Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

NATIONAL MARINE SANCTUARIES CONSERVATION SERIES

Stetson Bank Long-Term Monitoring: 2022 Annual Report

January 2024
National Marine Sanctuaries Conservation Science Series ONMS-24-01

U.S. Department of Commerce
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Suggested citation: O'Connell, K., Nuttall, M. F., Blakeway, R. D., Hannum, R., Johnston, M. A., Eisenbach, O., French, D., Hu, X., Schmahl, G. P., Sinclair, J. (2024). *Stetson Bank long-term monitoring: 2022 annual report*. National Marine Sanctuaries Conservation Series ONMS-24-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries.

Cover photo: A seaweed blenny (*Parablennius marmoreus*) is perched on a sponge (*Ircinia strobilina*) on the bank crest at Stetson Bank. Image: M. Nuttall/NOAA

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The Office of National Marine Sanctuaries, part of the National Oceanic and Atmospheric Administration, serves as the trustee for a system of underwater parks encompassing more than 620,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our nation's maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sites range in size from less than one square mile to almost 583,000 square miles. They serve as natural classrooms and cherished recreational spots, and are home to valuable commercial industries.

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Abstract

This document describes the methods used, field data analyses, significant observations, and challenges encountered during annual long-term monitoring of fish, benthic communities, and water quality at Stetson Bank in 2022. This bank is located 130 km southeast of Galveston, Texas within Flower Garden Banks National Marine Sanctuary in the northwestern Gulf of Mexico. It features a productive benthic community and dense fish assemblage. The bank crest has been monitored annually since 1993, and surveys of the mesophotic zone surrounding the bank crest began in 2015.

Monitoring activities completed in 2022 included water quality sampling, bank crest and mesophotic repetitive photostations and fish surveys, mesophotic random transects and fish surveys, bank crest video transects, and sea urchin and lobster surveys. Field work and data collection were, however, limited in 2022 due to challenges resulting from the COVID-19 pandemic, including vessel and diving restrictions. As a result, bank crest random transects and fish surveys, as well as contaminant analyses, were not completed.

Despite the limitations, 86% of bank crest repetitive photostations (51 of 59) were captured in 2022. Coral, hydrocoral, sponges, and macroalgae had mean percent cover of 4.42%, 3.96%, 14.02%, and 51.82%, respectively. Although *Millepora alcicornis* colonies exhibited some bleaching and/or paling, no signs of stony coral tissue loss disease were observed. Seawater temperatures did not exceed 30°C but remained at or above 29°C for 24 consecutive days.

In addition to extending an important long-term monitoring database for Stetson Bank, the report details the challenges encountered and resolutions to ensure future field work.

Key Words

benthic community, fish community, Flower Garden Banks National Marine Sanctuary, long-term monitoring, Stetson Bank, water quality

Chapter 1: Introduction

Stetson Bank, an uplifted claystone/siltstone feature in the Gulf of Mexico, is located approximately 130 km southeast of Galveston, Texas. Since 1996, it has been protected as part of the National Oceanic and Atmospheric Administration (NOAA) Flower Garden Banks National Marine Sanctuary (FGBNMS). The bank was formed by seabed uplift caused by an underlying salt dome and sustains a coral and sponge community that exists close to the northern limit of reef coral growth in the Gulf of Mexico. Although the environmental conditions at Stetson Bank are temperate compared to the Caribbean Sea and tropical Western Atlantic Ocean (Cummings et al., 2018), the area features a well-developed benthic community dominated by tropical marine sponges, along with hydrocorals, hermatypic corals, and other invertebrates. Seasonal variations in temperature and light availability inhibit coral reef development on the bank.

Beginning in 1993, the Gulf Reef Environmental Action Team, a non-profit organization composed of volunteer divers and citizen scientists, initiated an annual long-term monitoring program at Stetson Bank. On initial monitoring cruises, maps of the bank crest were made, repetitive photostations were installed, semiquantitative reef fish censuses were conducted, random benthic photographs were collected, and thermographs were installed. Following Stetson Bank's addition to FGBNMS in 1996, monitoring efforts were led by the Center for Coastal Studies at Texas A&M University, Corpus Christi until 2001 (Nuttall et al., 2020a). FGBNMS staff and volunteers took responsibility for the monitoring program thereafter (Bernhardt, 2000). Due to funding constraints between 2001 and 2014, annual long-term monitoring at Stetson Bank was limited to repetitive photostations, water temperature, salinity, nutrient analyses, and sporadic fish censuses. However, in 2015, the Bureau of Safety and Environmental Enforcement (BSEE) and FGBNMS entered into an interagency agreement to continue and expand annual long-term monitoring (Nuttall et al., 2020a). Annual benthic, fish, and water quality monitoring efforts were expanded to document spatial and temporal changes resulting from natural and anthropogenic influences, particularly those associated with the petrochemical industry. Early monitoring focused on the bank crest, which is within non-decompression scuba diving limits (<33.5 m). Following seafloor mapping and remotely operated vehicle (ROV) explorations, mesophotic communities were discovered on discrete uplifted seafloor features in the form of a ring surrounding Stetson Bank. Because information was limited for this newly discovered habitat, BSEE and FGBNMS expanded the monitoring program to include the mesophotic habitat.

In 2021, FGBNMS was expanded to include 14 additional reefs and banks along the continental shelf of the northwestern Gulf of Mexico, increasing the total sanctuary area from 145 km^2 to 414.4 km^2 (86 Fed. Reg. 4937 [Jan 19, 2021]). With this expansion, the boundary of FGBNMS was modified to fully encompass the mesophotic habitat at Stetson Bank (30–150 m water depth), increasing the protected area around Stetson Bank by 1.45 km^2 (2.18 km^2 before expansion to 3.63 km^2 after expansion; Figure 1.1). The ring around Stetson Bank (composed of outcrops with 0–3 m relief) was originally identified as an important associated feature in 1997 following the collection of high-resolution multibeam bathymetry (Gardner et al., 1998). FGBNMS mapped the ring surrounding Stetson Bank in 2001 using an ROV. In doing so, FGBNMS discovered that uplifted siltstone and claystone boulders compose the features of the ring, providing substrate and habitat for black corals (Anthipatharia), octocorals (Octocorallia), sponges, invertebrates, and deep reef fish.

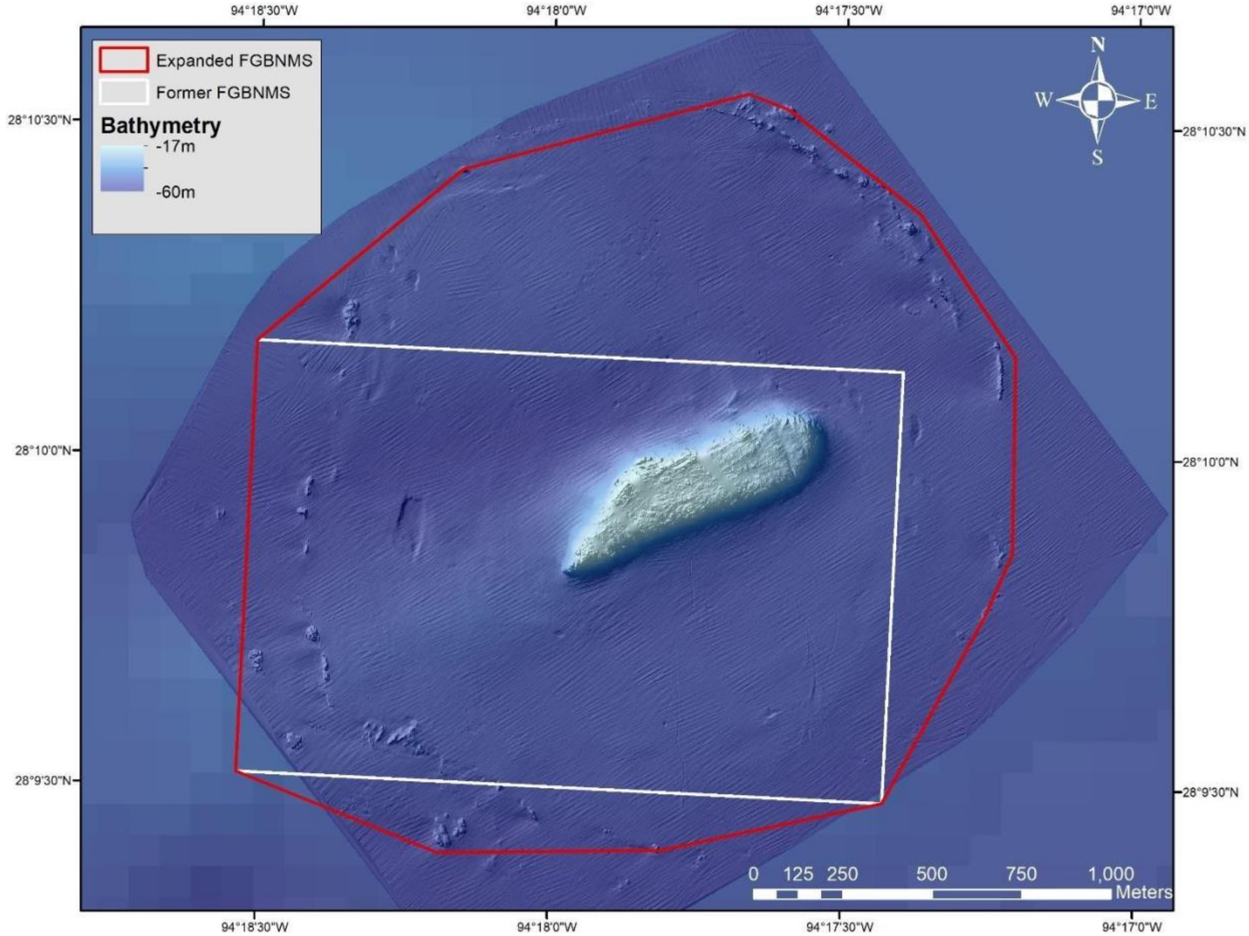


Figure 1.1. Map of FGBNMS boundaries surrounding Stetson Bank. The white line indicates the original boundary from 1996, while the red line represents the expanded boundary from 2021, encompassing the claystone/siltstone feature documented in 1997. Image: NOAA

Marine sponges, primarily *Neofibularia nolitangere*, *Ircinia strobilina*, and *I. felix*, are a major component of the benthic macrobiota on the crest of Stetson Bank (DeBose et al., 2012; Nuttall et al., 2020b). Although sponges remain the most prominent benthic cover, long-term monitoring data indicate a significant decline in sponge cover since 1999 (Nuttall et al., 2020a). For example, the sponge *Chondrilla nucula* was historically prevalent on the bank crest, but underwent a severe decline in 2005 and is now nearly absent at the bank. Additionally, the hydrozoan *Millepora alcicornis* was historically a prominent benthic species at Stetson Bank, but underwent rapid decline following a 2005 bleaching event and has not recovered (DeBose et al., 2012). Twelve species of hermatypic corals have maintained low but stable cover at Stetson Bank, including *Pseudodiploria strigosa*, *Stephanocoenia intersepta*, *Madracis brueggemanni*, *Madracis decactis*, and *Agaricia fragilis* (Nuttall et al., 2020b). Macroalgae cover, predominantly *Dictyota* sp. and turf algae, significantly increased over time (Nuttall et al., 2020a, 2020b). Since 1993, a distinct shift has occurred at Stetson Bank from a *Millepora*-sponge-dominated community (Rezak et al., 1985) to a macroalgae-sponge-dominated community (DeBose et al., 2012).

To date, the monitoring program at Stetson Bank comprises 30 years of benthic community monitoring efforts. As increasing anthropogenic stressors to marine environments are projected, long-term monitoring datasets are essential for understanding community stability, ecosystem resilience, and responses to changing conditions. Additionally, as both invasive and exotic species arrive, become established, and compete for resources, long-term datasets are vital for documenting and tracking impacts to native populations. Continuity and extension of this dataset will provide valuable insight for both research and management purposes.

Field operations in 2022 were limited to some extent by the COVID-19 pandemic. FGBNMS implemented COVID-19 precautions consistent with ONMS and NOAA small boat program guidance. Prior to departure, participants were required to provide a negative COVID-19 rapid test. While on board the R/V *Manta*, individuals were encouraged to maintain a six-foot distance, and face masks were encouraged for those traveling from other states or high-incidence areas. Despite these measures, a COVID-19 outbreak occurred on the ship during the bank crest monitoring cruise, with three confirmed positive cases. Though the affected parties were subsequently isolated, two additional positive cases were confirmed after returning to shore.

Despite the challenges of COVID-19 and other setbacks due to vessel maintenance problems and weather, scuba operations were conducted from the NOAA R/V *Manta* to capture benthic composition, conduct fish surveys, and exchange water quality instruments at Stetson Bank in 2022. Water samples were collected and water quality instruments were exchanged and downloaded. In total, data for this report were collected on four cruises in 2022 (Table 1.1).

Table 1.1. 2022 Stetson Bank cruise information.

Date(s)	Cruise Type and Monitoring Task	Participants
3/1/2022	Water quality: water sampling	Ryan Hannum, Kelly O'Connell, Kait Brogan
5/13/2022–05/14/2022	Water quality: SBE16 instrument exchange and download	Kelly O'Connell, Ryan Hannum, Kait Brogan, Marissa Nuttall, G.P. Schmahl
8/02/2022–08/04/2022	Water quality: HOBO temperature logger exchange and download; bank crest monitoring: benthic and fish community monitoring	Kelly O'Connell, Marissa Nuttall, Larry Lloyd, Jake Emmert, Donavon French, Ryan Hannum, Olivia Eisenbach, Jacque Emmert, Kait Brogan, Jessica Lee
9/13/2022–9/16/2022	Mesophotic monitoring: benthic and fish community monitoring	Kelly O'Connell, Chris Garder, Jason White, Eric Glidden, Samantha Flounders, Sarah Olmstead, Lauren Jackson, Sasha Francis, Ian Zink, Olivia Eisenbach, Donavon French

Chapter 2:
Bank Crest Repetitive Photostations

Introduction

Repetitive photostations were first installed at Stetson Bank in 1993; initially, 36 were installed. These stations were concentrated on the northwestern edge of the bank. Locations were selected along a series of high-relief hard bottom features with a diverse and dense benthic community compared to other habitat types on the bank. The stations were selected by scuba divers and marked using nails or eye bolts and numbered tags. Over time, many of these stations were lost due to tag breakage, loss of hardware, biotic overgrowth, or substrate loss; thus, new stations were established. Today, 59 stations exist at Stetson Bank, 18 of which are original stations installed in 1993.

All photostations are on hard bottom habitat and are accessible from permanent mooring buoys 1, 2, or 3 (Table 2.1; Figure 2.1). Each station is located by scuba divers using detailed maps of the study site (Figure 2.2; Figure 2.3) and photographed annually to monitor for temporal changes in the composition of benthic assemblages.

Table 2.1. Locations of buoys used to access repetitive photostations at Stetson Bank.

Buoy No.	Latitude (DD)	Longitude (DD)	Depth (m)
1	28.16551	-94.29768	22.6
2	28.16635	-94.29723	23.8
3	28.16643	-94.29610	22.3

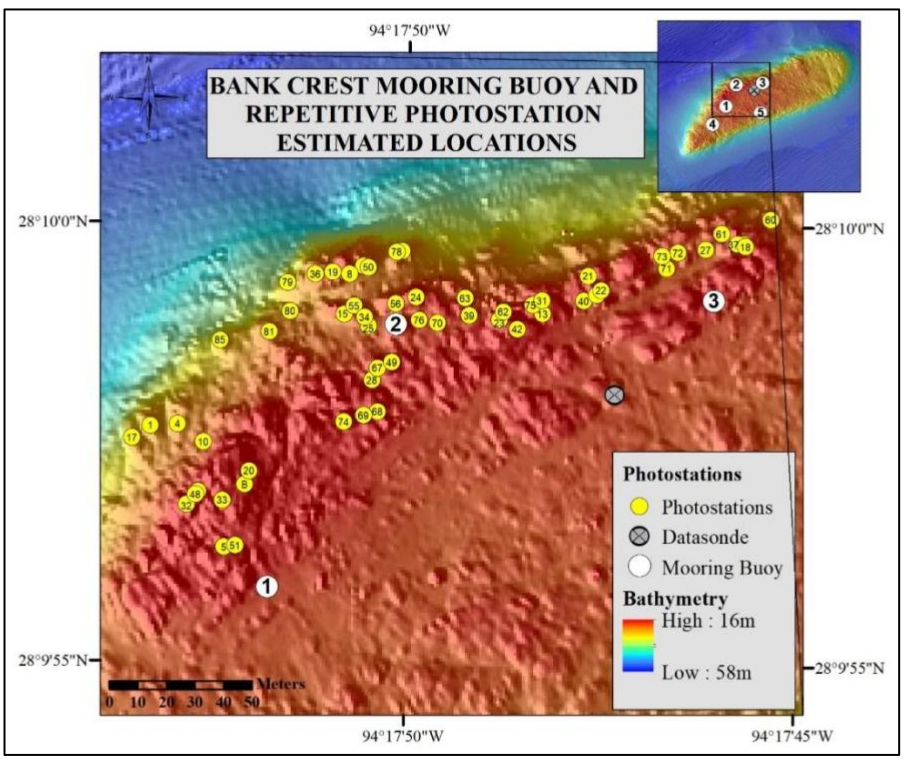


Figure 2.1. Stetson Bank study site map. Seafloor bathymetry with mooring buoy locations and approximate repetitive photostation locations. Image: NOAA

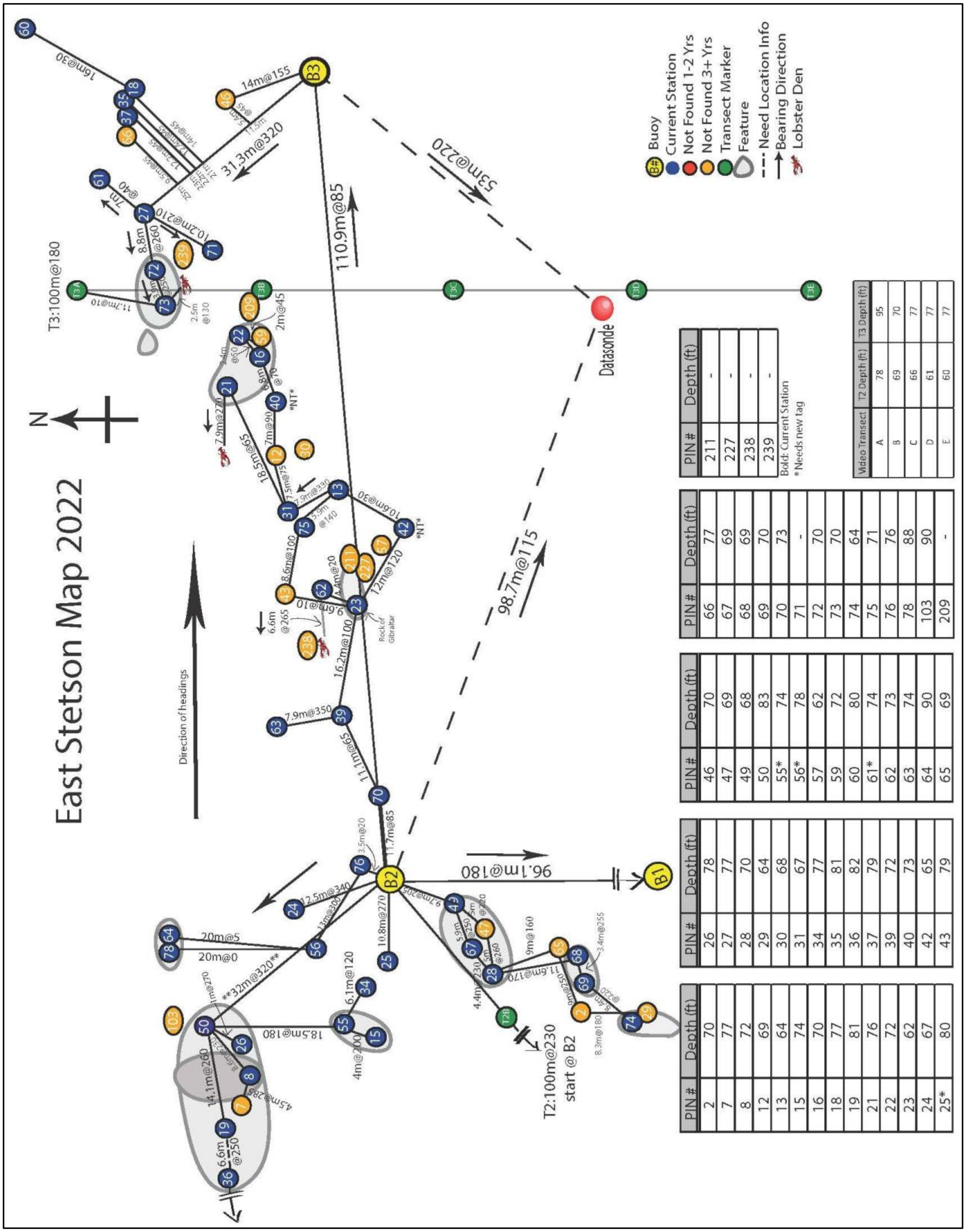


Figure 2.2. East Stetson map used by divers to locate repetitive photostations in the study site. The east map is used to locate stations between buoy 2 and buoy 3. Image: NOAA

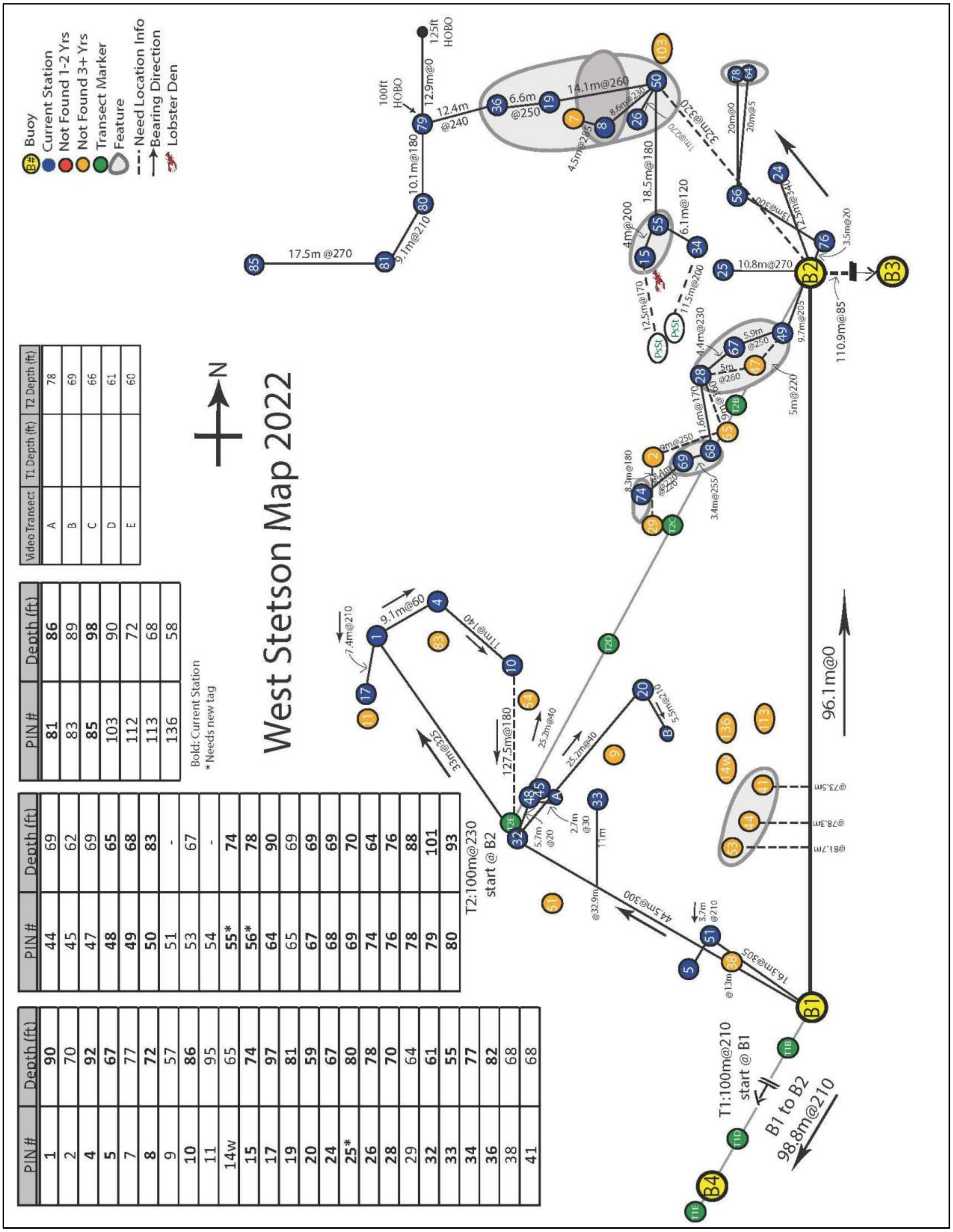


Figure 2.3. West Stetson map used by divers to locate repetitive photostations in the study site. The west map is used to locate stations surrounding buoy 1 and buoy 2. Image: NOAA

Methods

Repetitive photostations were located by divers using detailed maps and marked with floating plastic chains attached to small weights. Divers with cameras then photographed each station. In 2022, images were captured using a Sony® A6500 digital camera in a Nauticam® NA-A6500 housing with a Nikkor® Nikonos® 15 mm underwater lens. The camera was mounted onto a T-frame set at 1.75 m from the substrate to maintain coverage of 1.6 m^2, with two Inon® Z240 strobes set 1.2 m apart (Figure 2.4). A compass and bubble level were mounted to the center of the T-frame so images could be taken in a vertical and northward orientation to standardize the area captured and ensure repeatability.

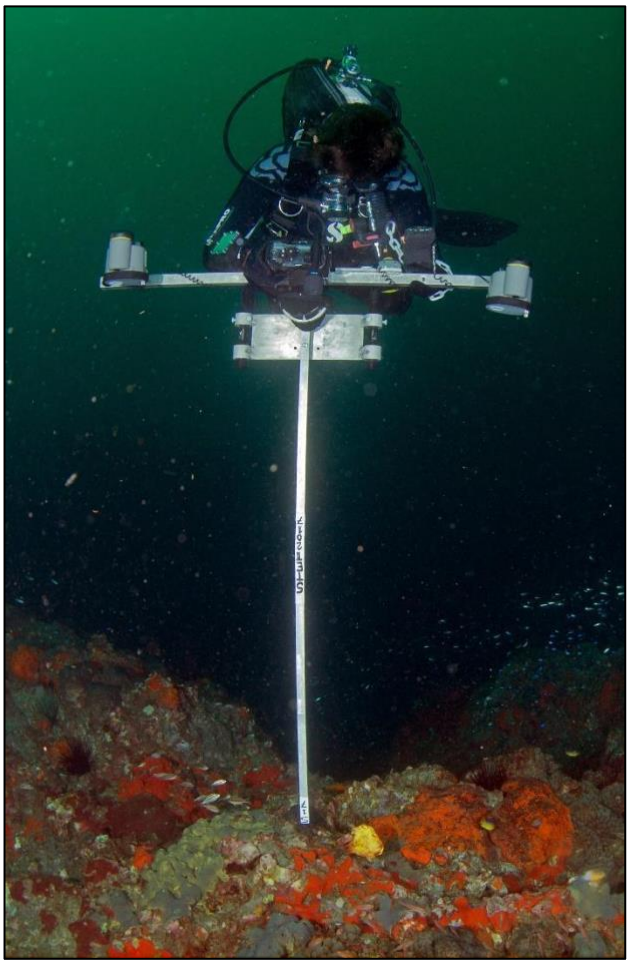


Figure 2.4. Camera and T-frame configuration for repetitive photostation images. Image: G.P. Schmahl/NOAA

Benthic cover in repetitive photostation images was analyzed using Coral Point Count with Excel extensions (CPCe) version 4.1, a spatial analysis software (Aronson et al., 1994; Kohler & Gill, 2006). A total of 30 random points were overlaid on each photograph and benthic species lying under these points were identified. Species identifications were verified in each photo by a benthic species expert. Organisms positioned beneath each random point were identified to the lowest possible taxonomic level, and cover was quantified for six groups: 1) coral, 2) sponges (including encrusting sponges), 3) macroalgae (algae longer than approximately 3 mm and thick algal turfs covering underlying substrate), 4) colonizable substrate (including fine turf algae and bare rock), 5) rubble, and 6) other (biotic components such as sea urchins, ascidians, fish, serpulid polychaetes, and unknown species). Additional features (photostation tags, tape measures, scientific equipment) and points with no data (shadows) were excluded from the analysis. Points that could not be differentiated because of camera angle or camera distortion were labeled as "unknown." Point count analysis was conducted for all images and mean percent cover for functional groups was determined by averaging across all samples (photostations) in the study site. Results are presented as mean percent cover + standard error (SE). Because photostations were not randomly selected, they are not intended to estimate bank-wide populations or benthic communities. Rather, they document changes in community structure at specific locations dominated by a similar habitat type and the fate of individual organisms, and may provide evidence of the causes of change.

Coral bleaching, paling, and mortality were also recorded as "notes" in CPCe, providing additional data for each random point. Any point that landed on a portion of coral that was white in color was characterized as "bleached." Any point that landed on coral that was pale relative to what is considered "normal" for the species was characterized as "paling" (Lang et al., 2012). If the colony displayed some bleaching or paling, but the point landed on a healthy area of the organism, the point was "healthy" and no bleaching or paling was noted in CPCe. Mortality included any point on recently dead but identifiable coral (exposed bare skeleton, with little to no algae growth).

Results

No new repetitive photostations were installed and 51 of the 59 repetitive photostations were photographed in 2022. Seven repetitive photostation pins were retagged, including pin numbers 10, 32, 75, 67, 49, 50, and 25. Repetitive photostations 19, 36, 69, 5, and 33 were searched for but not found, and number 5 was overgrown by sponge and will likely need to be reinstalled in 2023.

In 2022, mean percent cover was 4.42% for coral, 3.96% for hydrocoral, 14.03% for sponges, and 51.82% for macroalgae within 51 bank crest repetitive photostations (Figure 2.5). The dominant coral species were *M. alcicornis*, *M. decactis*, and *S. intersepta* (Figure 2.6). The dominant sponge species were *I. felix*, *I. strobilina*, and *N. nolitangere*, consistent with previous reports (Nuttall et al., 2020b; Figure 2.7). Bleaching and/or paling was observed in *M. alcicornis* colonies in 2022, but affected less than 1% of this species.

In late August 2022, disease-like lesions were reported on East and West Flower Garden Banks on seven coral species during routine monitoring surveys. Lesions were not observed at Stetson Bank in early August when long-term monitoring was conducted and no surveys were conducted to assess disease at Stetson Bank following the outbreak at East and West Flower Garden Banks.

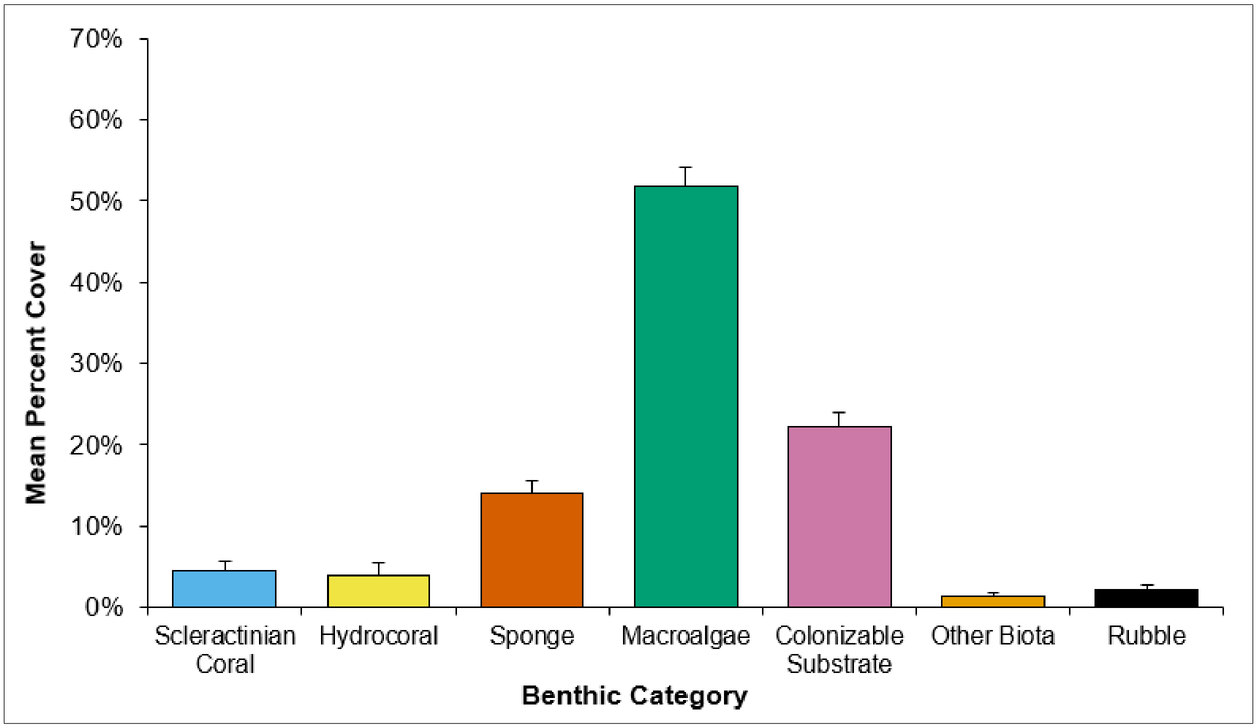


Figure 2.5. Mean percent cover (+SE) of major benthic categories at 51 repetitive photostations at Stetson Bank in 2022.

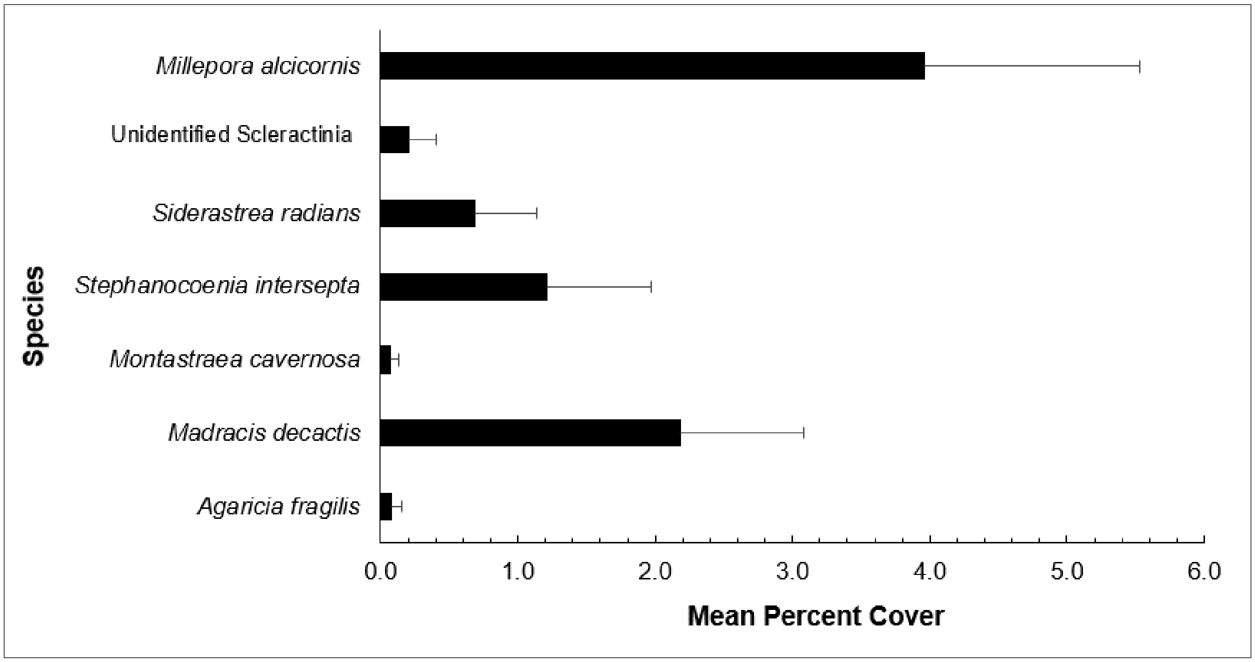


Figure 2.6. Mean percent cover (+SE) of dominant coral species at 51 repetitive photostations at Stetson Bank in 2022.

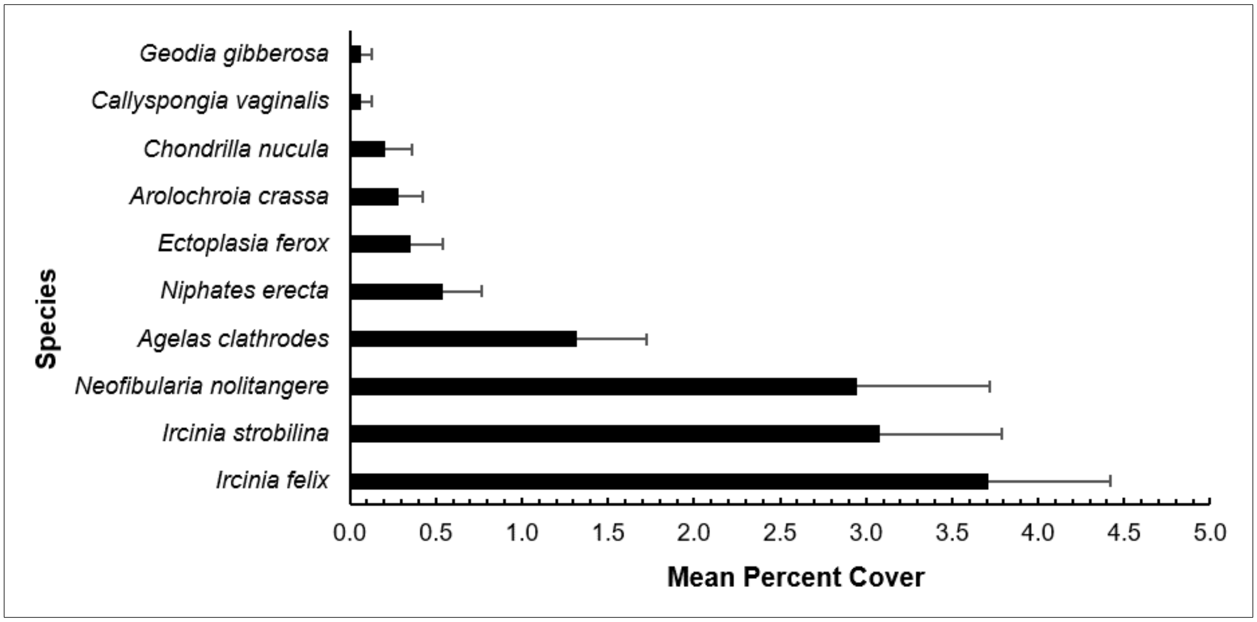
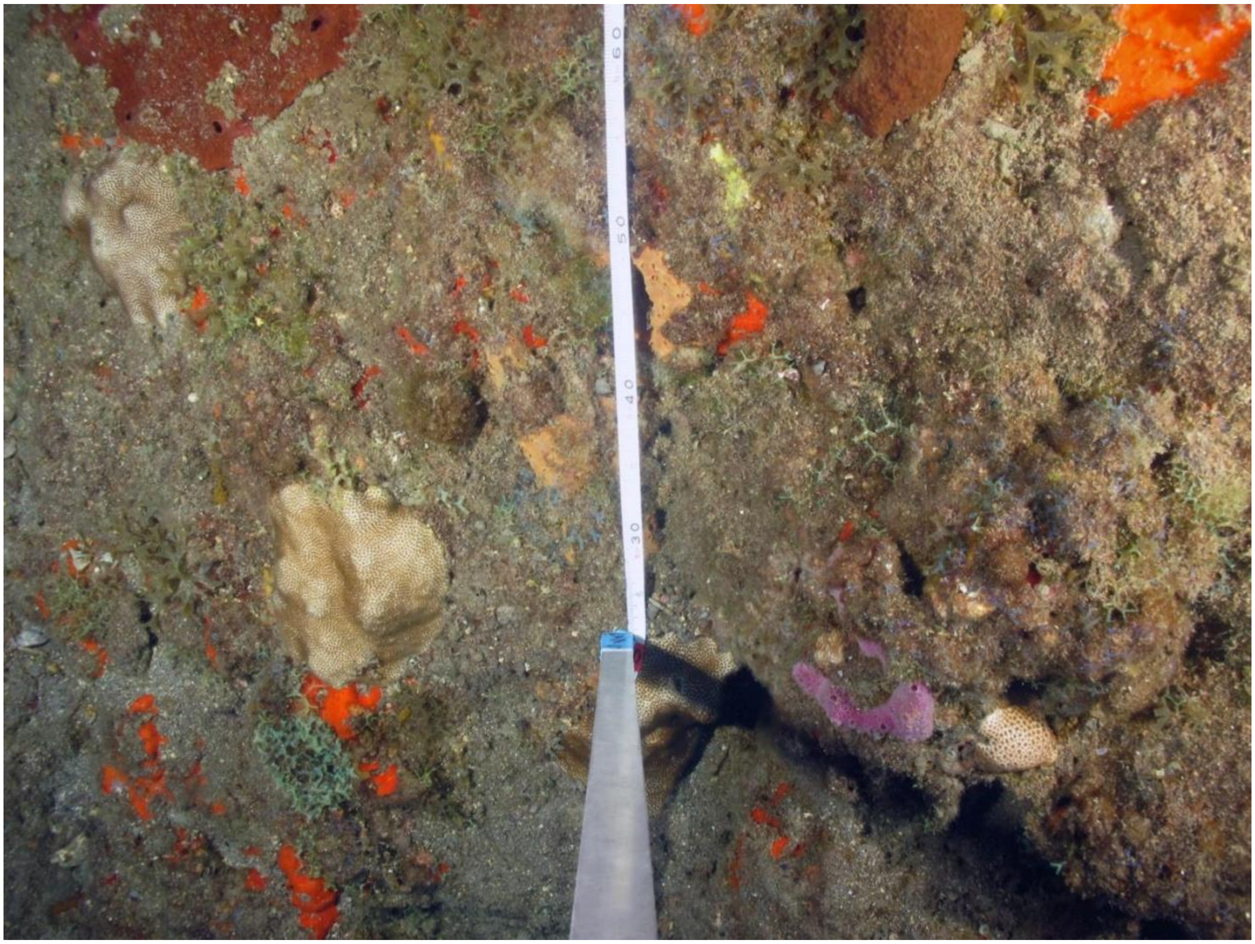


Figure 2.7. Mean percent cover (+SE) of dominant sponge species at 51 repetitive photostations at Stetson Bank in 2022.

Chapter 3:
Bank Crest Random Transects



A random transect image shows *S. intersepta*, sponge colonies, and macroalgae. Photo: K. O'Connell/NOAA

Introduction

Transect tapes were positioned at random locations within high- and low-relief habitat on Stetson Bank to estimate and compare the areal coverage of benthic components on the bank crest. Corals, sponges, and macroalgae were quantified.

Methods

Transect sites were preselected in a stratified random design (Figure 3.1). Habitat was defined using 1-m^2-resolution bathymetric data. Range (minimum to maximum depth) was calculated from the bathymetry data using the focal statistics tool in ArcGIS® (5 m x 5 m rectangular window calculating range). This layer was reclassified to define low-relief habitat (≤1 m range) and high-relief habitat (>1 m range). A 33.5-m contour was used to restrict the extent of the range layer, enabling divers to conduct surveys without decompression. Area was calculated for each habitat type in ArcGIS® to distribute transect start points equally by area. Total area available for conducting surveys was 0.12 km^2, with 0.08 km^2 of low-relief habitat and 0.04 km^2 of high-relief habitat. Thirty surveys were distributed among habitat types: 20 in low-relief habitat and 10 in high-relief habitat. Points representing the start location of a transect were generated using the ArcGIS® random point tool with a minimum of 15 m between sites (Figure 3.1). One transect was completed at each random point perpendicular to the random heading of the paired fish survey (Figure 3.1). However, surveyors were instructed to remain within the assigned habitat type and modify headings if needed. Where this was not possible, habitat type encountered was recorded and noted in the database.

Each transect was designed to capture at least 8 m^2 of benthic habitat. A still camera, mounted on a 0.65 m tall T-frame with bubble level and strobes, was used to capture non-overlapping images of the reef. Each image captured approximately 0.8 x 0.6 m (0.48 m^2), requiring 17 images to obtain the desired coverage (8.16 m^2). Spooled fiberglass 15-m measuring tapes, each with 17 pre-marked intervals (every 0.8 m), were used to provide guides for the camera T-frame, providing a 0.2-m buffer between each image to prevent overlap. A Canon Power Shot® G11 digital camera was used in an Ikelite® housing with a 28-mm equivalent wet mount lens adaptor and two Inon® Z240 strobes set 1.2 m apart on the T-frame.

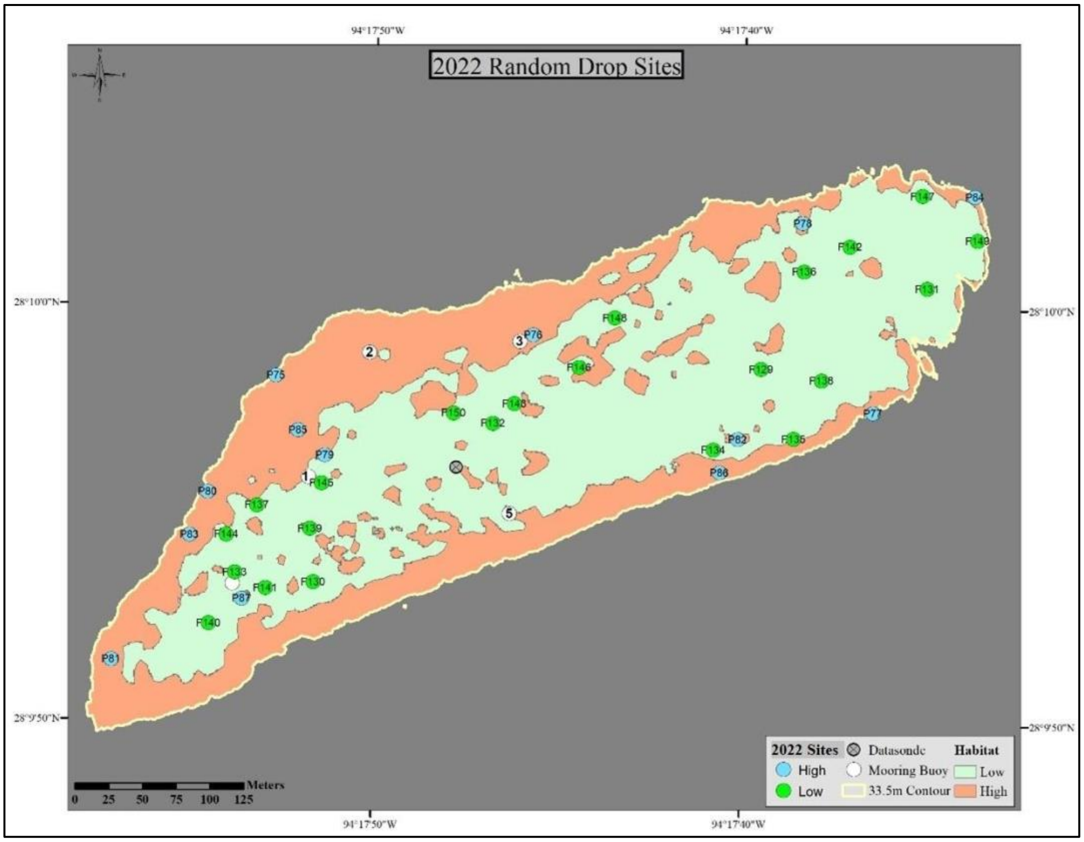


Figure 3.1. 2022 planned random transect locations. Blue points denote high-relief sites and green points denote low-relief sites. Image: NOAA

Results

In 2022, only five of the planned random transects were conducted before field operations were cut short: two in low-relief habitat and three in high-relief habitat. As a result of the low replicate number, these data were not processed.

Challenges and Resolutions

A combination of events prevented the collection of random transect data in 2022. These included a COVID-19 outbreak aboard the R/V *Manta*, a case of decompression sickness (although the diver's profile was within no-decompression limits and their ascent rate was safe), vessel maintenance issues, and weather disruptions.

Chapter 4:
Bank Crest Fish Monitoring

A school of horse-eye jacks (*Caranx latus*) at Stetson Bank. Photo: G.P. Schmahl/NOAA

Introduction

Modified Bohnsack-Bannerot (Bohnsack & Bannerot, 1986) stationary visual fish censuses were conducted in conjunction with reef-wide random transects to examine fish populations and composition and temporal changes (annually). Reef-wide surveys were conducted at stratified random locations in both low-relief and high-relief habitats.

Fish surveys were also conducted at six repetitive photostation locations. These surveys included modified Bohnsack-Bannerot stationary visual surveys done by divers as well as stationary camera surveys. The surveys conducted by cameras are meant to produce a permanent record and avoid known biases for different types of fish resulting from observer effects and diver-induced disturbances. While diver surveys have traditionally been the primary method for studying fish populations, stationary camera surveys are becoming more prevalent due to technological advancements in underwater cameras. By employing both methods for the first time, FGBNMS hopes to gain a better understanding of fish populations and compare methods.

Methods

Bohnsack-Bannerot

Scuba divers, using the modified Bohnsack-Bannerot stationary visual fish census technique, restricted observations to an imaginary cylinder with a radius of 7.5 m, extending from the seafloor to the surface (Bohnsack & Bannerot, 1986). All fish species observed within the first five minutes of the survey were recorded as the diver slowly rotated in place above the bottom. Immediately following this five-minute observation period, one rotation was conducted for each species noted in the original five-minute period to record abundance (number of individuals per species) and fork length (within size bins). Sizes were binned in eight groups: <5 cm, ≥5 cm to <10 cm, ≥10 cm to <15 cm, ≥15 cm to <20 cm, ≥20 cm to <25 cm, ≥25 cm to <30 cm, ≥30 cm to <35 cm, ≥35 cm. For fish ≥35 cm, each individual's size was recorded based on visual estimation by divers. Divers carried a 1-m PVC pole marked in 10-cm increments to provide a reference for size estimation.

Each survey required at least 15 minutes to complete. Transitory or schooling species were counted and measured at the time the individuals moved through the cylinder. Surveys began in the early morning (after sunrise) and were repeated throughout the day until dusk. Each survey represented one sample.

Surveys were paired with benthic transects, with location selected randomly in two habitat types defined by relief: low and high (see Chapter 3). One diver conducted the fish survey along a random heading while another diver conducted the benthic photo transect perpendicular to the fish survey area (Figure 4.1). For surveys conducted at repetitive photostations, the fish survey cylinder was centered on the repetitive station pin marker.

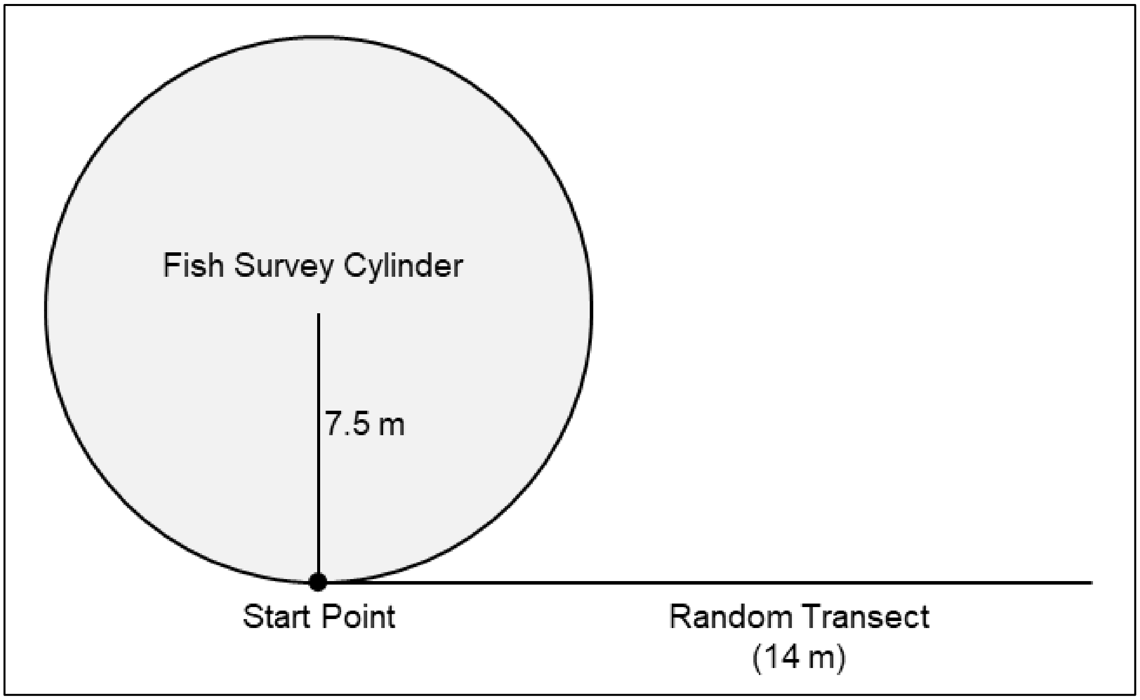


Figure 4.1. Random transect and fish survey area setup. Image: NOAA

In 2022, five random fish surveys were conducted: two in low-relief habitat and three in high-relief habitat (Chapter 3, Figure 3.1). Summary statistics of fish census data included abundance, density, sighting frequency, and species richness. Total abundance was calculated as the number of individuals per sample, and percent relative abundance was the total number of individuals for one species divided by the total of all species and multiplied by 100. Density was expressed as the number of individual fish per 100 m^2 ± SE, and calculated as the total number of individuals per sample by the area of the survey cylinder (176.7 m^2) and multiplied by 100. Sighting frequency for each species was expressed as the percentage of the total number of samples in which the species was recorded. Mean species richness was the average number of species per sample ± SE.

Stationary Camera Fish Surveys

Underwater video was collected in the bank crest study site using high-definition GoPro HERO10 digital cameras, enclosed in GolemGear GoPro camera housings with a depth rating of up to 150 m. The HERO10 Black camera used for the surveys is capable of capturing 5.3K video, has enhanced low-light performance, and has HyperSmooth 4.0 video stabilization features. The stationary cameras were deployed by divers at six repetitive photostations located throughout the study site. They were set up on tripods or secured to weights, with each camera positioned to capture a wide field of view of the surrounding habitat. To conserve battery life and capture video without the presence of divers, GoPro cameras were turned on by the divers at the end of their dives, then collected on the next dive rotation.

The video footage collected by the stationary cameras was analyzed using the MaxN method (Ellis & DeMartini, 1995). This involved reviewing a subset of video frames (21) during a 10-minute period and counting the number of individuals of each species present in each frame.

The data collected from the diver surveys were analyzed using standard statistical methods to calculate species richness, abundance, and diversity indices.

Figure 4.2. A video frame captured from a stationary GoPro camera at permanent photostation 19. Photo: K. O'Connell/NOAA

Results

Bohnsack-Bannerot

In 2022, a total of 66 species were recorded in bank crest repetitive fish surveys (n = 6) and surveys paired with benthic random transects (n = 5). Richness ranged from 12 to 23 species per survey, with an average of 17.82 ± 1.18. Mean fish density was 185.16 individuals/100 m^2 ± 31.10. Mean biomass was 10.984 kg/100 m^2 ± 3.044.

Regal demoiselle (*Neopomacentrus cyanomos*) had the highest density of all species (89.67/100 m^2 ± 20.67), followed by brown chromis (*Chromis multilineata*; 17.23 ± 6.57), cocoa damselfish (*Stegastes variabilis*; 13.89 ± 6.06), and bluehead (*Thalassoma bifasciatum*; 13.74 ± 2.87; Figure 4.3).

Bermuda chub (*Kyphosus saltatrix/incisor*) mean biomass was highest of all species (3.135 kg/100 m^2 ± 1.591), followed by great barracuda (*Sphyraena barracuda*; 1.555 ± 0.742), gray snapper (*Lutjanus griseus*; 1.266 ± 1.103), and Atlantic creolefish (*Paranthias furcifer*; 1.051 ± 0.430; Figure 4.4).

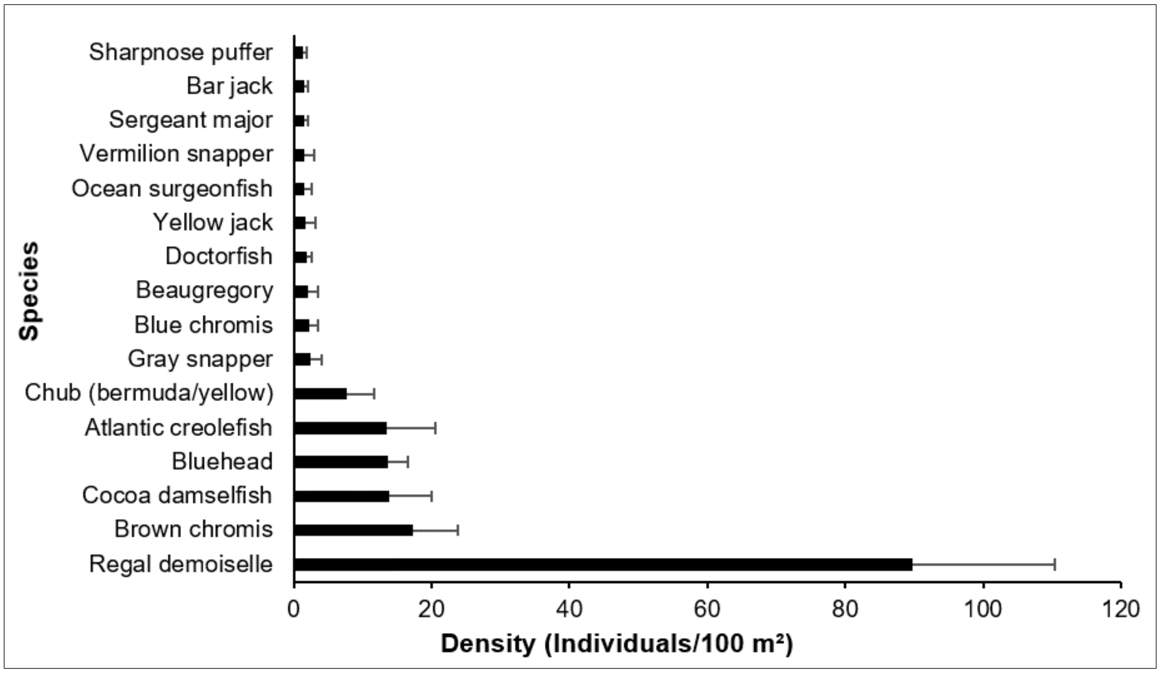


Figure 4.3. Densities (+ SE) of most abundant fish species in bank crest Bohnsack-Bannerot surveys.

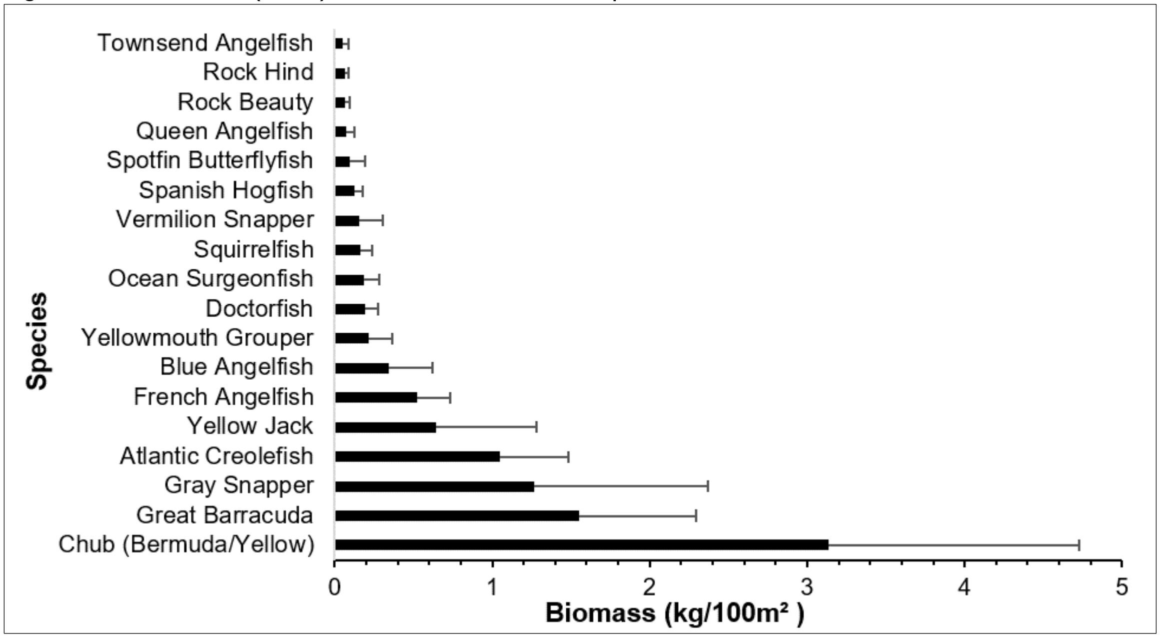


Figure 4.4. Biomass (+ SE) of highest contributing species in bank crest Bohnsack-Bannerot surveys.

Stationary Camera Fish Surveys

A total of 29 species were recorded in 2022 for all bank crest stationary camera surveys combined. Species richness ranged from 4 to 15 species per survey, with an average of 10.33 ± 1.87 per survey.

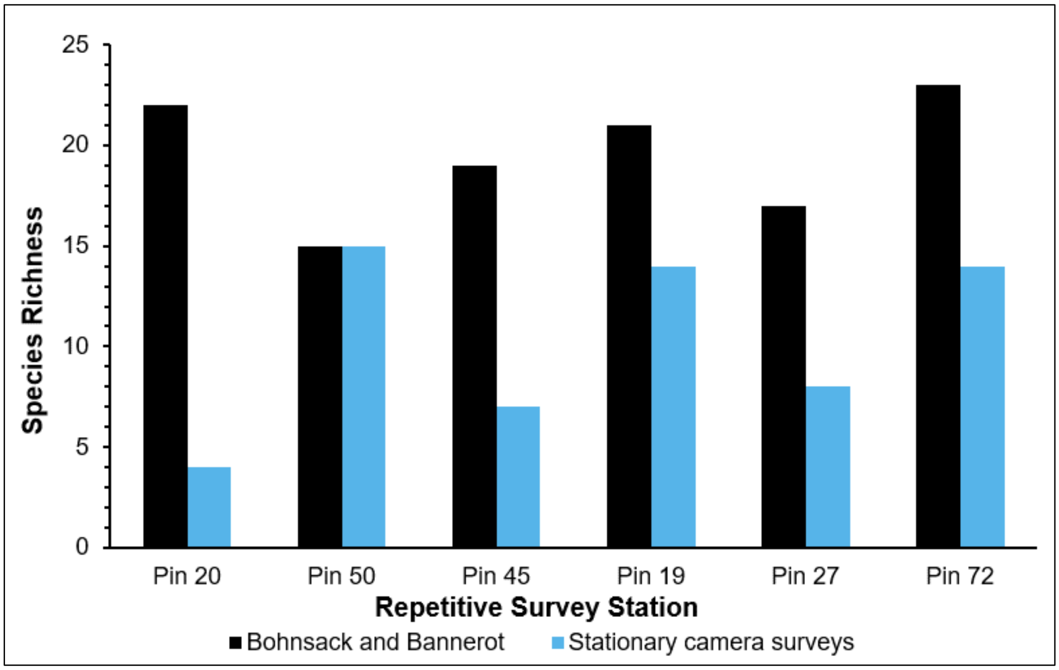


Figure 4.3. A comparison of species richness based on the two survey types at repetitive photostations.

Mean species richness was significantly lower in stationary camera surveys (10.33 ± 1.87) compared to Bohnsack-Bannerot method surveys (19.50 ± 1.26; $p = 0.01$); however, the absence of divers in stationary camera surveys may have resulted in different abundances of certain species and the detection of some species that were not observed in the Bohnsack-Bannerot method. For example, abundances of regal demoiselle were higher in stationary camera surveys. This may be due to underestimation of fish within their large schools by divers during Bohnsack-Bannerot surveys, or by the absence of diver disturbance during the stationary camera surveys.

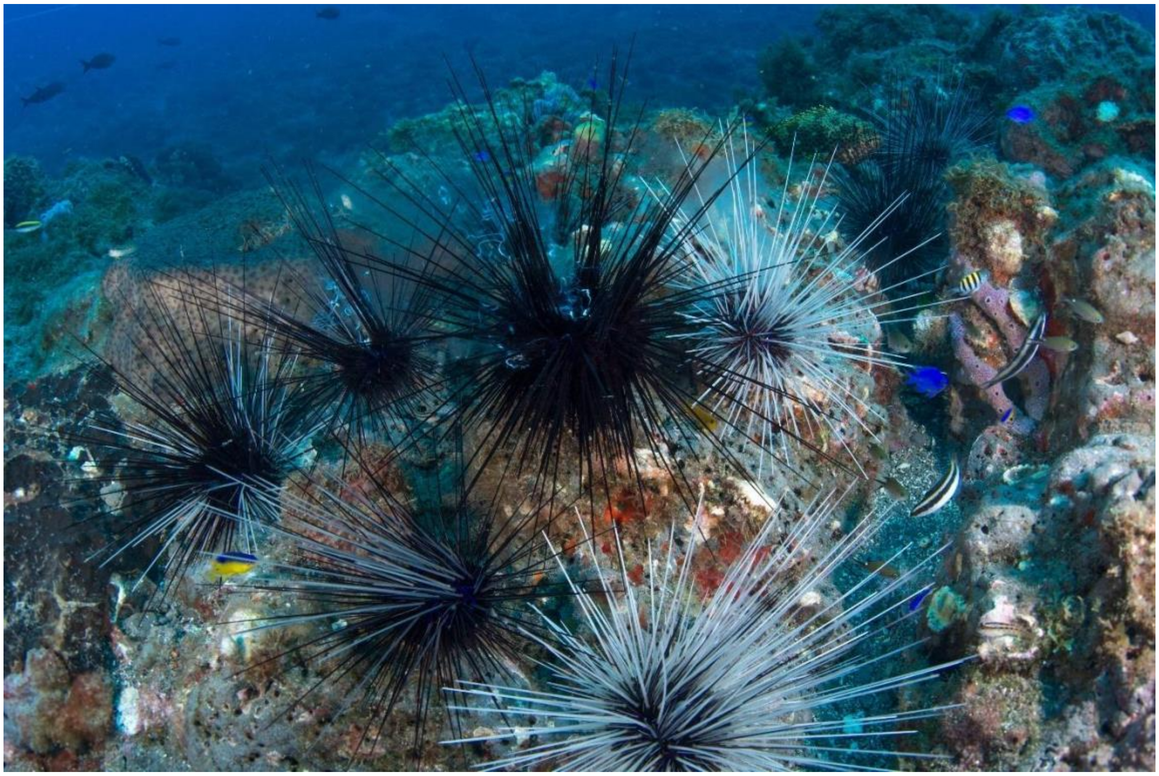
Stationary camera surveys captured the presence of spotted goatfish (*Pseudupeneus maculatus*), horse-eye jacks (*Caranx latus*), redspotted hawkfish (*Amblycirrhitus pinos*), striped grunt (*Haemulon striatum*), striped parrotfish (*Scarus iseri*), and tomtate (*Haemulon aurolineatum*), which were not present in the Bohnsack-Bannerot surveys. These differences are likely due to the unique strengths and limitations of each survey method. For example, estimates of fish sizes are possible when conducting visual census surveys, and more accurate counts of schooling fish can be made using stationary camera surveys.

Challenges and Resolutions

Only five fish surveys were completed alongside random transects due to the COVID-19 outbreak and dive complications.

Camera placement was not optimal in all stationary camera videos, as methods are still being fine-tuned. The camera tripod resulted in the GoPro camera being positioned too high off the reef, which was not ideal for obtaining an appropriate perspective. To address this issue, divers switched to using a soft weight as an anchor to obtain a camera angle closer to the reef.

Chapter 5:
Sea Urchin and Lobster Surveys



Long-spined sea urchins (*Diadema antillarum*) gather at Stetson Bank. Photo: G.P. Schmahl/NOAA

Introduction

Surveys of several important and conspicuous invertebrates are made during monitoring at Stetson Bank. The long-spined sea urchin (*Diadema antillarum*) was an important herbivore on coral reefs throughout the Caribbean until the 1980s. Between 1983 and 1984, an unknown pathogen decimated populations throughout the region, including FGBNMS. Since then, irregular, limited recovery has been documented in the region (Edmunds & Carpenter, 2001). Additionally, commercially important lobster population dynamics throughout this region are not well understood. These surveys are used to document the abundance of the long-spined sea urchin and multiple lobster species at Stetson Bank.

Methods

Due to the nocturnal nature of these species, visual surveys were conducted at night, a minimum of 1.5 hours after sunset. Two repetitive belt transects, 2 m wide and approximately 100 m long, were conducted by dive teams along lines between permanent mooring buoys (from buoy 1 to buoy 2 [100 m] and buoy 2 to buoy 3 [110 m]). In total, 420 m^2 were surveyed. The abundance of long-spined sea urchin, Caribbean spiny lobster (*Panulirus argus*), spotted spiny lobster (*Panulirus guttatus*), and slipper lobster species (Scyllaridae spp.) were noted.

These species were also counted in each repetitive photostation image and random transect, which were collected during daylight hours. In 2022, 420 m^2 of nighttime transects between buoys were completed, in addition to 51 repetitive photostations (covering 81.6 m^2) and five random benthic transects (covering 40.8 m^2).

Results

In 2022, a total of 264 urchins were counted during visual night surveys, with a mean density of 62.9 urchins per 100 m^2. Densities were higher in the repetitive photostations, with a total density of 142.2 urchins per 100 m^2 (Figure 5.1). Urchin counts from random transects were not included in the analysis because they were not completed in their entirety (see Chapter 4). One Caribbean spiny lobster and one slipper lobster were observed during nighttime visual surveys in 2022.

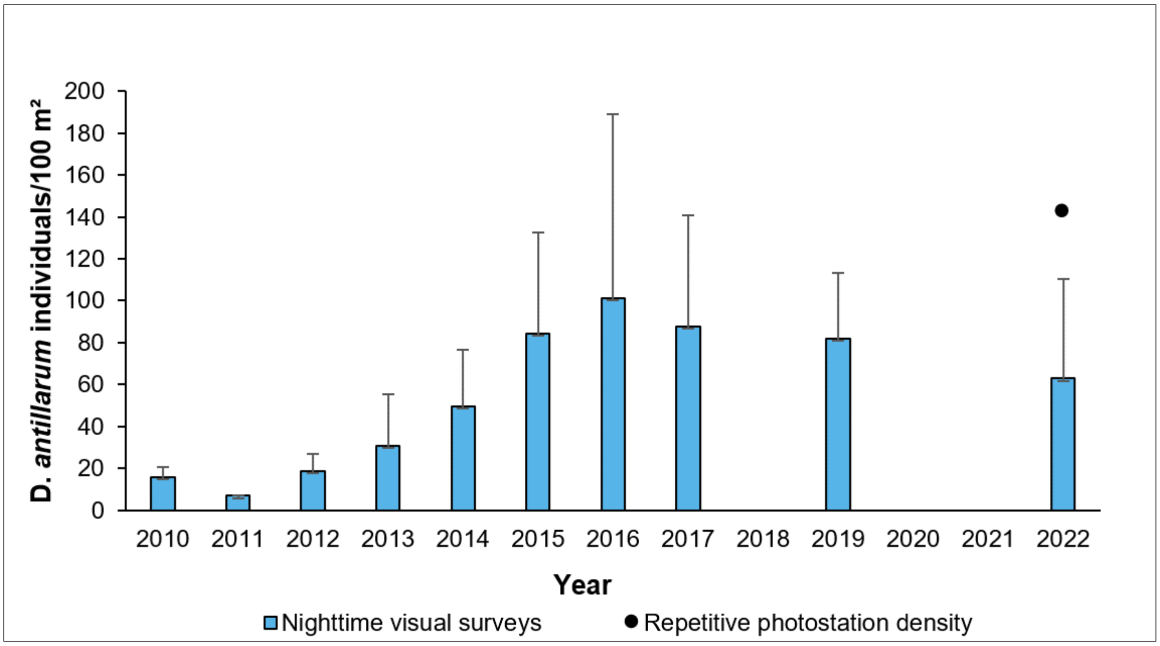
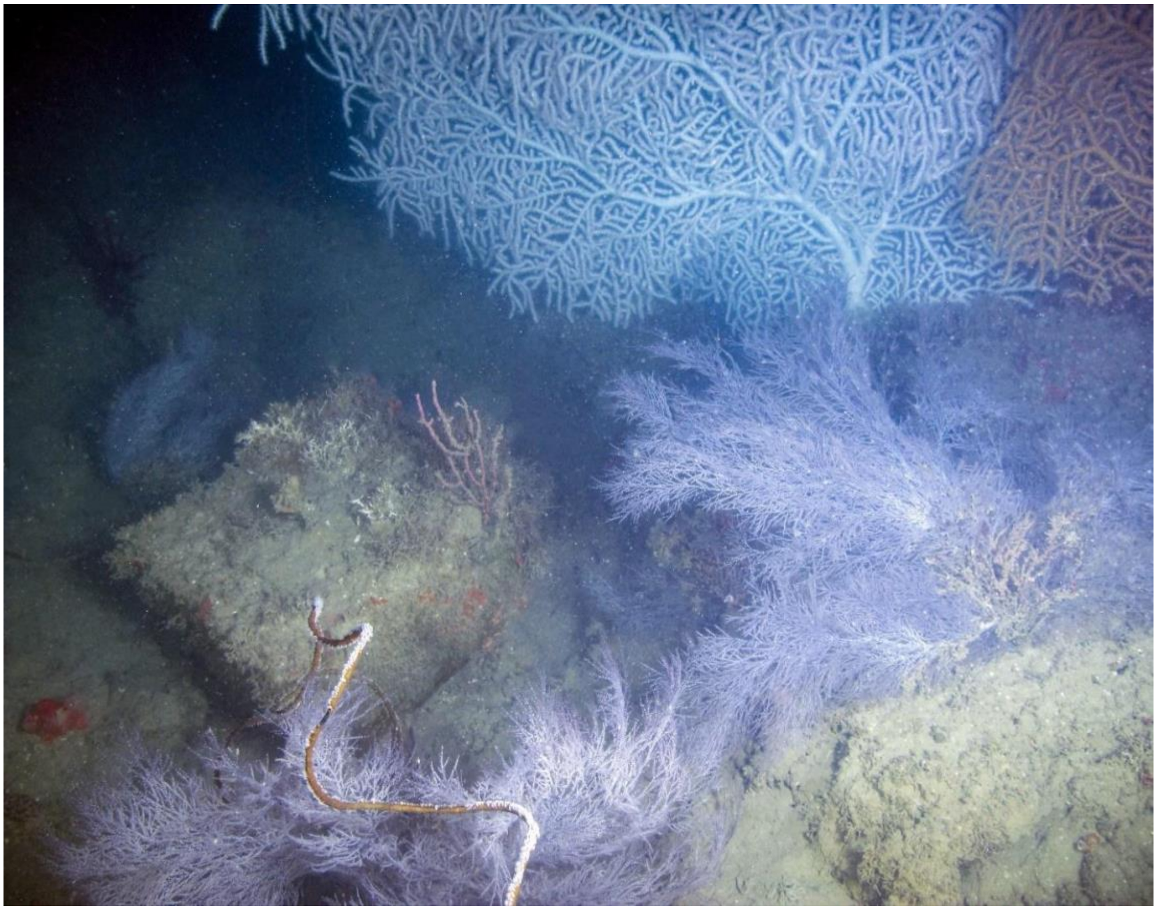


Figure 5.1. D. *antillarum* densities (+SE) since counts were first made in 2010.

Chapter 6:
Mesophotic Repetitive Photostations



Muricea sp. and black coral sea fans (*Antipathes atlantica*) next to repetitive mesophotic photostation M05. Photo: University of North Carolina at Wilmington Undersea Vehicle Program/NOAA

Introduction

Seven permanent photostations were established on the mesophotic reefs surrounding Stetson Bank in 2015. Locations of biological interest were selected along the hard bottom reef features and markers were deployed by ROV. Their latitude and longitude were recorded using the navigation system on the ROV (Figure 6.1). In 2022, five of the seven stations were located and photographed. Poor visibility made locating the station markers difficult, especially in deep reef habitat.

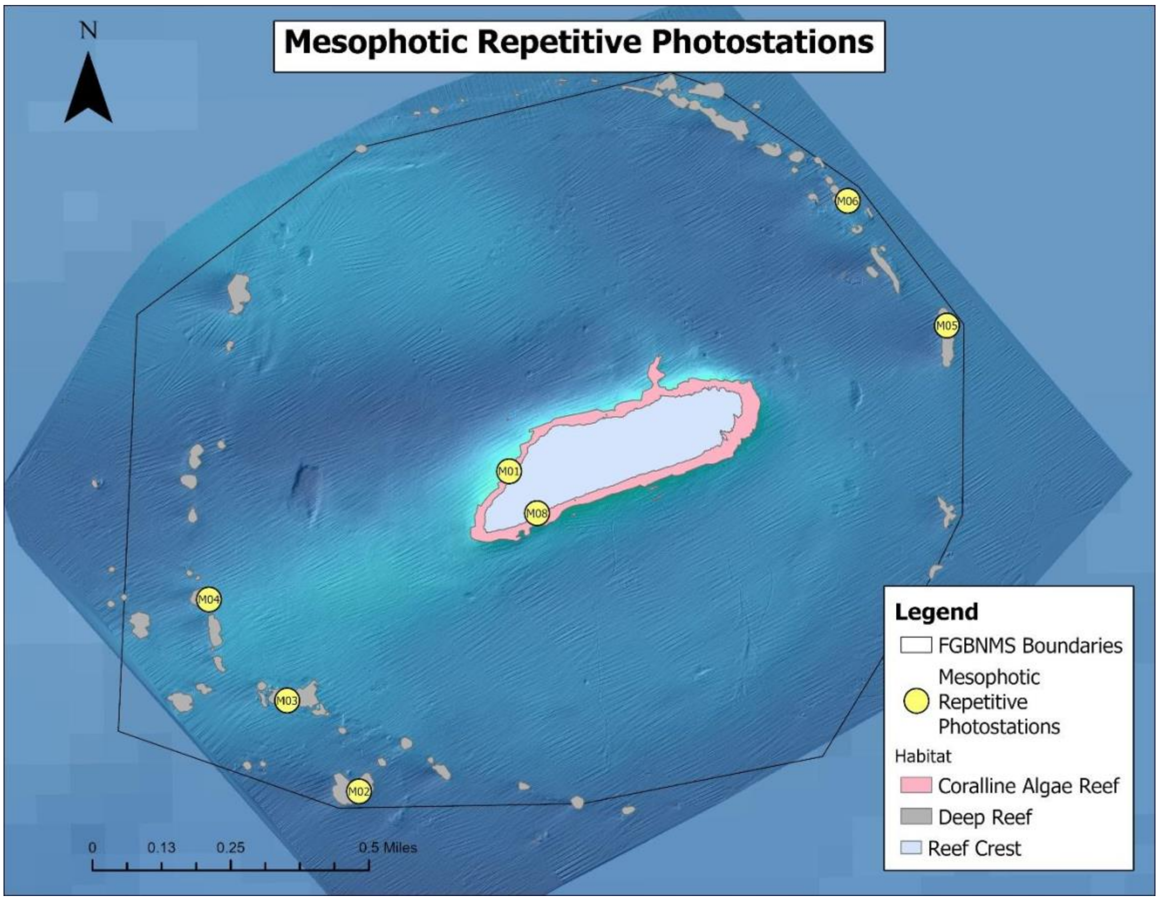


Figure 6.1. Mesophotic repetitive photostation locations. Image: NOAA

Methods

Repetitive photostations, marked with concrete blocks, were located and photographed by ROV using recorded latitude and longitude overlaid into the ROV navigation system. A heading assigned to each station was used to guide collection of high-definition video imagery of the site and old photographs were used to ensure all key features were observed in the video. Still frames for each repetitive station were extracted from the high-definition video feed and a downward-facing photograph of each station was also captured, with the ROV positioned directly above the station marker, approximately 1 m above the bottom.

In 2022, a SubAtlantic Mohawk 18 ROV, owned by the National Marine Sanctuary Foundation and FGBNMS and operated by University of North Carolina at Wilmington Undersea Vehicle Program, was used. The ROV was equipped with an Insite Pacific Mini Zeus II HD video camera with two Deep Sea Power and Light 3100 LED lights, and a tool skid with an ECA Robotics five-function all-electric manipulator. The ROV was also equipped with a Kongsberg Maritime OE14-408 10 mp digital still camera, OE11-442 strobe, and two Sidus SS501 50 mW green spot lasers set at 10 cm in the still camera frame for scale.

Results

Five of the seven sites were located and photographed. All five were photographed with both forward-facing and downward images. Poor visibility made locating sites difficult, especially in the deep reef ring surrounding the main feature. Multiple ROV dives were conducted during various times of day to search for repetitive stations. Photographs of the stations were compared to previous surveys and any changes were noted (Table 6.1). While the majority of key features at each station were captured in the images, the images were not identical between years.

Table 6.1. Qualitative description of changes to mesophotic repetitive photostations.

Repetitive Station	Depth (m)	Site Description 2015	2018–2019 Comparison	2019–2022 Comparison
M01	39.9	Coral (StIn) *Stephanocenia intersepta*: 50.3 x 30.4 x 12.4 cm. No bleaching present. (PoAs_1) *Porites asteroides*: 10.8 x 4.1 x 2.0 cm. Approximately 20% hard bottom covered in macroalgae and remaining consists of rubble.	New growth of encrusting orange sponge on top of concrete block	Possible *Millepora* sp. growth between boulders next to block
M02	54.7	Octocoral (HyW_1) white *Hypnogorgia* sp.: 50 x 96 cm. Black coral (Stic_1-2) sea whips. Poor visibility. 100% hard bottom.	Not found	Not found
M03	51.2	Sponges (IrW_1-4) white *Ircinia* sp., (IrB_1-12) brown *Ircinia* sp., and (NiEr_1-5) *Niphates erecta* with gastropods. Black coral sea fans (BCSF_1): 20 x 3 cm (BCSF_2): 24 x 10 cm. Black coral sea whips. 100% cover of trawl net on hard bottom.	No change apparent	Reduction of *Niphates erecta* sponge
M04	52.4	Sponges, (IrW_1) white *Ircinia* sp.: 25 x 7 x 8 cm, (IrW_2) white *Ircinia* sp.: 16 x 8 x 4 cm, and (IrB_1-2) brown *Ircinia* sp. Black coral sea fan (BCSF_1). 100% hard bottom.	Reduction of white *Hypnogorgia* sp. next to block (BCSF still present)	No apparent changes

Repetitive Station	Depth (m)	Site Description 2015	2018–2019 Comparison	2019–2022 Comparison
M05	53.6	Octocorals, (HyW_1-2) white *Hypnogorgia* sp., (HyR_1) red *Hypnogprgia* sp.: 28 cm in height. (HyG_1) gold *Hypnogorgia* sp. Black coral sea whip (Stic_1). 100% hard bottom.	2019 M05 photos not found	2018–2022 comparison: some octocoral growth
M06	49.1	Black coral (BCSF_1) sea fan: 25 x 29 cm and (Stic_1-3) sea whips. Sponges (NiEr_1-2) *Niphates erecta* and (IrB_1) brown *Ircinia* sp. 100% hard bottom	2019 M06 photos not found	Not found
M07	N/A	Lost marker during descent	N/A	N/A
M08	35.8	Coral (StIn_1) *Stephanocenia intersepta:* 58.6 x 48.3 x 4 cm. No bleaching present. (StIn_2) *Stephanocenia intersepta*: 32.6 x 18.0 x 3 cm. Sponge *Neofibularia nolitangere*. 80% hard bottom covered in macroaglae and remaining consists of rubble.	Increased encrusting sponge growth on surrounding rocky reef. StIn_1 paling patch closest to block. StIn_2 recovered.	No apparent changes

Challenges and resolutions

Some repetitive sites were not located. Poor visibility due to heavily silted water and overgrowth of markers by hydroids made locating markers difficult in 2022. Multiple ROV dives were conducted to search for markers. New, brightly colored floating markers are being considered for deployment on the next ROV cruise to make repetitive photostations more visible.

Chapter 7: Mesophotic Random Transects

A downward facing photograph highlights major benthic biota in Stetson Bank coralline algae habitat.
Photo: University of North Carolina at Wilmington Underwater Vehicle Program/NOAA

Introduction

A minimum of 15 random transects are conducted annually using a stratified random sampling design. Sites were selected on potential mesophotic habitat identified using bathymetric data. Transects were conducted using a downward-facing still camera mounted to the ROV. The transects were analyzed to assess community composition and coral density.

Methods

Bathymetric data were processed in Esri's ArcGIS® to highlight potential mesophotic reef habitat. A two-meter resolution bathymetry raster was imported into ArcMap® and focal statistics were calculated for range (minimum to maximum depth) within a 2 x 2 cell rectangle. Cells with a range >1 m were identified as potential habitat. Areas shallower than 33.5 m were removed. The raster was then converted to a polygon feature.

Two habitats were identified in 2015: coralline algae reef and deep reef. In 2022, a total of 30 surveys (15 in each habitat) were randomly distributed within the polygons defining habitat. Each point, representing the start location of transects, was generated using the tool "create random points," with a minimum of 30 m between sites (Figure 7.1). However, transects were not analyzed at all sites if transects overlapped or environmental conditions resulted in poor quality data.

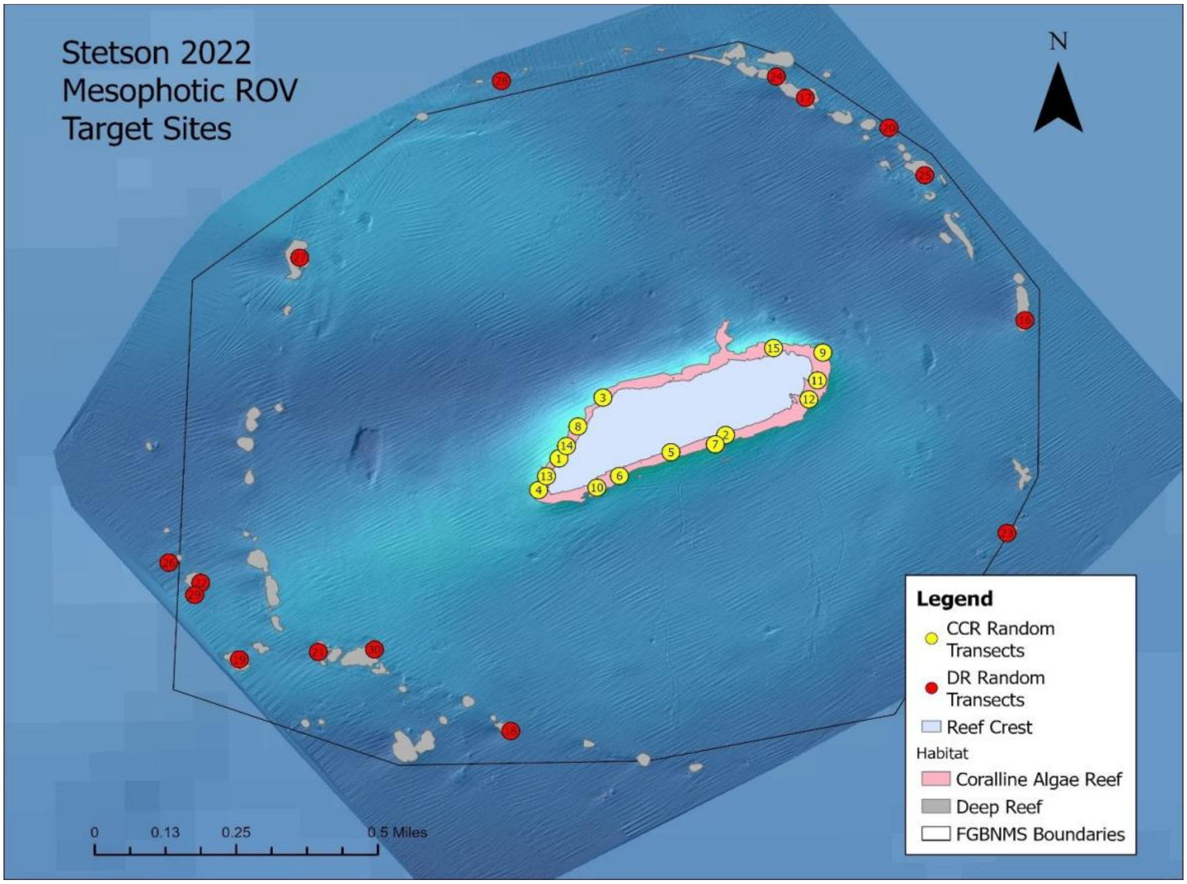


Figure 7.1. 2022 mesophotic target locations with random transects in coralline algae reef (CCR) and deep reef (DR). Image: NOAA

Surveys were conducted using the ROV with a downward-facing still camera and two lasers for scale. Transects started at each of the random drop sites and continued for 10 minutes along hard bottom habitat. The ROV traveled 1 m above the bottom at a speed of 1 knot, taking downward facing still images every 30 seconds during the transect.

In 2022, the same ROV system described in Chapter 5 was used. Twenty-nine transects were conducted in 2022, with 15 in coralline algae reef habitat and 14 in deep reef habitat.

Percent Cover

All images were analyzed for percent cover using CPCe (Kohler & Gill 2006). For stratified mesophotic random transects, each transect was treated as a sample with a minimum of 500 spatially random points apportioned evenly along the transect (for example, in a transect with 11 images, each image had 46 random points).

Organisms positioned beneath each random dot were identified to lowest possible taxonomic level for Cnidaria, Porifera, and macroalgae. Other organisms were grouped at higher taxonomic levels. Data were summarized for 14 functional groups, including: Scleractinia, hydrocoral, Antipatharia, Octocorallia, Alcyonacea, Porifera (encrusting and free standing), macroalgae (including algae longer than approximately 3 mm and thick algal turfs), colonizable substrate (crustose coralline algae, fine turfs, and bare rock), other biotic (ascidians, fish, serpulids, and unknown species), rubble (coral and substrate rubble), silted hard bottom, soft substrate (sand and silt), other abiotic (tape measures, tags, research equipment, and marine debris), and no data (no data and shadows). Rubble, silted hard bottom, soft substrate, other abiotic, and no data classifications were excluded from data analysis as they do not represent significant benthic biota.

Cnidarian Colony Counts

In addition to point count analysis, colony counts for cnidarians of interest (all cnidarians excluding hydroids) were conducted to the lowest possible taxonomic level for each image. Counts were summed across all images in a transect and presented as density per 1 m^2.

Results

In 2022, a total of 27 transects were processed, with 15 in coralline algae reef habitat and 12 in deep reef habitat. Transects were not analyzed at all sites if they overlapped or environmental conditions resulted in poor quality data.

Percent Cover

In 2022, the mesophotic benthic community was dominated by macroalgae in both coralline algae and deep reef habitat (48.3% and 48.2% cover, respectively). The main faunal component in coralline algae habitat was sponges (6.5%), which were primarily encrusting sponges. The primary deep reef habitat fauna was “other biota” (8.2%), primarily hydroids (Figure 7.2).

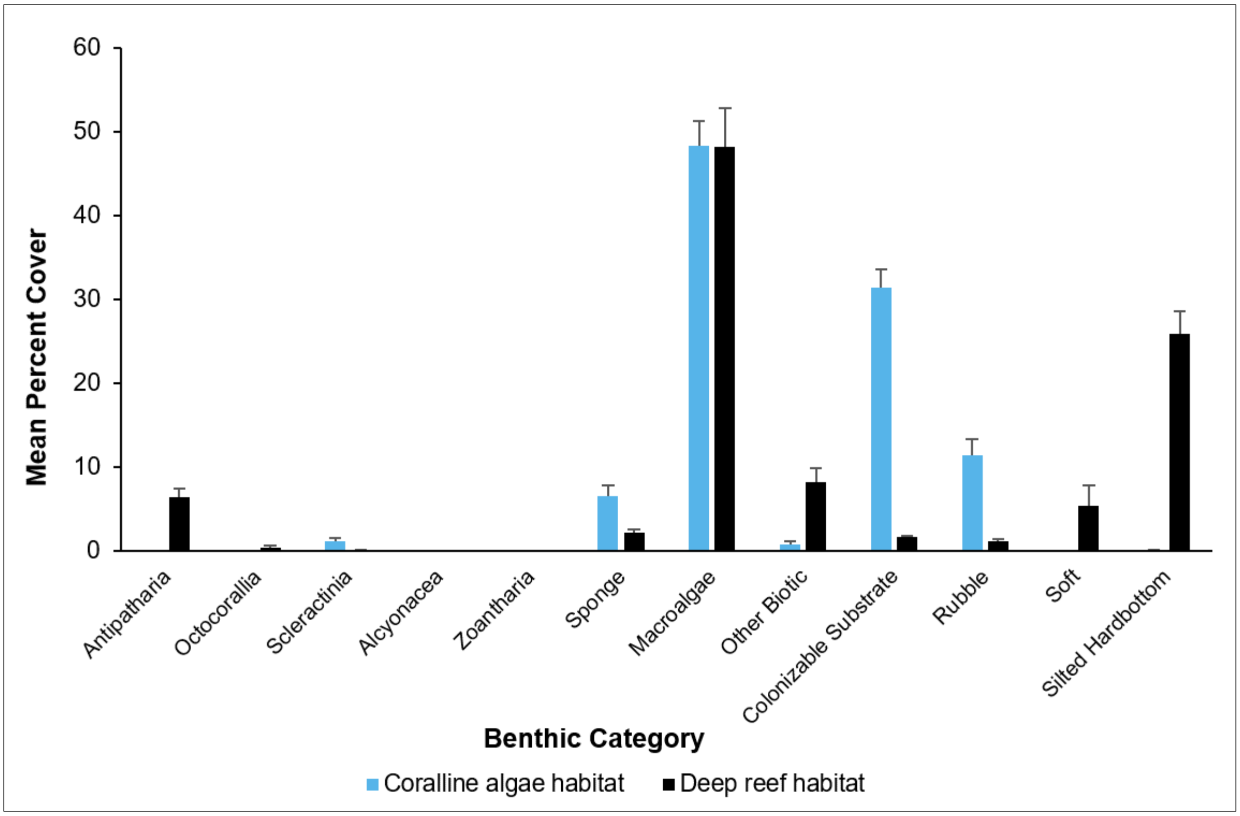


Figure 7.2. Mean percent cover (+SE) of major benthic categories in 27 mesophotic random transects.

Cnidarian Colony Counts

Of the cnidarian families (excluding hydroids), the densest families in deep reef habitat were Caryophylliidae (solitary cup corals), with a mean of 8.03 individuals per m^2, and Antipathidae (black coral sea fans, likely *Antipathes atlantica/gracilis*), with a mean of 6.68 individuals per m^2. The densest colonies in coralline algae reef habitat were Astrocoeniidae at 3.00 individuals per m^2 (Figure 7.3), primarily due to the abundance of *Madracis brueggemanni* and *Stephanocoenia intersepta*.

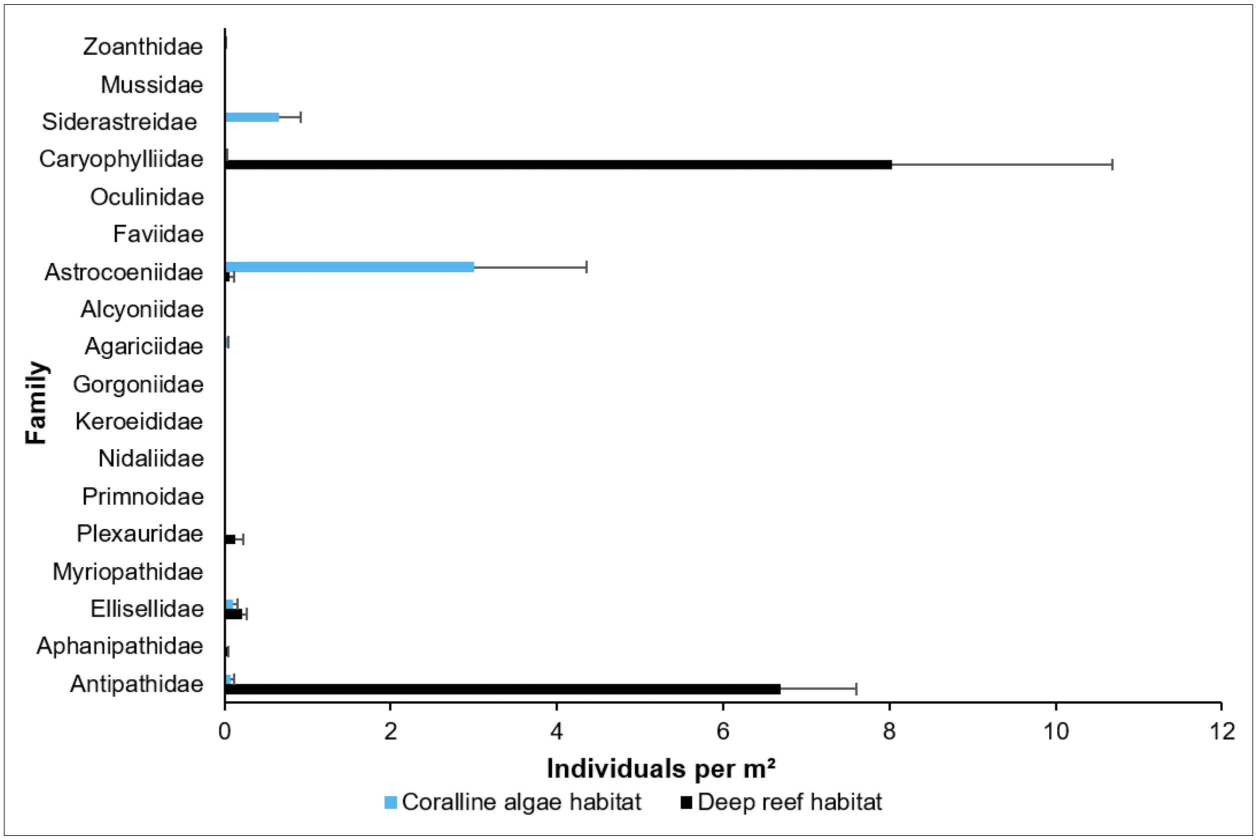


Figure 7.3. Density (+SE) of cnidarian families from random transects across coralline algae and deep reef habitat.

Chapter 8:
Mesophotic Fish Monitoring

A pair of spotfin butterflyfish (*Chaetodon* ocellatus) and an Atlantic bigeye (*Priacanthus arenatus*) in coralline algae habitat. Photo: University of North Carolina at Wilmington Underwater Vehicle Program/NOAA

Introduction

In addition to the mesophotic benthic transects described in the previous chapter, belt transect visual fish censuses were conducted at random locations in the mesophotic habitat surrounding Stetson Bank to characterize and compare fish community composition and temporal change. Fish surveys were also conducted at permanent photostations using stationary cameras. Stationary cameras have been proven to be a reliable method for conducting fish surveys in aquatic environments. Compared to ROVs, stationary cameras offer several advantages, including reduced disturbance to fish behavior and habitat. Stationary cameras may be more likely to detect rare and elusive fish species than ROVs because they do not produce noise or movement, allowing fish to behave naturally (Rooper et al., 2020). By employing both methods for the first time, FGBNMS hopes to gain a more comprehensive understanding of fish populations, search for cryptic species, and compare methods.

Methods

Belt Transects

Fishes were visually assessed by ROV using forward-facing video footage along belt transects, as discussed in Chapter 7. Observations of fishes were restricted to the field of view of the ROV's forward-facing high-definition video camera. All fish species observed were recorded, counted, and sized. Fork length estimates were made using mounted scale lasers in the field of view of the ROV for reference and binned into eight groups: <5 cm, ≥5 cm to 10 cm, ≥10 cm to 15 cm, ≥15 cm to 20 cm, ≥20 cm to 25 cm, ≥25 cm to 30 cm, ≥30 cm to 35 cm, and ≥35 cm. Each survey required 10 minutes to complete. Surveys began in the early morning (after sunrise), and were repeated throughout the day until dusk. Each survey represented one sample.

The surveys were conducted in conjunction with mesophotic random transects, where the survey starting location was selected using a stratified random sampling design (see Chapter 7). A minimum of 15 surveys are conducted annually. During the 2022 sampling period, 29 fish surveys were completed.

In 2022, the ROV system described in Chapter 5 was used. It was equipped with an ORE transponder to collect ROV position information with ORE TrackPoint II. A separate set of paired lasers, set at 10 cm apart, was used to size fish.

Stationary Camera Fish Surveys

Underwater video was collected in mesophotic coralline algal habitat using the high-definition GoPro Hero10 digital cameras discussed in Chapter 4. The stationary cameras were deployed by the ROV on the concrete block marker at two mesophotic repetitive photostations. They were secured to weights, with each camera positioned to capture a wide field of view that encompassed the surrounding habitat. The cameras were made visible by brightly covered electric tape to ensure the ROV could retrieve the camera (Figure 8.1). The ROV dropped off the cameras at the beginning of each dive and left the area to ensure the footage would capture the photostation in the absence of the lights and noise.

The video footage collected by the stationary cameras was analyzed using the MaxN method. This involved reviewing a subset of video frames (21) during a 10-minute period and counting the maximum number of individuals of each species present in each frame. The data collected from the diver surveys were analyzed using standard statistical methods to calculate species richness, abundance, and diversity indices.

Figure 8.1. A photo of the stationary camera following its placement at repetitive photostation M01. Photo: University of North Carolina at Wilmington Underwater Vehicle Program/NOAA

Results

Belt Transects

Due to visibility constraints, 24 of the 29 fish surveys conducted were used for analysis. A total of 78 species were recorded in mesophotic belt surveys. Richness ranged from 7 to 17 species per survey, with an average of 12.00 ± 0.42 species per survey. Mean fish density (individuals/100 m^2 ± SE) was 48.05 ± 7.89. Mean biomass (kg/100 m^2 ± SE) was 9.835 ± 2.540.

Yellowtail reeffish (*Chromis enchrysura*) had the highest density of all species (10.55 ± 2.34), followed by tomtate (*Haemulon aurolineatum*; 6.46 ± 2.82), regal demoiselle (*Neopomacentrus cyanomos*; 5.87 ± 2.21), and sunshinefish (*Chromis insolata*; 3.70 ± 1.28; Figure 8.2).

Red snapper (*Lutjanus campechanus*) average biomass was highest of all species (2.645 ± 1.049), followed by tomtate (*Haemulon aurolineatum*; 1.537 ± 0.653), greater amberjack (*Seriola dumerili*; 0.927 ± 0.473), and yellowmouth grouper (*Mycteroperca interstitialis*; 0.620 ± 0.268; Figure 8.3).

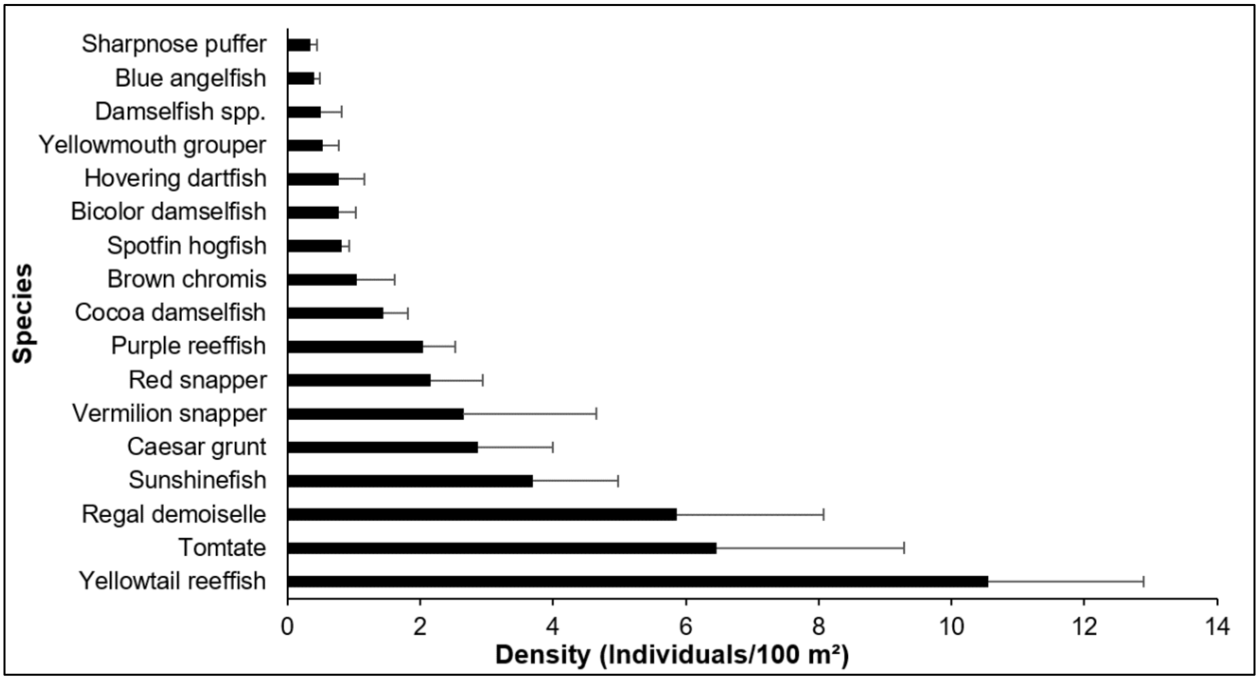


Figure 8.2. Overall density (individuals/100 m^2) of most abundant fish species in mesophotic belt surveys.

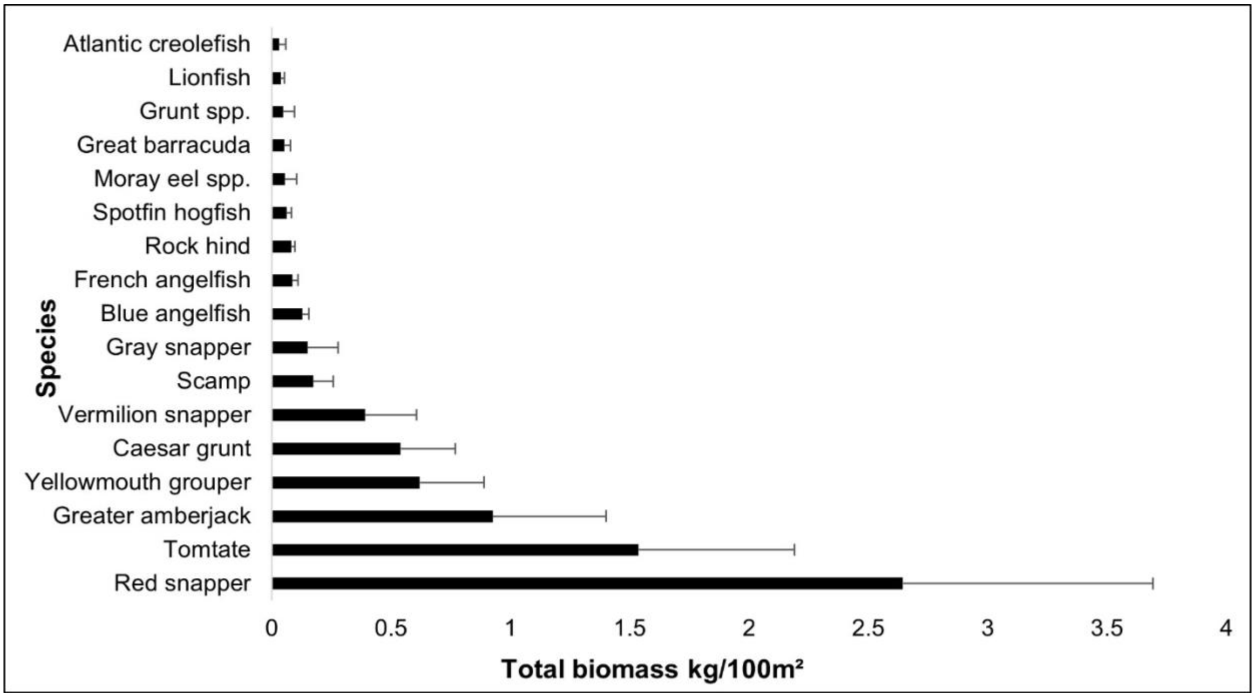


Figure 8.3. Total biomass (kg/100 m^2) for highest contributing species in mesophotic belt surveys.

Stationary Camera Fish Surveys

A total of 23 species were recorded in stationary camera surveys at permanent repetitive photostations (n = 2). Species richness was nine at M01 and 16 at M03. Stationary camera surveys captured the presence of mahogany snapper (*Lutjanus mahogoni*) and bridled goby (*Coryphopterus glaucofraenum*), which were not present in fish belt transects.

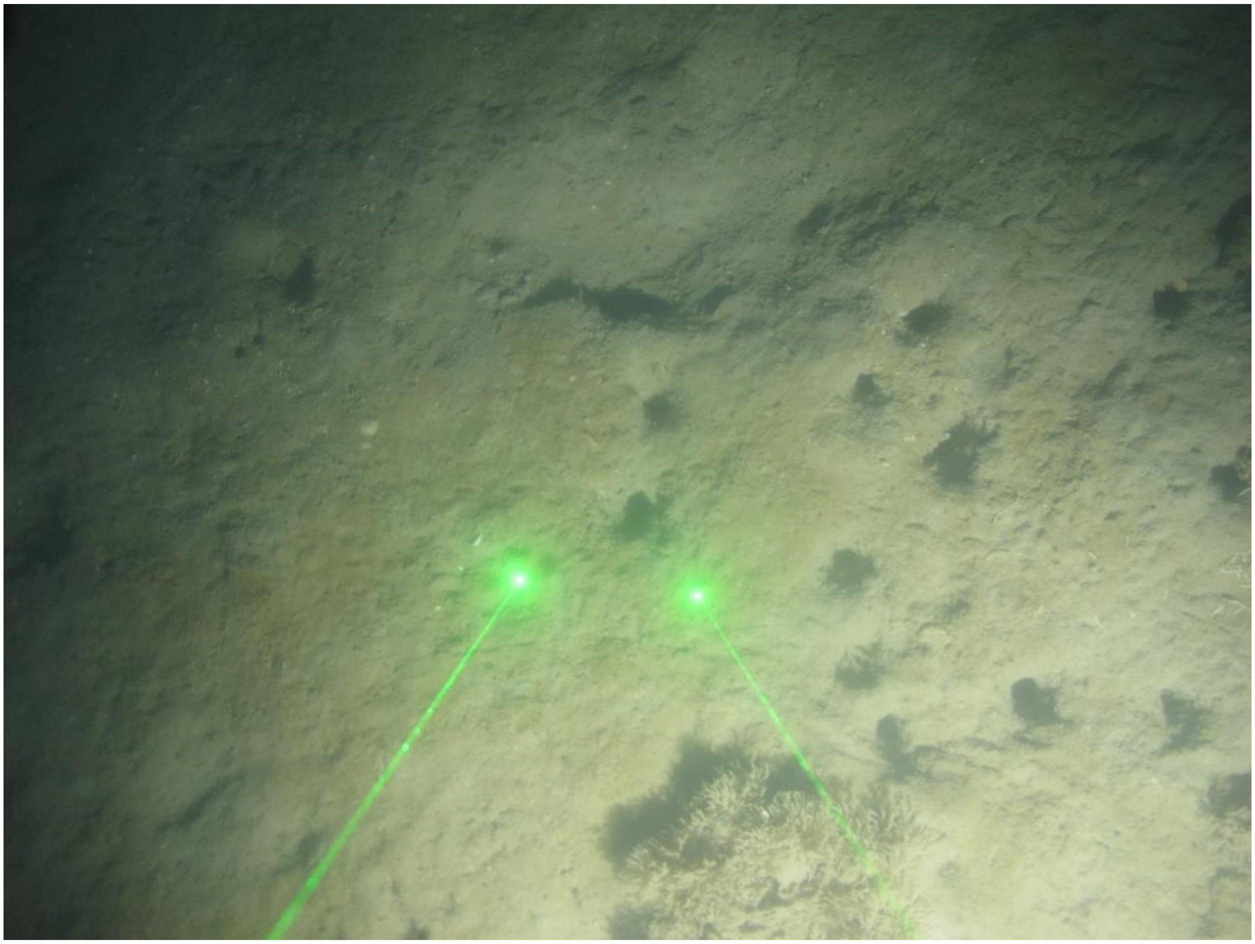
Challenges and Resolutions

Random fish surveys were challenging in low-visibility habitats, as some fish hid before coming into the field of view and the lack of water clarity made observation and species identifications difficult. In 2022, surveys were not conducted in locations with visibility less than 3 m.

Conducting stationary fish surveys in the mesophotic region proved to be challenging due to logistical issues with ROV-deployed cameras. As a result, surveys were only conducted in the coralline algae reef area, as visibility in the deeper reef habitat was not sufficient to guarantee that the cameras would not be lost.

Conducting fish surveys using stationary cameras was also challenging due to limited camera battery life. To address this issue, surveys were timed to occur at the beginning of each dive before continuing with ROV exploration. However, if all seven repetitive photostations were paired with stationary fish surveys, launching and retrieving the ROV frequently would have been time-consuming and inefficient. FGBNMS is currently piloting these methods to determine if stationary camera methods improve accuracy and/or capture more cryptic species. If stationary cameras are found to be helpful, FGBNMS may consider using drop cameras in the future.

Chapter 9:
Contaminant Analysis



Soft bottom habitat at Stetson Bank was targeted for sediment contaminant analysis. Photo: University of North Carolina at Wilmington Underwater Vehicle Program/NOAA

Introduction

FGBNMS analyzes contaminants at Stetson Bank, focusing specifically on polycyclic aromatic hydrocarbons (PAHs), which are associated with oil and gas activities. A dense network of oil and gas platforms and pipelines are distributed across the northern Gulf of Mexico and discharges can result in accumulations of PAHs, threatening marine life in the vicinity. PAHs are persistent, bioaccumulative, and toxic to both marine organisms and humans (Raeisi et al., 2016). Measuring PAHs provides both a baseline and recurring assessment of anthropogenic impacts that can occur as a result of this industry.

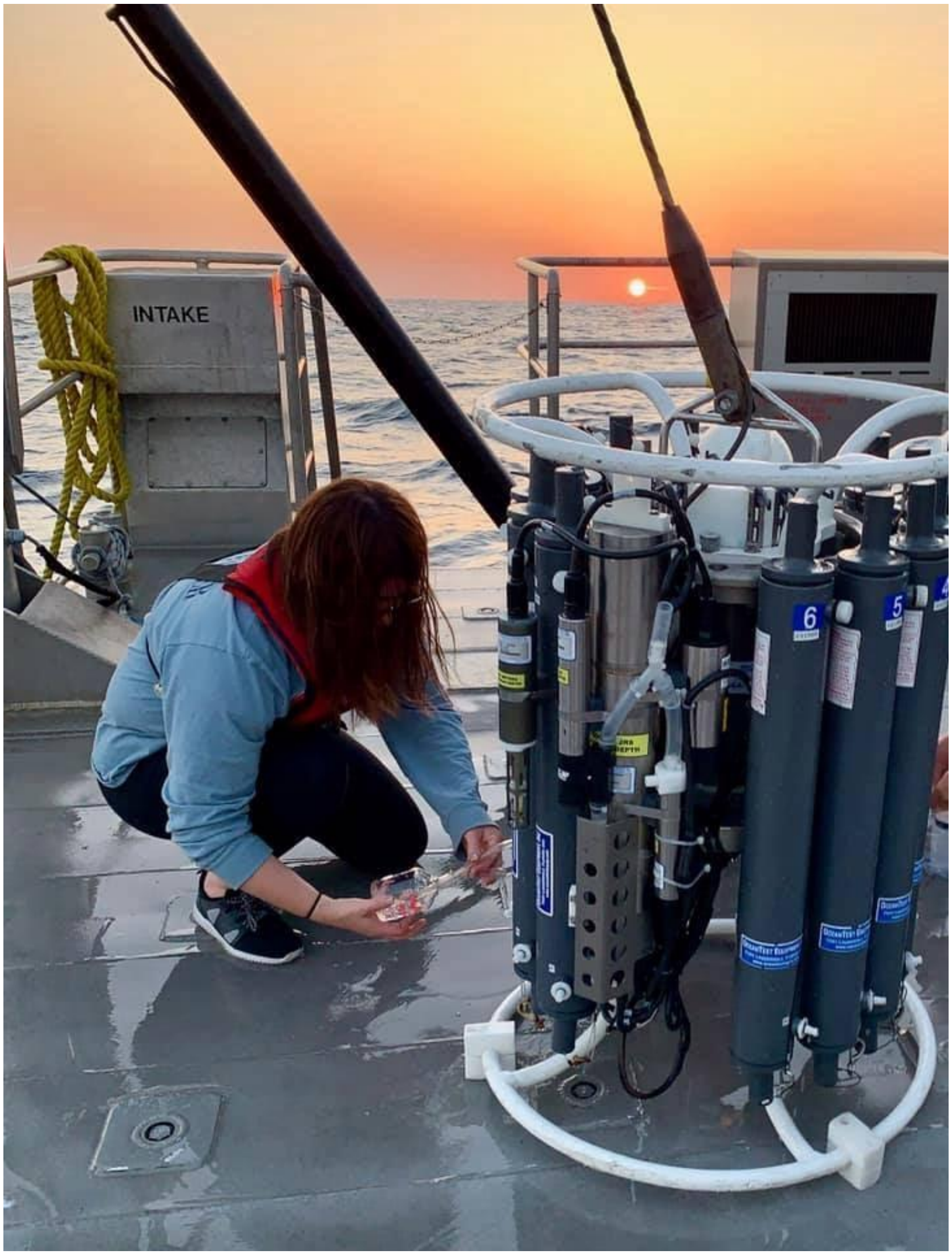
Sediment samples collected in mesophotic areas at Stetson Bank are analyzed by a U.S. Environmental Protection Agency (EPA)-certified laboratory, which tests for 16 types of PAHs in samples.

Because sediment is not readily available in on the bank crest, future contaminant assessments in this habitat will analyze fish tissue rather than sediments. PAHs and chlorinated phenols tend to biodegrade in fish tissues and may not accurately reflect exposure. Better indicators of exposure are more persistent organic pollutants, like polychlorinated biphenyls and dichlorodiphenyltrichloroethane (Van der Oost et al., 2003), which FGBNMS will be examining in the future.

Challenges and Resolutions

COVID-19 exposures, inclement weather, and vessel maintenance issues throughout the year shortened or postponed cruises, preventing the collection of sediment for contaminant analysis. No sediment samples were collected or analyzed in 2022. FGBNMS hopes to visit the target sites planned for 2022 during the 2023 season and develop methods to measure contaminants in the bank crest habitat.

Chapter 10:
Water Quality



FGBNMS researcher Kelly O'Connell collects an ocean carbonate sample onboard the R/V *Manta*. Photo: J. Embesi/NOAA

Introduction

Several water quality parameters were continually or periodically recorded at Stetson Bank from December 2019 through December 2022. Salinity, temperature, and turbidity were recorded every hour by data loggers permanently installed on the crest of Stetson Bank at a depth of 24 m. Additionally, temperature was recorded every hour at 30 m and 40 m stations.

Water column profiles and water samples were collected in March 2022. Water samples were collected at three depths within the water column and analyzed by a EPA-certified laboratory for chlorophyll *a*, ammonia, nitrate, nitrite, and total Kjeldahl nitrogen (TKN). Additionally, water samples were sent to the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi for ocean carbonate analysis. Water profiles and samples are usually collected on a quarterly basis, but cruises were canceled or scaled back due to COVID-19 restrictions. This chapter presents data from moored water quality instruments, water column profiles, and water samples collected in 2022.

Methods

Moored Water Quality Instruments

The primary instrument for recording salinity, temperature, and turbidity was a Sea-Bird® Electronics 16plus V2 conductivity, temperature, and depth (CTD) sensor (SBE 16plus) with a WET Labs ECO NTUS turbidity meter, deployed at a depth of 24 m. The logger collected data hourly, and was attached to a large railroad wheel on a low-relief surface in the midsection of the bank crest (Figure 10.1). Instruments were exchanged by divers for downloading and maintenance in May 2022. They were immediately exchanged with an identical instrument to avoid interruptions in data collection. Data were downloaded and reviewed, sensors were cleaned and confirmed to be operable, and battery duration was checked. Maintenance, as well as factory service and calibration of each instrument, was delayed in 2022 due to limitations on field work resulting from COVID-19 restrictions.

Onset® Computer Corporation HOBO® Pro v2 U22-001 thermograph loggers recorded temperature hourly. These instruments provided a highly reliable temperature backup for the primary SBE 16plus logging instrument located at 24 m on the bank crest. In addition, single HOBO loggers were attached to eyebolts at 30 m and 40 m to record temperature hourly (Figure 10.1). These instruments operated continuously from September 25, 2021 to August 3, 2022. When exchanged, data were downloaded and the loggers were cleaned and relabeled.

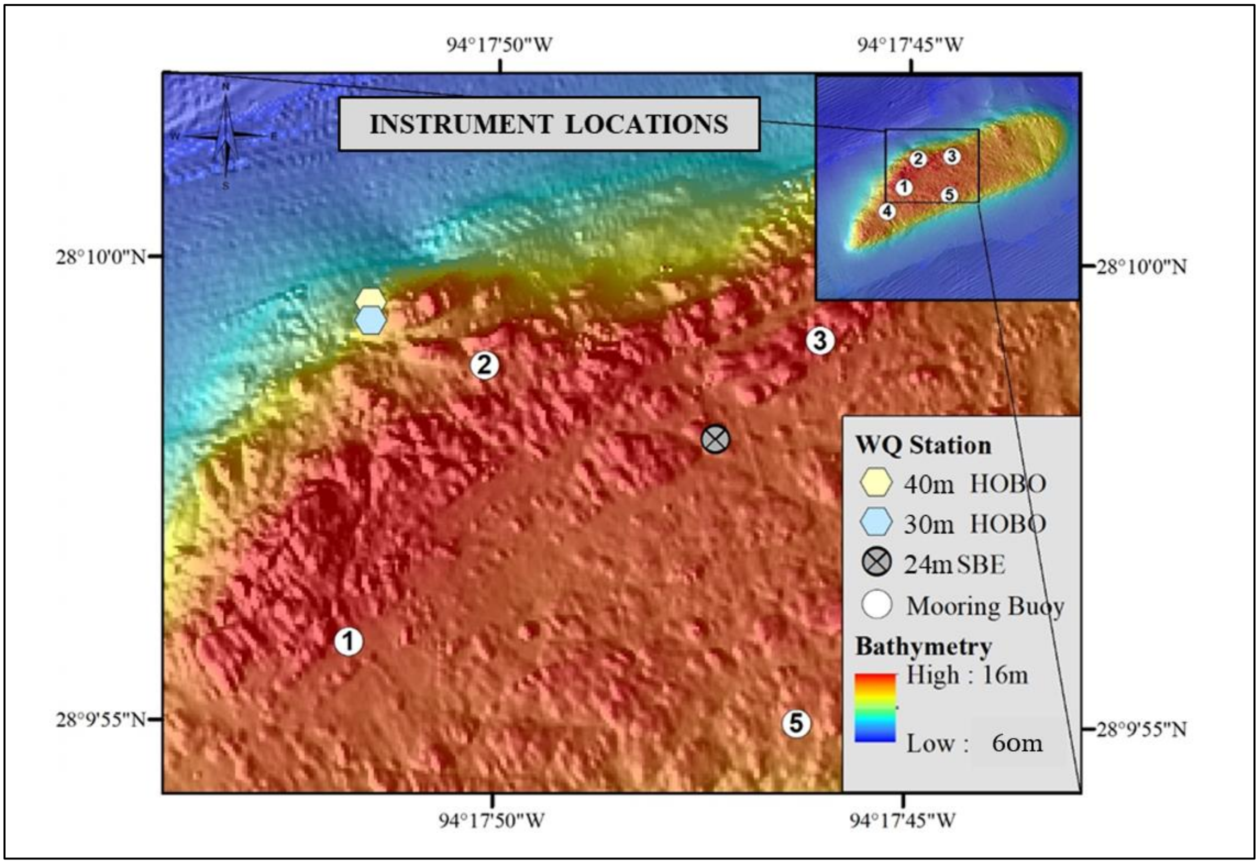


Figure 10.1 Locations of water quality instruments relative to Stetson Bank mooring buoys. Image: NOAA

Satellite Parameters

Daily sea surface temperature data and a suspended sediment proxy were downloaded from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor (4 km resolution) aboard the Aqua satellite (NASA, 2021; Otis, 2021). Satellite-derived one-day mean sea surface temperature data for Stetson Bank were available in 2022 as a level 4 global 0.01-degree grid produced at the NASA Jet Propulsion Laboratory Physical Oceanography Distributed Active Archive Center under support by the NASA MEaSUREs program.

Water Column Profiles

Water column profiles from the surface to the bank cap were acquired on March 1, 2022. A Sea-Bird® 55 Frame Eco water sampler equipped with twelve 4-liter Niskin bottles was used, along with a Sea-Bird® Electronics 19plus V2 CTD that records pH, turbidity, fluorescence, dissolved oxygen, conductivity, depth, salinity, and temperature (Table 10.1). Data were collected every ¼ second during a descent of <1 m/sec to distinguish differences and gradients between three target depths: the bank cap (~20 m), mid-water column (~10 m), and near the surface (~1 m). Data were recorded following an initial three-minute soaking period after deployment and the resulting profile data were processed to include only downcast data.

Table 10.1 Sensors for water quality profiles taken with the FGBNMS carousel in 2022. Sensors were secured to the SBE 19plus V2 CTD.

Sensor	Parameters Measured
SBE 19plus	pH, depth, salinity, and temperature
SBE 43	Dissolved oxygen
WET Labs ECO-FL-NTU	Fluorescence and turbidity

Water Samples

In conjunction with water column profiles collected using the sampling carousels described above, water samples were collected. Sampling bottles on the carousel were triggered at specific depths from the shipboard wet lab. Six nutrient and four carbonate samples were collected from twelve OceanTest® Corporation 2.5-l Niskin bottles attached to the carousel. Four Niskin bottle samples were collected near the bank crest (~20 m depth), mid-water (~10 m depth), and near the surface (~1 m depth) for subsequent transfer to laboratory collection bottles.

Water samples were analyzed for chlorophyll *a* and nutrients, including ammonia, nitrate, nitrite, soluble reactive phosphorus (ortho phosphate), and TKN. One sample bottle from each depth was distributed among three containers for nutrient analysis: chlorophyll *a* samples were distributed to 1000-ml glass containers with no preservatives; samples for soluble reactive phosphorus were distributed to 250-ml bottles with no preservatives; and ammonia, nitrate, nitrite, and TKN samples were distributed to 1000-ml bottles with a sulfuric acid preservative. An additional blind duplicate water sample was taken at one of the sampling depths. Within minutes of sampling, labeled sample containers were stored on ice and maintained at 0 °C; a chain of custody was initiated for processing at an EPA-certified laboratory. The samples were transported for analysis within 24 hours of collection.

Water samples for ocean carbonate measurements, including pH, alkalinity, CO_2 partial pressure, aragonite saturation state, and total dissolved inorganic carbon, were collected on March 1, 2022 following methods provided by the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi. Samples were collected in ground neck borosilicate glass bottles. Bottles were filled using a 20-cm plastic tube connected to the filler valve of the Niskin bottle. Bottles were rinsed three times using the sample water, filled carefully to reduce bubble formation, and overflowed by at least 200 ml. A total of 100 µl of saturated $HgCl_2$ was added to each bottle, which was then capped and the stopper sealed with Apiezon® grease and secured with a rubber band. The bottles were then inverted and shaken to ensure homogeneous distribution of $HgCl_2$ and secured at ambient temperature for shipment. Samples and CTD profile data were sent to the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi.

Data Processing and Analysis

Temperature, salinity, and turbidity data recorded on SBE 16plus instruments and temperature data recorded on backup HOBO loggers were downloaded and processed in March 2022. QA/QC procedures included a review of all files to ensure data accuracy and ensuring instruments were serviced based on manufacturer recommendations. The 24-hourly readings obtained each day were averaged into a single daily value and recorded in duplicate databases. Each calendar day was assigned a value in the database. Separate databases were maintained for each logger type as specified in the standard operating procedures.

SBE 16plus instruments and backup HOBO loggers located on the bank cap were exchanged in March 2022 and January 2023, generating a full year of data. Results of chlorophyll *a* and nutrient analyses were obtained from A&B Labs and compiled into a Microsoft Excel table. Ocean carbonate analyses have not yet been received from the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi.

Results

Moored Water Quality Instruments

Temperatures recorded on the SBE 16plus at 24 m ranged from 18.21 °C to 29.99 °C in 2022, with nearly identical data recorded by the backup HOBO logger (Figure 10.2). Bank cap temperatures at Stetson Bank did not exceed 30 °C at any point in the year but maintained a temperature of at least 29 °C for 24 straight days in July and August. Temperatures dropped by 2–3°C from August 17–24 before returning to higher temperatures for almost another month.

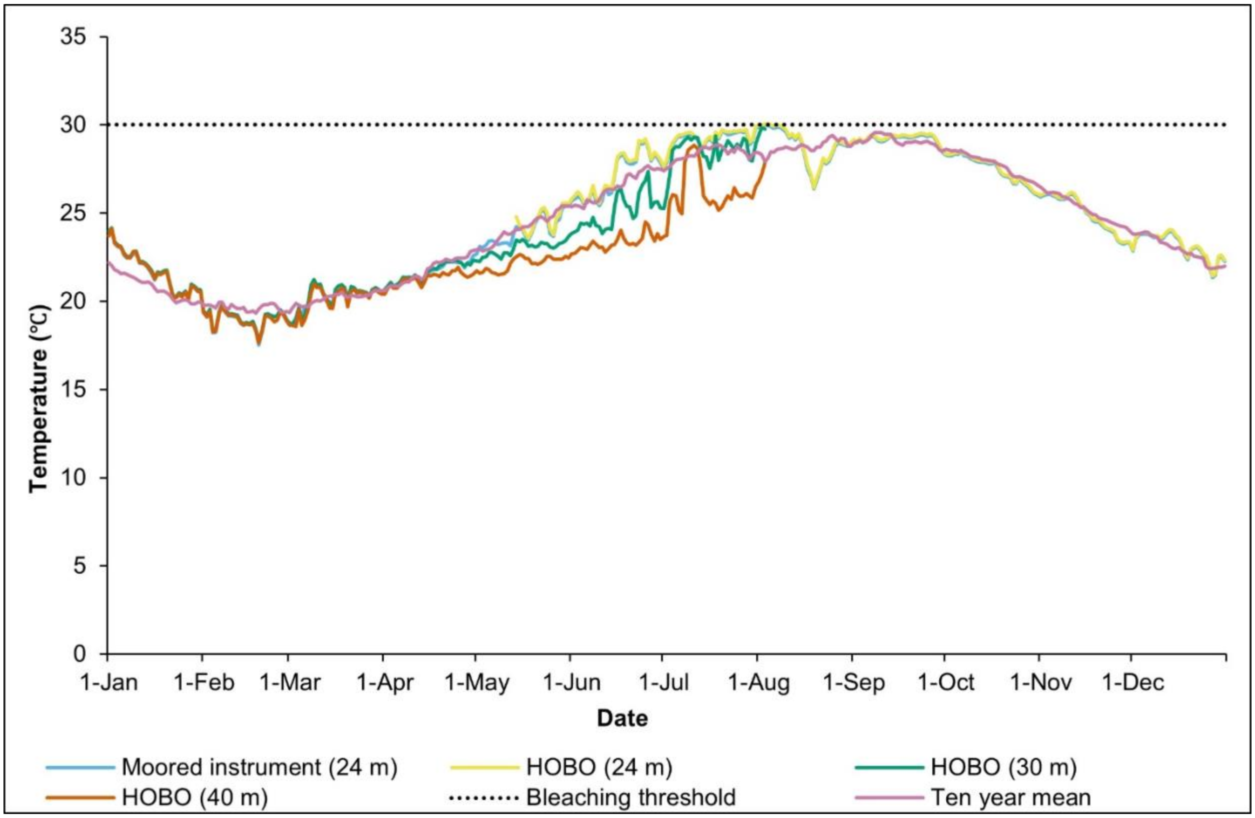


Figure 10.2. Daily mean seawater temperature (°C) at Stetson Bank from various depths in 2022. The dotted line at 30 °C is a threshold; prolonged exposure at or above this temperature can lead to coral bleaching.

Water temperatures recorded on HOBOs at 30 m and 40 m registered similar patterns in 2022, with lower temperatures compared to the bank cap, indicating the development of thermal stratification of the water column during spring and summer. Temperatures recorded on the HOBO at 30 m ranged from 17.67 °C to 29.83 °C in 2022 (Figure 10.2). The HOBO at 40 m recorded temperatures ranging from 17.66 °C to 27.86 °C in 2022 (Figure 10.2). Deep HOBOs were exchanged on August 3, but more recent attempts to exchange these were delayed in 2022 due to limitations on field work resulting from COVID-19 restrictions.

At 24 m, the SBE 16plus recorded salinity ranging from 33.02 to 36.59 psu in 2022 (Figure 10.3).

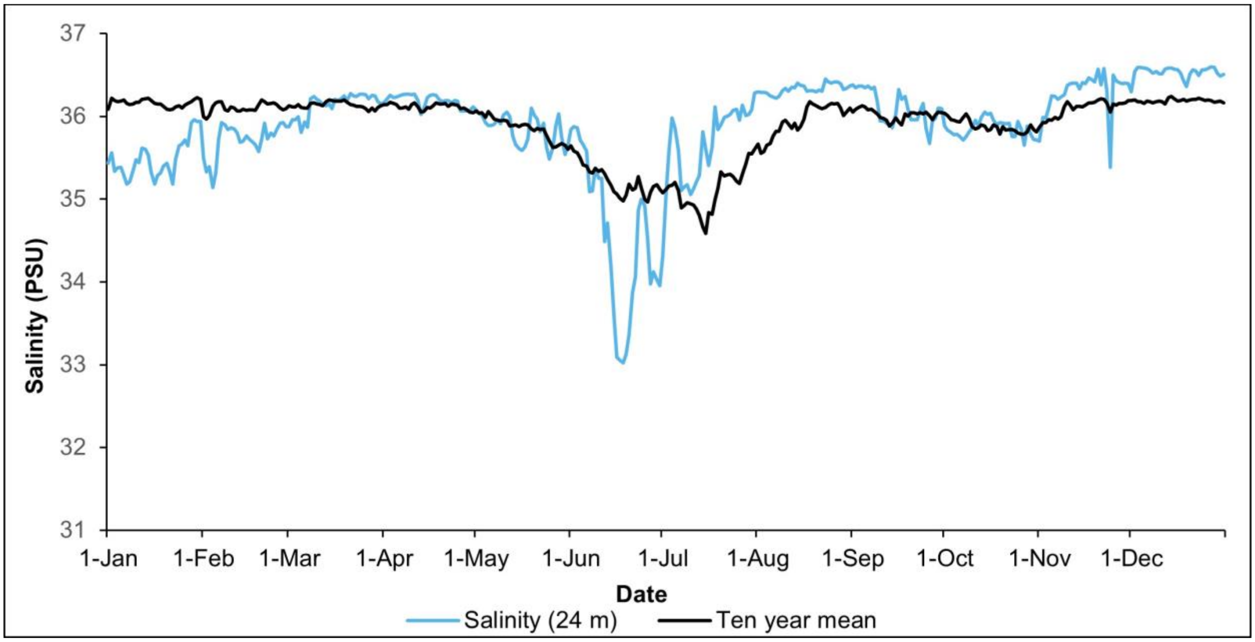


Figure 10.3. Daily mean seawater salinity at 24 m in 2022.

The turbidity sensor on the SBE 16plus experienced periodic malfunctions due to a lack of quarterly maintenance and recorded significant drifts in turbidity values; thus, data may not have been accurate for much of 2022. Variability, however, may reflect the fairly high turbidity recorded at Stetson Bank since data collection began in 2015 (Nuttall et al., 2020b). Figure 10.4 presents only data from January 1 to May 14, 2022 because turbidity values either drifted far above previously reported values (Nuttall et al., 2020b) or logged a negative error reading and were determined to be unreliable. From January to May 2022, turbidity readings averaged 0.14 ntu at 24 m, with peak anomalies on January 17 (1.68 ntu) and April 27 (0.59 ntu).

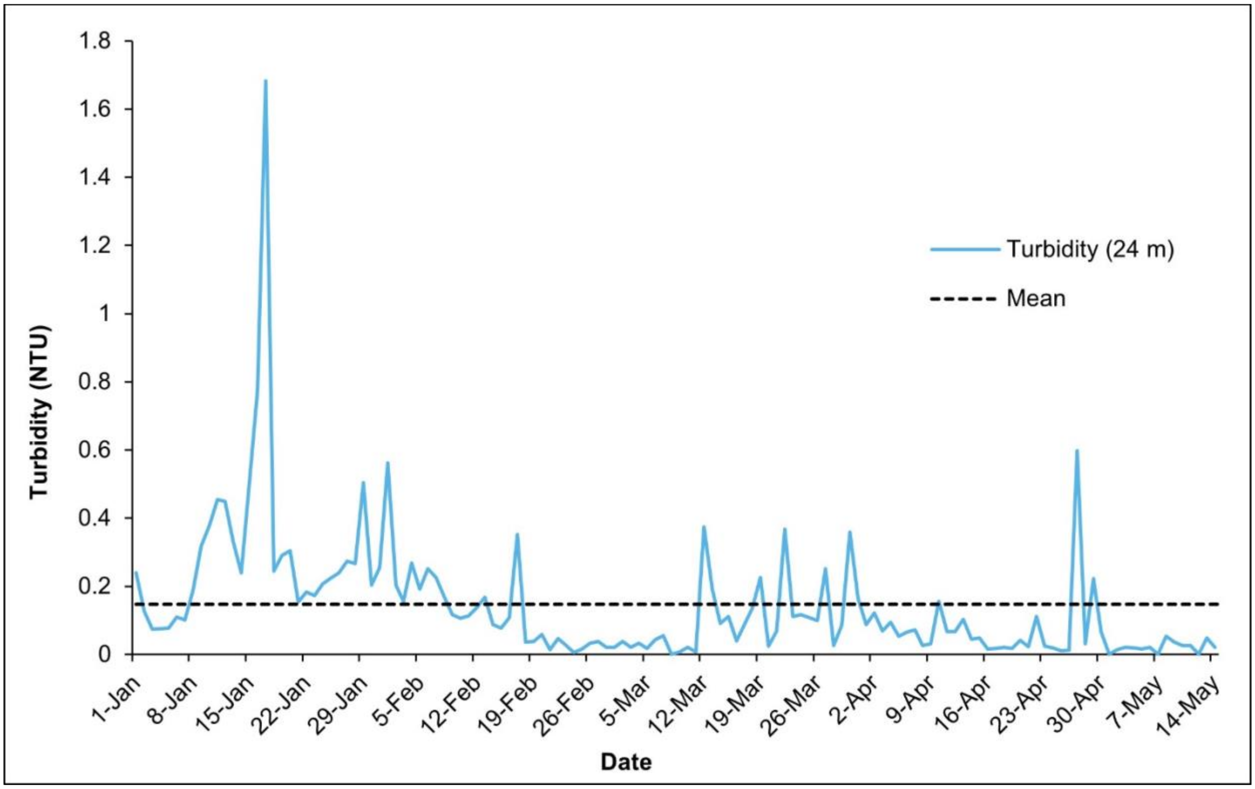


Figure 10.4. Daily mean turbidity values at 24 m in 2022. Data were unreliable after May 14, 2022 and were excluded from this report.

Water Column Profiles

The March water column was nearly isothermal from just below the surface to the bank cap and the profile varied less than 0.5 °C from the surface to the bottom (Figure 10.5). Salinity indicated virtually no stratification on the bank crest. Dissolved oxygen values were stable below two meters. Turbidity was higher in the upper 2–3 meters, and declined gradually below that, with a small instability (perhaps an anomaly or bottom contact) near the bank crest. Fluorescence increased gradually with depth and showed an instability at the same depth as the potentially anomalous turbidity reading at the bank crest. pH values were not presented, as there was an apparent problem with the sensor that requires repair.

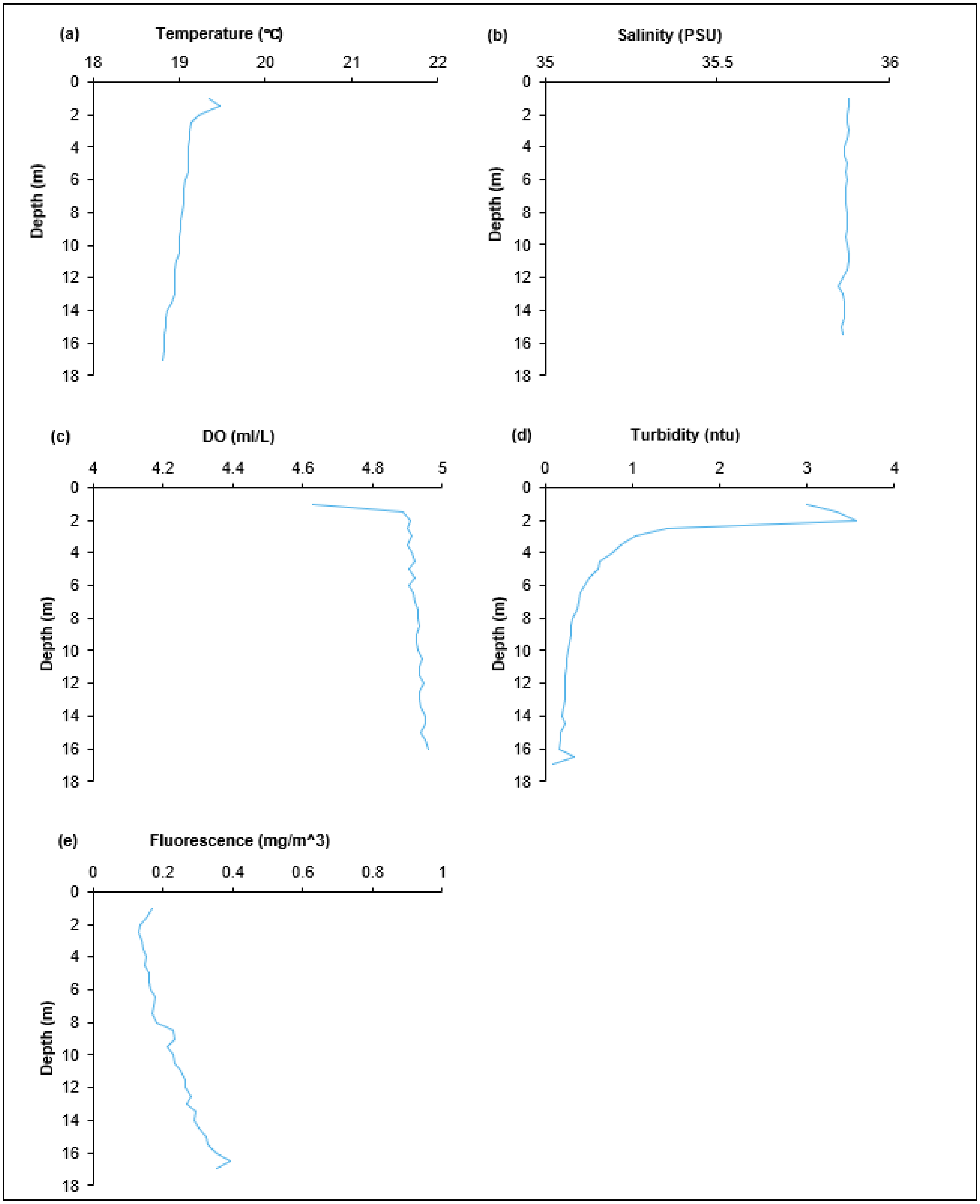


Figure 10.5. Stetson Bank (a) temperature, (b) salinity, (c) dissolved oxygen, (d) turbidity, and (e) fluorescence from water column profile on March 1, 2022.

Water Samples

The 2022 nutrient levels from each water column depth were below detection limits in all samples, consistent with oligotrophic oceanic conditions. Ocean carbonate measurements conducted in tandem with nutrient sampling were sent to Texas A&M University-Corpus Christi for analysis. At the time of this report, carbonate data are still being processed.

Challenges and Resolutions

In March 2022, the pH sensor attached to the SBE 19 plus was damaged as a result of the probe drying out and suffering from salt buildup. Thus, profiles for that month included temperature, salinity, dissolved oxygen, turbidity, and fluorescence. The turbidity sensor on the SBE 16plus experienced periodic malfunctions due to lack of maintenance during this period, resulting in data that were incomplete in 2022. COVID-19 and delayed ship maintenance reduced the number of cruises that could be made in 2022 to support quarterly water sampling.

FGBNMS intends to resume quarterly water quality sampling cruises to collect water samples, conduct water column profiles, and exchange and maintain moored water quality instruments at Stetson Bank in 2023.

Chapter 11:
Video and General Observations

Large schools of regal demoiselle (*Neopomacentrus cyanomos*) on the bank crest at Stetson Bank.
Photo: K. O’Connell/NOAA

Introduction

Permanent video transect locations were established on the bank crest, covering both low-relief and high-relief features, in addition to locations of high coral cover. As time permitted, video transects were conducted in the mesophotic habitat, traversing the extent of the bank and associated patch reef features. These transects were conducted for general condition observations.

Methods

Bank Crest Video Transects

Three 100-m permanent transects were installed on the bank crest in 2015. Each was marked using 30-cm stainless steel eyebolts drilled and epoxied into the reef at 25-m increments along the transect. Each eyebolt was labeled with a cattle tag denoting the transect number and the eyebolt position along the transect. Transect start locations are shown in Figure 2.2 and Figure 2.3. Before recording, a line was stretched between the eyebolts to mark the transect. Video was recorded using a Sony® Handycam® HDR-CX350 HD video camera in a Light and Motion® Stingray G2® housing.

A two-meter-long plumb bob was secured to the front of the camera housing. The diver followed the transect line, maintaining altitude above the bottom using the plumb bob. The camera was held at a 45° angle to the bottom during filming.

In 2022, all three video transects were completed on the bank crest.

Mesophotic Video Transects

No mesophotic video transects were completed in 2022.

General Observations

The observations below include those from video transects and others recorded during field work.

- Marine debris was noted on each transect.
- Video eyebolts were detached in some locations and will need to be reinstalled in 2023.
- Divers observed the continued presence of the exotic regal demoiselle (*Neopomacentrus cyanomos*). Populations appear to have increased, and they appeared to outnumber brown chromis (*Chromis multilineata*).
- While exchanging water quality instruments, divers witnessed a large bottlenose dolphin using a buoy line to scratch itself.

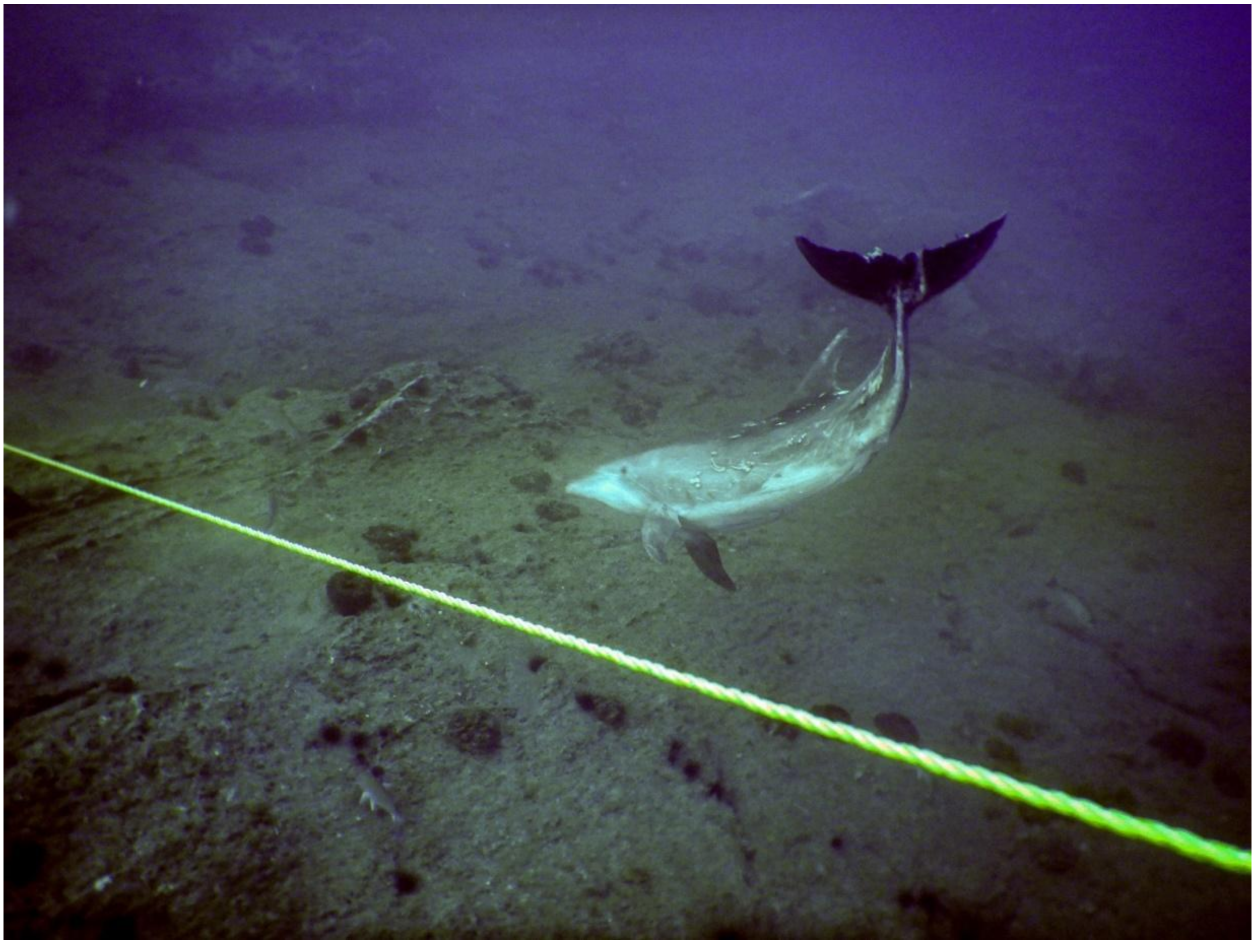


Figure 11.1. A bottlenose dolphin swims near divers at the bank crest. Photo: M. Nuttall/NOAA

Chapter 12: Other Research

Other Research

While not part of the FGBNMS long-term monitoring program, research with partners conducted in the 2022 field season at Stetson Bank included:

- An acoustic receiver was installed on Stetson Bank, and two lionfish were equipped with acoustic tags using underwater surgical techniques. This work was conducted as part of a project funded by NOAA's National Centers for Coastal Ocean Science, in partnership with Texas A&M University-Galveston, to study habitat use and connectivity of fish species on northern Gulf of Mexico banks under permit FGBNMS-2021-007.
- A Lionfish Invitational cruise was completed to remove lionfish in 2022. Divers removed 84 lionfish from Stetson Bank.
- NOAA's Deep Sea Coral Research and Technology Program, under guidance of Dr. Peter Etnoyer, provided an Onset Hobo Tidbit thermistor to deploy at Stetson Bank (next to repetitive photostation M03). This was successfully retrieved on 9/13/2022.

Chapter 13: Conclusions

The crest of Stetson Bank, which has been monitored for 30 years, has experienced a significant shift in benthic community structure over that time, from a *Millepora* and sponge dominated assemblage to an macroalgae and sponge dominated community (DeBose et al., 2012; Nuttall et al., 2020a). Although some monitoring could not be completed in 2022 due to COVID-19 restrictions and outbreaks, divers were able to assess benthic cover at 51 of 59 repetitive photostations on the bank, conduct ROV and video surveys, and collect water quality data.

Water sample collections, *in situ* measurements, and profiles in 2022 suggest nominal conditions, for the most part. This included oligotrophic, isothermal conditions in the spring and summer water columns, as well as summer stratification. High water temperatures for a sustained period in the summer of 2022 likely resulted in a small amount of bleaching and paling of hydrocorals on the bank. Whether those corals recover or succumb will be assessed in upcoming sampling at the same photostations.

The exotic regal demoiselle persisted in 2022, with schools of hundreds of small fish (5–10 cm) observed over many pinnacles on the bank and within vertical sponges. The results of counts using stationary cameras suggest that roving diver surveys underestimate the totals of these and some other fish. The impacts of regal demoiselles, particularly on species that may occupy similar niches (e.g., brown chromis, which are often found in the same schools) have not yet been assessed.

The monitoring program at Stetson Bank represents one of the longest running monitoring efforts of a northern latitude coral community that is periodically exposed to environmental conditions considered marginal for the communities it supports. It has already allowed for the documentation of one community phase shift caused by a significant intermediate disturbance event, and should provide a window into community dynamics as it continues to respond. Meanwhile, resource managers will be able to track known drivers of ecosystem variation and change in the northwestern Gulf of Mexico as a result of knowledge gained through monitoring. Continuing this program may also provide valuable information on species that can resist change in the face of declining conditions (Zweifler et al., 2021) and inform coral ecosystem protection and restoration.

Acknowledgements

FGBNMS would like to acknowledge the many groups and individuals that provided invaluable support to make this monitoring successful, including the R/V *Manta* crew, NOAA Dive Center, BSEE, Cardinal Point Captains, Inc., and volunteers who assisted with data collection or processing in 2022.

In particular, we acknowledge Dr. Jim Sinclair (BSEE) for his support and dedication to the project and Dr. Xinping Hu (Texas A&M University-Corpus Christi) for providing ocean carbonate data analysis. Finally, our sincere thanks are extended to the editors and reviewers who helped improve this report. Additionally, FGBNMS greatly appreciates the staff at ONMS that approved these operations and understood the value and importance of these long-term monitoring efforts.

This study was funded by the U.S. Department of the Interior, BSEE through Interagency Agreement E21PG00009 with NOAA's National Ocean Service, and ONMS, through FGBNMS. Field work in 2022 was carried out under permit FGBNMS-2019-001.

Literature Cited

Aronson, R. B., Edmunds, P. J., Precht, W. F., Swanson, D. W., & Levitan, D. R. (1994). Large-scale, long-term monitoring of Caribbean coral reefs: Simple, quick, inexpensive methods. *Atoll Research Bulletin*, *421*, 1–19. https://doi.org/10.5479/si.00775630.421.1

Aronson, R. B., & Precht, W. F. (2000). Herbivory and algal dynamics on the coral reef at Discovery Bay, Jamaica. *Limnology and Oceanography*, *45*(1), 251–255. https://doi.org/10.4319/lo.2000.45.1.0251

Aronson, R. B., Precht, W. F., Murdoch, T. J. T., & Robbart, M. L. (2005). Long-term persistence of coral assemblages on the Flower Garden Banks, northwestern Gulf of Mexico: Implications for science and management. *Gulf of Mexico Science*, *23*(1), 84–94. https://doi.org/10.18785/goms.2301.06Bernhardt, S. P. (2000). *Photographic monitoring of benthic biota at Stetson Bank, Gulf of Mexico* [Unpublished master's thesis]. Texas A&M University.

Bohnsack, J. A., & Bannerot, S. P. (1986). *A stationary visual census technique for quantitatively assessing community structure of coral reef fishes*. NOAA Technical Report NMFS 41. http://hdl.handle.net/1834/20569

Cummings, K. E., Ruzicka, R. R., Semon-Lunz, K., Brenner, J., Goodin, K. L., & Ames, K. W. (2018). Ecological resilience indicators for coral ecosystems. In K. L. Goodin, D. Faber-Langendoen, J. Brenner, S. T. Allen, R. H. Day, V. M. Congdon, C. Shepard, K. E. Cummings, C. L. Stagg, C. A. Gabler, M. Osland, K. H. Dunton, R. R. Ruzicka, K. Semon-Lunz, D. Reed, & M. Love (Eds.), *Ecological resilience indicators for five northern Gulf of Mexico ecosystems* (pp. 249–319). NatureServe.

DeBose, J. L., Nuttall, M. F., Hickerson, E. L., & Schmahl, G. P. (2012). A high-latitude coral community with an uncertain future: Stetson Bank, northwestern Gulf of Mexico. *Coral Reefs*, *32*, 255–267. https://doi.org/10.1007/s00338-012-0971-3

Edmunds, P. J., & Carpenter, R. C. (2001). Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. *Proceedings of the National Academy of Sciences*, *98*(9), 5067–5071. https://doi.org/10.1073/pnas.071524598

Ellis, D. M., & DeMartini, E. E. (1995). Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. *Oceanographic Literature Review*, *9*(42), 786.

Gardner, J. V., Mayer, L. A., Hughes, C. J., & Kleiner, A. (1998). High-resolution multibeam bathymetry of East and West Flower Gardens and Stetson Banks, Gulf of Mexico. *Gulf of Mexico Science*, *16*, 131–143. https://doi.org/10.18785/goms.1602.03

Kohler, K. E., & Gill, S. M. (2006). Coral point count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences*, *32*(9), 1259–1269. https://doi.org/10.1016/j.cageo.2005.11.009

Lang, J. C., Marks, K. W., Kramer, P. A., Kramer, P. R, & Ginsburg, R. N. (Eds.). (2012). *Atlantic and Gulf Rapid Reef Assessment Protocols* (Version 5.4). Atlantic and Gulf Rapid Reef Assessment.

NASA. (2021). *Ocean color feature: World map of Chlorophyll-a* [Data set]. https://oceancolor.gsfc.nasa.gov/

Nuttall, M. F., Somerfield, P. J., Sterne, T. K., MacMillan, J. T., Embesi, J. A., Hickerson, E. L., Johnston, M. J., Schmahl, G. P., Sinclair, J. (2020a). *Stetson Bank long-term monitoring: 1993–2015*. National Marine Sanctuaries Conservation Series ONMS-20-06. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary.

https://sanctuaries.noaa.gov/science/conservation/stetson-bank-long-term-monitoring-1993-2015.html

Nuttall, M. F., Blakeway, R. D., MacMillan, J., Sterne, T., O'Connell, K., Hu, X., Embesi, J. A., Hickerson, E. L., Johnston, M. A., Schmahl, G. P., & Sinclair, J. (2020b). *Stetson Bank long-term monitoring: 2015–2018 synthesis report*. National Marine Sanctuaries Conservation Series ONMS-21-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. https://sanctuaries.noaa.gov/science/conservation/stetson-bank-long-term-monitoring-synthesis-report.html

Otis, D. (2021). *Flower Garden Banks National Marine Sanctuary data dashboard* [Data set]. http://fgbnms-dashboard.marine.usf.edu:3000

Raeisi, A., Arfaeinia, H., Seifi, M., Shirzad-Siboni, M., Keshtkar, M., & Dobaradaran, S. (2016). Polycyclic aromatic hydrocarbons (PAHs) in coastal sediments from urban and industrial areas of Asaluyeh Harbor, Iran: Distribution, potential source and ecological risk assessment. *Water Science and Technology*, *74*(4), 957–973. https://doi.org/10.2166/wst.2016.265

Rezak, R., Bright, T. J., & McGrail, D. W. (1985). *Reefs and banks of the northwestern Gulf of Mexico: Their geological, biological, and physical dynamics*. John Wiley and Sons.

Rooper, C. N., Williams, K., Towler, R. H., Wilborn, R., & Goddard, P. (2020). Estimating habitat-specific abundance and behavior of several groundfishes using stationary stereo still cameras in the southern California bight. *Fisheries Research*, *224*, 105443. https://doi.org/10.1016/j.fishres.2019.105443

Van der Oost, R., Beyer, J., & Vermeulen, N. P. (2003). Fish bioaccumulation and biomarkers in environmental risk assessment: A review. *Environmental Toxicology and Pharmacology*, *13*(2), 57–149. https://doi.org/10.1016/S1382-6689(02)00126-6

Zweifler, A., O'Leary, M., Morgan, K., & Browne, N. K. (2021). Turbid coral reefs: Past, present, and future—a review. *Diversity*, *13*(6), 251. https://doi.org/10.3390/d13060251

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