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Stetson Bank Long-Term Monitoring: 2023 Annual Report

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Cover photo: A volunteer conducts a fish survey on the Stetson Bank reef crest. Image: D. French/NOAA

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Abstract

This document describes the methods used, field data analyses performed, significant observations made, and challenges encountered during annual long-term monitoring of fish, benthic communities, and water quality at Stetson Bank in 2023. 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 2023 included water quality sampling, bank crest repetitive photostations and fish surveys, and random bank crest photo transects and fish surveys. However, field work and data collection were limited in 2023 due to challenges resulting from inclement weather and vessel maintenance.

Despite these limitations, 54 bank crest repetitive photostations were captured in 2023. Coral, hydrocoral, sponges, and macroalgae had mean percent cover of 4.90%, 2.77%, 12.28%, and 48.12%, respectively.

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 warm-water coral growth in the Gulf of Mexico. Although the environmental conditions at Stetson Bank are more temperate than the Caribbean Sea and tropical Western Atlantic Ocean (Cummings et al., 2018), the area features a well-developed benthic community historically dominated by tropical marine sponges, along with hydrocorals, hermatypic corals, and other invertebrates. Seasonal variations in temperature and light availability limit 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 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 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, where non-decompression scuba operations could be employed (<33.5 m). Following seafloor mapping and remotely operated vehicle (ROV) explorations, mesophotic communities were discovered on discrete uplifted seafloor features that form 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 on 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 explored 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 (Antipatharia), octocorals (Octocorallia), sponges, invertebrates, and deep reef fish.

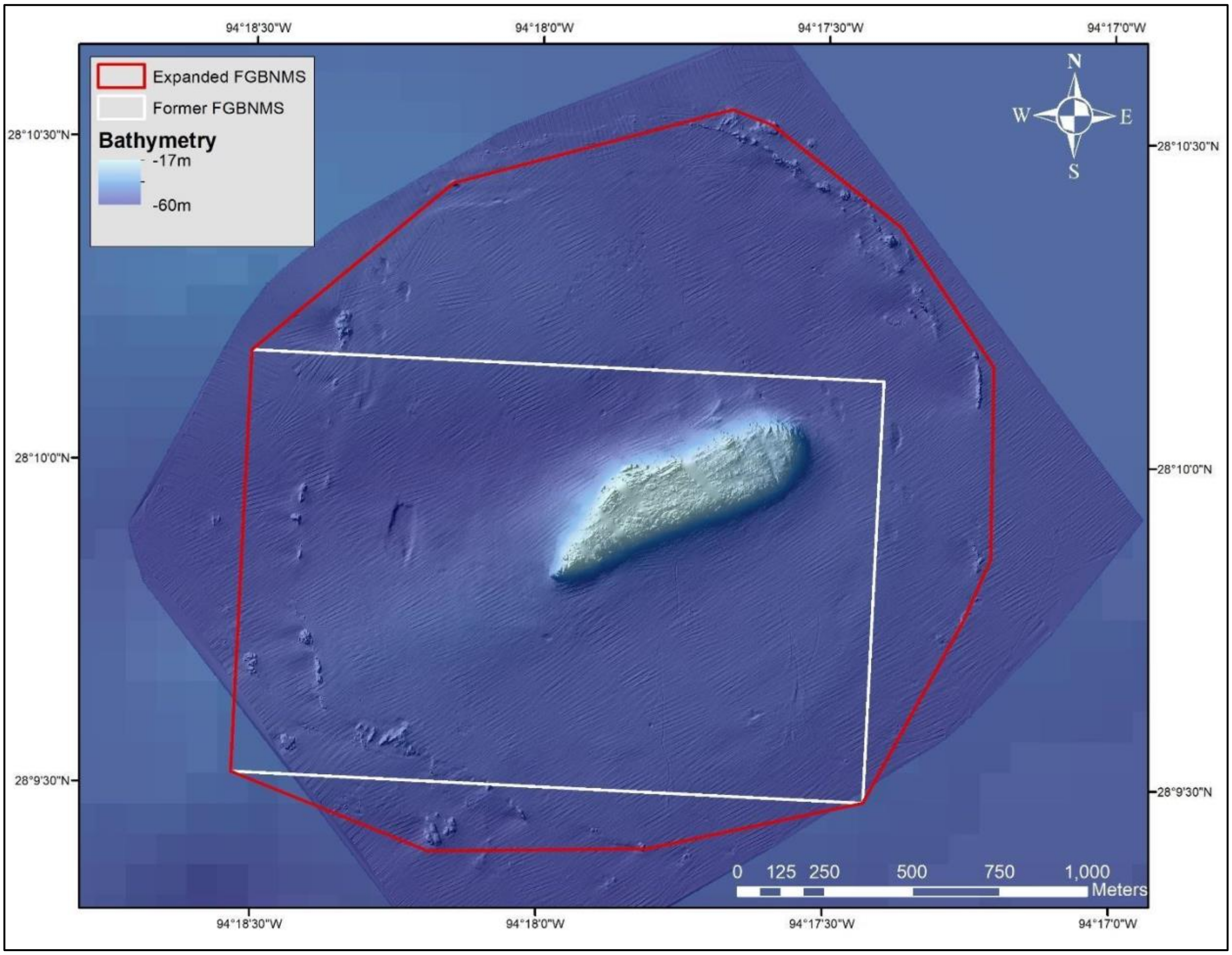


Figure 1.1. Map of pre- and post-expansion FGBNMS boundaries surrounding Stetson Bank. The new boundary encompasses the claystone/siltstone feature documented in 1997. Image: NOAA

Marine sponges, primarily *Neofibularia nolitangere*, *Ircinia strobilina*, and *I. felix*, have been major components of the benthic macrobiota on the crest of Stetson Bank throughout monitoring history (DeBose et al., 2012; Nuttall et al., 2020b). Although sponges remain the most prominent component of 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*, formerly abundant on the bank crest, experienced a significant reduction in population in 2005, rendering it nearly absent from the bank. Furthermore, the once-abundant *I. strobilina* has become rare, and is now seen infrequently (O'Connell et al., 2024). The hydrozoan *Millepora alcicornis* was also historically a prominent benthic species at Stetson Bank, but underwent a 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* spp. and turf algae, has 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).

Benthic monitoring at Stetson Bank has been conducted for 31 years. As increasing anthropogenic stressors to marine environments are projected, long-term monitoring data sets are essential for understanding community stability, ecosystem resilience, and responses to changing conditions. Additionally, as non-native species arrive, and some become established and compete for resources, long-term data sets are vital for documenting and tracking impacts to native populations. Continuity and extension of this data set will provide valuable insight for both research and management purposes.

Field operations in 2023 were constrained by unanticipated vessel maintenance and adverse weather conditions. Typical monitoring tasks, such as evening lobster and *Diadema antillarum* surveys, permanent video transects, stationary video fish surveys, fish surveys at repetitive stations, and water quality profiles and moored instrument exchanges, were not completed. Despite the challenges, scuba operations were conducted from the NOAA R/V *Manta* to capture benthic composition and conduct fish surveys. Repetitive photostation pins located on the reef crest were also refurbished and replaced where necessary. In total, data for this report were collected over five cruises in 2023 (Table 1.1).

Table 1.1. 2023 Stetson Bank cruise information.

Date(s)	Cruise Type and Monitoring Task	Participants
01/08/2023–01/10/2023	Water quality: water sampling and SBE19 profile; SBE16 instrument exchange and download; acoustic receiver exchange	Ryan Hannum, Marissa Nuttall, Kelly O’Connell, Olivia Eisenbach, Michelle Johnston, Donavon French, Daniel Lippi, Gaby Carpenter
5/02/2023–05/04/2023	Water quality: SBE16 instrument exchange and download; YSI profile; inspect/exchange acoustic receivers	Ryan Hannum, Kelly O’Connell, Olivia Eisenbach, Donavon French, Kait Brogan, Marissa Nuttall, Terry Palmer, Hang Yin
06/07/2023–06/09/2023	Mooring buoy exchanges	Ryan Hannum, Kelly O’Connell, Olivia Eisenbach, Jacque Emmert, Kait Brogan, Kaitlin Buhler, Marissa Nuttall, Jenny Vander Pluym, Josh Harvey
07/12/2023–07/14/2023	Water quality: HOBO temperature logger exchange and download; YSI profile; bank crest monitoring: benthic and fish community monitoring	Kelly O’Connell, Marissa Nuttall, Alyssa Lawton, Kaitlin Buhler Donavon French, Ryan Hannum, Olivia Eisenbach, Jacque Emmert, Kait Brogan, Jenny Vander Pluym
08/14/2023–08/18/2023	Water quality: water sampling and YSI profile	Michelle Johnston, Kait Brogan, Kaitlin Buhler, Gaby Carpenter, Olivia Eisenbach, Ben Farmer, Donavon French, Alex Good, Ryan Hannum, Josh Harvey

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, 54 stations exist at Stetson Bank, 15 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

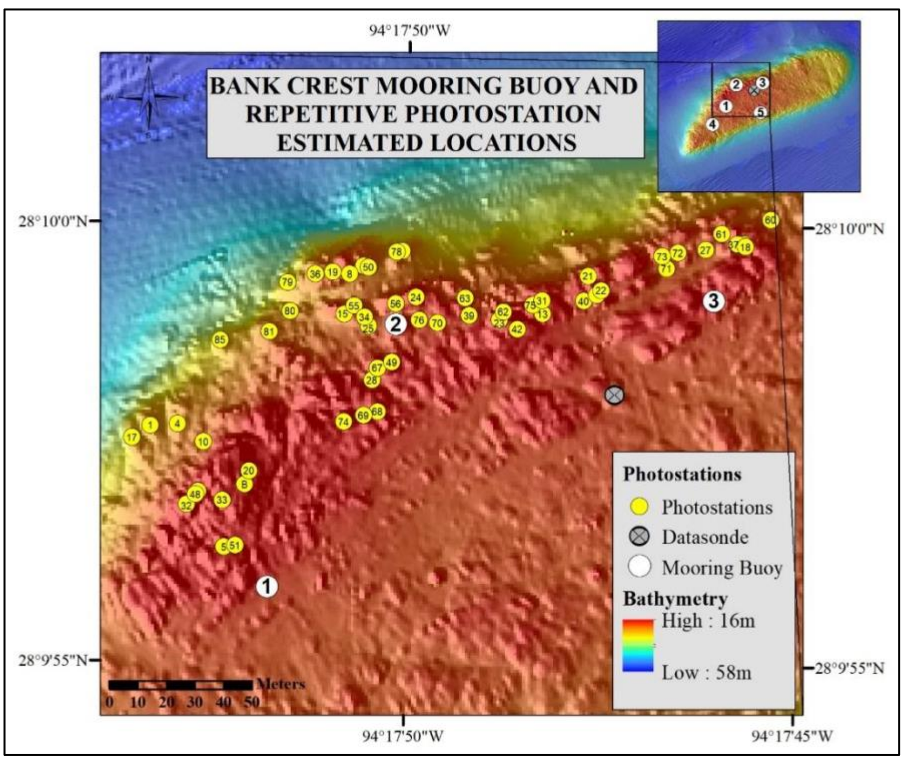
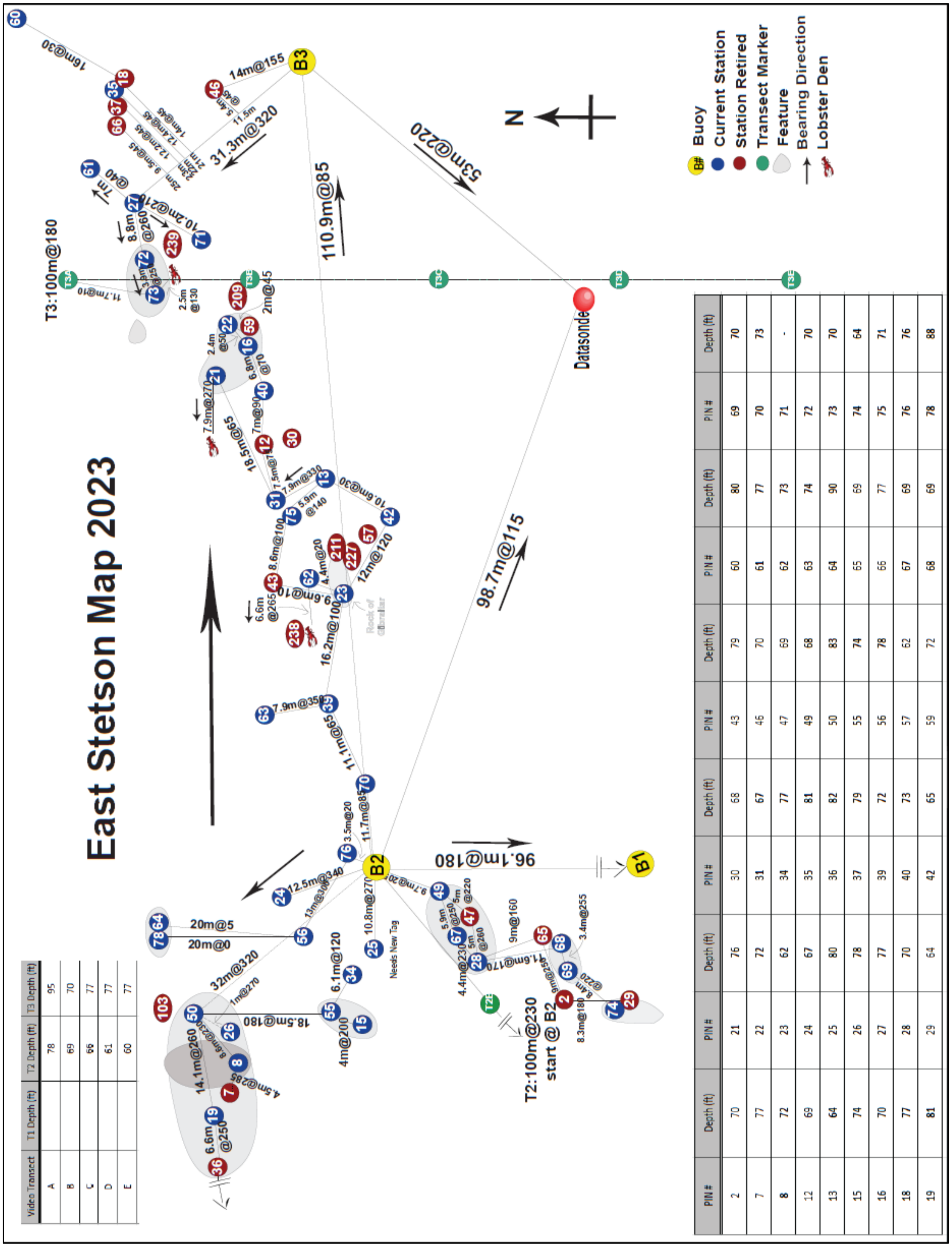


Figure 2.1. Stetson Bank study site map. Seafloor bathymetry with mooring buoy locations and approximate repetitive photostation locations. Image: NOAA



Video Transect	T1 Depth (ft)	T2 Depth (ft)	T3 Depth (ft)
A		78	95
B		69	70
C		66	77
D		61	77
E		60	77

PIN #	Depth (ft)	PIN #	Depth (ft)	PIN #	Depth (ft)	PIN #	Depth (ft)	PIN #	Depth (ft)	PIN #	Depth (ft)
2	70	21	76	30	68	43	79	60	80	69	70
7	77	22	72	31	67	46	70	61	77	70	73
8	72	23	62	34	77	47	69	62	73	71	-
12	69	24	67	35	81	49	68	63	74	72	70
13	64	25	80	36	82	50	83	64	90	73	70
15	74	26	78	37	79	55	74	65	69	74	64
16	70	27	77	39	72	56	78	66	77	75	71
18	77	28	70	40	73	57	62	67	69	76	76
19	81	29	64	42	65	59	72	68	69	78	88

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

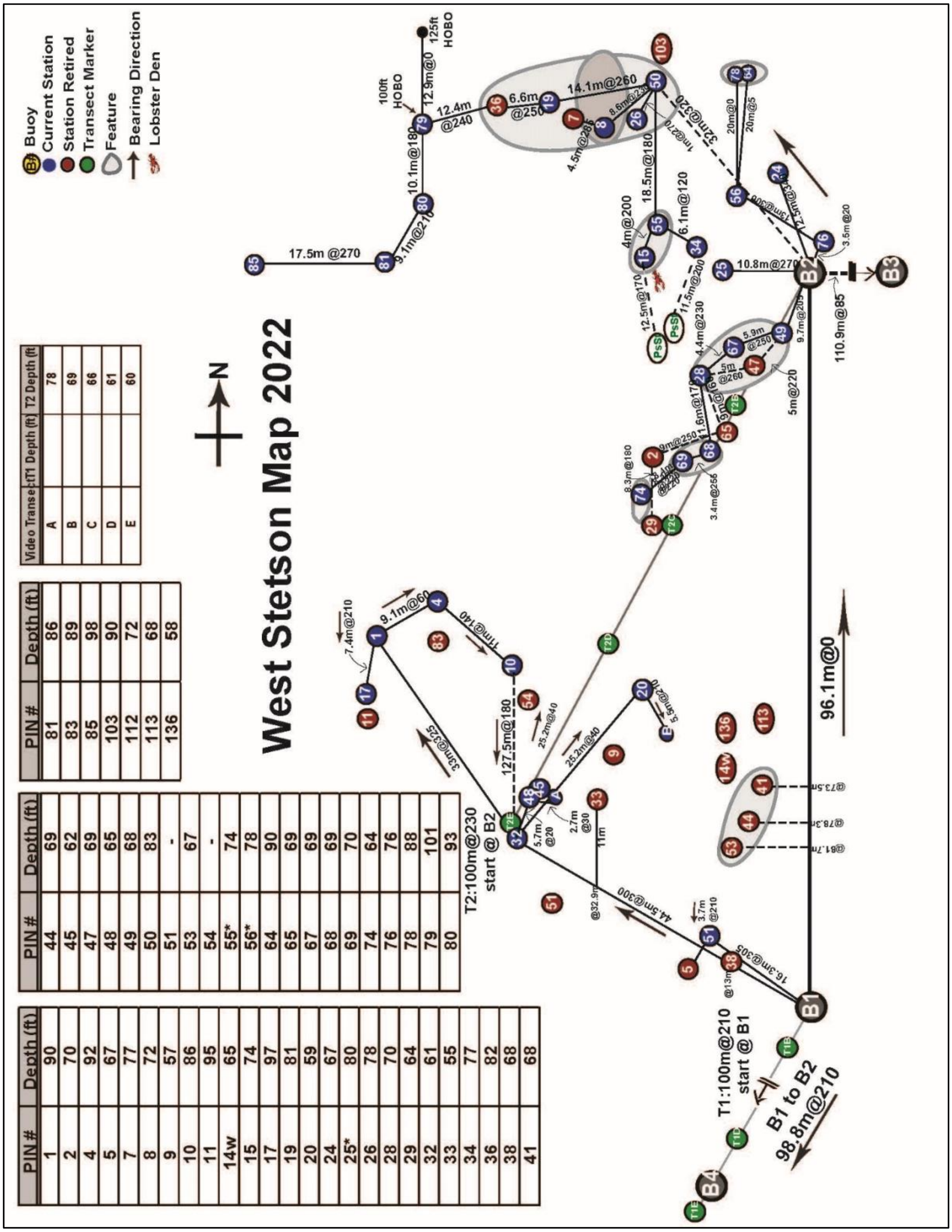


Figure 2.3. West Stetson map used by divers to locate repetitive photostations in the study site. The west map is used to locate stations surrounding buoy 1 and buoy 2. Image: NOAA

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 2023, 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 1.5 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.

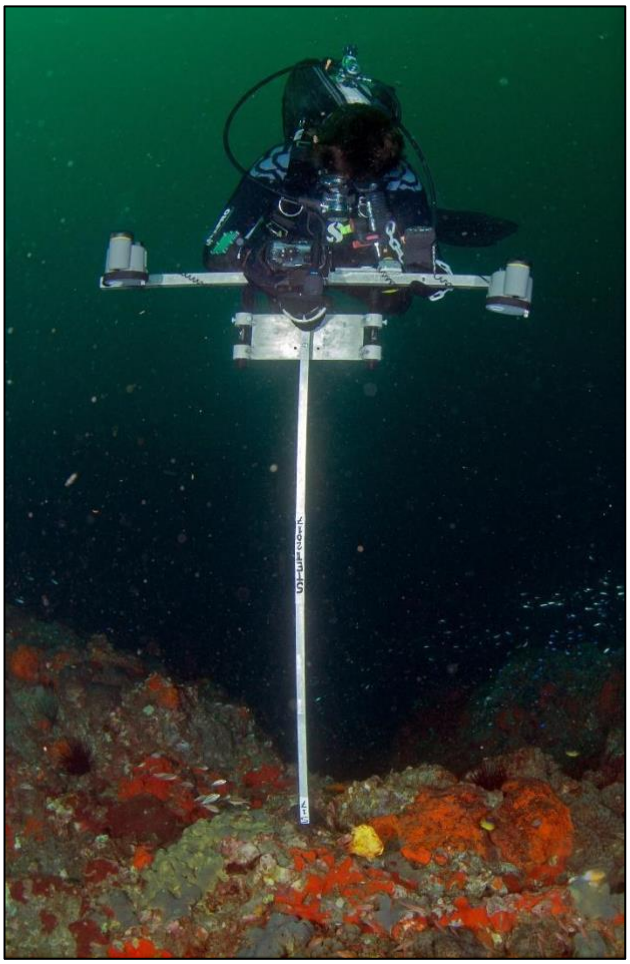


Figure 2.4. Camera and T-frame configuration for repetitive photostation images. Image: G.P. Schmahl/NOAA

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).

All repetitive photostation images were qualitatively compared to the image from the previous year. The loss, reduction, expansion, or gain of species of interest and key features, in addition to changes in general conditions, were noted in Microsoft® Excel®.

Results and Discussion

No new repetitive photostations were installed, but five stations were missing eyebolts and redrilled in 2023. Fifty-four of the 59 repetitive photostations were photographed in 2023 and the remaining five stations were missing, unrecognizable, or had not been located in a number of years and were therefore retired. Twenty repetitive photostation pins were retagged, including pin numbers 85, 80, 79, 78, 76, 71, 69, 61, 56, 55, 51, 42, 31, 26, 22, 21, 19, 16, 15, and 13.

In 2023, mean percent cover was 4.90% for scleractinian coral, 2.77% for hydrocoral, 12.28% for sponges, and 48.12% for macroalgae within 54 bank crest repetitive photostations (Figure 2.5). The dominant coral species were *Millepora alcicornis*, *Madracis decactis*, and *Stephanocoenia intersepta* (Figure 2.6). For several months in 2023, global sea surface temperatures soared to unprecedented heights, driven by both human-induced climate change and a recent intensification from the natural climate phenomenon El Niño. Notwithstanding the generally low coral cover observed on Stetson Bank, sporadic occurrences of bleaching have been noted, typically accounting for less than 1% of the coral population (Nuttall et al., 2020a, 2020b; O'Connell et al., 2024). However, in 2023, a notable increase was observed, with approximately 16.44% ± 7.60% of corals exhibiting signs of bleaching.

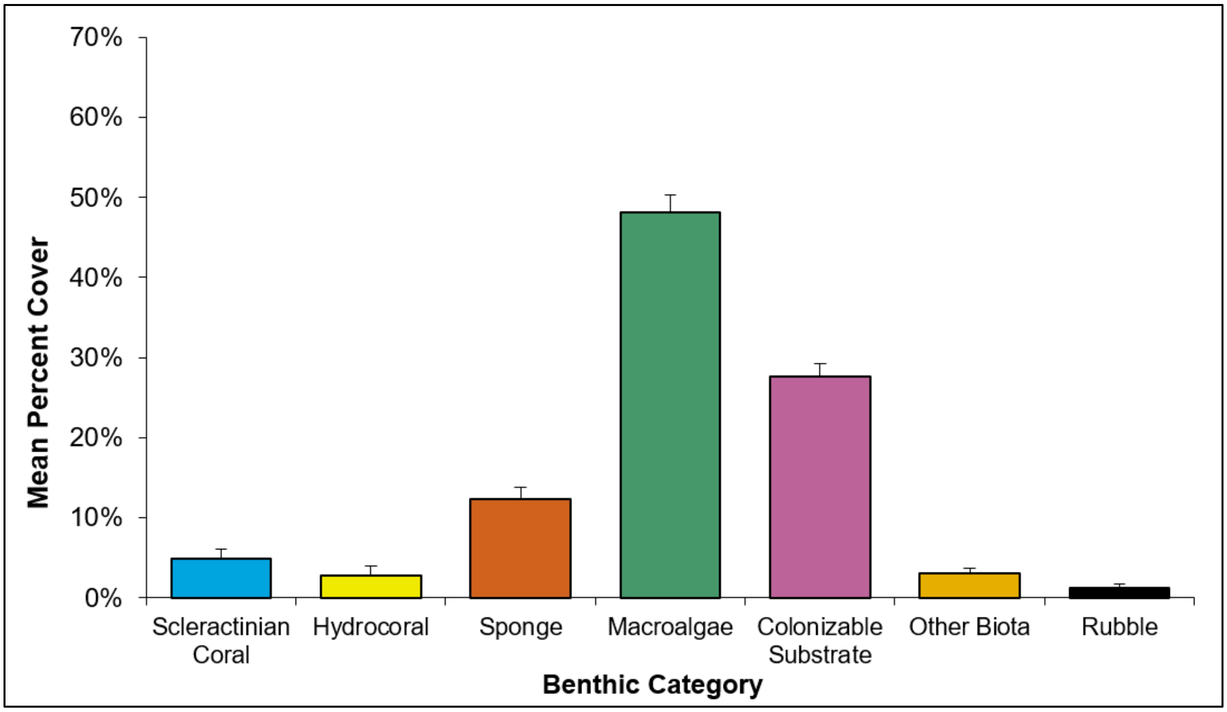


Figure 2.5. Mean percent cover (+SE) of major benthic categories at 54 repetitive photostations at Stetson Bank in 2023.

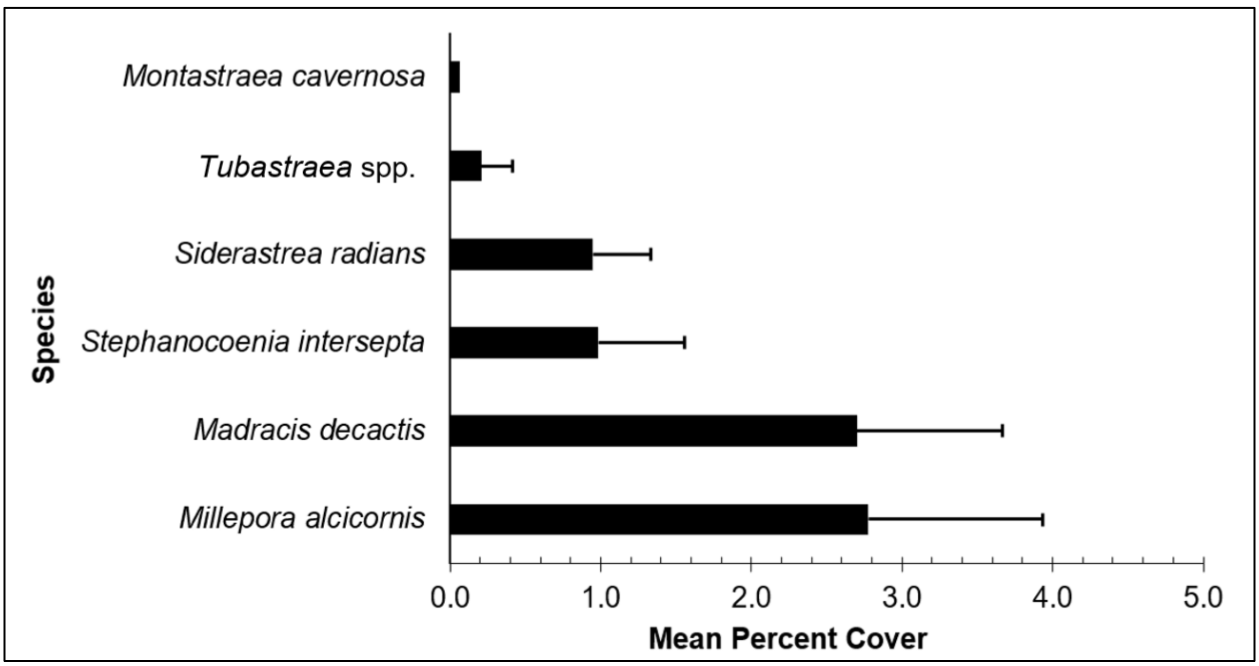


Figure 2.6. Mean percent cover (+SE) of dominant coral species at 54 repetitive photostations at Stetson Bank in 2023.

The dominant sponge species in 2023 were *Neofibularia nolitangere, Ircinia felix*, and *Agelas clathrodes* (Figure 2.7). Cover of *Ircinia strobilina* has declined in Stetson Bank repetitive photostations since 2021. In 2023, its cover was 0.06%, a stark decline from the 3.1% recorded in 2022 and 6.6% recorded in 2015 (Nuttall et al., 2017; O'Connell et al., 2024; Figure 2.8;

Figure 2.10). Additionally, qualitative analysis of repetitive photostations indicates that, on average, 2.7 sponge colonies have been lost between 2022 and 2023 across stations (Figure 2.9). This decline raises concerns, given the recognized ecological importance of sponges, which have been noted to play roles similar to scleractinian corals (Schönberg & Fromont, 2012). Their presence provides vital habitats for various coral reef fish species, facilitating recruitment, growth, reproduction, feeding, and breeding (Coppock et al., 2022).

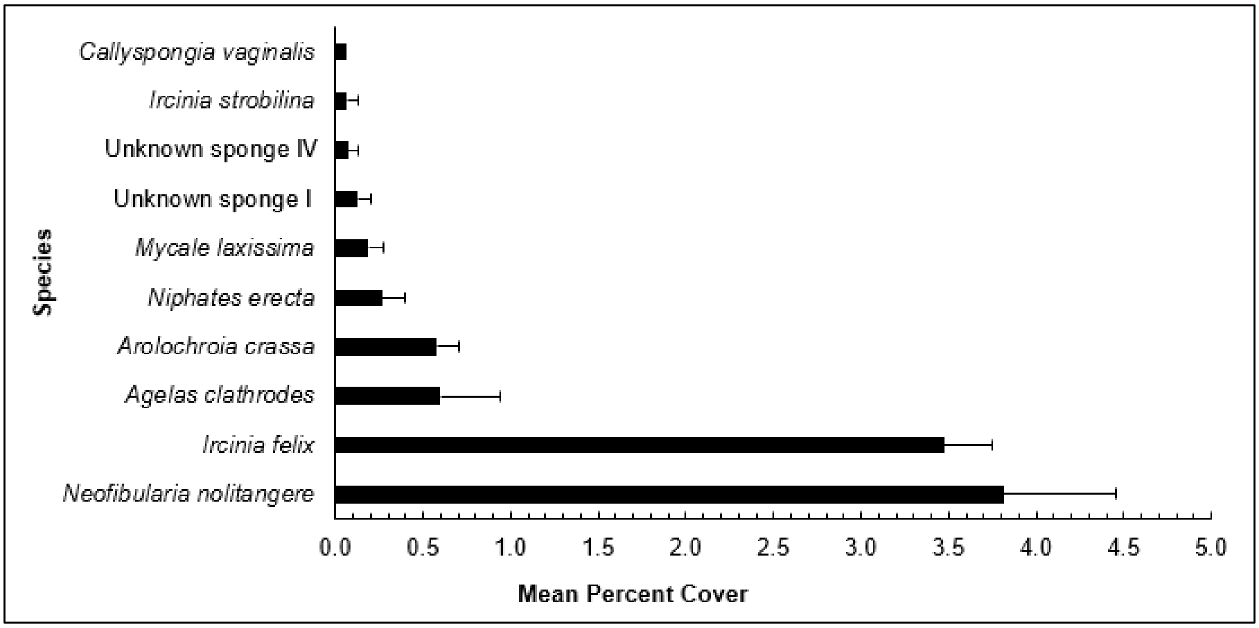


Figure 2.7. Mean percent cover (+SE) of dominant sponge species at 54 repetitive photostations at Stetson Bank in 2023.

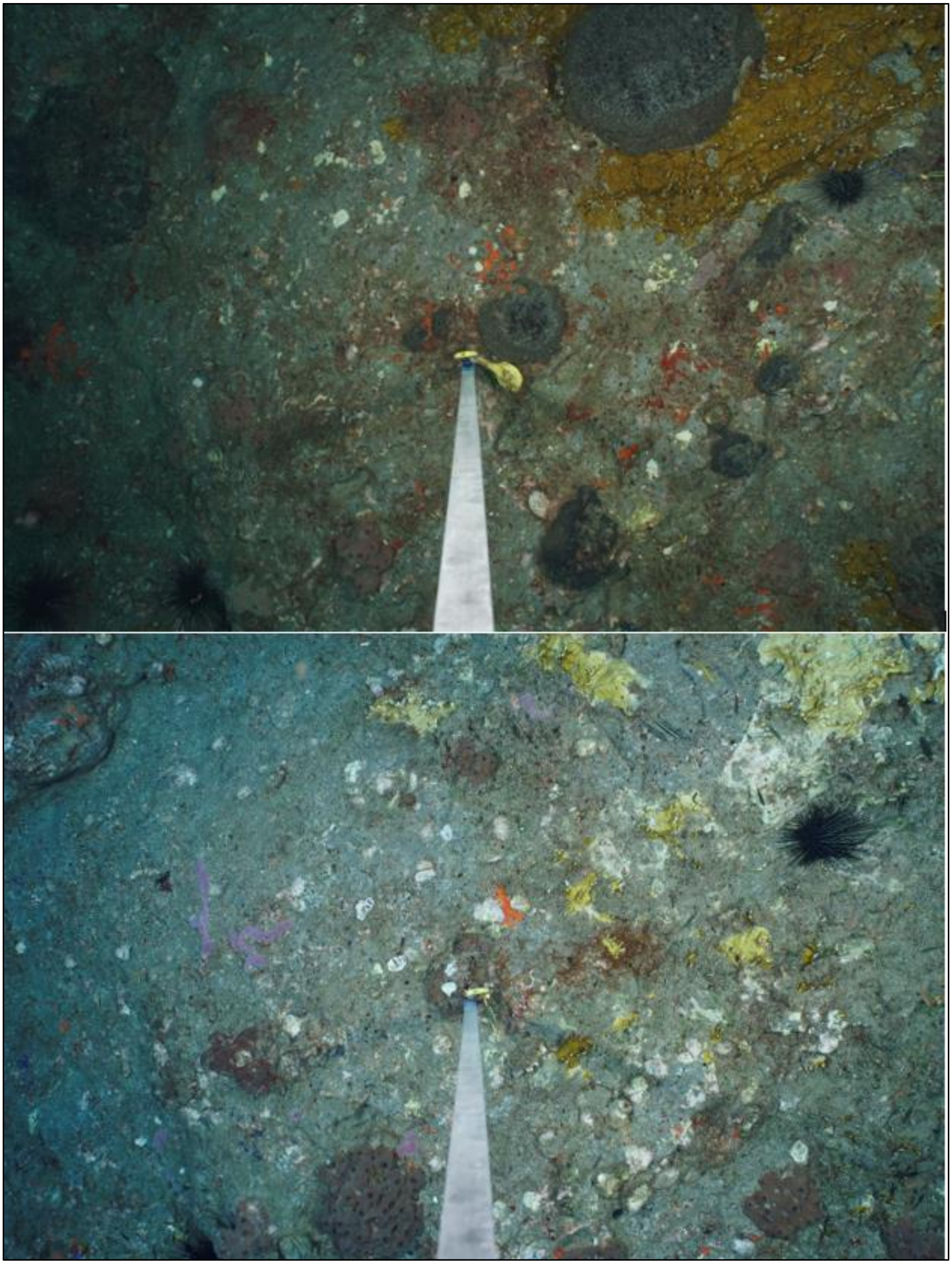


Figure 2.8. Photostation at Pin 40 showing *I. strobilina* colonies present in 2019 (top) and absent in 2023 (bottom).

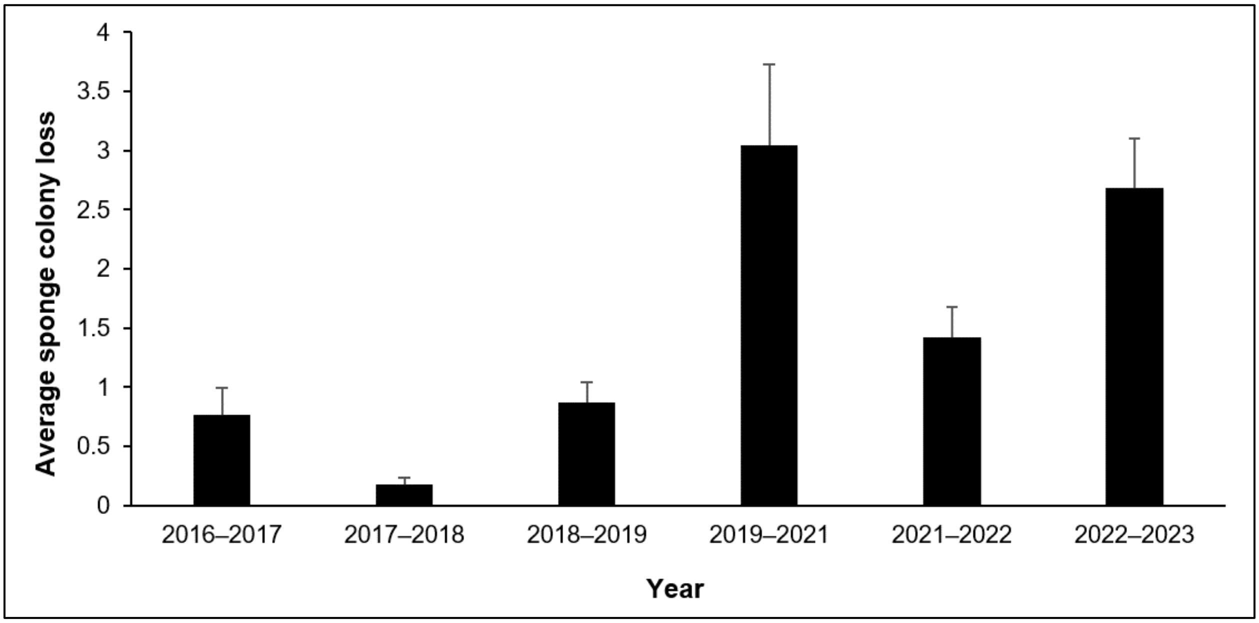


Figure 2.9. Mean sponge colony loss in permanent repetitive photostations from 2016 to 2023.

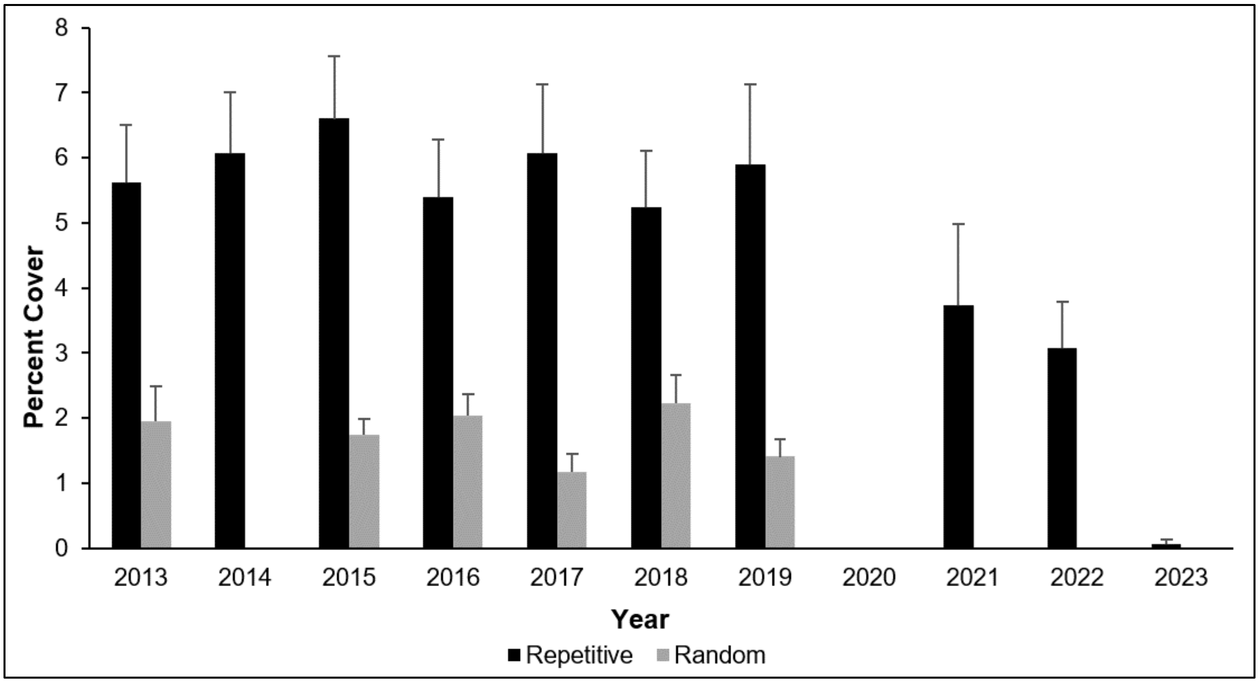
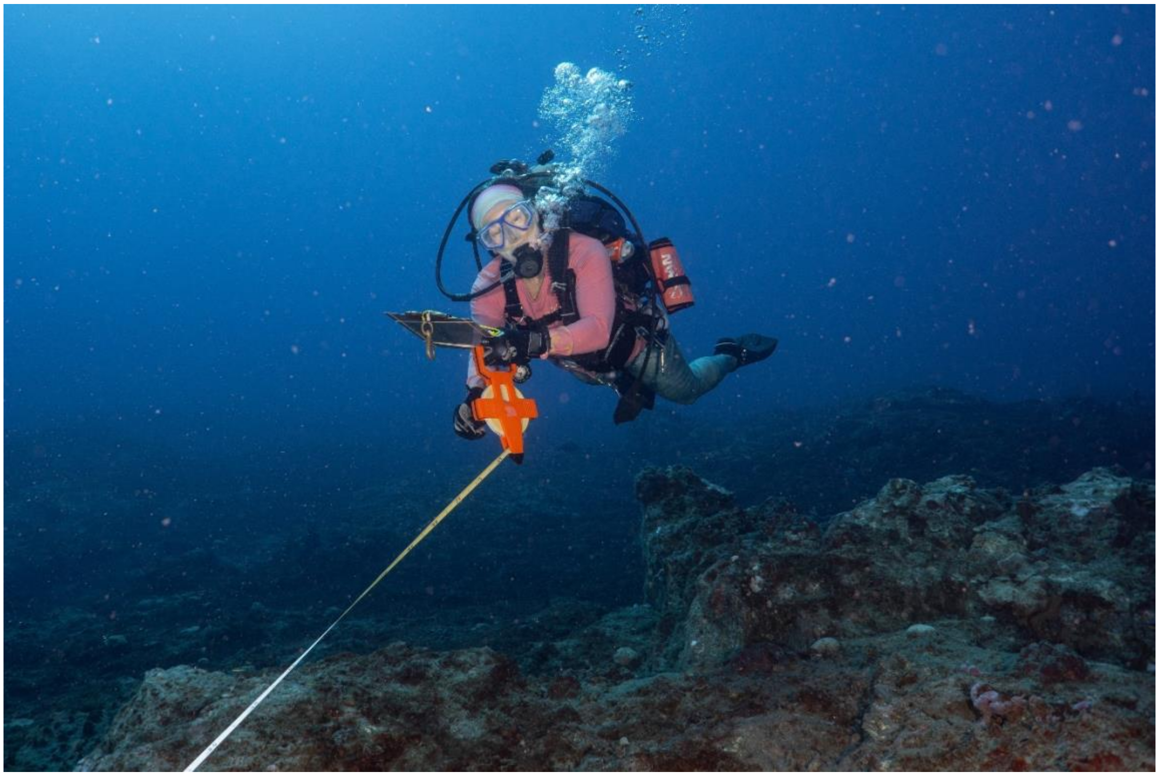


Figure 2.10. Mean *I. strobilina* percent cover in repetitive photostations and random transects. Repetitive photostations were not photographed in 2020. Random transects were not collected in 2014, 2020, 2021, and 2022.

Chapter 3:
Bank Crest Random Transects



Volunteer NOAA diver Jenny Vander Pluym rolls up a transect tape after completing a survey. Photo: Donavon French/CPC

Introduction

While repetitive photostations detect and evaluate long-term changes at the stations and in individual coral colonies, controlling for small-scale environmental heterogeneity, random transects document benthic cover for the entire reef crest and provide a greater representation of the reef crest community. Transect tapes were positioned at random locations within high- and low-relief habitat on Stetson Bank to estimate and compare the areal cover of benthic components on the bank crest. Corals, sponges, and macroalgae were quantified.

Methods

In preparation for the 2023 field season, the random transect camera system underwent significant upgrades, transitioning from the Canon Power Shot® G11 to the Sony® Alpha 6600. This decision was necessitated by the deteriorating condition of the previous equipment, characterized by increasingly frequent malfunctions. The Ikelite housings exhibited noticeable signs of wear and tear, resulting in unresponsive buttons and unreliable flash connections. Moreover, the evolving landscape of the camera industry, marked by a shift away from the 4:3 aspect ratio, presented challenges in sourcing suitable replacements for the Canon Power Shot® G11.

Given these circumstances, the decision was made to transition to a camera with a 3:2 aspect ratio, ultimately leading to the adoption of the Sony® Alpha 6600. This choice was driven not only by its compatibility with the desired aspect ratio, but also by its favorable price-to-performance ratio. The Nauticam® NA-A6600 housing, complemented by the 4.33-in fisheye dome port, was selected based on the brand's established reputation for reliability and user-friendly design. To ensure consistency in the area captured by each image, the new camera was equipped with the Sony® E 16mm f/2.8 lens, providing an equivalent focal length of 24 mm, and the T-frame was appropriately shortened.

This upgrade underscores the commitment of FGBNMS to keeping long-term monitoring efforts aligned with advancements in technology, all within the constraints of a fixed budget. The enhanced capabilities of the new camera system resulted in images of superior detail, facilitating more precise data processing and ensuring a more dependable experience during offshore operations. With diligent maintenance and care, the new setup is anticipated to serve as a reliable tool for years to come, building upon the successes of its predecessor.

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 0.58 m tall T-frame with bubble level and strobes, was used to capture non-overlapping images of the reef. Each image captured approximately 0.85 x 0.57 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 0.23-m buffer between each image to prevent overlap. A Sony® Alpha 6600 digital camera with a Sony® E 16mm f/2.8 lens was used in an Nauticam® NA-A6600 housing with a Nauticam® 4.33-inch fisheye dome port and two Inon® Z240 strobes set 1.2 m apart on the T-frame.

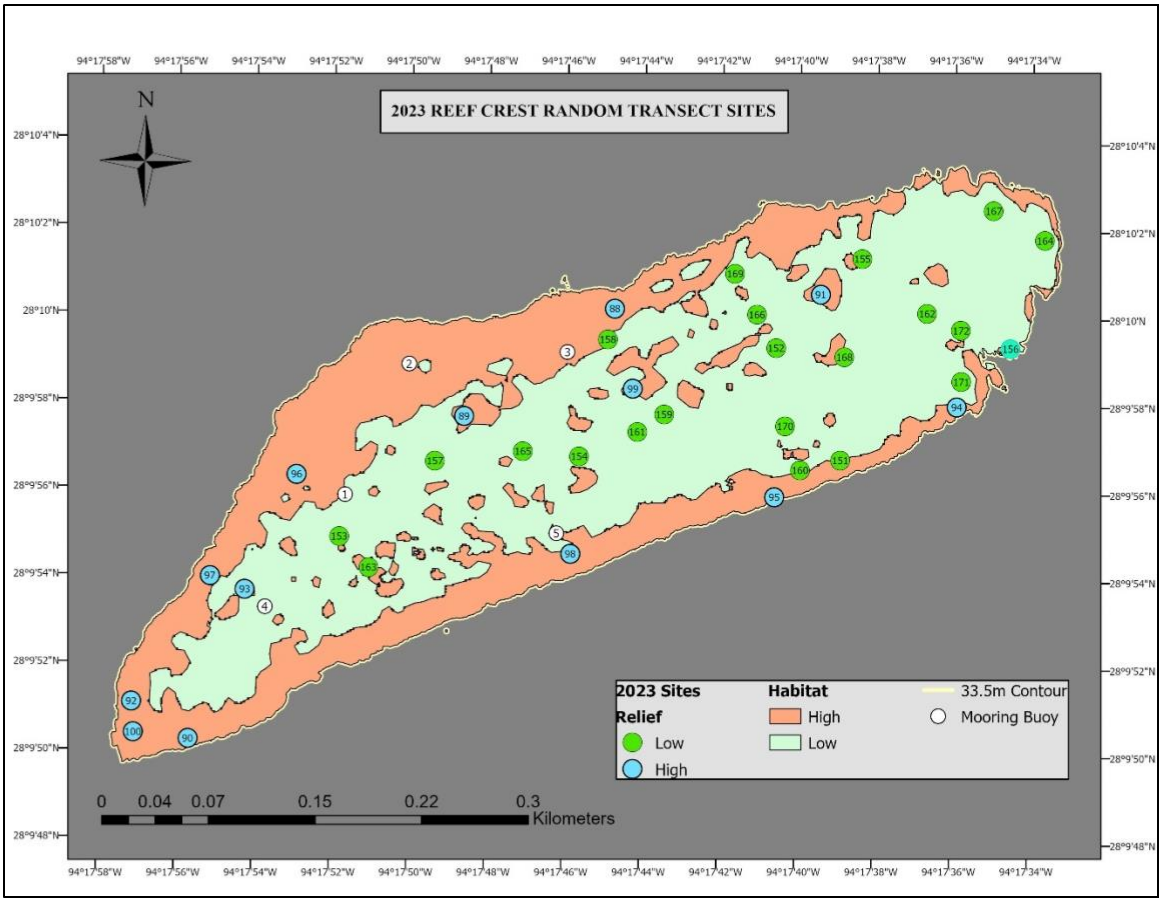


Figure 3.1. 2023 planned random transect locations. Image: NOAA

Results

In 2023, 22 random transects were conducted: 15 in low-relief habitat and seven in high-relief habitat. Mean percent cover was 0.55% for scleractinian coral (0.35% for low-relief habitat and 1.03% for high-relief habitat), 0.46% for hydrocoral (0.19% for low-relief habitat and 0.96% for high-relief habitat), 8.61% for sponges (8.07% for low-relief habitat and 9.76% for high-relief habitat), and 64.42% for macroalgae (66.36% for low-relief habitat and 60.24% for high-relief habitat; Figure 3.2). The dominant coral species were *Millepora alcicornis*, *Stephanocoenia intersepta,* and *Pseudodiploria strigosa* (Figure 3.3) and the dominant sponge species was *Neofibularia nolitangere* (Figure 3.4). No random transects had been completed since 2019, when the overall mean sponge cover was 15.32% ± 1.64%, indicating a declining trend similar to that reported in Chapter 2.

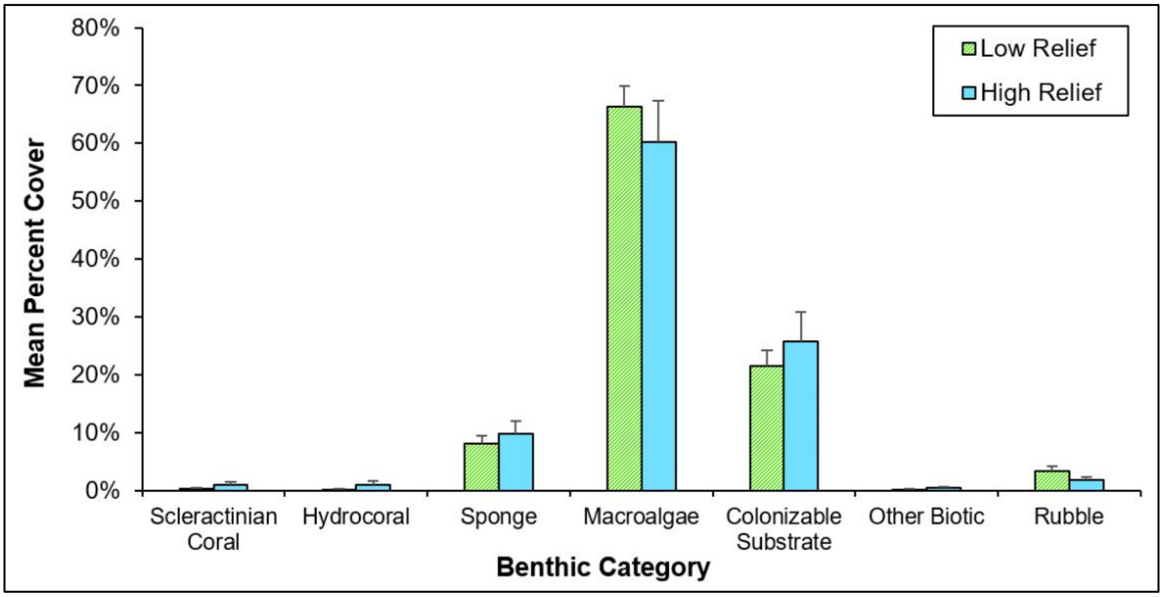


Figure 3.2. Mean percent cover (+SE) of major benthic categories at 22 random transects (15 low-relief; 7 high-relief) in 2023.

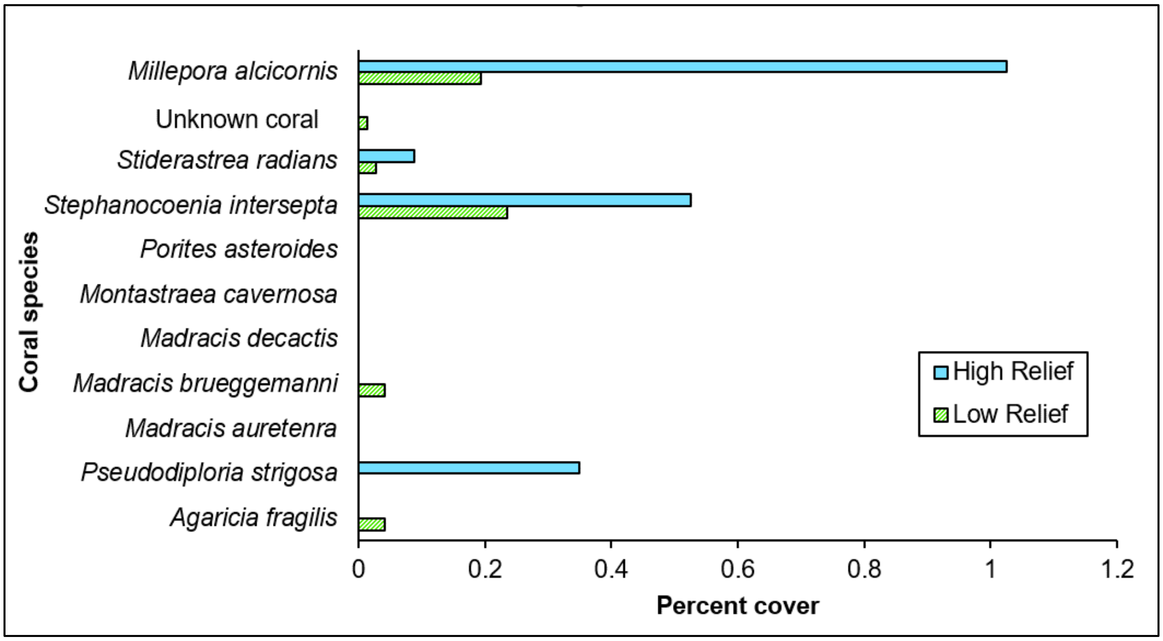


Figure 3.3. Mean percent cover (+SE) of dominant coral species at 22 random transects (15 low-relief; 7 high-relief) in 2023.

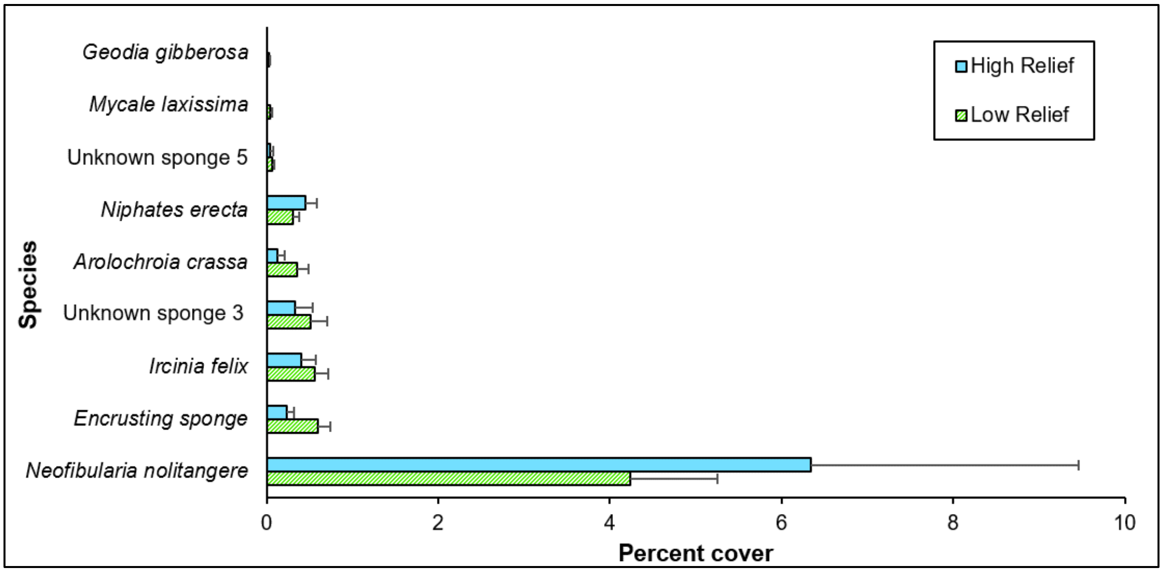


Figure 3.4. Mean percent cover (+SE) of dominant sponge species at 22 random transects (15 low-relief; 7 high-relief) in 2023.

Chapter 4:
Bank Crest Fish Monitoring

A gray angelfish (*Pomacanthus arcuatus*) at Stetson Bank. Photo: Tiffany Crumbley/Texas Caribbean Charters

Introduction

Modified Bohnsack-Bannerot stationary visual fish censuses (Bohnsack & Bannerot, 1986) 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- and high-relief habitats.

The sanctuary tracks invasive and exotic species populations to monitor their impact on the native reef ecosystem. Lionfish, a venomous fish species from the Indo-Pacific region, have proliferated in waters off the southeast U.S., Caribbean, and Gulf of Mexico since their likely introduction through the aquarium trade in the 1980s. Lionfish (*Pterois volitans*) were first observed at Stetson Bank in 2011. Starting in 2015, once or twice annually, NOAA-sanctioned Lionfish Invitational cruises are conducted on the recreational dive charter vessel M/V *Fling*, allowing volunteer divers to remove lionfish at buoy sites on the reef crest. Although density and biomass of lionfish are not assessed before removal occurs, the number of fish removed is recorded every year.

Regal demoiselles (*Neopomacentrus cyanomos*), native to the Indo-West Pacific, were first reported in the northern Gulf of Mexico in 2017 and have since become established in the region. Their establishment has been speculated to be the result of various factors, including the effects of global climate change, which has led to milder and shorter cold events (Townhill et al., 2019), and the establishment of artificial structures in the region (Addis et al., 2013; Robertson et al., 2018). Furthermore, in places where small native damselfish populations have been reduced by lionfish predation, the regal demoiselle may face less competition for resources and space (Dahl et al., 2017; Tarnecki et al., 2021). It should be noted that there is no evidence to date of native fish declines caused by lionfish in sanctuary monitoring data. In 2018, regal demoiselles were first observed at Stetson Bank in fish surveys, and were observed schooling with other reef fish such as brown chromis (*Azurina multilineata*).

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).

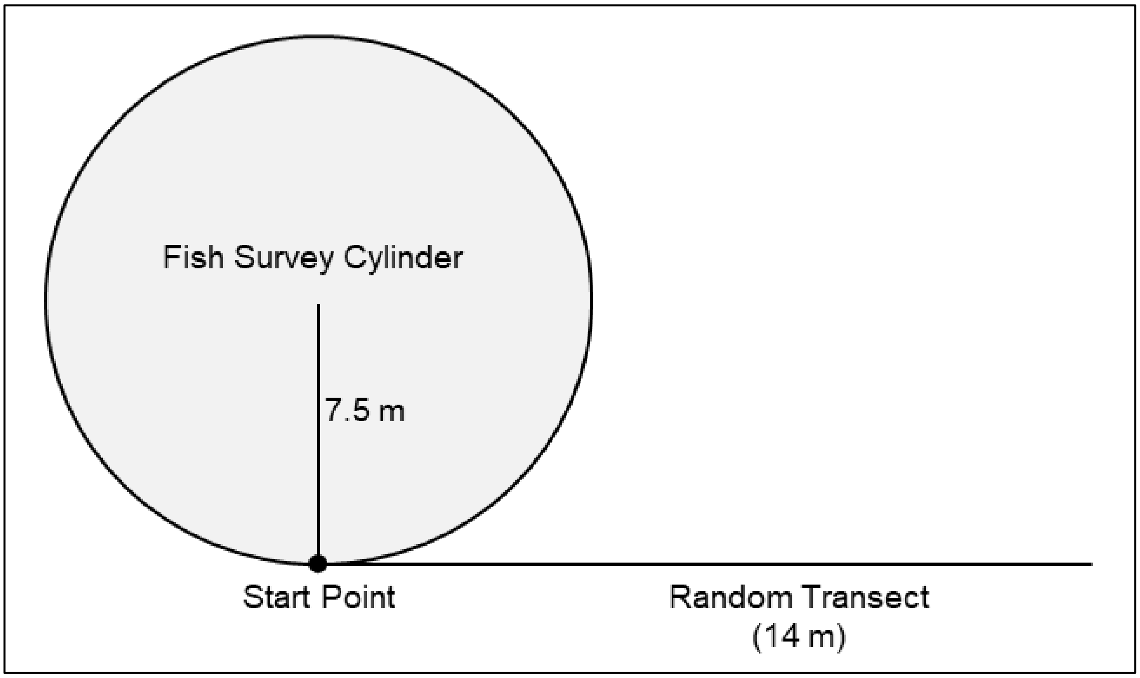


Figure 4.1. Random transect and fish survey area setup. Image: NOAA

In 2023, 22 random fish surveys were conducted: 15 in low-relief habitat and seven in high-relief habitat (Chapter 3; Figure 3.1). Summary statistics of fish census data included abundance, density, biomass, 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.

Results and Discussion

In 2023, a total of 74 species were recorded in bank crest surveys paired with benthic random transects (n = 22). Richness ranged from 11 to 19 species per survey, with an average of 15.68 ± 0.58. Mean fish density was 156.25 ± 19.48 individuals/100 m^2. Mean biomass was 5.87 ± 2.534 kg/100 m^2.

Regal demoiselle (*Neopomacentrus cyanomos*) had the highest density of all species (35.99 ± 9.47 individuals/100 m²), followed by brown chromis (*Chromis multilineata*; 20.37 ± 13.15 individuals/100 m²), bluehead (*Thalassoma bifasciatum*; 17.06 ± 2.36 individuals/100 m²), and cocoa damselfish (*Stegastes variabilis*; 15.10 ± 2.71 individuals/100 m²; Figure 4.2). The rapid increase in regal demoiselle density on the reef crest at Stetson Bank raises concerns about potential impacts on native fish populations (Figure 4.3). The potential for direct competition with native damselfishes is of particular interest, as reducing populations of regal demoiselle could prove challenging due to their small size and schooling behavior, which makes them difficult to capture without significant impact on other fish species. Understanding, tracking, and managing the ecological implications of this shift in fish community composition are crucial for the long-term health of the reef ecosystem at Stetson Bank.

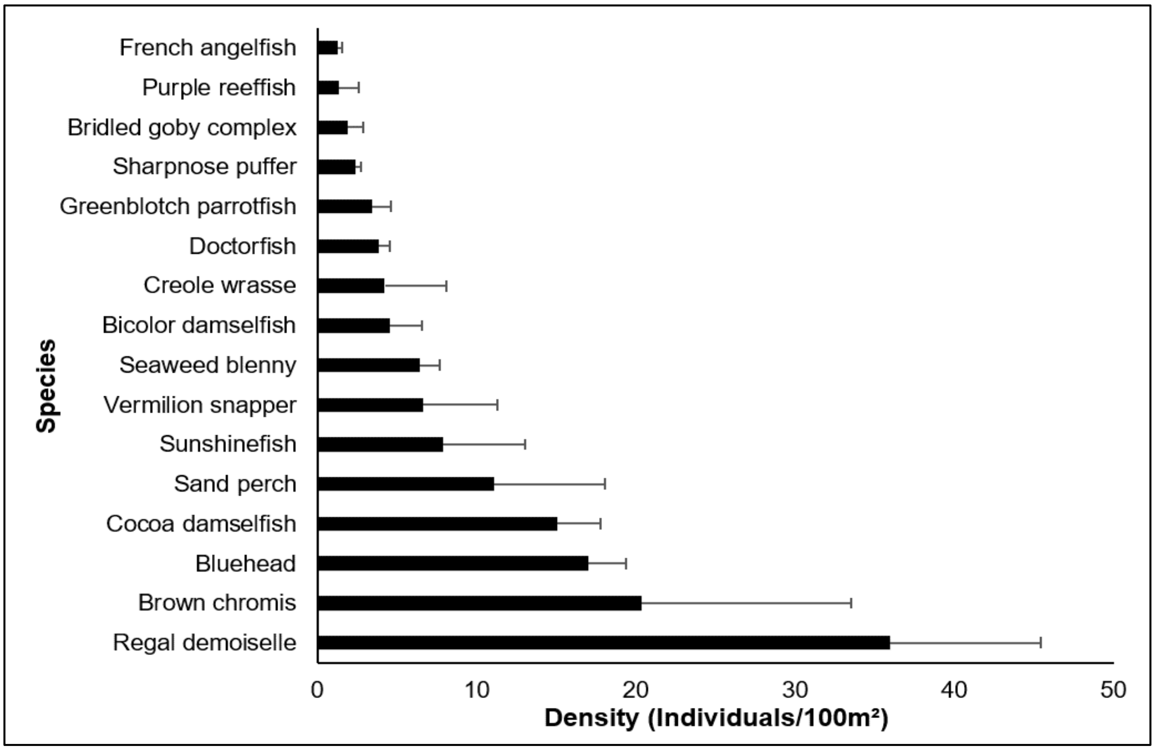


Figure 4.2. Densities (+ SE) of the most abundant fish species in bank crest Bohnsack-Bannerot surveys on Stetson Bank in 2023.

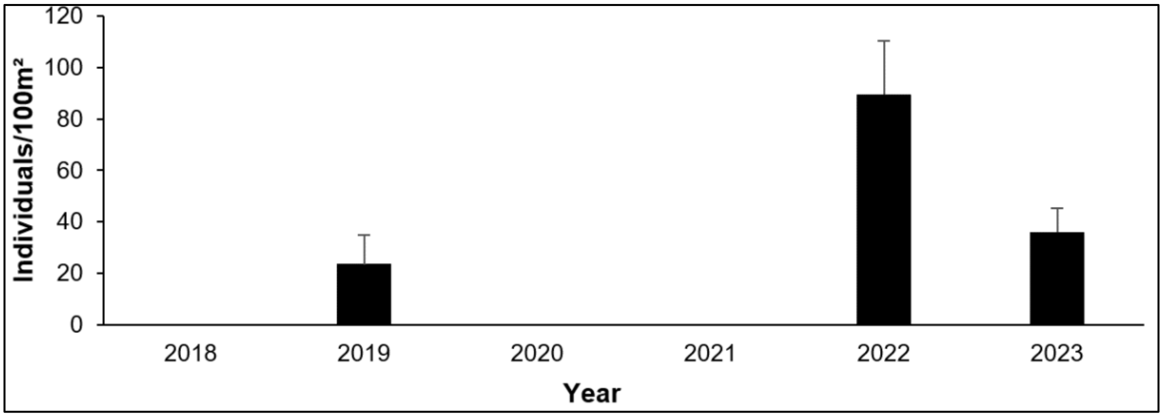


Figure 4.3. Densities (+ SE) of regal demoiselles in bank crest Bohnsack-Bannerot surveys. Regal demoiselles were first observed in 2018, but were absent in surveys. Fish surveys were not completed in 2020 or 2021.

To examine the food preferences of lionfish on Stetson Bank, lionfish removed from the sanctuary were measured and their gut contents were analyzed. Similar to other invaded regions (Blakeway et al., 2022), lionfish at Stetson Bank were found to be generalists, with species in their diet reflecting the presence and availability of fish locally. Prey fish densities (<15 cm) from long-term monitoring surveys showed no significant changes at Stetson Bank since the lionfish invasion.

Although periodic recruitment pulses occur, there is no evidence that current lionfish densities are reducing prey fish density at Stetson Bank. Lionfish have not been captured in Bohnsack-Bannerot surveys since 2019 and historically, densities have been low (Figure 4.4). This aligns with other studies suggesting lionfish densities below 0.25 per 100m² are unlikely to deplete local prey resources (Green & Grosholz, 2021). However, the lionfish invitational removals show that they are still present on the Stetson Bank reef crest (Figure 4.4). Factors such as minimally altered food webs and high recruitment of native fish may enhance resistance and resilience against lionfish impacts. Even with control efforts, the lionfish invasion represents a significant environmental and economic threat in the region.

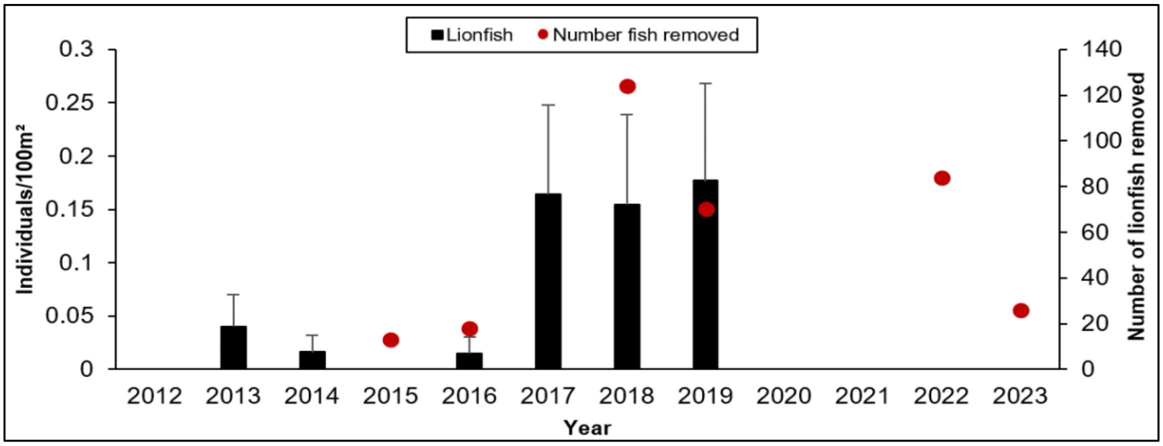


Figure 4.4. Lionfish densities (+ SE) from Bohnsack-Bannerot surveys. Lionfish invitational cruises started in 2015. Red circles indicate the number of lionfish removed during these cruises. Invitationals did not occur in 2017, 2020, or 2021.

French angelfish (*Pomacanthus paru*) mean biomass was highest of all species (0.85 ± 0.18 kg/100 m²), followed by great barracuda (*Sphyraena barracuda*; 0.56 ± 0.39 kg/100 m²), doctorfish (*Acanthurus chirurgus*; 0.43 ± 0.08 kg/100 m²), and blue angelfish (*Holocentrus adscensionis*; 0.15 ± 0.06 kg/100 m²; Figure 4.5).

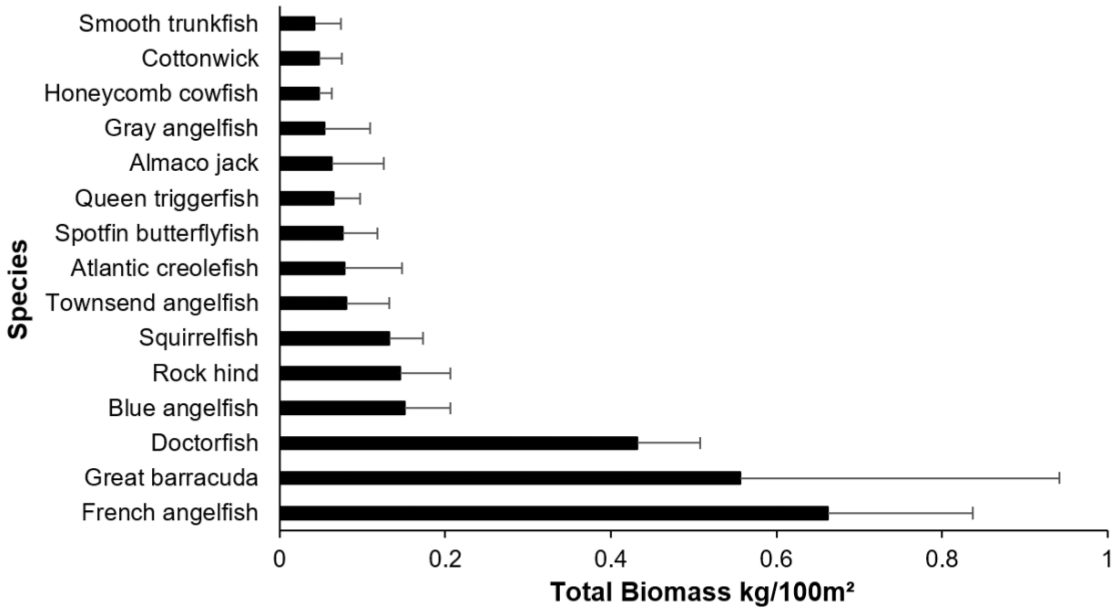


Figure 4.5. Biomass (+ SE) of the highest contributing species in bank crest Bohnsack-Bannerot surveys at Stetson Bank in 2023.

Chapter 5:
Sea Urchin and Lobster Surveys

Long-spined sea urchins (*Diadema antillarum*) gather under a feature at Stetson Bank. Photo: Tiffany Crumbley/Texas Caribbean Charters

Introduction

Sea urchins are essential organisms in coral reef ecosystems, undertaking various roles vital for the health and stability of these environments. Historically pervasive throughout coral reefs in the western Atlantic and Gulf of Mexico, the long-spined sea urchin (*Diadema antillarum*) played a critical role in top-down control of macroalgae cover, thus facilitating the settlement and growth of other sessile benthic organisms, including corals (de Breuyn et al., 2023). Their primary function lies in algae grazing, a process crucial for preventing algal overgrowth, which could endanger coral survival.

In the mid-1980s, an unknown pathogen decimated *D. antillarum* populations throughout the region, including FGBNMS. Following the die-off, irregular, limited, and inconsistent recovery has been documented in the region (Edmunds & Carpenter, 2001). Estimates of pre-mortality populations ranged from about 50 to 164 individuals/100 m^2 at the Flower Garden Banks (Bright & Pequegnat, 1974). Since 1995, significant increases have been observed in *D. antillarum* populations at Stetson Bank. Despite fluctuations in densities and changes in survey methodologies over the years, repetitive photostation data suggest that *D. antillarum* densities appear to have rebounded to pre-die-off levels. In February 2022, widespread *D. antillarum* die-offs were again reported throughout the Caribbean (Hylkema et al., 2023) but have not been observed on the banks of the sanctuary at the time of this report. *D. antillarum* populations are closely monitored in the sanctuary and reported to the *Diadema* Response Network.

Stetson Bank monitoring surveys include assessments of both *D. antillarum* and several lobster species.

The survey regimen employs both nocturnal and diurnal methodologies to comprehensively assess sea urchin and lobster populations. Nighttime visual surveys are conducted to capture the nocturnal activity of these species, ensuring a thorough examination of their distribution. During daytime, *D. antillarum* sea urchins are counted in repetitive photostations and random transects to provide additional insights into population densities across various reef habitats.

Methods

Visual surveys are typically conducted at night along two repetitive belt transects. Due to inclement weather, night surveys were not conducted in 2023. Sea urchin abundances were assessed during daytime by counting individuals in each repetitive photostation image and random transect. In 2023, 54 repetitive photostations (covering 86.4 m^2) and 22 random benthic transects (covering 179.5 m^2) were examined for sea urchin density.

Results and Discussion

In 2023, a total of 174 *D. antillarum* sea urchins were counted in repetitive and random transects, with a mean density of 117.5 ± 16.3 per 100 m^2. Densities were higher in the repetitive photostations than in random transects, with a total density of 156.8 ± 19.75 per 100 m^2 in repetitive photostations and 25.6 ± 16.5 per 100 m^2 in random transects (Figure 5.1).

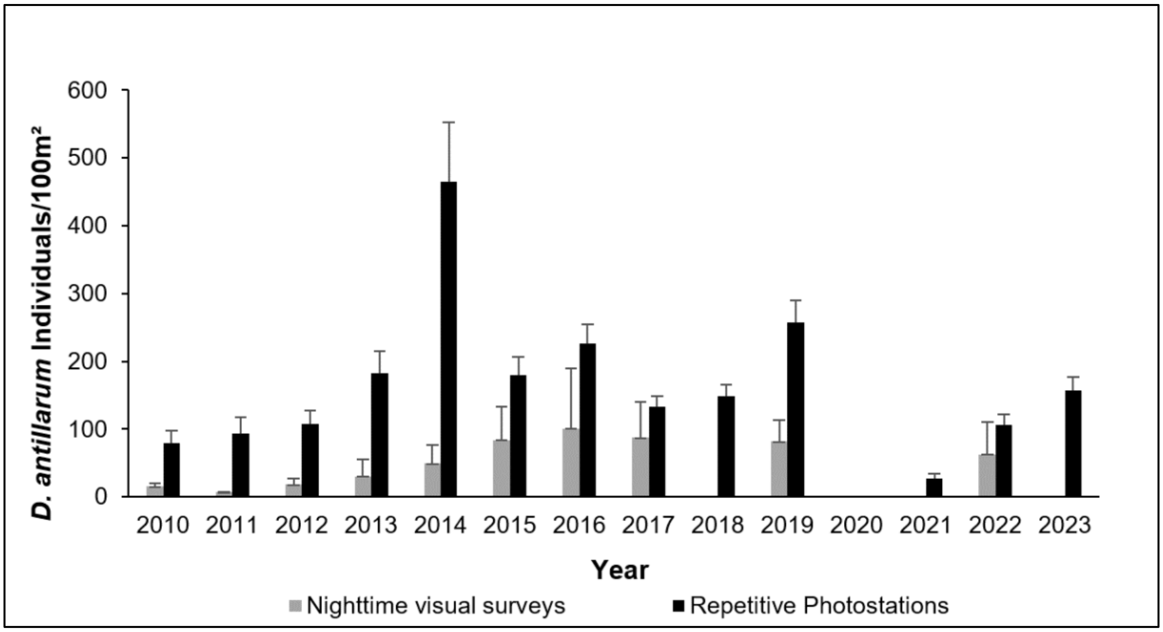


Figure 5.1. *D. antillarum* densities (+SE) since counts were first made in 2010. Data was not collected in 2020 and nighttime visual surveys were not conducted in 2021 or 2023.

Nighttime visual surveys were specifically designed to obtain more accurate density estimates of sea urchins on the bank crest. During daytime, sea urchins tend to cluster beneath overhangs, potentially skewing density estimates, but become active at night, and thus easier to observe. The high density estimates from repetitive photostation data are likely caused by this tendency to aggregate in high-relief areas during daytime, as such areas were intentionally selected for the placement of many repetitive photostations. The nighttime surveys would be expected to produce more accurate density estimates, but more investigation is needed to ensure consistently accurate quantification of sea urchin populations within bank and reef ecosystems.

Chapter 6: Water Quality

FGBNMS researchers prepare to deploy water sampling carousel aboard the R/V *Manta*. Photo: Emma Hickerson

Introduction

Several water quality parameters were continually or periodically recorded at Stetson Bank from January 1st to December 31st, 2023. 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 were taken at all three banks in January using the Sea-Bird® 19plusV2 and again in May, July, and August using a YSI handheld sensor. Water samples were collected in January, May, and August, 2023 at three depths within the water column and analyzed by a U.S. Environmental Protection Agency (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 the time series was disrupted in 2023 as a result of cruises that were canceled or scaled back due to weather, vessel malfunctions, or malfunctions in water quality instrumentation. This chapter presents data from moored water quality instruments, water column profiles, and water samples collected in 2023.

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 6.1). Instruments were exchanged by divers for downloading and maintenance in January, May, June, July, and August, 2023. 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 affected in 2023 due to weather and vessel delays.

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 6.1). These instruments operated continuously from August 3, 2022 to July 12, 2023 and again from July 12, 2023 to June 14, 2024. When exchanged, data were downloaded and the loggers were cleaned and relabeled.

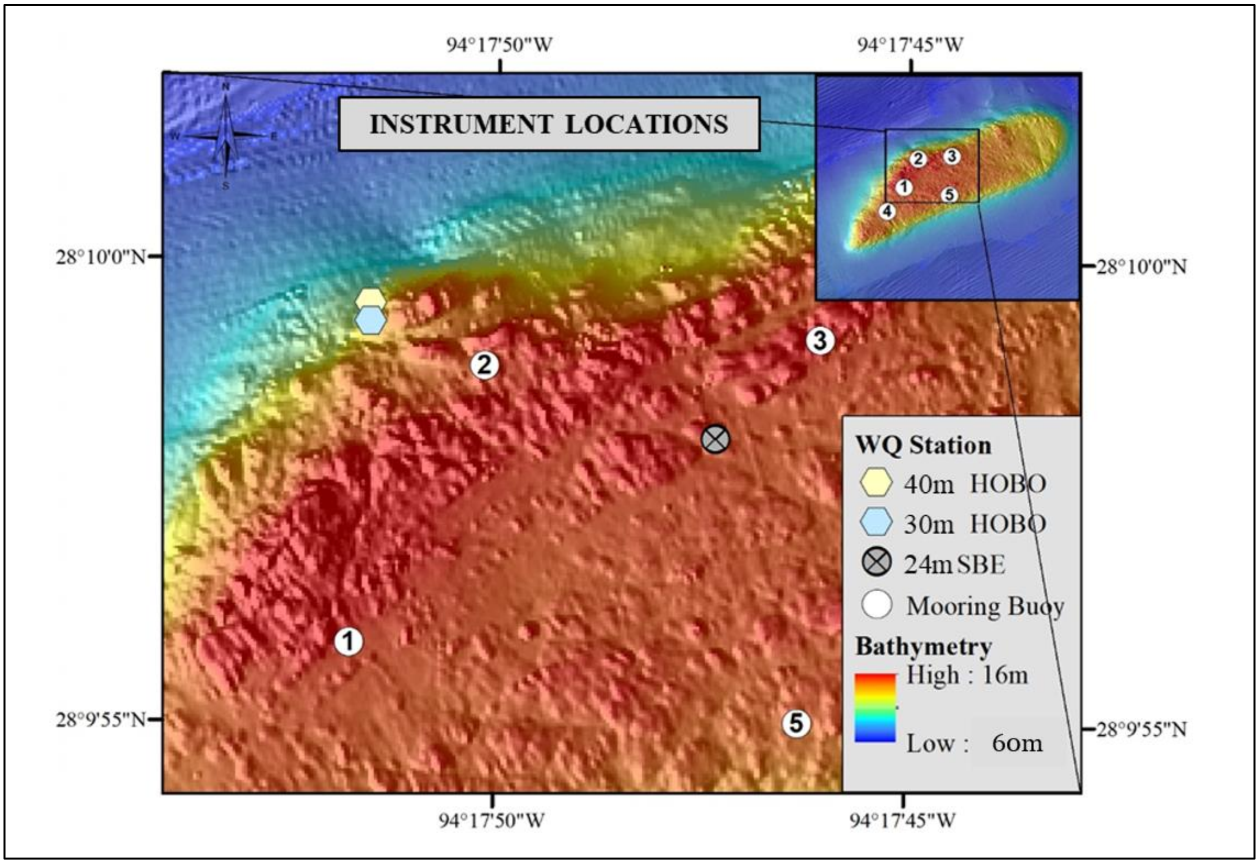


Figure 6.1. Locations of water quality instruments relative to Stetson Bank mooring buoys. Image: NOAA

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 2023 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 crest were acquired on January 10, 2023, using a Sea-Bird® 55 Frame Eco water sampler equipped with 12 four-liter Niskin bottles. The Sea-Bird® Electronics 19plus V2 CTD sensor (SBE 19plus), equipped with external sensors, recorded pH (SBE 18), turbidity and fluorescence (WET Labs ECO NTUS), dissolved oxygen (SBE 43), conductivity, depth, salinity, and temperature (Table 6.1). Data were collected every ¼ second during a descent of <1 m/sec to distinguish differences and gradients between three target depths: the bank crest (~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 6.1 Sensors for water quality profiles taken with the FGBNMS carousel in 2023. Sensors were secured to the SBE 19plus V2 CTD.

Sensor	Parameters Measured
SBE 19plus	Depth, salinity, and temperature
SBE 43	Dissolved oxygen
WET Labs ECO NTUS	Fluorescence and turbidity
SBE 18	pH

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 12 OceanTest® Corporation 4-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 May 4^{th} and August 17^{th}, 2023 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, CTD profile, and YSI 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 January, May, June July, and August, 2023. 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 crest were exchanged in January 2023, May 2023, and August 2023, generating nearly 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 were received from the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi for May and August.

Results

Weather and ship maintenance reduced the number of cruises that could be made in 2023 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 2024.

Moored Water Quality Instruments

Temperatures recorded by the SBE 16plus at 24 m ranged from 19.36 °C to 30.28 °C in 2023, with nearly identical data recorded by the backup HOBO logger (Figure 6.2). Bank crest temperatures at Stetson Bank exceeded 30 °C for five consecutive days in July but maintained a temperature of at least 29 °C for 13 consecutive days in July and August. As temperature data beyond August 18th were not recovered and processed at the time of this report, it is possible this period of elevated temperature continued through August and much of September, as satellite sea surface temperatures suggest.

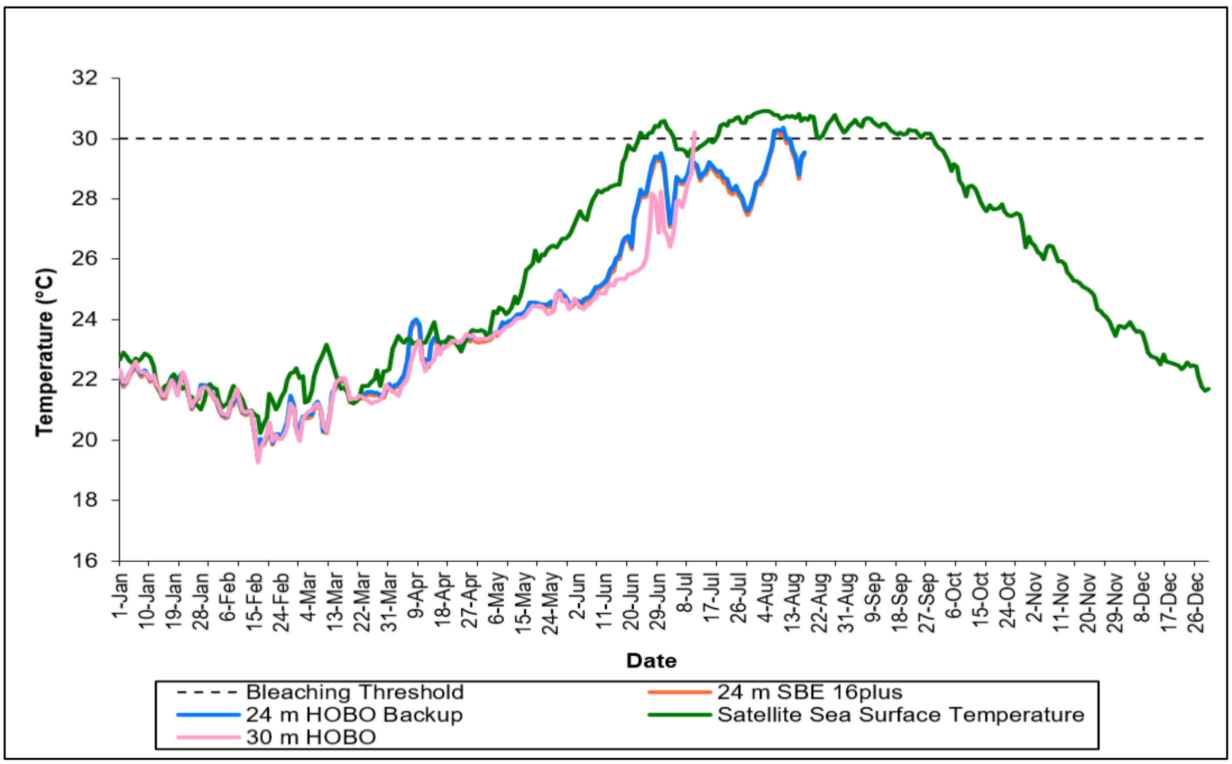


Figure 6.2. Daily mean seawater temperature at Stetson Bank from various depths in 2023. Coral bleaching can occur following prolonged exposure at or above the 30 °C threshold (shown by the dashed line).

Water temperatures recorded on HOBOs at 30 m registered similar patterns in 2023, with lower temperatures than the bank crest during June and into July, likely indicating the development of thermal stratification of the water column. Temperatures recorded on the HOBO at 30 m ranged from 19.25 °C to 30.20 °C in 2023 (Figure 6.2). The HOBO at 40 m was lost and not recovered during the recovery cruise in July, 2023. A new HOBO logger was deployed at the 40 m site to record temperatures for the latter half of the year. Deep HOBOs were exchanged on July 12th, but more recent attempts to exchange these were delayed in 2023 by the need for vessel maintenance and repairs.

At 24 m, the SBE 16plus recorded salinity ranging from 33.64 to 36.62 psu in 2023 (Figure 6.3).

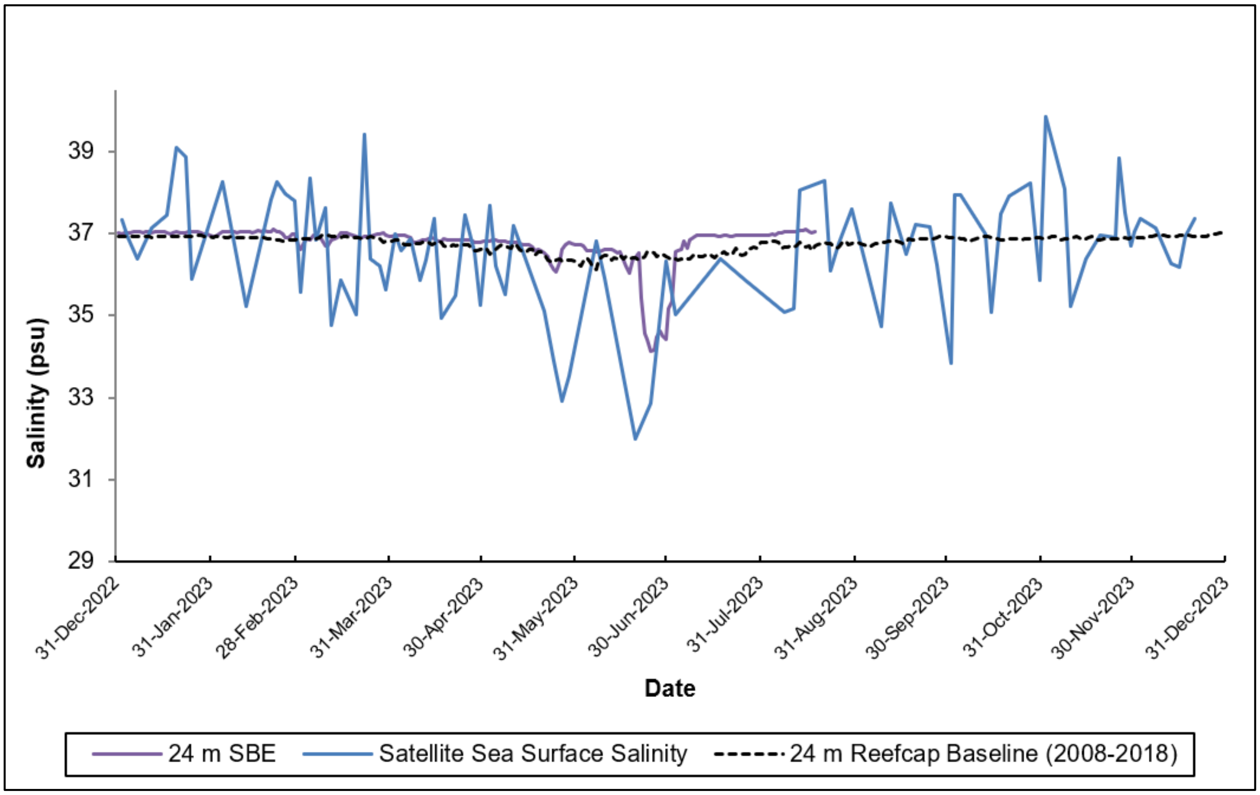


Figure 6.3. Daily mean seawater salinity at the surface and at 24 m on Stetson Bank in 2023, along with the average daily salinity from 2008–2018.

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 2023. Levels of variability, however, are similar to other data recorded at Stetson Bank since 2015 (Nuttall et al., 2020b). Figure 6.4 presents only data from May 4 to August 18, 2023 because turbidity values during prior periods either drifted far above previously reported values (Nuttall et al., 2020b) or logged a negative error reading and were determined to be unreliable. From May to August 2023, turbidity readings averaged 2.09 ntu at 24 m, with peak anomalies on July 11 (12.38 ntu) and July 18 (20.92 ntu).

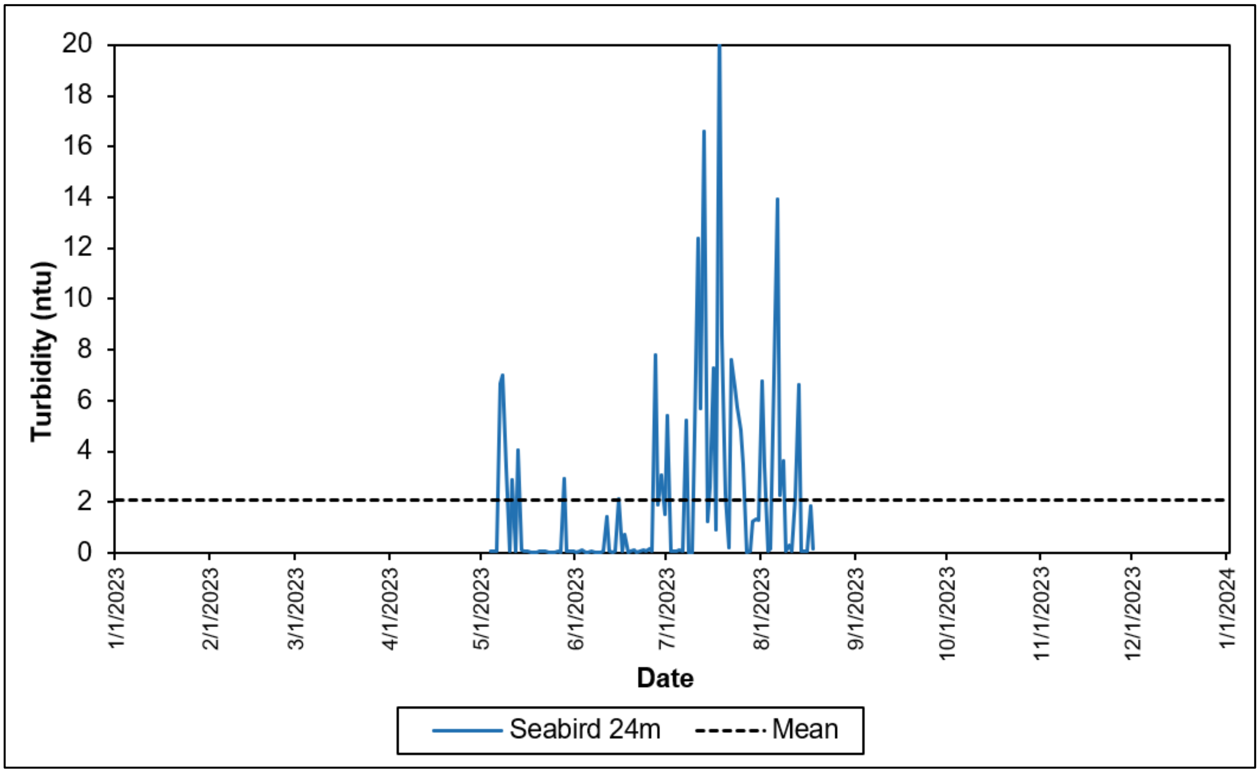


Figure 6.4. Daily mean turbidity values at 24 m in 2023. Data were unreliable before May 4, 2023 and were excluded from this report. Data after August 18, 2023 have not yet been recovered.

Water Column Profiles

In May 2023, the SBE 19plus was damaged as a result of water intrusion into the main body of the sensor. The instrument returned from service and has been reintegrated into the carousel for future sampling. Consequently, profiles performed after January utilized a YSI handheld multiparameter instrument to record temperature, salinity, dissolved oxygen, and pH. Fluorescence profiles were only taken in January. The pH profile from July was omitted from this report due to the sensor calibration failing, resulting in unreliable readings. Profiles were taken to a depth of 15 m at Stetson bank in May, July, and August, 2023.

The January column was nearly isothermal from just below the surface to the bank crest and the profile varied less than 0.5 °C from the surface to the bottom (Figure 6.5). Likewise, salinity and dissolved oxygen indicated virtually no stratification above the bank crest. Turbidity was higher in the upper 1–2 meters, spiking at 6 ntu at 2 m, and declined gradually below that. pH values fluctuated at the surface but then stabilized at 2 m and were consistent down to the reef crest. Fluorescence increased gradually with depth.

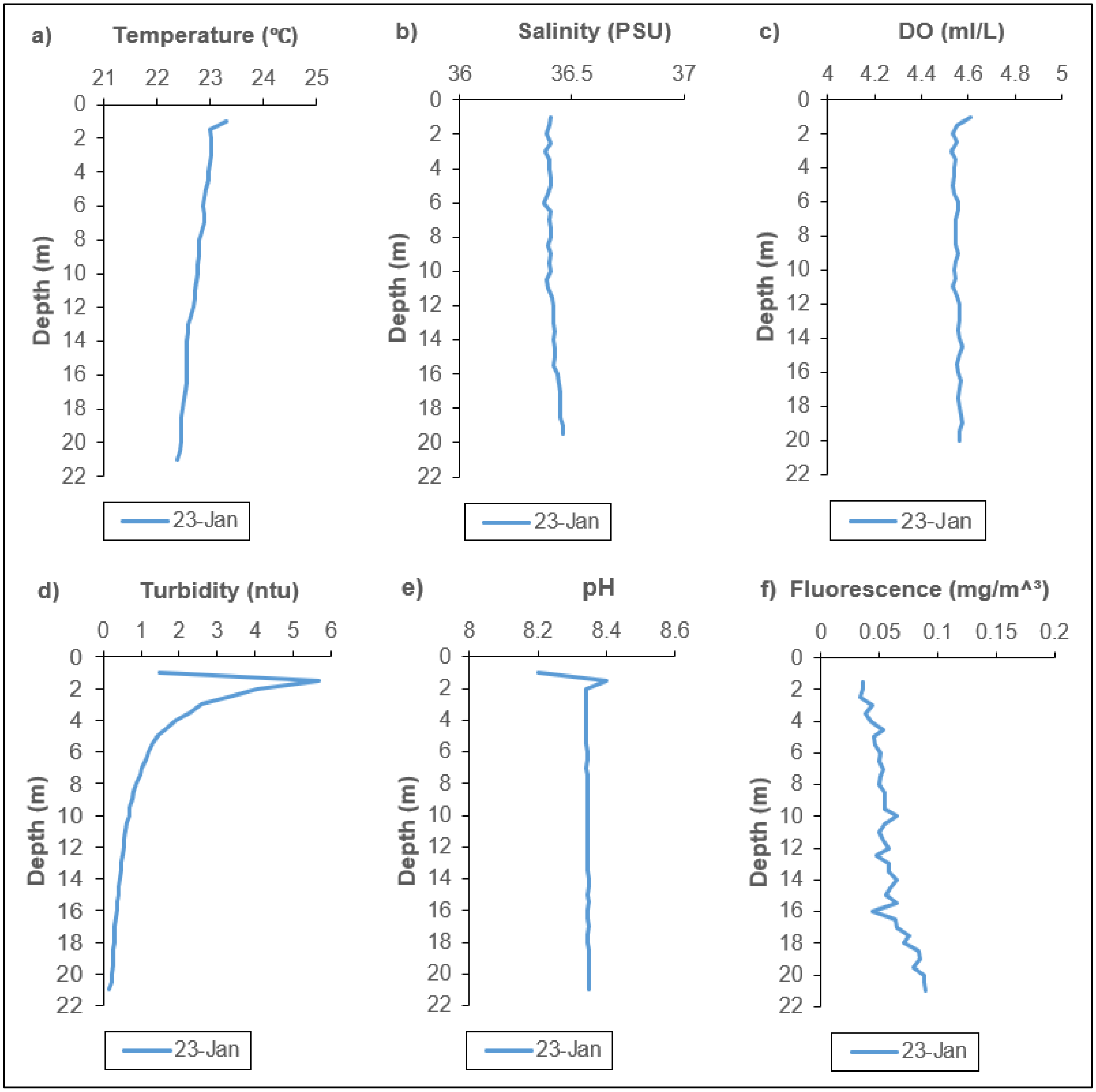


Figure 6.5. Stetson Bank water column profiles for (a) temperature, (b) salinity, (c) dissolved oxygen, (d) turbidity, (e) pH, and (f) fluorescence on January 10, 2023.

Water Samples

The 2023 nutrient levels from each water column depth were below detection limits in all samples, with the exception of phosphorus, which was detected at 0.01 mg/L, consistent with oligotrophic oceanic conditions (Figure 6.6). Ocean carbonate measurements conducted in tandem with nutrient sampling were sent to Texas A&M University-Corpus Christi for analysis.

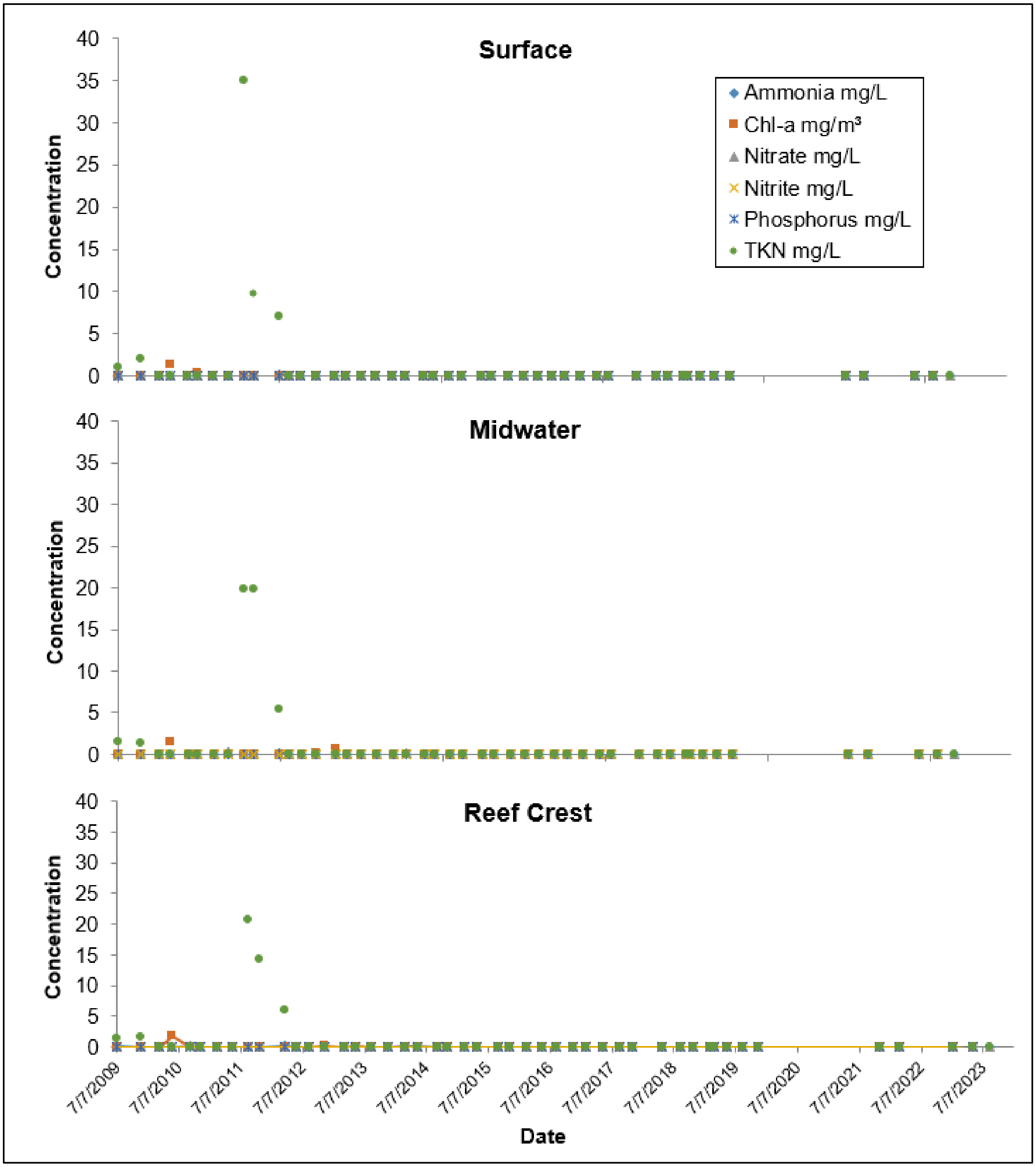


Figure 6.6. Nutrient concentrations from Stetson Bank water samples taken at the surface (~1 m), midwater (~10 m), and reef crest (~20 m) from 2009 through 2023.

Water samples taken on May 4th and August 18th, 2023 at approximately 20, 10, and 1 m were submitted to the Carbon Cycle Laboratory at Texas A&M University-Corpus Christi for multiple analyses, including pH, alkalinity, CO_2 partial pressure (pCO_2), aragonite saturation state (Ω_{ar}), and total dissolved CO_2 (DIC). Results, along with concurrent salinity and temperature data collected during the cruises, are shown in Table 6.2. Both salinity and temperature in May and August 2023 were typical of monthly measures observed since 2013. Deviations in pH and Ω_{ar}

remained fairly small in 2023 and over the nine-year period of carbonate chemistry monitoring. 2023 surface water pCO_2 was less variable and higher on average compared to 2020–2022 values. In May 2023, the lower surface water pCO_2, driven by increased air-sea gas exchange, led to higher in situ pH levels. The more alkaline conditions resulted in lower Ω_{ar} and higher DIC.

Table 6.2. Carbonate sample results for 2023 from water collected at three depths.

Sample Date	Depth (m)	Salinity (ppt)	Temp (°C)	pH (Total)	Alkalinity (µmol/kg)	DIC (µmol/kg)	pH *in situ*	Ω_{ar}	pCO_2 (µatm)
5/4/2023	1	36.3	23.5	8.0359	2402.5	2108.2	8.058	3.52	401.4
5/4/2023	10	36.3	23.6	8.0357	2406.6	2095.8	8.057	3.50	400.8
5/4/2023	20	36.3	23.7	8.0339	2405.7	2080.8	8.053	3.47	401.4
8/17/2023	1	36.5	29.9	8.0817	2401.7	2068.2	8.008	3.96	451.9
8/17/2023	10	36.6	30.2	8.0849	2400.5	2053.7	8.006	3.97	450.4
8/17/2023	20	36.6	30.4	8.0859	2405.5	2059.5	8.005	4.00	454.1

Chapter 7: Other Research

While not part of the long-term monitoring program, research was conducted with partners during the 2023 field season at Stetson Bank in partnership with FGBNMS under the superintendent's permit or a standalone permit, as noted.

- In 2023, researchers continued their study into the habitat requirements and connectivity of reef fishes in the northwestern Gulf of Mexico, marking the second year of this investigation. This five-year study investigates migration ecology and habitat requirements of reef fishes in the Gulf of Mexico (NA21NOS4780151). The study, led by Dr. Jay Rooker at Texas A&M University at Galveston and Dr. Mike Dance from Louisiana State University and funded by NOAA's National Centers for Coastal Ocean Science, uses acoustic and satellite telemetry, biophysical modeling, and sound to examine how native and invasive mesopredators, reef fish, and demersal/pelagic fishes that form aggregations utilize habitats within and outside FGBNMS. To date, infrastructure has been deployed across the entire sanctuary (including Stetson Bank) to detect tagged fish. Roughly 50% of the tags for this project have been deployed on target species, including greater amberjack, silky sharks, scalloped hammerhead sharks, sandbar sharks, wahoo, black durgon, Atlantic creolefish, yellowmouth grouper, gray snapper, graysby, and lionfish. Initial data are being processed to examine home range, movement distances, and connectivity across banks and within habitats. Research is being conducted under permit FGBNMS-2021-007.
- Of growing interest to FGBNMS is the occurrence of microplastics in the environment, including their presence within fish tissues. Given the ever-increasing amount of plastic waste in the ocean, there is growing concern worldwide about the impacts of ingestion of plastics, as well as the effects of the chemicals they contain, on marine life. Drs. Karl Kaiser and David Hala from Texas A&M University at Galveston are leading fish tissue sample processing. Research partners and volunteer divers participated in the eighth and ninth Lionfish Invitational cruises on June 12–13, 2023 and July 23–26, 2023 aboard the M/V *Fling* (Permit: FGBNMS-2023-006). A total of 250 lionfish were removed from the sanctuary, including 26 from Stetson Bank. These lionfish were provided to Texas A&M University at Galveston on 11/07/23 for processing. Analysis will include indicators of organic pollutants, such as polychlorinated biphenyls and dichlorodiphenyltrichloroethane, as well as the presence of microplastics.
- A passive acoustic recording device (SoundTrap) was installed at Stetson Bank in May 2023. It records underwater sound continuously and is funded by the NOAA Office of National Marine Sanctuaries. This installation is part of a larger project that aims to use passive acoustic recording devices to build soundscape information across FGBNMS and other national marine sanctuaries. Acoustic data can be used to quantify vessel usage, explore biodiversity, identify fish aggregations, and examine marine mammal visitation. Research is being conducted under FGBNMS superintendent's permit FGBNMS-2019-001.
- NOAA Ship *Pisces* departed Pascagoula, Mississippi in March of 2023 to conduct the SEAMAP reef fish survey of natural hard bottom areas located on the continental shelf

and shelf edge of the northern Gulf of Mexico. The ship sampled 374 stations in 56 blocks with the camera arrays, with one sample occurring at Stetson Bank. A CTD profiler was also deployed to collect information on conductivity, depth, and temperature as well as serve as backup system for collecting eDNA water samples. Research is being conducted under permit FGBNMS-2023-002.

- A report was published in NOAA's Conservation Series detailing marine debris on the reefs and banks in the vicinity of FGBNMS (O'Connell et al., 2023). This report assessed marine debris in and around the recently expanded sanctuary by determining the spatial distribution, abundance, and composition of litter. The results reflected the heavy influence of local fishing activities, with derelict fishing gear as the dominant debris type in the study area, composing 63.7% of all litter. Stetson Bank had the highest marine debris average encounter rate at 2.1 items recorded for every ROV dive. This report serves as a baseline for spatial and quantitative assessment that can be used in future efforts to target debris removal and research.
- In July of 2022, FGBNMS convened an expert workshop to assess the climate vulnerability of two habitat types, the coral reef crest (18–50 m) and mesophotic reef habitat (>50 m), as well as 23 key species or groups of species occurring within the sanctuary. In 2023, NOAA's Office of National Marine Sanctuaries published a *Rapid Climate Vulnerability Assessment for Flower Garden Banks National Marine Sanctuary* (Dias et al., 2023). The report identified increasing seawater temperatures, ocean acidification, and increasing storm intensity as significant threats to many species and ecosystems of the sanctuary over the next 50 years. The report also identified adaptive management strategies to improve protection of sanctuary resources, including continued invasive species removal, mooring buoy maintenance, coral disease management, strengthening collaborative partnerships, and addressing non-climate impacts. Stetson Bank long-term monitoring data sets provided valuable information for the composition of this report.
- A mesophotic sponge guide was published in May of 2023 (Díaz et al., 2023). This publication includes field descriptions, distribution, and abundance of 64 sponge species, including Demospongiae, Hexactinellida (glass sponges), and Homoscleromorpha (encrusting sponge). Many of these species are present at Stetson Bank.
- A paper authored Sporre et al. (2024) was published in *Coral Reefs*, presenting findings on the life history characteristics of cryptobenthic reef fishes. These characteristics, such as fast growth and reproductive rates, near-shore larval retention, and high turnover, suggest rapid diversification and cryptic speciation, especially in isolated cryptobenthic reef fish populations. The sailfin blenny, *Emblemaria pandionis*, found on the reefs of the Flower Garden Banks in the northwestern Gulf of Mexico and throughout the Caribbean, was studied using DNA barcoding and multilocus delimitation. The research revealed that *E. pandionis* is a species complex comprising at least four distinct taxonomic units across the Caribbean, with one unit at the Flower Garden Banks, another in eastern Florida, a third in the central Caribbean, and a fourth in Curaçao. These findings underscore the roles of isolated reefs and ocean currents in the speciation of cryptobenthic reef fishes.

Chapter 8:
Conclusions

The crest of Stetson Bank, which has been monitored for 31 years, has experienced a significant shift in benthic community structure over that time, from a community dominated by *Millepora* and sponges to one dominated by macroalgae and sponges (DeBose et al., 2012; Nuttall et al., 2020a). While sponges represented a dominant component of the community before and after the shift, sponge community composition has changed significantly.

Though some monitoring could not be completed in 2023 due to vessel restrictions and weather, divers were able to assess benthic cover at 54 of 59 repetitive photostations on the bank, conduct fish surveys, photograph random transects, and collect water quality data.

The water quality monitoring efforts conducted at Stetson Bank in 2023 provide valuable insights into the environmental conditions and dynamics of this marine ecosystem. The moored water quality instruments recorded variations in temperature throughout the year, including prolonged exposure to high temperatures, particularly in July and August. This underscores the potential impacts of thermal stress on the marine environment, with implications for coral bleaching and ecosystem health.

The exotic regal demoiselle persisted in 2023, with schools of hundreds of small fish (5–10 cm) observed over many pinnacles on the bank and within vertical sponges. It has become the most abundant reef fish on the bank, based on density estimates. 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. This, combined with the decline of the once-dominant sponge species *Chondrilla nucula* and *Ircinia strobilina*, raise concerns about the ecological ramifications of prior and potential future community shifts on Stetson Bank. The drastic reduction in sponge cover over the years underscores the vulnerability of these organisms to changing environmental conditions, potentially impacting the habitat availability for various coral reef fish species.

The monitoring program at Stetson Bank represents one of the longest running monitoring efforts for an ecosystem of its type—a high latitude coral community that is periodically exposed to environmental conditions deemed marginal for the tropical assemblages it supports. This initiative has already documented one community phase shift caused by a significant intermediate disturbance event, and is poised to offer valuable insights into the dynamics of community response, particularly amid continuing sponge loss within the bank's ecosystem. Concurrently, resource managers stand to benefit from the insights gained through the monitoring program, as it enables the tracking of established drivers underlying ecosystem variability and transformations within the northwestern Gulf of Mexico. Furthermore, the continuation of this program holds promise in providing valuable data on species and community resilience amid deteriorating environmental conditions (Zweifler et al., 2021). Such knowledge stands to inform strategic initiatives aimed at the protection and restoration of marine ecosystems.

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