* spp., *Madracis* spp.) were evidenced from nine monitoring stations (TOUR30, CANO30, BOTE20, BOTE15, PALN20, TRES20, TRES10, TRES05, CROS10). Of outmost relevance was the catastrophic loss of live elkhorn coral (*Acropora palmata*) cover at TRES05, where it represented 89.4% of the total cover by stony corals.

4- The decline of reef substrate cover by live stony corals was 60.0% higher (-61.98%) in West coast reefs (Mayaguez, Rincon, Isla Desecheo) than in East coast reefs (Fajardo, Isla de Culebra, Isla de Vieques, Carolina) (mean: -36.98%), consistent with the pattern evidenced in the 2023 survey for the alternate set of 21 reef monitoring stations included in the PRCRMP. The marked geographical pattern appears to be related to the contagion of coral disease infections that appear to have travelled from east coast reefs in a westerly direction across the Puertorrican coastlines after 2021 with lingering effects up until 2025.

5- The exceptionally high sea surface temperatures recorded from May thru October 2023 that prompted the 2023 "global coral bleaching event" had very severe effects upon Puertorrican west coast reefs included in our PRCRMP, such as TRES05, TOUR30, TOUR20, and TOUR10 that had been relatively resilient to coral bleaching and disease related mortalities.

6- Fish community structure evidenced marked increments of density (mean change: 114.8%) and species richness (mean change: 8.6%) during the 2025 survey relative to the previous 2023 survey for the same set of reef monitoring stations. Fish density increments were measured from 15 stations, and such density increments were statistically significant in seven out of the 21 monitoring stations. The observed increments of fish density and species richness is indicative of a full recuperation from the drastic declines measured after the pass of Hurricanes Irma and Maria in 2017 and winter storm Riley in 2018. Given the massive losses of live coral cover from most reef stations surveyed, increments of fish density and species richness suggest that such variations are largely independent from live coral cover at the community level.

7- Fish size data, as evidenced by the re-occurrence of recruitment (1 - 5cm), juvenile, and adults (including terminal phase males) show that most of the reefs surveyed function as recruitment, nursery, and residential habitats for a wide variety of the larger reef fish herbivores, such as parrotfishes (*Scarus spp, Sparisoma spp*) and doctorfishes (*Acanthurus spp*).

8- Mid-sized carnivores, including the red hind, coney and graysby groupers (*Epinephelus guttatus*, *Cephalopholis fulva, C. cruentata*), yellowtail and schoolmaster snappers (*Ocyurus chrysurus, Lutjanus apodus*), and lionfish (*Pterois sp*.) were observed as juvenile and/or adults in many of the reefs surveyed without any evident pattern associated with depth, geographical location, and/or distance from shore.

9- Large demersal predators were generally absent or in very low densities from belt-transect areas indicative of the still critical condition of these populations, particularly the large groupers (*Epinephelus spp, Mycteroperca spp*), and snappers (*Lutjanus spp*.).

10- Consistent with similar observations on the previous 2024 survey, a total of eight Nassau groupers (*Epinephelus striatus*), including seven juveniles and one adult were observed during the 2025 survey, suggesting that a strong recruitment pulse of this ESA species is now established across Puertorrican reefs.

11- Reef stations off the San Juan and Carolina coastlines are mostly drowned eolianite structures colonized by benthic algae, cyanobacteria, and encrusting reef biota including sponges, soft corals, zoanthids and stony corals.

12- Topographic relief from reef stations surveyed off the San Juan and Carolina coastlines was largely associated with features of sedimentary origin with minor biogenic contributions, perhaps with the exception of DOMI05, where the relict elkhorn coral (*Acropora palmata*) skeletons still provide significant structural habitat.

13- Stony corals from reef stations surveyed off the San Juan and Carolina coastlines were mostly observed as small to moderate sized encrusting and isolated colonies with minor contributions to reef topographic relief and structural habitat complexity. The dominant species in terms of reef substrate cover were the mustard-hill coral (*Porites astreoides*), and symmetrical brain coral (*Pseudodiploria strigosa*).

14- The giant barrel sponge (Xestospongia muta) was the main species of the sponge assemblage from most reef stations surveyed off the San Juan and Carolina coastlines and the main biotic component contributing topographic relief and benthic habitat complexity.

X. Research Priorities and Management Recommendations

1- Neritic coral reefs in Puerto Rico are in a critical state, having lost an average of 71.1% of the reef substrate cover relative to their baseline condition (Garcia-Sais et al., this volume). Therefore, the highest research priority must be addressed towards developing a stock of resilient corals to the present and projected future stressors associated with climate change.

2- Climate change and its effects on higher-than-normal seawater surface temperatures (SST) were advanced as a generic explanation to regional coral bleaching events. Coral monitoring data from the PRCRMP has shown that increased SST has not been the sole factor influencing coral degradation of PR reefs, as distinct gradients of coral mortality related with depth, distance from shore, and influenced by estuarine conditions were evidenced in reefs within the insular shelf exposed to mostly uniform SST under the Caribbean Surface Mixed Layer water mass. Therefore, it is here recommended that resilient coral colonies of different species and thriving at different depths be analyzed in the context of the now available in-situ water quality information, such as water temperature, pH, salinity, chlorophyll-a concentrations, light penetration, and turbidity.

3- It would be highly effective if the PRCRMP water quality sampling program collect data reflecting extreme water quality conditions because these extreme conditions are most likely, the causes and/or the precursors of coral bleaching, disease outbreaks, and water quality stressors potentially influencing coral mortality. Samplings should be scheduled to characterize conditions in late September, coinciding with the SST maximum, and prior to the recurrent onset of coral bleaching events in PR. Another priority of the water quality program should be the characterization of conditions immediately following strong rainfall events when salinity and perhaps dissolved oxygen minimums, and maximum concentrations of nutrients, total and dissolved organic carbon (TOC/DOC), water turbidity, pesticides, trace metals, biological oxygen demand (BOD), and chemical oxygen demand (COD) are likely to occur and impact coral reef systems of the insular shelf.

4- The massive mortality of elkhorn coral (*Acropora palmata*) and another reef biota at DOMI05 (Garcia-Sais et al., 2022) that appeared to be related to chronic deterioration of water quality conditions prompted recommendations that a more comprehensive reef monitoring structure be in place to allow evaluations of potential factors responsible for such coral deterioration. Based on the recent baseline characterizations (Garcia-Sais et al., this volume) we recommend that reefs stations MARI20 (off Punta Las Marias), and ESCA10 (off El Escambrón) be added to the PRCRMP station matrix to provide (along with DOMI05) a depth-stratified design for analyses of factors potentially affecting coral reef communities along the San Juan – Carolina coastlines.

5- The PRCRMP has identified a differential resilience/vulnerability of coral species to environmental stressors, such as bleaching and hurricanes. Supported by reef-specific, in-situ water quality information (extreme/maximum SST/light exposure data is required) determinations can be made from the PRCRMP database to select particular coral species that have been shown to be more resilient to the specific water quality features of insular shelf areas where high coral degradation has been observed and replenish these areas with the more resilient coral species from (coral) nursery sources. The end result should be a fast-track increment of reef substrate cover by resilient corals for the specific water quality conditions of particular reefs. Also, diversification of the coral/endosymbionts genetic pool should aid/accelerate the natural selection process in development of corals with more stressor resistant genomes.

6- To ensure coral restoration remains effective under climate change and warming oceans, restoration practioners should use an adaptive, ecosystem-based strategy that combines prevention, rapid response, and long-term resilience. Restoration should focus on maintaining genetic diversity through coral propagation (fragmentation and sexual reproduction), while incorporating key herbivores like sea urchins and crabs to sustain balanced reef ecosystems. Outplanting is strategically timed and targeted to thermally resilient reef sites, with emergency protocols ready to rescue, house, and treat corals during bleaching or disease events. Continuous monitoring of sea surface temperature, bleaching thresholds, and coral survival triggers adaptive decisions, while partnerships with local and international organizations ensure knowledge-sharing, training, and innovation in techniques such as selective breeding, symbiont research, and shading trials. This flexible, science-driven approach will strengthen the long-term survival of coral reefs under a changing climate.

7- The predominant substrate at all sites is benthic algae. Most sites show high abundance of fleshy macroalgae like *Dictyota* and *Lobophora* spp., while others display high densities of peyssonnelids such as *Ramicrusta* spp. Enhancing herbivore diversity is essential for the health and resilience of coral reef ecosystems because different species of herbivores play complementary roles in controlling algal growth. Sea urchins, herbivorous crabs, and various fish species each graze in distinct ways, targeting different types of algae and reef surfaces. By maintaining this functional diversity, reefs are kept cleaner, which reduces competition for space and resources, and allows corals to settle, grow, and recover more effectively after disturbances such as bleaching events or storms. Diverse herbivore populations also buffer against the loss of any single species, ensuring that critical grazing functions continue even under changing environmental conditions. This ecological balance strengthens the overall stability of reef ecosystems and increases the success of restoration efforts.

8- PRCRMP reef stations should be the main target of restoration initiatives considering placement of coral implants along permanent transects in reef sections where live stony corals previously thrived. This strategy will allow an (alternate year) evaluation of the restoration initiative through the regular monitoring program facilitating management decisions regarding adjustments/modifications to the coral implant process.

9- Preservation of the PR coral reef system's ecological integrity has been severely compromised both due to the population crash of its keystone grazer, the long-spined urchin (*Diadema antillarum*) during the 1983-84 regional mass mortality, and by the drastic decline of the large reef demersal predators, particularly groupers and snappers after more than a decade of intense fishing exploitation during and at their seasonal spawning aggregation sites. Despite active state and federal seasonal fishing closure regulations, fishing pressure still occurs due to the lack of enforcement. Therefore, the specific recommendation is to establish an effective surveillance program during the grouper/snapper seasonal spawning aggregations facilitated by drones, remote sensing, land-based telescopic monitoring, and/or any other direct and/or indirect surveillance strategies.

10- The Caribbean Fishery Management Council (CFMC) has active regulations of annual catch limits and seasonal closures on many of the commercially exploited coral reef fish and shellfish populations occurring within the federal Exclusive Economic Zone (EEZ) that includes shelf habitats outside a nine-nautical mile boundary around PR. We recommend that DNER should work in closer association with the CFMC to convey parallel regulation criteria on coral reef fishery management, research, and enforcement.

11- In line with the goal objective of preservation of the coral reef system's ecological integrity, the DRNER should consider the creation of cross-shelf marine conservation districts (MCD). These are conceptualized as entire shelf areas (from the shoreline to the shelf-edge) closed to fishing and of limited recreational uses. Such MCDs would be managed for intense coral reef related research, with particular attention on the reef ecosystem's response to a large area fishing closure and recreational constraints, such as what has been achieved in the USVI for the Saint Thomas MCD, where a bold recuperation of its fishery resources has been reported.

12- Understanding of the dispersal forces, such as wind, currents and eddies acting during the reef fish species seasonal spawning aggregations is a research priority of outmost relevance for designation of specific localities and areal extensions of MCDs. Such investigations must identify pelagic larval sinks, where fish/shellfish recruitment success is enhanced by both current drift and presence of ideal benthic habitats for post-larval recruitment. To this effect, it is essential to produce comprehensive water current dynamics studies during and shortly after the species' spawning events on strategic localities as to establish, relative to the fish larval duration periods local and regional (larval) connectivity maps. This data, in conjunction with existing, improved, and prospective information on benthic habitat maps should identify the most appropriate locations and geographical extensions of MCDs.

13- The construction of a marine aquarium with mariculture facilities would be of outmost cultural, socioeconomic, and ecological value for Puerto Rico, and it is here recommended that DNER take the initiative to bring this idea to the governmental agenda. The infrastructure for in-house mariculture capabilities that could facilitate the production, seeding and replenishment of threatened and/or desired species for our coral reefs is of vital importance given the present ecosystem degradation trends. It is possible that in the future management of coral reef systems will require man-assisted actions that include construction of artificial reef habitats, reconstruction of extensively degraded habitats, and seeding with species tolerant to the new and evolving environmental stressors. Aside from the ecological value, a modern marine aquarium would be an immediate asset to the economy boosting a much-needed increase in high quality family and educational/scientific tourism, with far-reaching effects in terms of direct and indirect new employment possibilities. At the same time, it would represent an excellent platform for the educational system at all levels, from primary school to cutting-edge scientific research, enhancing the much-needed awareness of the public for the value of coral reef systems and support for best management policies and regulations.

14- Research efforts are needed for better understanding of the recruitment dynamics of commercially exploited reef fish and shellfish populations, such as large groupers, snappers, hogfish, lobsters, and queen conch. Information is critically lacking regarding their pelagic larval dispersal dynamics, factors influencing larval and post larval survival, and identification of preferred benthic recruitment habitats. The latter is of outmost management concern since it is possible that such recruitment habitats may not be adequately protected due to the lack of information regarding such critically relevant function for coral reef ecosystems.

15- The PRCRMP has identified the masked goby (*Coryphopterus personatus*) as a numerically dominant species that drives statistically significant fluctuations of total fish density and possibly ichthyofaunal community biodiversity associated with cascading effects in many of our monitored reef stations. Its role in the trophodynamics of our reef systems is poorly understood and requires particular research attention. Information regarding fundamental aspects of its life history and its role as a forage species for coral reef demersal piscivores is needed for understanding coral reef food webs and the reef system productivity dynamics.

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XIV. Appendices

Appendix 1. Life history characteristics and feeding habits of commercially important reef fishes. From: Froese, R. and D. Pauly (Eds.) 2019. World Wide Web electronic publication. (Version 02/2019). http://www.fishbase.org [details]

Fish Species	Common Name	Length at maturity (cm)	Maximum Length (cm)	Main Diet
Acanthurus chirurgus	Doctorfish	17	39	Algae
Acanthurus coeruleus	Blue Tang	13	39	Algae
Acanthurus tractus	Five-band Surgeonfish	15.5	38.1	Algae
Caranx ruber	Bar-Jack	26	73	Nekton
Cephalopholis cruentata	Graysby	16	42.6	Nekton
Cephalopholis fulva	Coney	14.7	41	Nekton
Epinephelus guttatus	Red Hind	25	76	Zoobenthos
Epinephelus striatus	Nassau Grouper	48	122	Nekton
Gymnothorax moringa	Spotted Moray	n/d	200	Nekton
Lachnolaimus maximus	Hogfish	18.1	91	Zoobenthos
Lutjanus analis	Mutton Snapper	28	94	Nekton
Lutjanus apodus	Schoolmaster	25	67.2	Nekton
Lutjanus jocu	Dog Snapper	31	128	Nekton
Lutjanus mahogoni	Mahogany Snapper	n/d	48	Nekton
Lutjanus synagris	Lane Snapper	16	60	Nekton
Mycteroperca interstitialis	Yellowmouth Grouper	40	84	Nekton
Ocyurus chrysurus	Yellowtail Snapper	15	83.6	Nekton
Pterois sp.	Lionfish	16	38	Nekton
Scarus iseri	Striped Parrotfish	16	35	Algae
Scarus taeniopterus	Princess Parrotfish	17	35	Algae
Scarus vetula	Queen Parrotfish	n/d	61	Algae
Scomberomorus regalis	Cero	38	183	Nekton
Sparisoma aurofrenatum	Redband Parrotfish	15	28	Algae
Sparisoma chrysopterum	Redtail Parrotfish	n/d	46	Algae
Sparisoma radians	Bucktooth Parrotfish	n/d	20	Algae
Sparisoma rubripinne	Yellowtail Parrotfish	16	47.8	Algae
Sparisoma viride	Stoplight Parrotfish	16.3	64	Algae

Appendix 2. Stony coral colonies and disease prevalence at reef monitoring stations. PRCRMP 2025

Reef Monitoring Stations	Total # Coral colonies	# Diseased Coral Colonies	Disease Prevalence (%)	Stony Coral Species
BOTE15	24	0	0	
BOTE20	11	0	0	
CANO30	23	1	4.35	*1-Siderastrea siderea*
CABE05	31	0	0	
DIAB05	37	0	0	
PALT10	52	1	1.92	*1-Orbicella faveolata*
PALN20	37	0	0	
TOUR10	33	0	0	
TOUR20	21	0	0	
TOUR30	15	0	0	
TRES05	5	0	0.00	
TRES10	40	2	5.00	*1-Porites astreoides*
				1-Stephanocoenia intercepta
TRES20	21	3	14.29	
LPEN	48	0	0	
CROS	42	1	2.38	*1-Orbicella faveolata*
DAKI20	45	4	8.89	*2-Orbicella faveolata*
				2-Siderastrea siderea
ESPE10	19	1	5.26	*1-Siderastrea siderea*
CANJ20	26	0	0	
SECO30	68	1	1.47	*1-Orbicella franksi*
CIBU05	27	0	0	
DOMI05	20	0	0	
Baseline Characterizations of San Juan - Carolina Reefs				
CANG05	25	0	0	
CANG10	14	0	0	
CANG15	21	2	9.52	*1-Porites astreoides*
				1-Siderastrea siderea
MARI10	30	0	0	
MARI20	23	0	0	
ESCA05	33	0	0	
ESCA10	23	1	4.35	*1-Siderastrea siderea*
ESCA20	24	0	0	
Totals:	**814**	**17**	**2.09%**	

Appendix 3. Percent change of reef substrate cover by stony corals at PRCRMP monitoring stations. ANOVA analyses of temporal differences.

Reef	Baseline	Mean % Coral Cover			% Change	ANOVA	% Change	ANOVA
Station	**Survey**	**Baseline**	**2023**	**2025**	**Baseline**	**p-value**	**Previous**	**p-value**
CANO30	2004	48.42	15.04	4.14	-91.45	< 0.001*	-72.47	0.008*
BOTE20	2000	48.01	10.95	1.49	-96.90	< 0.001*	-86.39	0.019*
BOTE15	2004	19.23	5.70	3.09	-83.93	< 0.001*	-45.79	0.254
PALN20	2016	30.72	16.92	6.28	-79.56	< 0.001*	-62.88	0.010*
PALT10	2016	32.75	16.97	13.04	-60.18	< 0.001*	-23.16	0.131
DIAB05	2016	20.89	13.08	9.77	-53.23	0.433	-25.31	0.627
TOUR10	1999	48.71	28.63	11.48	-76.43	0.138	-59.90	0.167
TOUR20	2004	31.79	10.09	3.54	-88.86	< 0.001*	-64.92	< 0.001*
TOUR30	2004	13.54	10.18	2.21	-83.68	< 0.001*	-78.29	0.005*
CABE05	2018	13.3	4.23	3.47	-73.91	< 0.001*	-17.97	0.566
TRES05	2015	37.42	25.97	1.47	-96.07	< 0.001*	-94.34	0.001*
TRES10	2004	20.92	8.52	7.30	-65.11	< 0.001*	-14.32	0.444
TRES20	2004	23.15	5.92	3.47	-85.01	< 0.001*	-41.39	0.036*
LPEN05	2016	16.98	6.91	3.46	-79.62	< 0.001*	-49.93	0.056
CROS10	2016	19.83	11.96	5.16	-73.98	< 0.001*	-56.86	0.045*
DAKI20	2016	15.1	8.90	6.62	-56.16	0.008*	-25.62	0.295
ESPE10	2001	36.03	3.52	2.58	-92.84	< 0.001*	-26.70	0.442
CANJ20	2001	24.54	13.57	3.32	-86.47	< 0.001*	-75.53	0.003*
SECO30	2011	43.68	24.03	15.68	-64.10	< 0.001*	-34.75	0.010*
CIBU05	2011	47.3	14.65	15.32	-67.61	< 0.001*	4.57	0.929
DOMI05	2018	58.34	3.57	3.28	-94.38	< 0.001*	-8.12	0.852
	Means:	**30.98**	**12.35**	**6.01**	**-78.55**		**-45.72**	

San Juan/Carolina Reefs

Reef Station	Baseline Survey	Mean % Cover
MARI10	2025	6.58
MARI20	2025	9.12
CANG05	2025	3.76
CANG10	2025	3.40
CANG15	2025	3.89
ESCA05	2025	6.39
ESCA10	2025	5.75
ESCA20	2025	5.65
	Mean:	**5.57**

Appendix 4. Percent change of reef substrate cover by soft corals at PRCRMP monitoring stations. ANOVA analyses of temporal differences.

Reef	Baseline	Mean % Coral Cover			% Change	ANOVA	% Change	ANOVA
Station	**Survey**	**Baseline**	**2023**	**2025**	**Baseline**	**p-value**	**Previous**	**p-value**
CANO30	2004	0	0.00	0	n/a	n/a	n/a	n/a
BOTE20	2000	0	1.00	0	n/a	n/a	n/a	n/a
BOTE15	2004	0	0.00	0	n/a	n/a	n/a	n/a
PALN20	2016	18	10.20	12.4	-31.11	0.014*	21.57	0.380
PALT10	2016	19.8	18.00	17	-14.14	0.334	-5.56	0.270
DIAB05	2016	6.8	5.40	6.4	-5.88	0.387	18.52	0.355
TOUR10	1999	20.6	15.40	15.6	-24.37	< 0.001*	1.30	0.966
TOUR20	2004	8.8	10.20	4.2	-52.27	< 0.001*	-58.85	0.013*
TOUR30	2004	7	8.80	6	-14.28	< 0.001*	-31.82	0.079
CABE05	2018	1.4	3.00	3.6	157.14	0.389	0.20	0.732
TRES05	2015	5	0.10	2	-60.00	< 0.001*	1900.00	0.021*
TRES10	2004	21.2	28.00	20.4	-3.77	0.148	-27.14	0.041*
TRES20	2004	11.4	10.80	15.4	35.09	0.277	42.59	0.085
CIBU05	2011	0.6	0.40	0.8	33.33		100.00	
LPEN05	2016	19.2	12.00	12	-37.50	0.002*	0.00	1.000
CROS10	2016	16.6	13.00	15.8	-4.82	0.828	21.54	0.432
DAKI20	2016	4.6	1.60	1.8	-60.87	0.001*	12.50	0.760
ESPE10	2001	21.2	10.60	9.6	-54.72	0.001*	-9.43	0.568
CANJ20	2001	19.4	15.00	11.6	-40.21	0.029*	-22.67	0.204
SECO30	2011	0.2	0.00	0	-100.00	n/a	n/a	n/a
DOMI05	2018	2.6	3.20	2.2	-15.38	0.949	-31.25	0.565
MARI10	2025	5.20						
MARI20	2025	2.8						
CANG05	2025	36.4						
CANG10	2025	1.0						
CANG15	2025	0.2						
ESCA05	2025	8.2						
ESCA10	2025	12.2						
ESCA20	2025	1.0						
	MEANS:	**9.36**	**7.94**	**7.47**	**-16.32**		**113.62**	

Appendix 5. Percent change of mean fish density at reef monitoring stations between monitoring surveys. ANOVA analyses of temporal differences.

PRCRMP Regular Monitoring Station						Baseline		Previous
Reef	Baseline	Ind/30m2			% Change	ANOVA	% Change	ANOVA
Station	Survey Yr	Baseline	2023	2025	Baseline	p-value	Previous	p-value
BOTE15	2004	133.8	129.2	329.0	145.9	< 0001*	154.6	0.098
BOTE20	2000	241.4	177.6	303.2	25.6	0.002*	70.7	0.116
CANO30	2004	495.4	195.2	314.2	-36.6	< 0001*	61.0	0.125
TOUR10	1999	96.8	54.8	111.2	14.9	0.179	102.9	0.127
TOUR20	2004	116.8	37.8	100.8	-13.7	< 0001*	166.7	< 0001*
TOUR30	2004	111.8	30.6	114.2	2.1	< 0001*	273.2	< 0001*
CABE05	2018	25.8	48.4	45.8	77.5	0.0003*	-5.4	0.759
DIAB05	2016	49.8	75.8	55.8	12.0	0.026*	-26.4	0.361
PALT10	2016	85.6	37.6	55.2	-35.5	0.192	46.8	0.158
PALN20	2016	263.4	98.2	404.6	53.6	< 0001*	312.0	0.003*
TRES20	2004	531.4	114.6	153.0	-71.2	< 0001*	33.5	0.296
TRES10	2004	111.4	55.0	89.6	-19.6	< 0001*	62.9	0.048*
TRES05	2015	74.0	46.6	45.6	-38.4	0.110	-2.1	0.928
LPEN05	2016	179.0	93.0	194.8	8.8	<0.001*	109.46	0.006*
CROS10	2016	922.6	147.2	1282.2	39.0	<0.001*	771.06	<0.001*
DAKI20	2016	284.2	135.4	555.4	95.4	< 0001*	310.19	< 0001*
ESPE10	2001	63.4	108.8	60.4	-4.7	0.003*	-44.49	0.054
CANJ20	2001	36.8	64.2	52.8	43.5	0.105	-17.76	0.704
SECO30	2011	117.4	71.0	21.2	-81.9	0.015*	-70.14	0.093
CIBU05	2011	54.4	47.4	86.2	58.5	0.211	81.86	0.347
DOMI05	2018	24.6	24.2	29.2	18.7	0.334	20.66	0.292
	Means:	**191.4**	**85.4**	**209.7**	**14.0**		**114.8**	

San Juan-Carolina Reefs		
Reef	Baseline	Mean Density
Station	Survey Yr	Ind/30m2
CANG05	2025	47.0
CANG10	2025	40.6
CANG20	2025	49.0
MARI10	2025	52.2
MARI20	2025	64.6
ESCA05	2025	84.8
ESCA10	2025	106.4
ESCA20	2025	61.4
	Means:	**63.3**

Appendix 6. Percent change of mean fish species richness at reef monitoring stations between monitoring surveys. ANOVA analyses of temporal differences.

PRCRMP Regular Monitoring Stations						**Baseline**		**Previous**
Reef	**Baseline**	**Spp/30m2**			**% Change**	**ANOVA**	**% Change**	**ANOVA**
Station	**Survey Yr**	**Baseline**	**2023**	**2025**	**Baseline**	**p-value**	**Previous**	**p-value**
BOTE15	2004	23.6	15.8	17.0	-27.97	<0.001*	7.59	0.557
BOTE20	2000	25.2	17.0	19.2	-23.81	<0.001*	12.94	0.278
CANO30	2004	34.2	22.2	22.8	-33.33	<0.001*	2.70	0.673
TOUR10	1999	22.0	15.8	18.4	-16.36	<0.001*	16.46	0.019*
TOUR20	2004	25.4	14.6	16.4	-35.43	<0.001*	12.33	<0.001*
TOUR30	2004	23.0	14.2	18.6	-19.13	<0.001*	30.99	<0.001*
CABE05	2018	8.8	9.2	10.6	20.45	0.164	15.22	0.156
DIAB05	2016	13.0	15.8	14.0	7.69	0.005*	-11.39	0.373
PALT10	2016	13.4	16.2	13.2	-1.49	<0.001*	-18.52	0.007*
PALN20	2016	19.0	20.0	16.8	-11.58	0.062	-16.00	0.006*
TRES20	2004	26.0	17.6	20.6	-20.77	<0.006*	17.05	0.062
TRES10	2004	17.8	13.4	16.6	-6.74	<0.001*	23.88	0.064
TRES05	2015	10.5	8.8	9.4	-10.48	0.150	6.82	0.494
LPEN05	2016	18.4	15.0	19.4	5.43	0.103	29.33	0.014*
CROS10	2016	19.8	19.4	23.8	20.20	0.089	22.68	0.011*
DAKI20	2016	16.2	14.4	17.4	7.41	0.696	20.83	0.143
ESPE10	2001	19.8	21.8	18.6	-6.06	<0.001*	-14.68	0.174
CANJ20	2001	17.0	16.6	17.4	2.35	0.003*	4.82	0.742
SECO30	2011	15.8	8.2	8.2	-48.10	<0.001*	0.00	1
CIBU05	2011	13.6	14.0	16.0	17.65	<0.001*	14.29	0.141
DOMI05	2018	9.0	6.0	6.6	-26.67	0.009*	10.00	0.511
	Means:	**18.6**	**15.0**	**16.2**	**-9.8**		**8.9**	

San Juan-Carolina Reefs		
Reef	**Baseline**	**Spp/30m2**
Station	**Survey Yr**	**Baseline**
CANG05	2025	14.4
CANG10	2025	10.2
CANG15	2025	11.6
DOMI05	2018	6.6
MARI10	2025	11.4
MARI20	2025	17.4
ESCA05	2025	19.0
ESCA10	2025	17.2
ESCA20	2025	15.8
	Mean:	**13.7**

Appendix 7. Geographic coordinates and depths of individual transects surveyed off the San Juan – Carolina coastlines. PRCRMP 2025

Reef Station	Station Code	Survey Date	Depth (m)	Transect	Latitude	Longitude
Maria Grande 20m	MARI20	8/14/25	18.5	1	18.46812	-66.03678
			18.2	2	18.46811	-66.03691
			17.9	3	18.46803	-66.03696
			18.5	4	18.46795	-66.03696
			18.2	5	18.46784	-66.03696
Maria Grande 10m	MARI10	8/14/25	12.7	1	18.4677	-66.04604
			12.7	2	18.46764	-66.04609
			12.1	3	18.46755	-66.04616
			11.5	4	18.46744	-66.04619
			9.7	5	18.46741	-66.04627
Boca de Cangrejos 5m	CANG05	8/14/25	3.6	1	18.45981	-66.00975
			3.6	2	18.45989	-66.00984
			3.3	3	18.45999	-66.00982
			3.3	4	18.46005	-66.00979
			3.3	5	18.46013	-66.00973
Boca de Cangrejos 10m	CANG10	8/15/25	8.8	1	18.46375	-66.02043
			9.1	2	18.46371	-66.02029
			9.1	3	18.46359	-66.02025
			8.5	4	18.46347	-66.02027
			8.5	5	18.46337	-66.02026
Boca de Cangrejos 15m	CANG15	8/14/25	17.3	1	18.46511	-66.01622
			15.8	2	18.46504	-66.01614
			16.4	3	18.46499	-66.01605
			16.4	4	18.46494	-66.01596
			16.1	5	18.46489	-66.01603
El Escambron 20m	ESCA20	8/15/25	17.9	1	18.47309	-66.08348
			17.6	2	18.47302	-66.08351
			17.6	3	18.47294	-66.08353
			16.4	4	18.47284	-66.08354
			15.8	5	18.47286	-66.08362
El Escambron 10m	ESCA10	8/15/25	9.1	1	18.47136	-66.08887
			9.1	2	18.47122	-66.08889
			9.1	3	18.47114	-66.08888
			9.1	4	18.47105	-66.08885
			9.1	5	18.47088	-66.08882
El Escambron 5m	ESCA05	8/15/25	5.8	1	18.47072	-66.08861
			5.2	2	18.47062	-66.08862
			4.5	3	18.47055	-66.08865
			4.5	4	18.47046	-66.08864
			3.9	5	18.47039	-66.08875