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National Oceanic and Atmospheric Administration

NATIONAL MARINE SANCTUARIES CONSERVATION SCIENCE SERIES

STETSON BANK LONG-TERM MONITORING: 2017 ANNUAL REPORT

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Cover photo:
A variety of fish, including gray snapper, vermilion snapper, and tomtate school above high relief pinnacles at Stetson Bank. Photo: G.P. Schmahl /NOAA

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Abstract

This report documents study methods and summarizes key findings and field notes from the 2017 annual long-term monitoring study of fish and benthic communities at Stetson Bank. Stetson Bank is an uplifted claystone/siltstone feature located within Flower Garden Banks National Marine Sanctuary in the northwestern Gulf of Mexico. It supports a diverse benthic community of sponges and coral. Benthic monitoring has occurred at the site since 1993 and was expanded in 2015 to include monitoring in the mesophotic zone surrounding the bank crest.

In 2017, bank crest high relief habitat was documented to have higher scleractinian coral cover in comparison to low relief habitat. Macroalgae cover on the bank crest has been increasing in recent years. In the mesophotic zone, two habitats were documented: coralline algae reef and deep reef. Coralline algae reef biotic cover was predominately algae and deep reef cover was mostly Cnidaria. The majority of both bank crest and mesophotic fish communities comprised small individuals and exhibited an inverted biomass pyramid. The mesophotic fish community was predominately piscivores, of which the juvenile stages were seen in high abundance on the bank crest.

Keywords

Benthic community, fish community, Flower Garden Banks National Marine Sanctuary, long-term monitoring, mesophotic coral ecosystem, Stetson Bank, and water quality.

Introduction

Stetson Bank, located approximately 130 km southeast of Galveston, Texas, is an uplifted claystone feature associated with an underlying salt dome. It is a coral community, and is near the northern limit of coral community ranges in the Gulf of Mexico, in “marginal” environmental conditions for coral reef development and growth due to varying temperature and light availability. However, Stetson Bank supports a well-developed benthic community that includes tropical marine sponges, corals, and other invertebrates.

Sponges, primarily *Neofibularia nolitangere*, *Ircinia strobilina*, and *Agelas clathrodes*, compose a large portion of the benthic biota, but have been in steady decline since 1999. The sponge *Chondrilla nucula* was historically prevalent on the bank, but underwent dramatic decline after 2005 following a coral bleaching event and is now almost absent. Similarly, the hydrozoan *Millepora alcicornis* (fire coral) was historically the most prominent benthic biota at Stetson Bank, but underwent rapid decline in 2005 due to bleaching and has not recovered to pre-2005 levels.

Twelve species of hermatypic corals have been documented at Stetson Bank, including *Pseudodiploria strigosa*, *Stephanocoenia intersepta*, *Madracis brueggemanni*, *Madracis decactis*, and *Agaricia fragilis*, maintaining low, but stable, cover over time. The benthic cover of algae, predominately *Dictyota* sp. and turf algae, is variable between years. Since the initiation of monitoring at Stetson Bank, a distinct shift has been documented from a benthic community characterized by *Millepora* and sponges to an algal dominated community (DeBose et al. 2013).

In 1993, an annual long-term monitoring program was initiated at Stetson Bank by the Gulf Reef Environmental Action Team (GREAT), and later conducted by Flower Garden Banks National Marine Sanctuary (FGBNMS). These monitoring programs have focused on the reef habitat within non-decompression scuba diving limits (<33.5 m) and contributed to the addition of Stetson Bank as part of Flower Garden Banks National Marine Sanctuary in 1996. While the designated boundaries were based on the best available data at that time, subsequent mapping and exploration led to the discovery of mesophotic reefs surrounding Stetson Bank that occur outside of the current sanctuary boundary (Figure I).

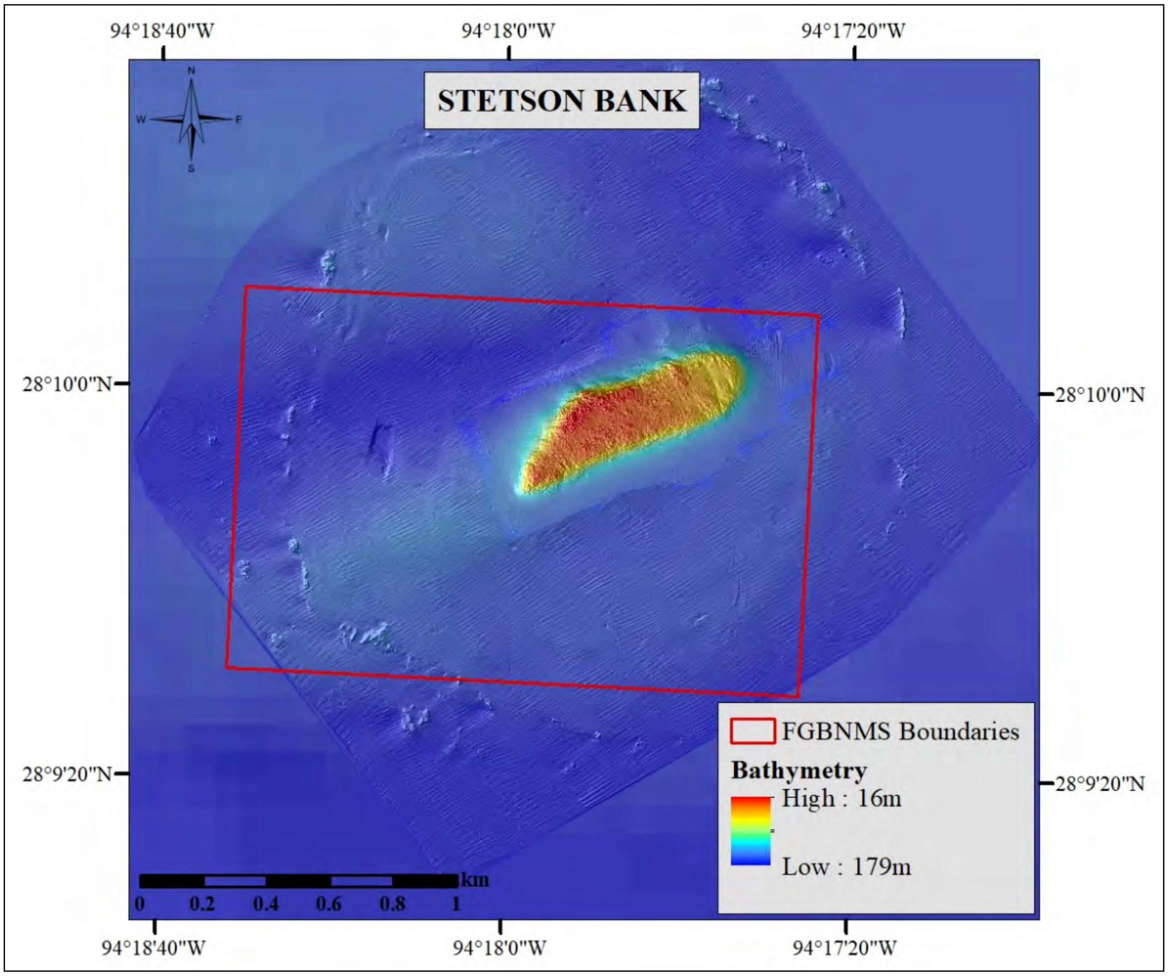


Figure I. Bathymetric map of Stetson Bank. Red lines indicate sanctuary boundary. Image: NOAA

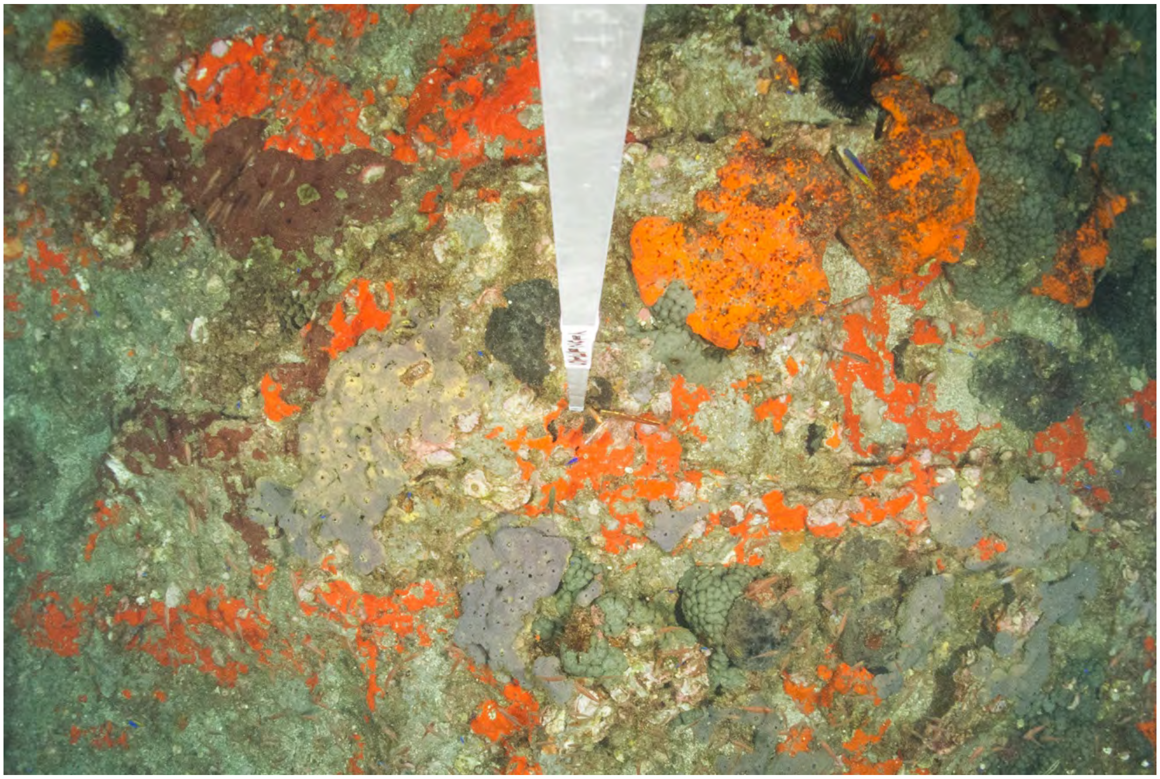
In 2015, the Bureau of Safety and Environmental Enforcement (BSEE) and FGBNMS expanded monitoring at Stetson Bank to include both the historically monitored bank crest and the surrounding mesophotic reef habitat. The results from the third year of the study are presented in this report. Data were collected on several cruises throughout the year (Table I).

Table I. Dates and primary tasks of data collection cruises at Stetson Bank for the 2017 monitoring period.

Date	Main Task
11/13/2016 – 11/15/2016	Water quality: Instrument download and sample collection
2/2/2017	Water quality: Sample collection (East & West Stetson Bank February water quality cruise)
2/17/2017	Water quality: Instrument download
5/6/2017 – 5/8/2017	Water quality: Instrument download and sample collection
7/17/2017 – 7/21/2017	Reef crest monitoring: Benthic and fish community monitoring
8/23/2017	Water quality: Sample collection (West Flower Garden Bank long-term monitoring cruise)
9/17/2017	Post-hurricane Harvey assessment
10/13/2017 – 10/15/2017	Mesophotic monitoring: Benthic and fish community monitoring
11/1/2017	Water quality: Sample collection (East & West Stetson Bank October water quality cruise)
11/8/2017	Water quality: Instrument download

To date, the monitoring program at Stetson Bank presents 25 years of continual coral community monitoring efforts. As increasing anthropogenic stressors to marine environments are projected to continue, long-term monitoring datasets are essential to understanding community stability and ecosystem resilience. Additionally, as exotic species invade and establish, these long-term data sets are vital for documenting and tracking species impacts on the natural populations. Continuation and expansion of this extensive dataset will provide valuable insight for both research and management purposes.

CHAPTER 1: REPETITIVE PHOTOSTATIONS



Repetitive photostation 19 captures a variety of sponges along with the stony coral *M. decactis*. Photo: Marissa Nuttall/NOAA

Introduction

Permanent photostations have been in place on Stetson Bank since 1993, concentrated on the northwestern edge of the bank. Locations were selected along high relief features with a diverse benthic community. The stations were selected by scuba divers on biologically interesting locations and marked using nails or eyebolts and numbered tags. Initially, 36 permanent photostations were installed in 1993. Over time, many of these stations have been lost for a variety of reasons, and new stations have been established.

As of 2017, a total of 59 stations were in use, including 18 of the original stations. All of these photostations occur on diverse and biologically-interesting habitat that is accessible from either permanent mooring buoys 1, 2, or 3 (Table 1.1, Figure 1.1). Each station is located by scuba divers using detailed maps (Figures 1.2 to 1.3), and photographed annually to monitor changes in the composition of benthic assemblages, presenting a time series of how the biota in the image has changed.

Table 1.1. Coordinates and depths of buoys at Stetson Bank.

Buoy No.	Latitude (DMD)	Longitude (DMD)	Depth (m)
1	28 09.931	94 17.861	22.6
2	28 09.981	94 17.834	23.8
3	28 09.986	94 17.766	22.3

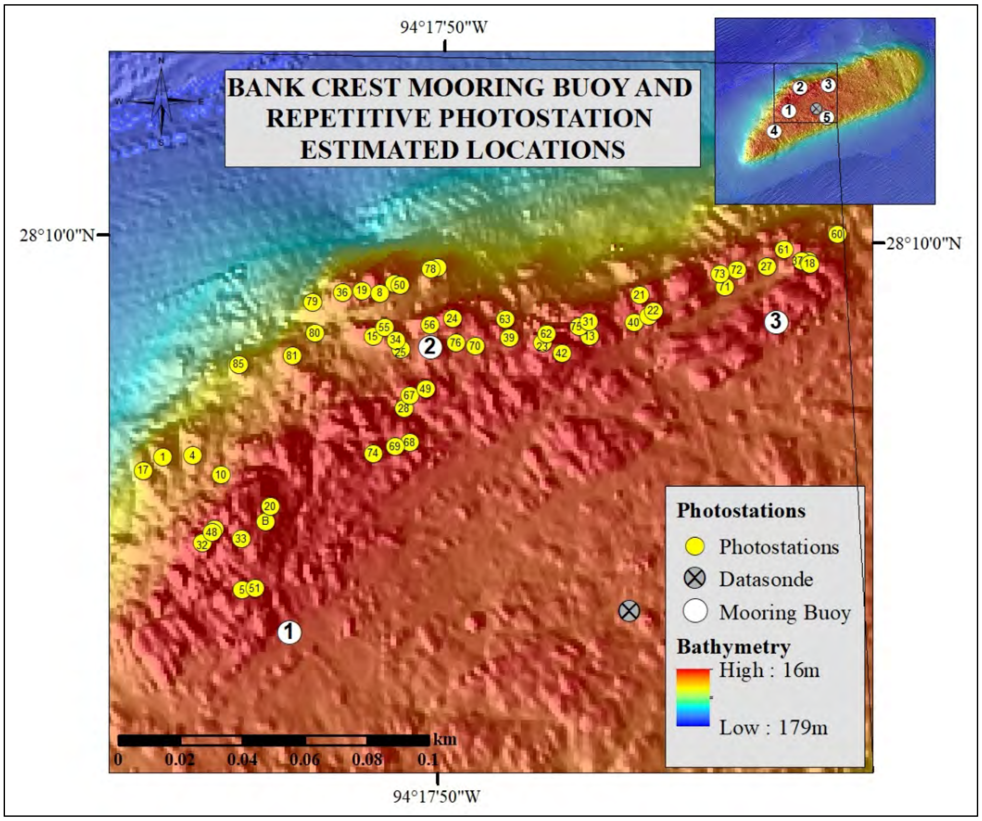
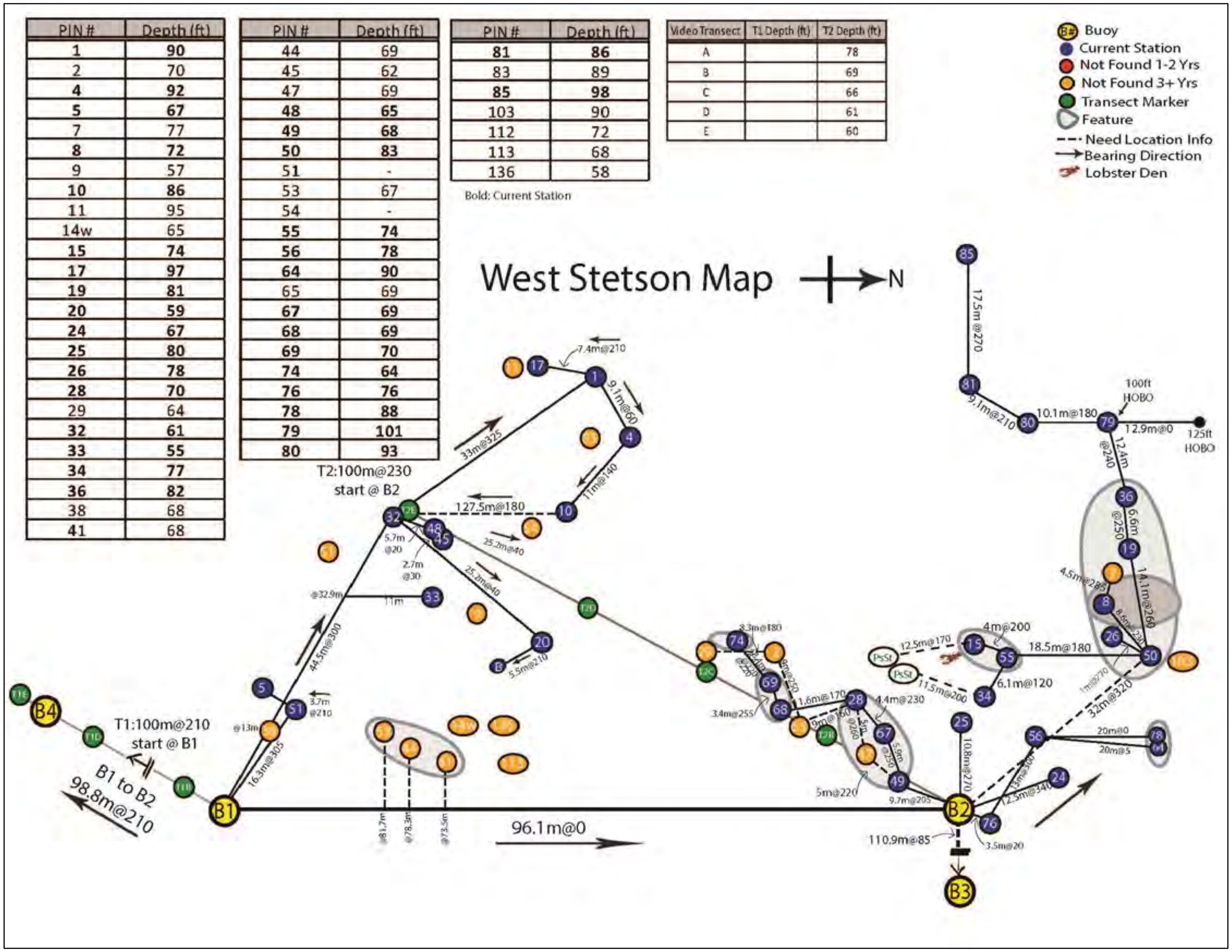


Figure 1.1. Mooring buoy locations and approximate repetitive photostation locations. Image: NOAA



PIN #	Depth (ft)
1	**90**
2	70
4	**92**
5	**67**
7	77
8	**72**
9	57
10	**86**
11	95
14w	65
15	**74**
17	**97**
19	**81**
20	**59**
24	**67**
25	**80**
26	**78**
28	**70**
29	64
32	**61**
33	**55**
34	**77**
36	**82**
38	68
41	**68**

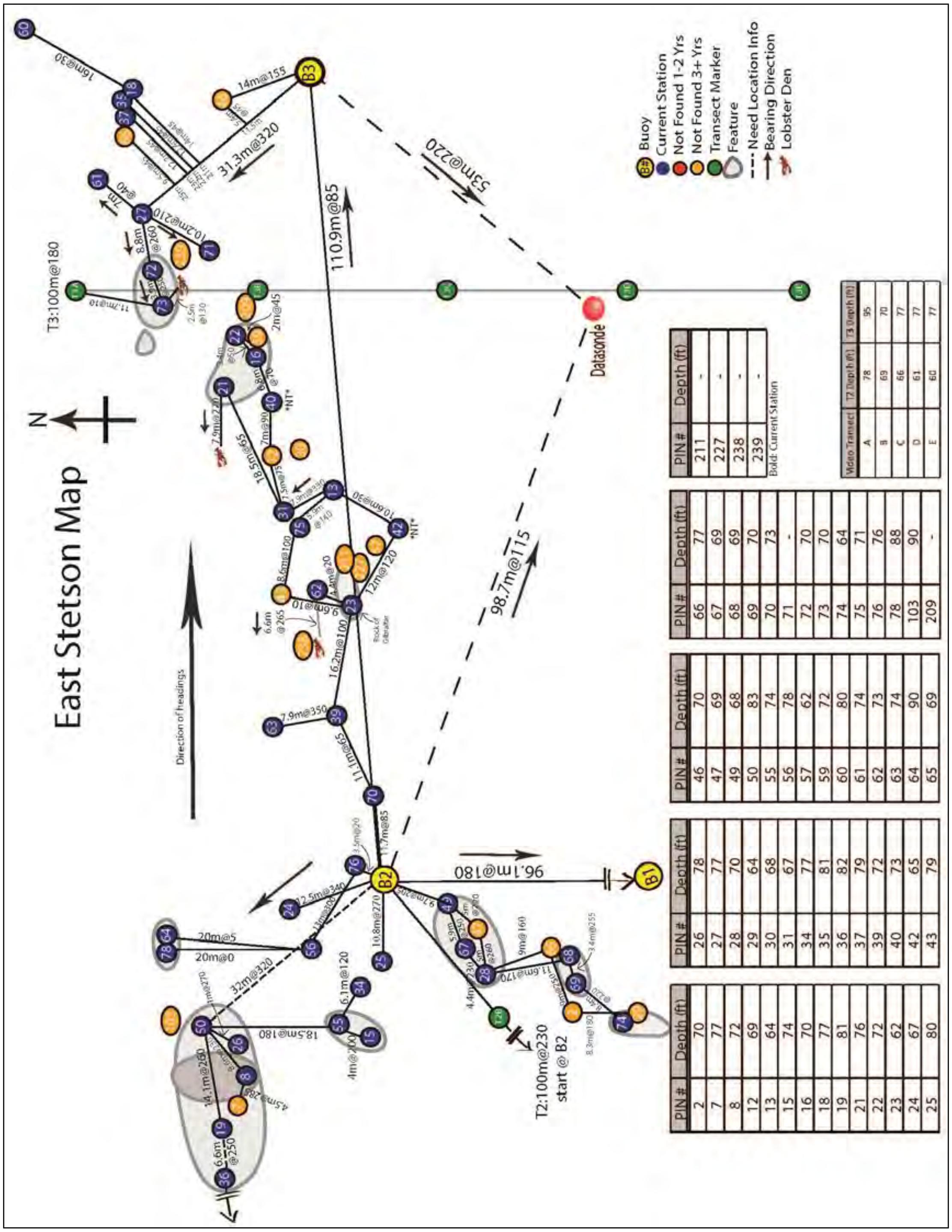
PIN #	Depth (ft)
44	69
45	62
47	**69**
48	**65**
49	**68**
50	**83**
51	-
53	67
54	-
55	**74**
56	**78**
64	**90**
65	69
67	**69**
68	**69**
69	**70**
74	**64**
76	**76**
78	**88**
79	**101**
80	**93**

PIN #	Depth (ft)
81	**86**
83	**89**
85	**98**
103	90
112	72
113	68
136	58

Bold: Current Station

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

Figure 1.2. West Stetson map, used by divers to locate the repetitive photostations in the study site. Image: NOAA



PIN #	Depth (ft)
2	70
7	77
8	72
12	69
13	64
15	74
16	70
18	77
19	81
21	76
22	72
23	62
24	67
25	80

PIN #	Depth (ft)
26	78
27	77
28	70
29	64
30	68
31	67
34	77
35	81
36	82
37	79
39	72
40	73
42	65
43	79

PIN #	Depth (ft)
46	70
47	69
49	68
50	83
55	74
56	78
57	62
59	72
60	80
61	74
62	73
63	74
64	90
65	69

PIN #	Depth (ft)
66	77
67	69
68	69
69	70
70	73
71	-
72	70
73	70
74	64
75	71
76	76
78	88
103	90
209	-

PIN #	Depth (ft)
211	-
227	-
238	-
239	-

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

Figure 1.3. East Stetson map, used by divers to locate the repetitive photostations in the study site. Image: NOAA

Methods

Field Methods

Repetitive photostations were located and marked by scuba divers with floating plastic chains with attached weights. Divers with cameras then photographed each station. In 2017, images were captured using a Canon Power Shot® G11 digital camera in a G11 Fisheye FIX® housing with a wide-angle dome port. The camera was mounted onto a T-frame, set at 1.5 m from the substrate, with two Inon® Z240 strobes set 1.2 m apart (Figure 1.4). A compass and bubble level were mounted to the center of the T-frame in order for images to be taken in a vertical and northward orientation, and to standardize the area captured. Images were corrected as necessary in Adobe Photoshop® CS2 and cropped using a template from previous years, to maintain 1.6 m^2 coverage.

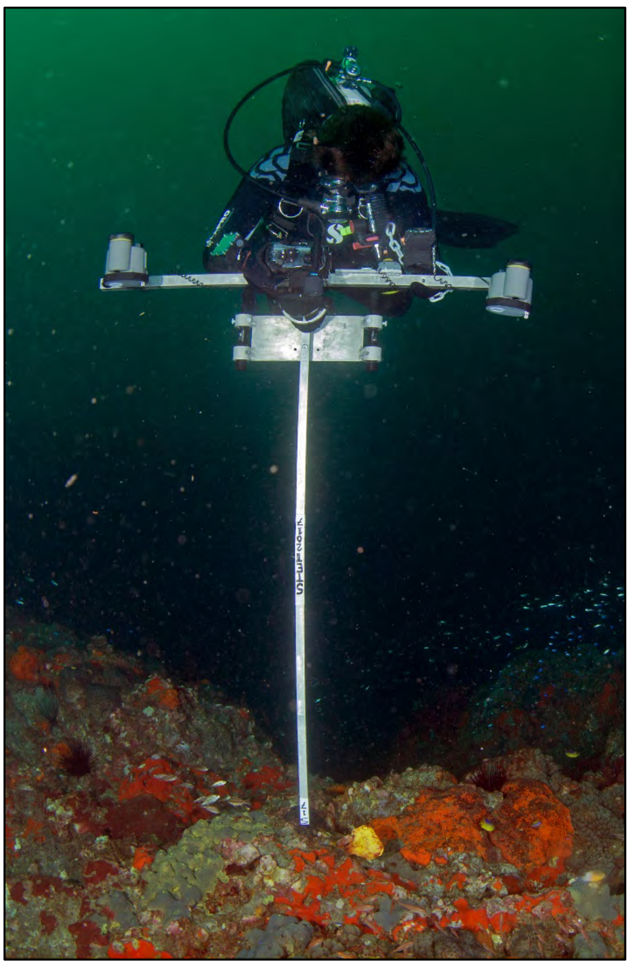


Figure 1.4. T-frame configuration. G11 Fisheye FIX® housing mounted to the frame, set at 1.5 m from the substrate, with two Inon® Z240 strobes, set 1.2 m apart. Photo: G.P. Schmahl/NOAA

Data Processing

Percent cover in each image was analyzed using Coral Point Count® with Excel® extensions (CPCe), provided by the National Coral Reef Institute (Kohler and Gill 2006). Thirty spatially random points were distributed on each image, and benthic species lying under these points were identified. Microsoft® Excel® spreadsheets were created automatically in the program using customized coral code files pertinent to the species in the region.

Organisms positioned beneath each random dot were identified as follows: scleractinian, hydrocoral, sponges, and macroalgae, to the lowest possible taxonomic group (macroalgae included algae longer than approximately 3 mm and included thick algal turfs). Crustose coralline algae, fine turfs, and bare rock were combined into a group denoted as colonizable substrate, formerly called "CTB" (Aronson and Precht 2000). Other live components (ascidians, fish, serpulids, etc.) and unknown species were recorded in an additional category, "other biota." Rubble was recorded in its own category. Unknown species that were visually distinct were recorded in a photo identification guide and assigned a unique key code. The coverage of coral bleaching, paling, fish biting, disease, and other anomalies were recorded as a note with each point. Summary data were grouped into six functional categories: scleractinia, hydrocoral, sponge, macroalgae, colonizable substrate, and other biota. Rubble was not reported in the results.

Qualitative comparisons were made for each photostation from the previous year, when available. Comparisons included notes on the loss, reduction, expansion, or gain of coral and sponge colonies and changes in their general condition.

Results

Fifty-nine repetitive photostations were located and photographed, five of which required refurbishment. No new stations were installed in 2017. Depth of the stations ranged from 16.8 - 30.8 m, with an average station depth of 23.0 m.

Mean cover for scleractinia was 4.2% (± 1.1 SE), hydrocoral was 1.4% (± 0.7 SE), sponge was 16.2% (± 1.5 SE), macroalgae was 44.9% (± 2.1 SE), colonizable substrate was 27.9%. (± 1.9 SE), and other biota was 2.7% (± 0.5 SE) (Figure 1.5). The average species richness at each station was 6.0 (± 0.2 SE).

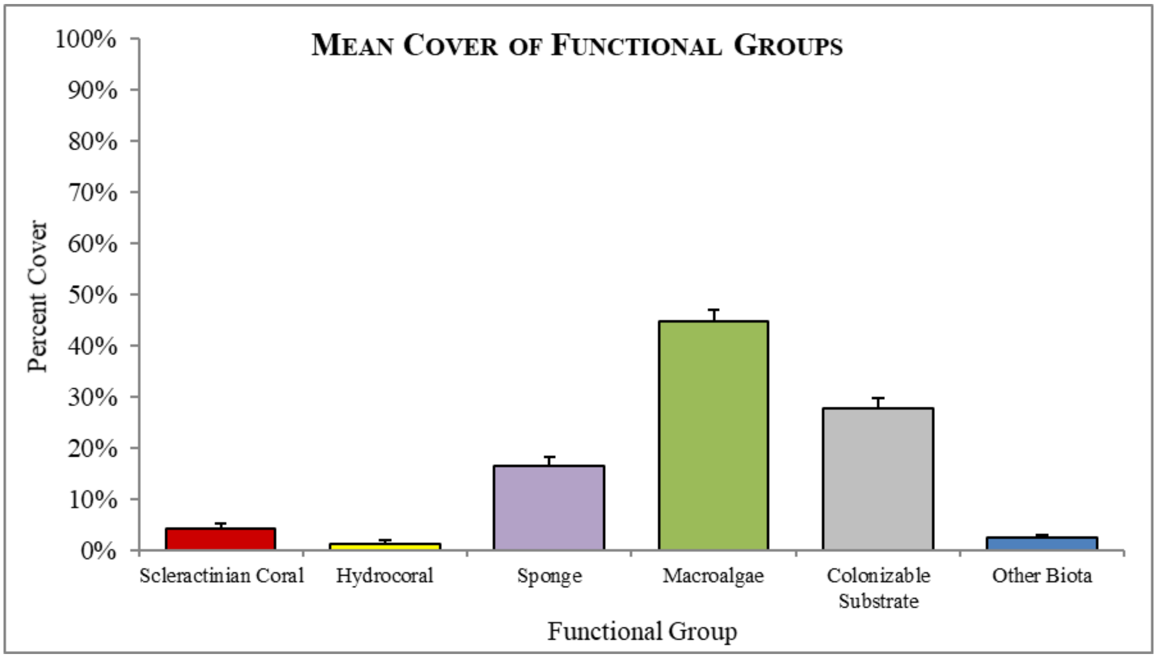


Figure 1.5. Mean functional group percent cover (with standard error bars).

Of the five species of scleractinian coral and one species of hydrocoral observed, *M. decactis* was the predominant species (2.5% ± 1.0 SE) in repetitive photostations (Figure 1.6).

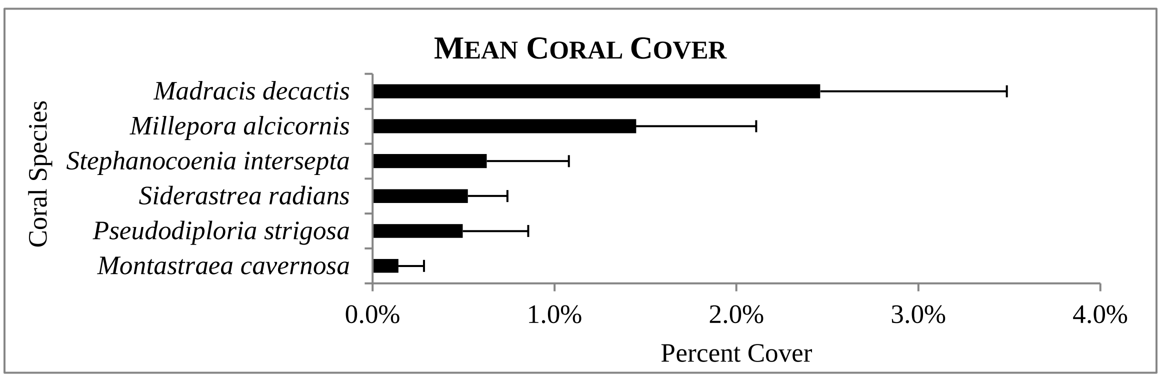


Figure 1.6. Mean coral cover of the observed coral species (with standard error bars).

Eleven species and five morphospecies of sponge and encrusting sponge were observed, with *I. strobilina* being the predominant species present with 6.1% (± 1.1 SE) cover in repetitive photostations (Figure 1.7).

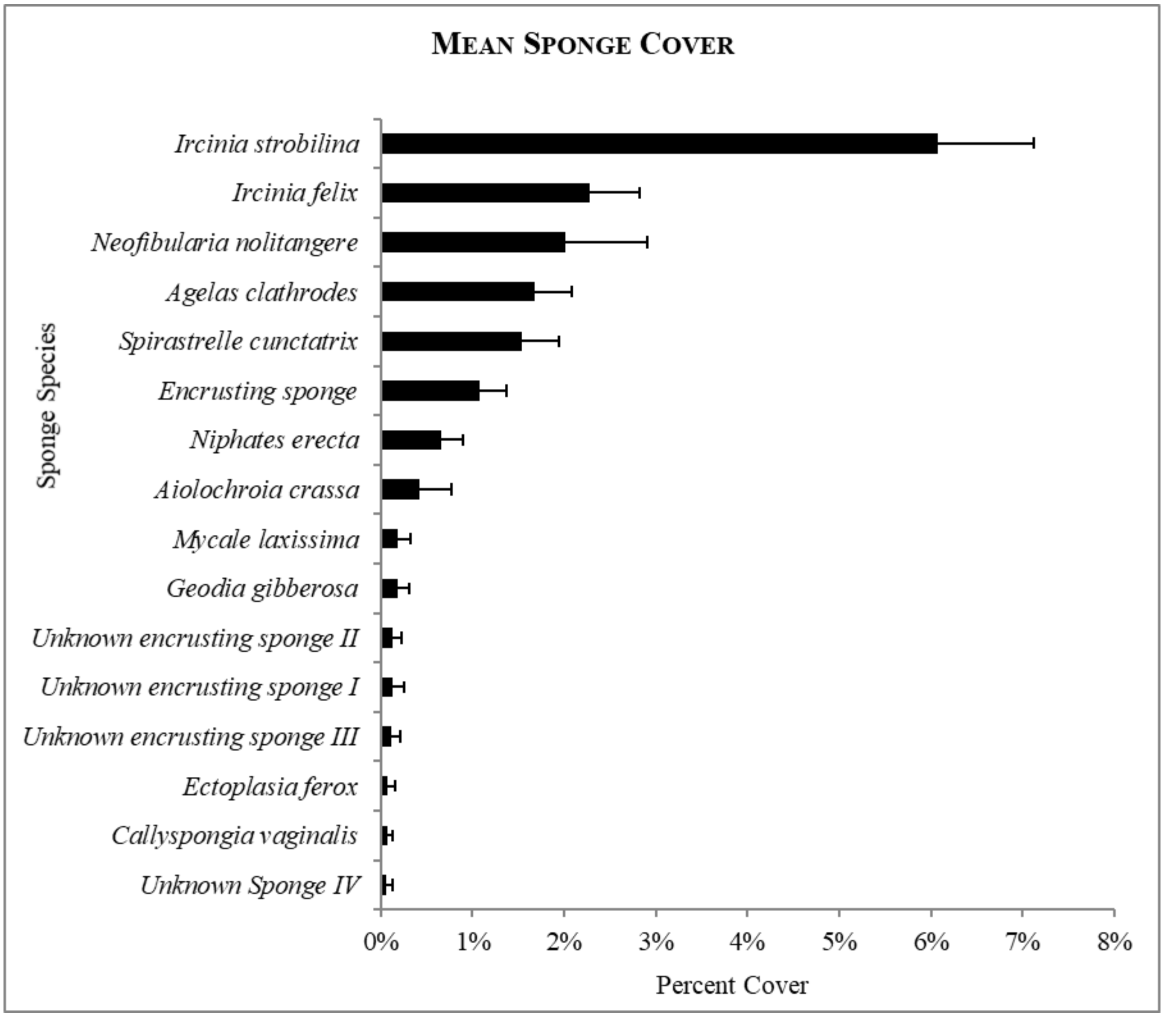


Figure 1.7. Mean sponge cover of the observed sponge species (with standard error bars).

Qualitative comparisons of stations from 2016 noted the loss of several complete sponge colonies between 2016 and 2017. The largest losses were I. strobilina and Ircinia felix colonies with no apparent spatial pattern (Figure 1.8). The hydrocoral M. alcicornis was noted to have reduced in cover at most stations while other corals appeared stable between years. Additionally, brown and green turf algae were noted to increase at multiple stations.

Following the 2017 field season, on August 29, 2017, the track of Hurricane Harvey passed within 26 km of Stetson Bank. At that time, Harvey was rated as a Tropical Storm with 72 to 80 kph winds. National Data Buoy Center buoy 42019, located 100 km east of Stetson Bank, recorded a maximum wave height of 7.1 m, with sustained wave height of >5 m for over 12 hours on August 25, 2017.

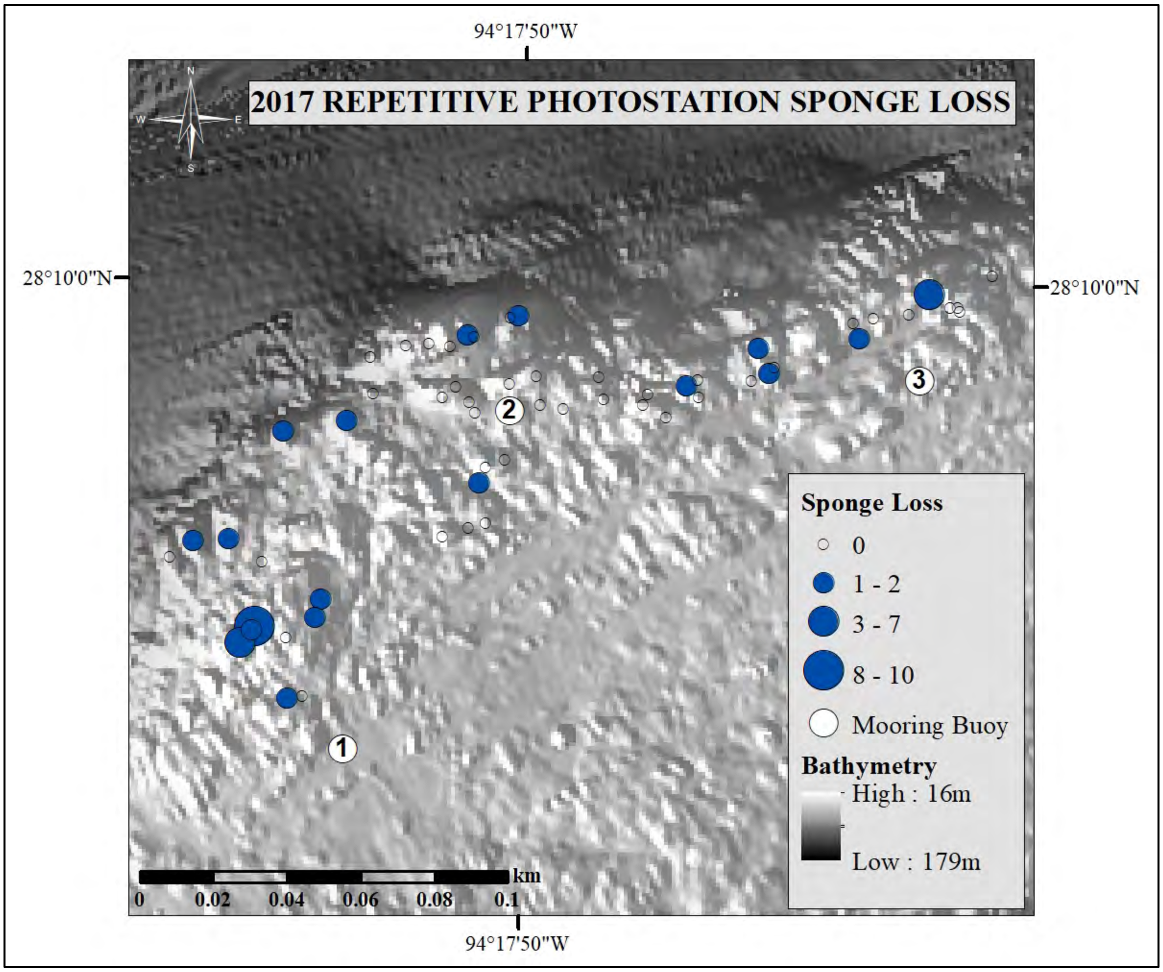


Figure 1.8. Count of sponge colony loss at each repetitive photostation. Larger blue circles represent greater sponge colony loss than smaller circles and clear circles represent no loss of sponge colonies. Image: NOAA

On September 17, 2017, FGBNMS researchers conducted a post-hurricane assessment of the bank aboard the M/V Fling, collecting 25 repetitive photostation images. While no major changes in most functional categories were documented, point count data showed an increase in macroalgae cover of 9.6% with a similar 7.2% decline in colonizable substrate (Figure 1.9). Average species richness for each station was similar to pre-Hurricane Harvey conditions, at 6 (± 0.3 SE). Qualitative assessment of these images supports these findings with a notable increase in turf algae. Qualitative comparisons also noted the complete loss of one colony of M. decactis, but no other changes were evident.

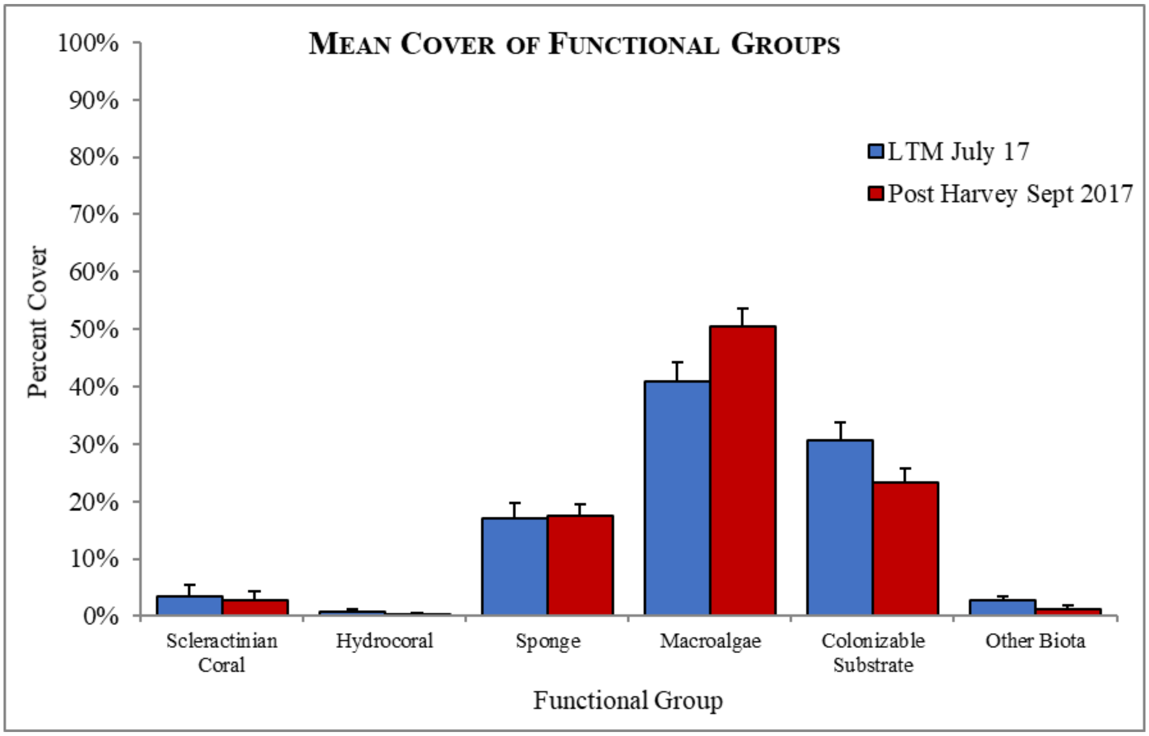


Figure 1.9. Pre- and post-Hurricane Harvey mean functional group percent cover (with standard error bars).

Discussion

Percent cover of each functional group varied annually (Figure 1.10). Macroalgae cover was in decline, from a high in 2012 of 72.5% (± 2.30 SE) to a low of 27.9% (± 2.22 SE) in 2015, but has increased from 2015 to present. As macroalgae cover has changed, colonizable substrate cover has varied inversely. Algal cover can rapidly fluctuate, often leading to shifts in percent cover of functional groups; however, causality for macroalgae cover increase was not apparent in 2017.

In 2017, the predominant coral species was *M. decactis* and the predominant sponge species was *I. strobilina*. It should be noted that the repetitive photostations do not provide a comprehensive view of the predominant species on the bank, as stations were biasedly placed on diverse high relief habitat. (See Chapter 1 Methods for details on site selection.) While the only noted change in the benthic community at repetitive photostations following the passage of Hurricane Harvey in August 2017 was an increase in turf algae, between June 2016 and July 2017, qualitative comparisons indicated that both sponge communities and the hydrocoral *M. alcicornis* were reduced at multiple stations.

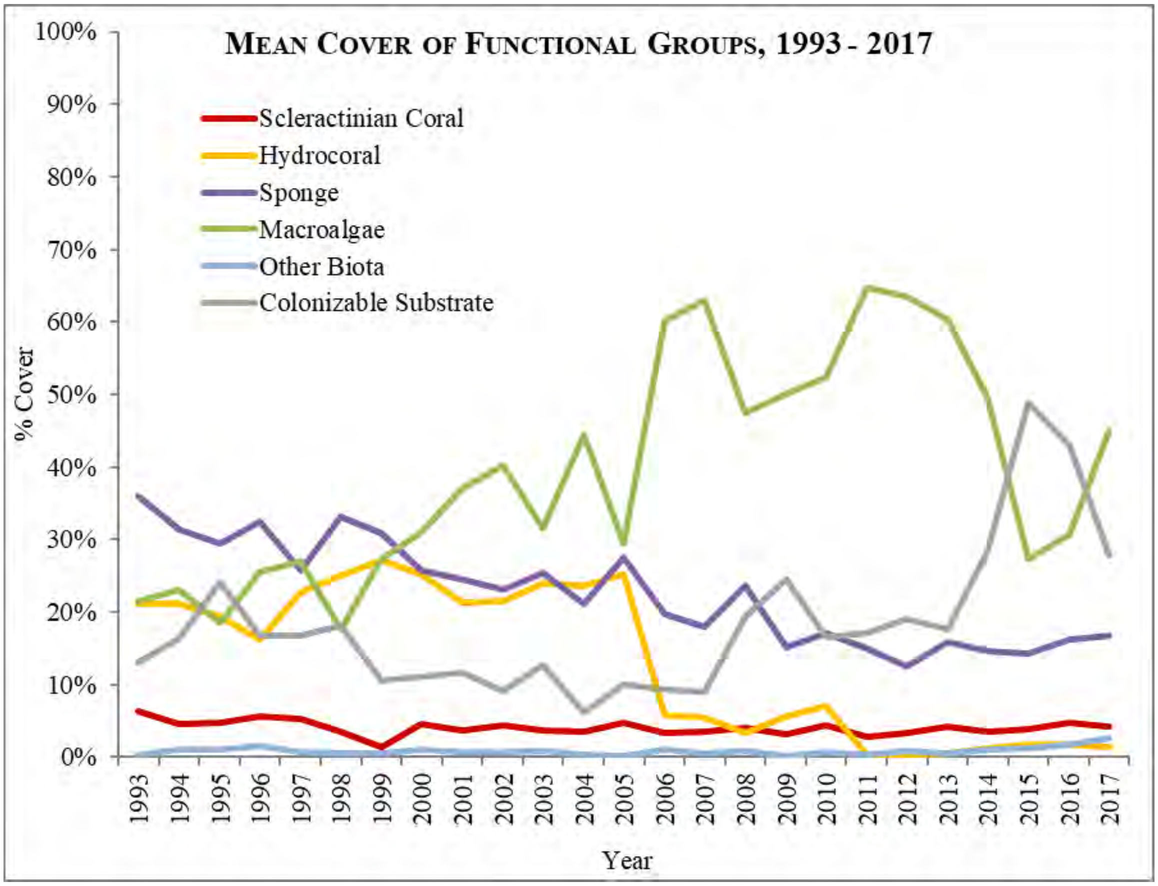
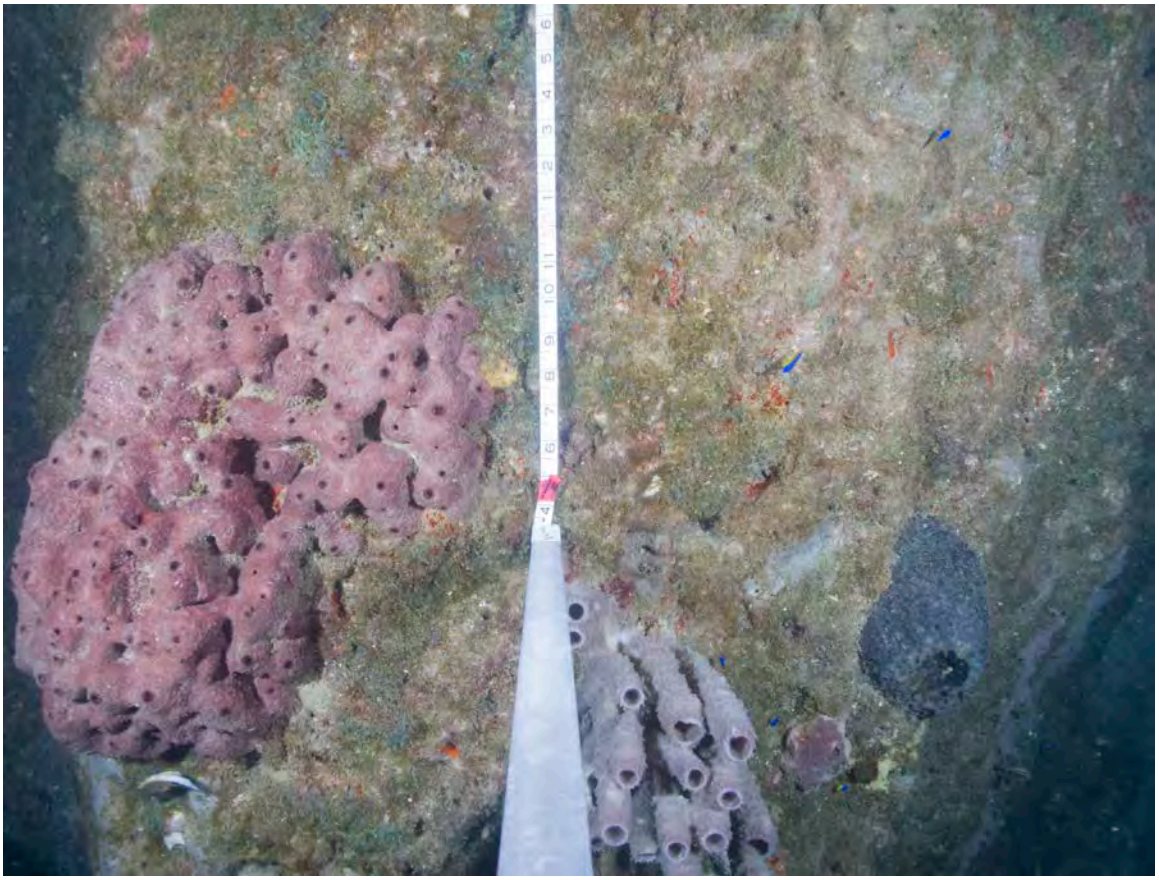


Figure 1.10. Mean percent cover of each functional group from 1993-2017.

Challenges and Resolutions

No problems were encountered in the 2017 field season.

CHAPTER 2: RANDOM TRANSECTS



Random transect image with sponge and macroalgae. Photo: Marissa Nuttall/NOAA

Introduction

To estimate the areal coverage of benthic components such as corals, sponges, and macroalgae, transect tapes were positioned at stratified random locations within high relief and low relief habitat on Stetson Bank. These transects were conducted at random locations around the reef and used to compare habitat types and provide information on the sessile benthic community of the entire bank.

Methods

Field Methods

Transect sites were selected in a stratified random design (Figure 2.1). 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 (>1.1 m range). A 33.5 m contour was used to restrict the extent of the range layer, limiting surveys to within non-decompression diving limits. 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: 0.08 km^2 low relief habitat and 0.04 km^2 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 2.1). One transect was completed at each random point. Surveyors were instructed to remain within the assigned habitat type. 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 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, 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, 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, was used.

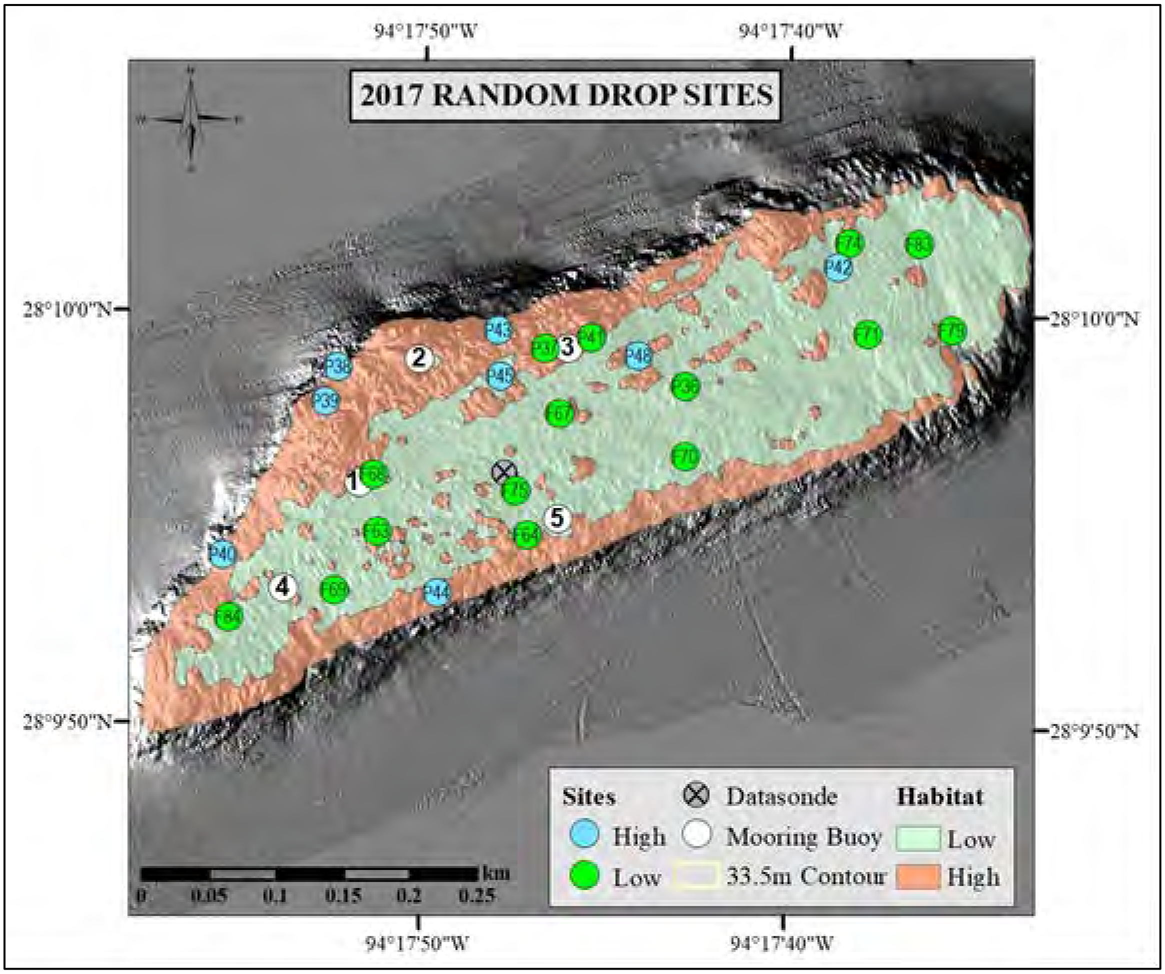


Figure 2.1. Locations of random drop sites in 2017. Image: NOAA

Data Processing

Percent cover was analyzed using CPCe® (Kohler and Gill 2006). A total of 500 points were randomly overlaid on each transect. Points were equally distributed between the photos that comprised each transect. Identifications and data summaries were made in the same manner described in the Repetitive Photostations chapter (Data Processing).

Each transect represented one sample, and resulting percent cover data for each sample were imported into ArcMap®. Surveys were projected over a hillshade map of Stetson Bank with a shapefile delineating low relief and high relief habitat. Attribute tables for each survey where populated with percent benthic cover data for each functional group and projected as pie charts using ArcGIS® symbology.

Results

A total of 23 random transects were conducted during this study period: 15 in low relief habitat and eight in high relief habitat. The depth of the stations ranged from 21.6 m to 32.6 m. Cover on transects in both the low relief and high relief habitat was predominately macroalgae (thick turfs and fleshy macroalgal species) and colonizable substrate. Scleractinian coral cover was low in both habitats, but slightly greater in high relief habitat than in low relief habitat.

In low relief habitat, scleractinian coral cover was 0.5% (± 0.1 SE), hydrocoral <0.1% (± 0.1 SE), sponge 9.8% (± 1.3 SE), macroalgae 51.9% (± 3.1 SE), and colonizable substrate 24.0%. (± 1.6 SE). In high relief habitat, scleractinian coral cover was 1.5% (± 0.8 SE), hydrocoral 0.1% (± 0.1 SE), sponge 10.1% (± 1.3 SE), macroalgae 37.1% (± 4.0 SE), and colonizable substrate 36.3%. (± 3.2 SE) (Figure 2.2). In low relief habitat, average species richness was 11 (± 0.6 SE), and in high relief habitat, average species richness was 13 (± 0.6 SE).

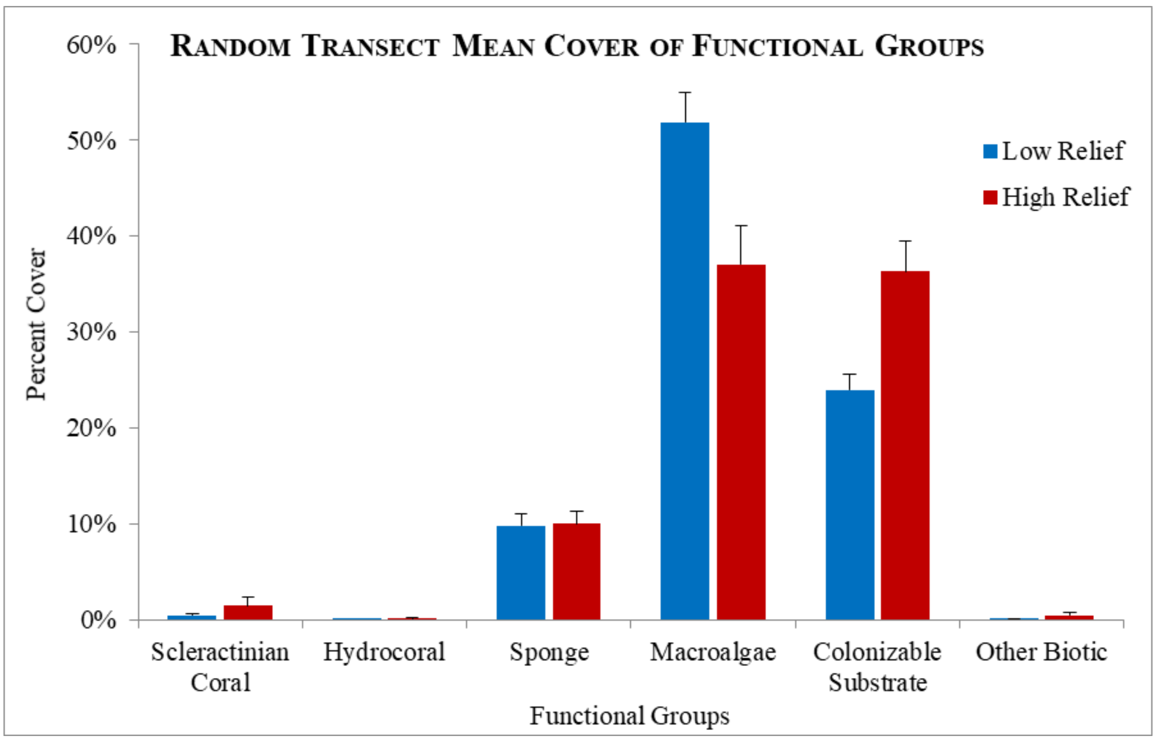


Figure 2.2. Random transect functional group percent cover (with standard error bars) for 2017, where low relief is represented by blue and high relief is represented by red.

Five species of coral were observed in all habitats. In low relief habitat, *S. intersepta* had the greatest cover at 0.25% (± 0.07 SE), and in high relief habitat, *M. decactis* had the greatest cover at 0.90% (± 0.90 SE) (Figure 2.3).

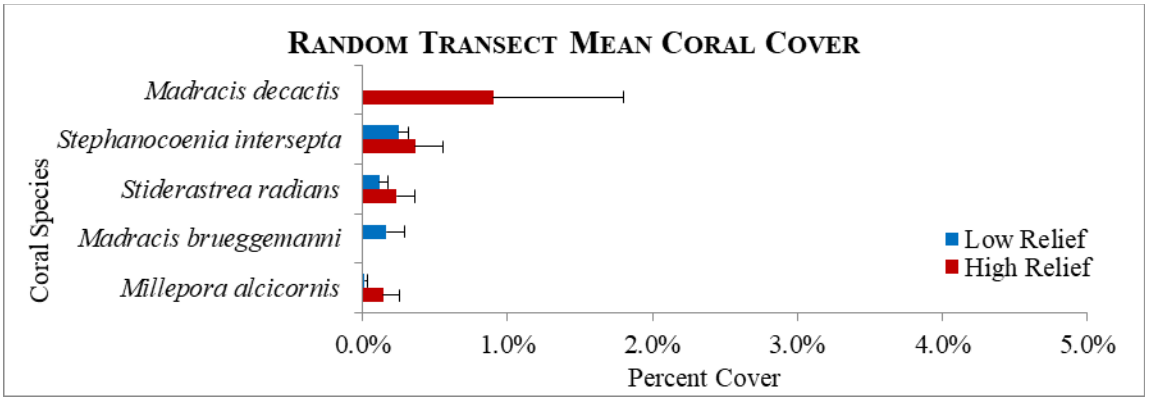


Figure 2.3. Random transect percent cover of each coral species (with standard error bars) for 2017, where low relief is represented by blue and high relief is represented by red.

Ten species of upright sponge, four unknown upright sponges, one species of encrusting sponge, and two unknown encrusting sponges were observed in all surveys. In both the low relief and high relief habitat, *N. nolitangere* was the predominant species, constituting 5.20% (± 1.08 SE) and 3.60% (± 1.02 SE), respectively (Figure 2.4).

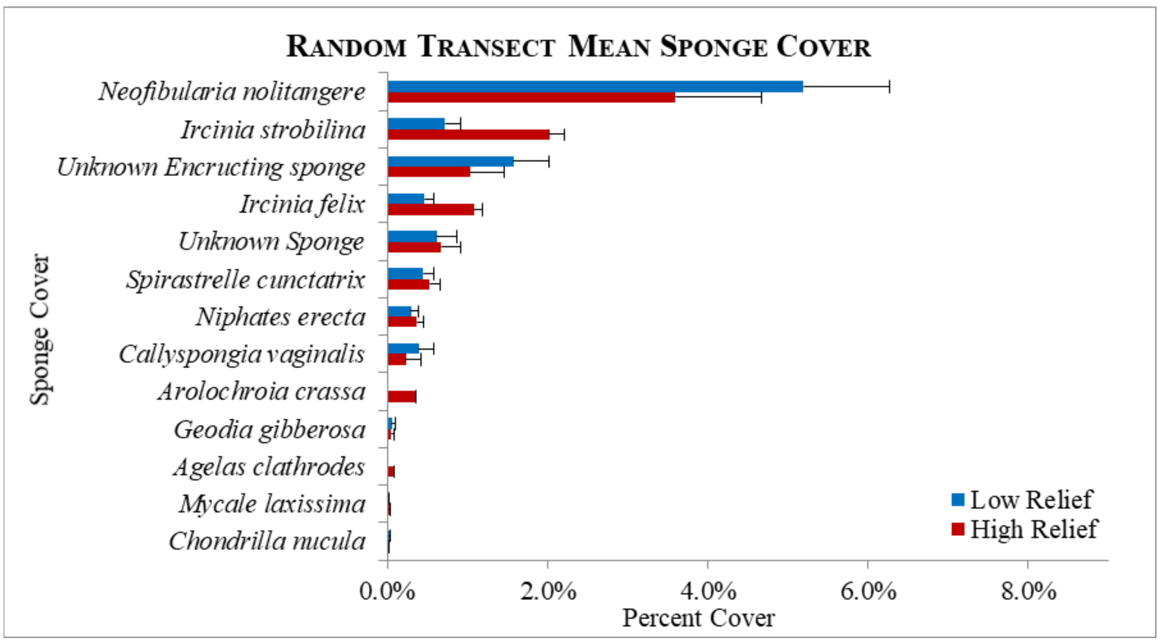


Figure 2.4. Random transect percent cover of each sponge species (with standard error bars) for 2017, where low relief is represented by blue and high relief is represented by red.

When percent cover data were projected spatially, no additional trends in benthic cover were observed (Figure 2.5).

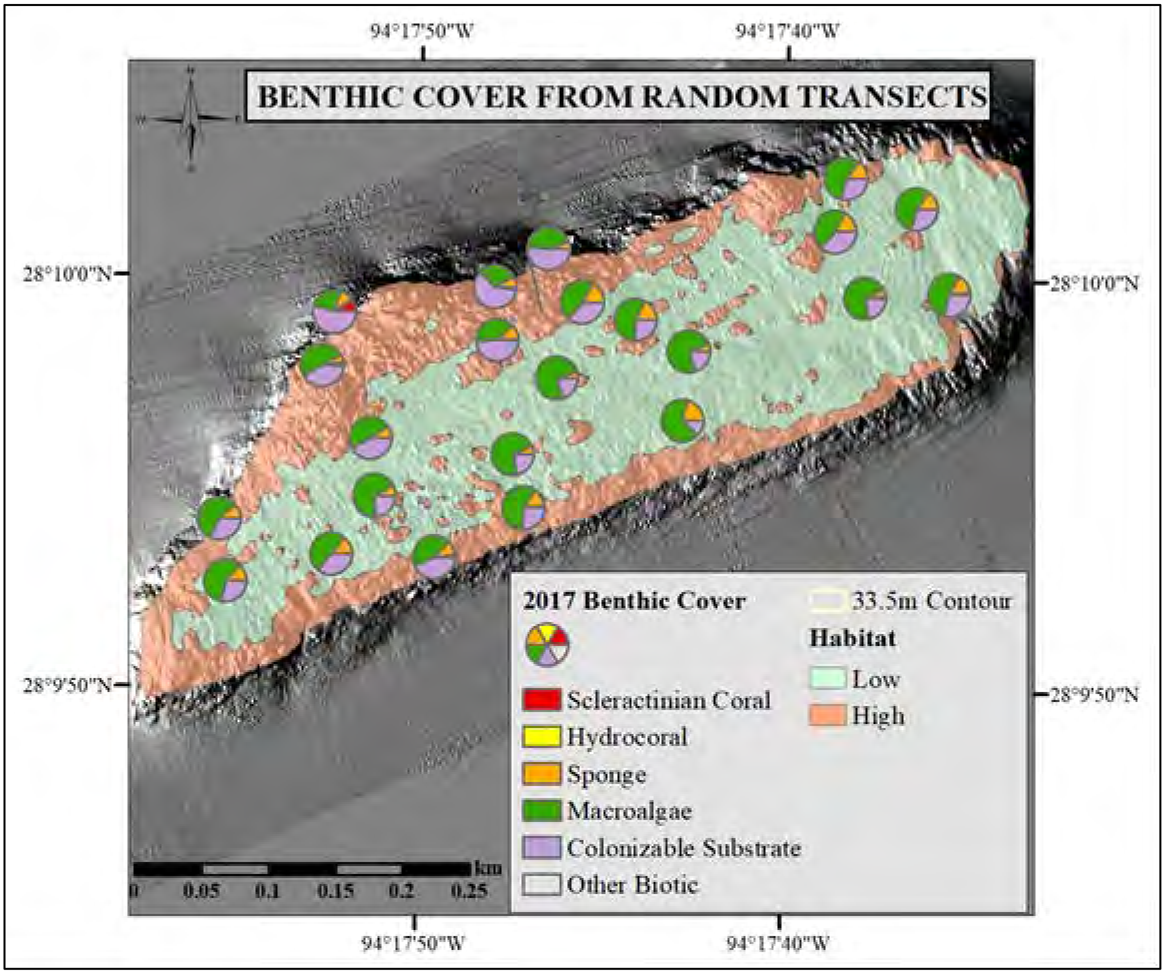


Figure 2.5. Spatial projection of random transect study results. Each pie chart represents the location at which a survey was conducted and the proportion of percent cover represented by each functional group. Image: NOAA

Discussion

Randomly selected transect surveys, appropriately distributed between habitat types, allows for inferences to be made about the reef as a whole. While the repetitive photostations discussed in Chapter 1 provide a valuable long-term dataset, they cannot be used to represent the entire benthic community due to the biased original selection criteria of those sites.

Macroalgae is a highly dynamic component of the ecosystem, documented in other reef habitats to vary in relation to eutrophication, upwelling, nutrient availability, season, and the grazing community composition (Naim 1993; Diaz-Pulido and Garzon-Ferreira 1997; Diaz-Pulido and Garzon-Ferreira 2002; Bonaldo and Bellwood 2011). Due to the high variability of this component of the benthic community, care should be taken when interpreting changes in cover, and monitoring efforts should attempt to evaluate these variables. Because algae grow primarily on unoccupied substrate, variations in macroalgae cover at Stetson Bank were often inversely proportional to changes in cover of the colonial substrate category, effecting little or no significant change in cover of corals and sponges. It is possible, however, that algae limit recruitment of corals and other benthic species, and may be affecting the recovery of the *Millepora* and sponge assemblage following the dramatic declines that occurred over a decade ago (Carpenter and Edmunds 2006).

Overall, coral cover was low in both low relief and high relief habitats in comparison to other Caribbean reefs (Jackson et al. 2014). The predominant coral species in low relief habitat was *S. intersepta* and *M. brueggemanni*, whereas high relief habitat, where coral cover was slightly greater, was predominately characterized by *M. decactis*. While sponge cover was marginally lower in low relief habitat, in both habitats the predominant sponge species was *N. nolitangere*.

Observations of *M. decactis* being the predominant coral species in high relief habitat in random transects was similar to the observations from repetitive photostations. However, predominant sponge species were distinctly different from the observations from repetitive photostations, where *I. strobilina* was the predominant sponge species. This reflects selection bias inherent in the original establishment of the stations, which were primarily placed on features dominated by *M. alcicornis* and *I. strobilina*, the dominant benthic biota at the time.

Challenges and Resolutions

- During data collection dives, divers had trouble selecting camera settings to provide sufficient lighting for images. This was corrected in subsequent dives.
    - Standardized camera settings that can be changed as conditions warrant. In addition, train divers unfamiliar with the camera equipment time to use them in water before data collection begins.
- Random transect P41 site was identified to be low relief habitat by divers.
    - Transect reclassified to low relief habitat for data processing.
- Only 23 of the 30 random transect were collected.
    - Deteriorating weather conditions shortened the time frame to collect data during the shallow long-term monitoring cruise. Additional transects were attempted on subsequent water quality cruises, but poor visibility (<6 m) inhibited data collection.

CHAPTER 3: FISH SURVEYS

Gray snapper, *Lutjanus griseus*, schooling at Stetson Bank. Photo: G.P. Schmahl/NOAA

Introduction

To examine fish population composition and changes over time, modified Bohnsack and Bannerot (1986) stationary visual fish censuses were conducted in conjunction with reef-wide random transects. Reef-wide surveys were conducted at stratified random locations in both low relief and high relief habitat on the reef.

Methods

Field Methods

Scuba divers, using the modified Bohnsack and Bannerot (1986) stationary visual fish census technique, restricted observations to an imaginary cylinder with a radius of 7.5 m, extending from the bottom to the surface. 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). Size was binned into eight groups; <5 cm, ≥5 to <10 cm, ≥10 to <15 cm, ≥15 to <20 cm, ≥20 to <25 cm, ≥25 to <30 cm, ≥30 to <35 cm. If fish were noted to be >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 minimum 15 minutes to complete. Transitory or schooling species were counted and measured at the time the individuals moved through the cylinder during the initial five-minute period. Surveys began in the early morning (after sunrise), and were repeated throughout the day until dusk. Each survey represented one sample.

Survey start location was selected using a stratified random sampling design (see Chapter 2 Methods). This design requires a minimum of 15 surveys: 10 in low relief habitat and five in high relief habitat. In 2017, 25 fish surveys were conducted: 13 in low relief and 12 in high relief habitat.

Data Processing

Fish survey data were entered into a Microsoft® Excel database by the surveyor. Entered data were checked for quality and accuracy prior to processing. For each entry, family, trophic guild, and biomass were recorded. Species were classified by primary trophic guilds – herbivores (H), piscivores (P), invertivores (I), and planktivores (PL) – based on information provided from FishBase (Froese and Pauly 2016).

Observations of rays and sharks were removed from all biomass analyses due to their rare nature and large size.

Statistical Analyses

Sighting frequency for each species was expressed as the percentage of surveys in which a species was recorded. From this, ranks of the top 10 most frequently sighted species were obtained for each habitat type.

Fish densities are expressed as the number of fish per 100 m^2, where densities were calculated by dividing the number of individuals per survey by the horizontal area of the survey cylinder (176.7 m^2), then multiplying by 100 to provide density per 100 m^2.

Biomass was computed using the allometric length-weight conversion formula (Bohnsack and Harper 1988) based on information provided by FishBase (Froese and Pauly 2016). Fish biomass was expressed as grams per 100 m^2.

Relative abundance is the number of individuals of one species divided by the total number of individuals of all species observed and multiplied by 100 to obtain a percentage. Size frequency, using relative abundance, was calculated for each trophic guild and presented as bar graphs.

Based on species abundance and biomass, dominance plots (k-dominance or ABC curves) were generated using PRIMER®. W-values (difference between the abundance curve and biomass curve) were calculated for each survey (Clarke 1990). This value can range between -1 and 1, where w=1 indicates that the population is dominated by a few large species, and w=-1 indicates that the population is dominated by many small species.

Density (individuals/100 m^2) and biomass (g/100 m^2) data from geo-referenced stratified random fish surveys were imported into ArcMap, and projected as pie charts as described in Chapter 2 Methods.

Results

In conjunction with random transects, a total of 25 fish surveys were conducted, 13 of which were in low relief habitat, and 12 of which were in high relief habitat. Total species richness from all surveys was 83, and total family richness from all surveys was 28. Average species richness per survey was similar in low relief and high relief habitats, with 18 (± 1.1 SE) and 19 (± 1.4 SE), respectively. Average family richness per survey was also similar between habitats, with 12 (± 0.7 SE) in low relief and 12 (± 0.6 SE) in high relief habitats.

Sighting Frequency and Occurrence

Overall, bluehead (*Thalassoma bifasciatum*), doctorfish (*Acanthurus chirurgus*), and seaweed blenny (*Parablennius marmoreus*) had the highest sighting frequency of all species. Differences were observed in the sighting frequency of the top 10 most frequently sighted species between habitat types (Table 3.1; Figure 3.1). However, the top three observed species were represented by the same species in both habitat categories.

Table 3.1. Sighting frequency of the 10 most observed species in the two habitat categories (high and low relief). Of these, species indicated in bold were among the 10 most frequently observed in both habitats.

Species ID Family Name: Species Name (Common Name - Trophic Guild)	Sighting Frequency (%)		
	Com bined	Low relief	High Relief
Labridae: *Thalassoma bifasciatum* (bluehead - I)	96.0	100.0	91.7
Acanthuridae: *Acanthurus chirurgus* (doctorfish - H)	80.0	84.6	75.0
Blenniidae: *Parablennius marmoreus* (seaweed blenny - I)	80.0	84.6	75.0
Pomacanthidae: *Pomacanthus paru* (French angelfish - I)	76.0	76.9	75.0
Tetraodontidae: *Canthigaster callisterna* (sharpnose puffer - I)	76.0	92.3	58.3
Pomacentridae: *Stegastes partitus* (bicolor damselfish - H)	72.0	69.2	75.0
Pomacentridae: *Stegastes variabilis* (cocoa damselfish - H)	72.0	69.2	75.0
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish - I)	68.0	69.2	66.7
Pomacentridae: *Chromis multilineata* (brown chromis - I)	64.0	46.2	83.3
Labridae: *Bodianus rufus* (Spanish hogfish - I)	60.0	46.2	75.0
Haemulidae: Haemulon aurolineatum (tomtate - I)	52.0	38.5	66.7
Labridae: *Sparisoma atomarium* (greenblotch parrotfish - H)	48.0	61.5	33.3
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish - I)	48.0	61.5	33.3

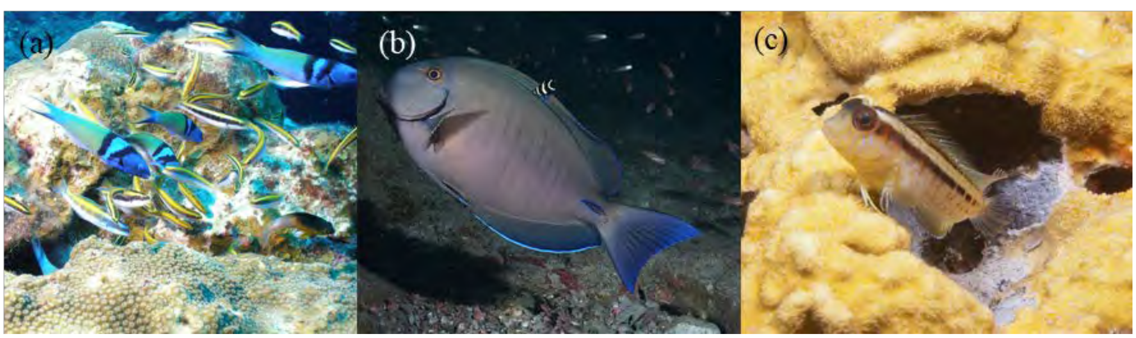


Figure 3.1. Most frequently observed species. (a) bluehead (Photo: G.P. Schmahl/NOAA), (b) doctorfish (Photo: G.P. Schmahl/NOAA), and (c) seaweed blenny (Photo: Emma Hickerson/NOAA)

In this report, species were considered “rare” if they were recorded in less than 20% of all surveys, while “prevalent” species were recorded in ≥20% of surveys (Zimmer et al. 2010). Overall, a total of 49 species were characterized as “rare,” while 34 species were characterized as “prevalent.” Most shark and ray species are considered rare throughout the Caribbean (REEF 2014), and, although divers observed them while completing other tasks, none were recorded in surveys at Stetson Bank during this study period.

Density

Average fish density was greatest in high relief habitat, with 358 individuals per 100 m^2 (± 60.9 SE). Low relief habitat density was 204 individuals per 100 m^2 (± 48.1 SE).

When averaged by habitat type, some similarities were noted between the densest species in each habitat type, with four of the same species occurring in both (Table 3.2). In low relief habitat mackerel scad (*Decapterus macarellus*) and in high relief habitat bonnetmouth (*Emmelichthyops atlanticus*) had the greatest average density.

Table 3.2. Average density (individuals/100 m^2) of the 10 densest species, ± standard error, in each habitat. Of these, species indicated in bold were among the 10 densest species in both habitats. Dashes indicate that the species was not observed.

Species ID	Density (Individuals/100 m^2)		
Family Name: Species Name (Common Name - Trophic Guild)	Combined	Low relief	High Relief
Haemulidae: Emmelichthyops atlanticus (bonnetmouth - P)	64.3 ± 32.8	23.5 ± 21.7	108.5 ± 63.3
Haemulidae: *Haemulon aurolineatum* (tomtate - I)	41.7 ± 15.0	8.3 ± 6.2	77.9 ± 27.4
Pomacentridae: *Chromis multilineata* (brown chromis - I)	36.3 ± 16.7	2.9 ± 1.2	72.6 ± 32.2
Carangidae: *Decapterus macarellus* (Mackerel scad - PL)	31.7 ± 24.0	60.9 ± 45.5	-
Lutjanidae: Rhomboplites aurorubens (vermilion snapper-P)	16.0 ± 10.9	29.4 ± 20.7	1.6 ± 1.4
Labridae: *Thalassoma bifasciatum* (bluehead - I)	15.2 ± 3.3	17.1 ± 5.4	13.2 ± 3.9
Pomacentridae: *Stegastes variabilis* (cocoa damselfish - H)	12.3 ± 2.8	9.4 ± 2.6	15.5 ± 5.0
Epinephelidae: Paranthias furcifer (Atlantic creolefish - PL)	7.3 ± 4.7	-	15.2 ± 9.5
Pomacentridae: Chromis enchrysura (yellowtail reeffish - I)	6.8 ± 2.6	11.4 ± 4.7	1.9 ± 1.1
Pomacentridae: Chromis insolata (sunshinefish - PL)	5.6 ± 2.3	7.1 ± 4.1	4.0 ± 1.9
Pomacentridae: Stegastes partitus (bicolor damselfish - H)	5.4 ± 2.7	2.3 ± 0.7	8.8 ± 5.5
Blenniidae: Parablennius marmoreus (seaweed blenny - I)	5.0 ± 1.2	6.0 ± 2.0	3.9 ± 1.4
Pomacentridae: Chromis scotti (purple reeffish - PL)	3.5 ± 1.6	1.2 ± 0.8	5.9 ± 3.1
Labridae: Sparisoma atomarium (greenblotch parrotfish - H)	2.1 ± 0.8	3.1 ± 1.4	1.0 ± 0.6
Carangidae: *Caranx crysos* (blue runner - P)	1.1 ± 1.0	-	2.2 ± 2.1

Biomass

Average biomass across all surveys was 6035.7 g/100 m^2 (± 1279.0 SE). High relief habitat possessed the greatest average biomass, with 7946.3 g/100 m^2 (± 2443.0 SE) while low relief habitat had 4272.0 g/100 m^2 (± 837.3 SE).

When averaged by habitat type, some similarities were observed between the species contributing the greatest biomass. Table 3.3 shows the 10 species contributing the most to observed biomass in each habitat, and overall. In low relief habitat, French angelfish (*Pomacanthus paru*) had the greatest average biomass, with 1441.2 g/100 m^2 (± 407.5 SE). In high relief habitat, crevalle jack (*Caranx hippos*) had the greatest average biomass, with 2152.1 g/100 m^2 (± 2067.7 SE).

Table 3.3. Average biomass of the top 10 species, ± standard error, in each habitat. Of these, species indicated with bold text were among the top 10 biomass contributors in both habitats. Dashes indicate that the species was not observed.

Species ID Family Name: Species Name (Common Name - Trophic Guild)	Biomass (g/100 m^2)		
	Combined	Low relief	High Relief
Pomacanthidae: *Pomacanthus paru* (French angelfish - I)	1218.1 ± 283.1	1441.2 ± 407.5	976.4 ± 380.8
Carangidae: *Caranx hippos* (crevalle jack - P)	1033.0 ± 1033.0	-	2152.1 ± 2067.7
Acanthuridae: *Acanthurus chirurgus* (doctorfish - H)	507.8 ± 146.2	337.3 ± 116.1	692.5 ± 268.4
Lutjanidae: *Lutjanus campechanus* (red snapper - P)	354.3 ± 281.5	107.1 ± 107.1	622.0 ± 555.7
Kyphosidae: *Kyphosus saltatrix/incisor* (chub [bermuda/yellow] - H)	307.8 ± 141.7	270.8 ± 174.8	347.9 ± 225.9
Epinephelidae: *Paranthias furcifer* (Atlantic creolefish - PL)	301.6 ± 186.7	-	628.3 ± 361.5
Sphyraenidae: *Sphyraena barracuda* (great barracuda - P)	254.9 ± 131.6	94.1 ± 94.1	429.1 ± 242.6
Lutjanidae: *Lutjanus griseus* (gray snapper - I)	199.7 ± 95.9	13.5 ± 13.5	401.3 ± 178.6
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish - I)	184.4 ± 82.0	146.0 ± 81.6	226.1 ± 150.6
Carangidae: *Decapterus macarellus* (mackerel scad - PL)	145.9 ± 143.5	280.6 ± 275.8	-
Scombridae: *Acanthocybium solandri* (wahoo - P)	144.4 ± 144.4	277.8 ± 277.8	-
Scorpaenidae: *Pterois volitans* (red lionfish - P)	128.8 ± 70.7	193.3 ± 131.0	58.8 ± 38.3
Carangidae: Caranx crysos (blue runner - P)	128.1 ± 117.8	-	266.9 ± 235.0
Pomacanthidae: *Holacanthus townsendi* (Townsend angelfish - I)	110.3 ± 79.5	157.7 ± 144.8	58.9 ± 56.6
Haemulidae: *Emmelichthyops atlanticus* (bonnetmouth - P)	88.8 ± 75.9	150.8 ± 146.2	21.7 ± 12.2
Epinephelidae: *Epinephelus adscensionis* (rock hind - I)	70.6 ± 31.3	120.6 ± 56.8	16.4 ± 16.9

Trophic Guilds

Species richness within trophic guild was calculated overall and between habitats (Table 3.4). Overall, invertivores possessed the greatest species richness, with the guild comprising 39 species and 16 families, and planktivores possessed the lowest species richness, with the guild comprising nine species and three families. The same trend was observed when surveys were analyzed by habitat type.

Table 3.4. Species and family richness by trophic guild. Grouped by habitat and overall, where the number in parenthesis represents family richness.

Trophic Guild	Combined	Low relief	High Relief
Herbivore	15 (4)	13 (4)	13 (4)
Invertivore	39 (16)	31 (16)	32 (12)
Piscivore	13 (5)	10 (5)	10 (4)
Planktivore	9 (3)	8 (3)	7 (3)

Density and biomass were calculated for each trophic guild and averaged across survey and habitat type, then converted to percent contribution (Table 3.5). Invertivores contributed most to overall density, at 42.3%, and herbivores contributed the least, at 9.2%. However, in low relief habitat, while herbivores represented the trophic guild with the lowest density, planktivores represented the greatest density. In high relief habitat, invertivores represented the trophic guild with the greatest density, planktivores had the lowest density. For all surveys combined, invertivores and piscivores contributed the greatest biomass while planktivores contributed the least (38.6%, 38.5%, and 7.5%, respectively). In low relief habitat, biomass was dominated by invertivores and the lowest contributor to biomass was planktivores. In high relief habitat, biomass was dominated by piscivores and the lowest contributor to biomass was planktivores.

Table 3.5. Percent composition of trophic guild to density and biomass.

Trophic Guild	Density (% Contribution)			Biomass (% Contribution)		
	Combined	Low relief	High Relief	Combined	Low relief	High Relief
Herbivore	9.2	9.8	8.9	15.3	17.1	14.3
Invertivore	42.3	28.0	51.1	38.6	55.9	28.5
Piscivore	29.9	26.6	31.9	38.5	20.4	49.1
Planktivore	18.6	35.6	8.1	7.5	6.7	8.0

The three species contributing the most to observed density (Table 3.6) and biomass (Table 3.7) within each habitat type and from each trophic guild were calculated. The invasive species red lionfish (*Pterois volitans*) contributed to >20% of the biomass to the piscivore guild.

Table 3.6. Percent contribution of density of the top three species in each habitat and trophic guild. Of these, species indicated in bold were among the three densest species in both habitats.

Trophic Guild	Species ID Family Name: Species Name (Common Name)	% Contribution to Trophic Density		
		Combined	Low relief	High Relief
H	**Pomacentridae: *Stegastes variabilis* (cocoa damselfish)**	11.7	9.4	15.5
	Pomacentridae: *Stegastes partitus* (bicolor damselfish)	6.1	2.3	8.8
	Acanthuridae: *Acanthurus chirurgus* (doctorfish)	2.1	1.6	3.1
	Labridae: *Sparisoma atomarium* (greenblotch parrotfish)	1.7	3.1	1.0
I	**Haemulidae: *Haemulon aurolineatum* (tomtate)**	58.7	8.3	77.9
	Pomacentridae: *Chromis multilineata* (brown chromis)	48.7	2.9	72.6
	Labridae: *Thalassoma bifasciatum* (bluehead)	15.1	17.1	13.2
	Pomacentridae: *Chromis enchrysura* (yellowtail reeffish)	5.5	11.4	1.9
P	**Haemulidae: *Emmelichthyops atlanticus* (bonnetmouth)**	51.8	23.5	108.5
	Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper)	13.4	29.4	1.6
	Carangidae: *Caranx crysos* (blue runner)	7.2	-	2.2
	Scombridae: *Acanthocybium solandri* (wahoo)	0.2	0.6	-
PL	Carangidae: *Decapterus macarellus* (mackerel scad)	25.6	60.9	-
	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish)	13.8	-	15.2
	Pomacentridae: *Chromis scotti* (purple reeffish)	6.8	1.2	5.9
	Pomacentridae: *Chromis insolata* (sunshinefish)	6.4	7.1	4.0
	Chaenopsidae: *Emblemaria pandionis* (sailfin blenny)	0.8	1.5	0.4

Table 3.7. Percent contribution of biomass of the top three fish species from each trophic guild in 2017. Grouped by habitat type, where bold text indicates species that were among the three greatest biomass species in the trophic guild in both habitats.

Trophic Guild	Species ID Family Name: Species Name (Common Name)	% Contribution to Trophic Biomass		
		All	Low relief	High Relief
H	**Acanthuridae: *Acanthurus chirurgus* (doctorfish)**	55.0	46.1	61.2
	Kyphosidae: *Kyphosus saltatrix/incisor* (chub [Bermuda/yellow])	33.3	37.0	30.7
	Acanthuridae: *Acanthurus coeruleus* (blue tang)	4.6	7.8	2.3
I	**Pomacanthidae: *Pomacanthus paru* (French angelfish)**	52.1	60.4	42.6
	Lutjanidae: *Lutjanus griseus* (gray snapper)	8.5	0.6	17.5
	Pomacanthidae: *Holacanthus bermudensis* (blue angelfish)	7.9	6.1	9.9
	Pomacanthidae: *Holacanthus townsendi* (Townsend angelfish)	4.7	6.6	2.6
P	Carangidae: *Caranx hippos* (crevalle jack)	44.5	-	55.3
	Lutjanidae: *Lutjanus campechanus* (red snapper)	15.3	12.3	16.0
	Sphyraenidae: *Sphyraena barracuda* (great barracuda)	11.0	10.8	11.0
	Scombridae: *Acanthocybium solandri* (wahoo)	6.2	31.9	-
	Scorpaenidae: *Pterois volitans* (red lionfish)	5.6	22.2	1.5
	Haemulidae: *Emmelichthyops atlanticus* (bonnetmouth)	3.8	17.3	0.6
PL	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish)	66.5	-	98.8
	Carangidae: *Decapterus macarellus* (mackerel scad)	32.2	98.4	-
	Pomacentridae: *Chromis insolata* (sunshinefish)	0.3	0.7	0.1
	Pomacentridae: *Chromis scotti* (purple reeffish)	0.3	0.1	0.4
	Ptereleotridae: *Ptereleotris helenae* (hovering dartfish)	0.3	0.5	0.3
	Apogonidae: *Apogon pseudomaculatus* (twospot cardinalfish)	0.2	0.1	0.3

Size-Frequency

Size-frequency, using relative abundance, was calculated for each survey and averaged between habitat types. In both low and high relief habitat, most individuals were <5 cm, comprising 81.8% and 82.4% of individuals, respectively.

Size frequency distributions, using the relative abundance of individuals for each trophic guild, were graphed for each habitat type and overall (Figure 3.2). For all habitat types and all trophic guilds, smaller individuals were predominant.

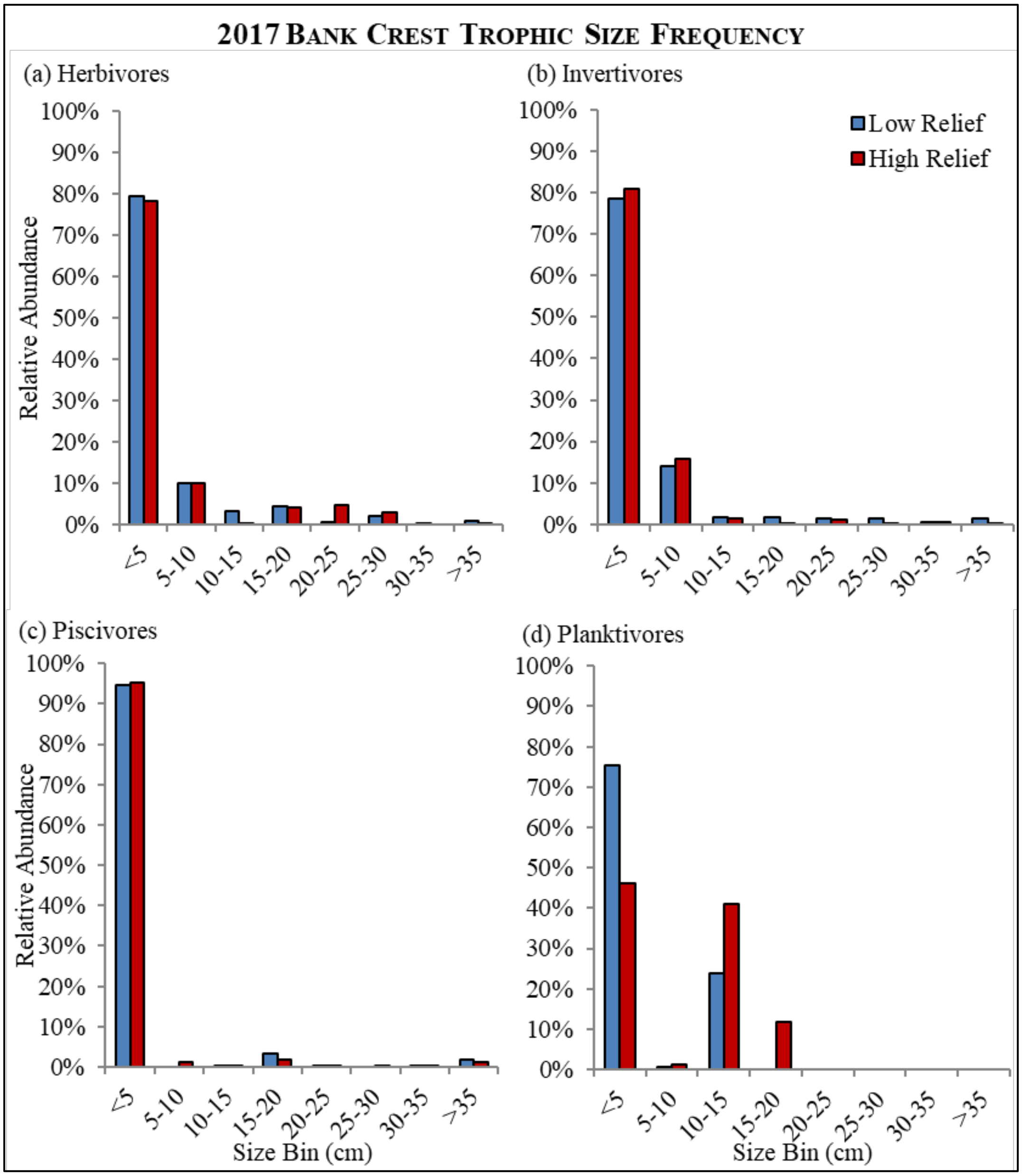


Figure 3.2. Size distribution by trophic guild. Blue columns represent low relief habitat and red columns are high relief habitat in 2017.

Dominance Plots

When averaged between all samples, the dominance plot *w* value was slightly positive, 0.07 (± 0.02 SE) overall. All average values were near zero within each habitat type (Table 3.8), indicating that accumulated biomass was evenly distributed between large and small species.

Table 3.8. Averaged dominance plot w values. Values ± standard error, for each habitat type and overall.

Low relief	High Relief	All Surveys
0.10 ± 0.04	0.05 ± 0.05	0.07 ± 0.03

Spatial Analysis

Density results from stratified random surveys projected spatially showed additional trends in species distribution (Figure 3.3). Piscivore density appeared higher at the western and eastern extremes of the bank crest, while planktivore density was greater in the central portion of the bank.

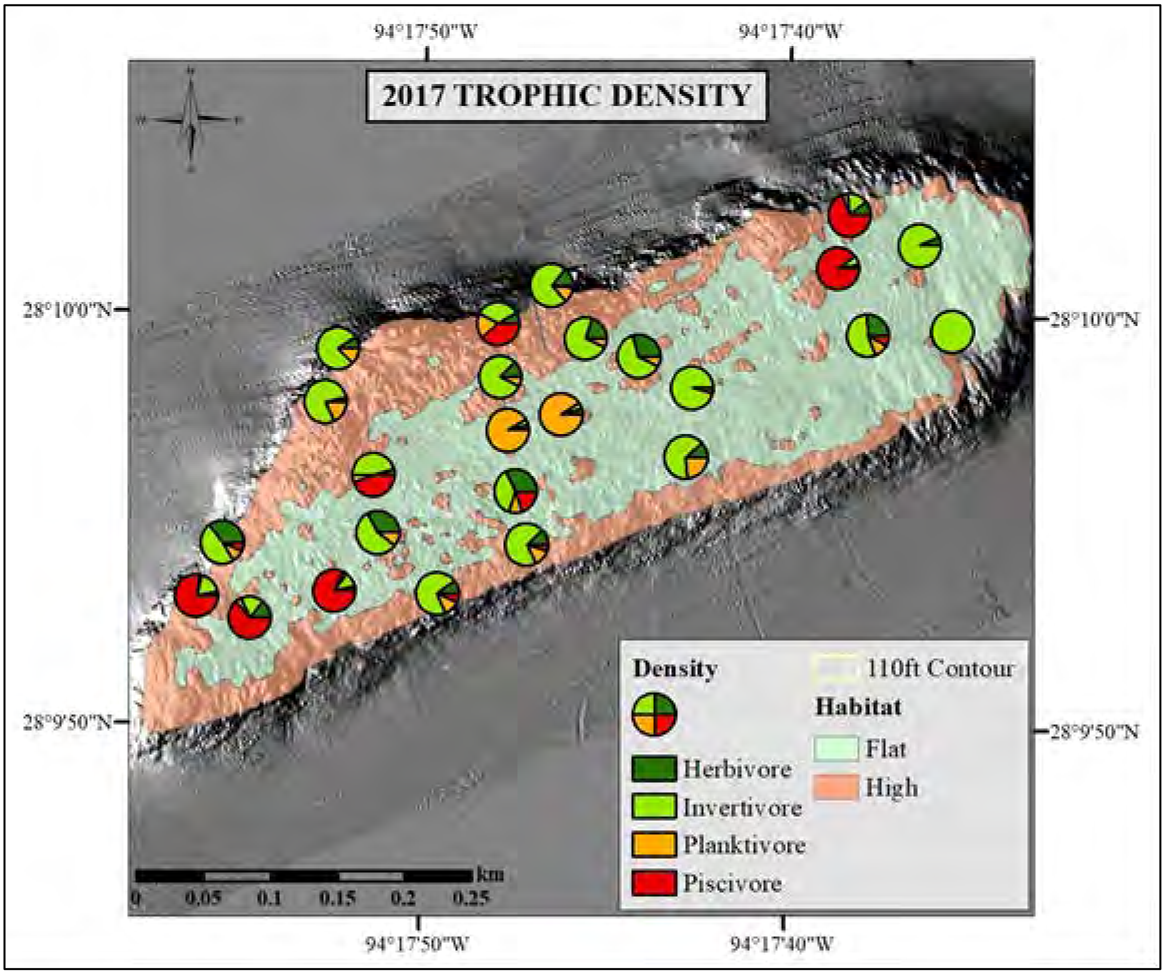


Figure 3.3. Spatial projection of fish trophic group density in 2017. Each pie chart represents the location at which a survey was conducted and the proportion of density represented by each trophic guild. H=Herbivore, I=Invertivore, PL=Planktivore, and P=Piscivore. Image: NOAA

The biomass of each trophic guild at each survey site was also projected (Figure 3.4). During the study period, no overall spatial trends in biomass were observed.

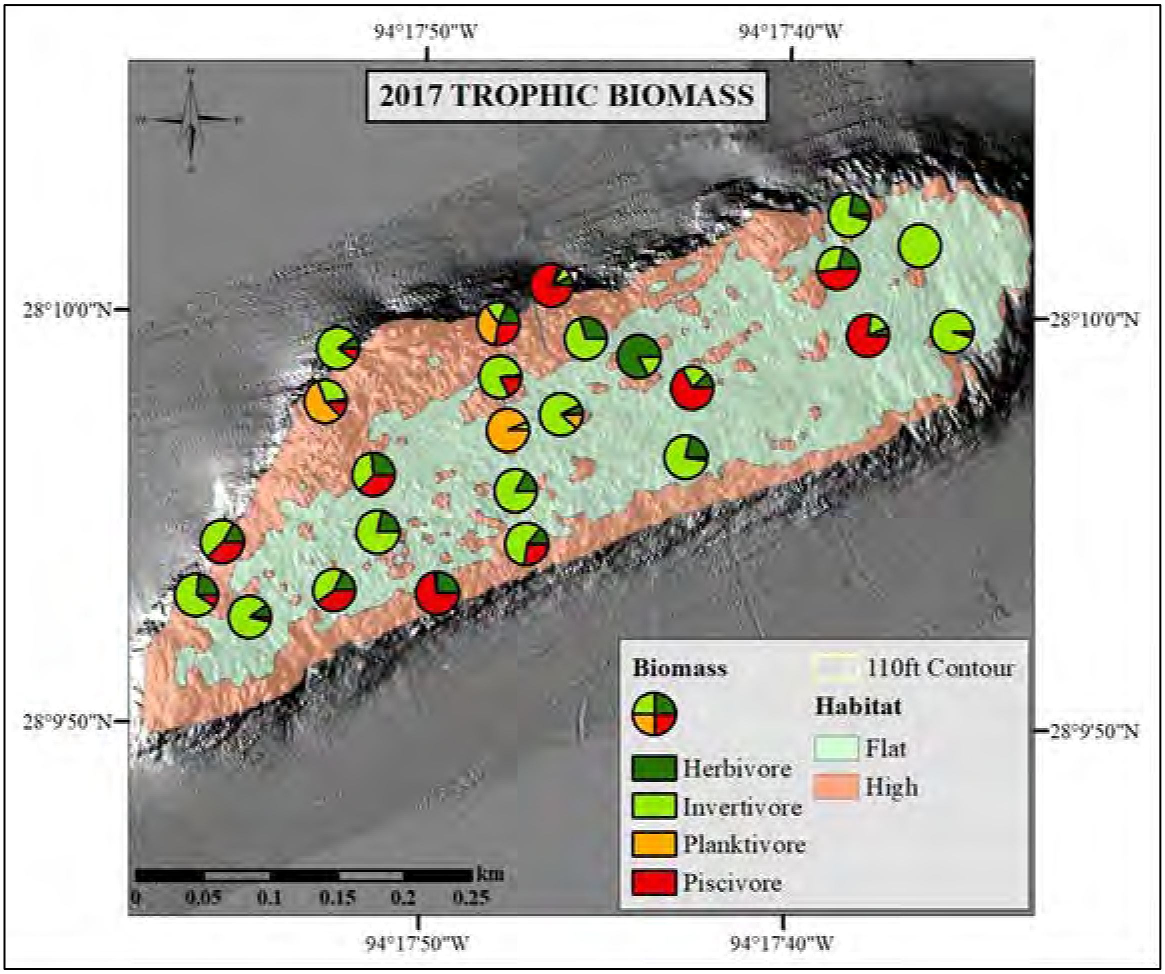


Figure 3.4. Spatial projection of fish trophic group biomass in 2017. Each pie chart represents the location at which a survey was conducted and the proportion of biomass represented by each trophic guild. H=Herbivore, I=Invertivore, PL=Planktivore, and P=Piscivore.Image: NOAA

Discussion

Fish communities are considered indicators of ecosystem health and are therefore an important component to long-term monitoring programs (Sale 1991). Monitoring fish community changes over extended periods of time is valuable in detecting changes or variations in the community.

Small invertivorous fish comprised the greatest density at Stetson Bank. Additionally, the invertivore guild was represented by the most species and families, and possessed the greatest overall density of any trophic guild. However, this was only true for biomass in low relief habitat as biomass in high relief habitat was predominately piscivorous fish. In

2017, high densities of small mackerel scad, bonnetmouth, and juvenile vermilion snapper were documented on the reef, and reflected in both density and biomass data. In addition, lionfish were the second largest contributor to biomass of piscivores in low relief habitat.

Piscivore biomass was greater than herbivore biomass in both habitats. Piscivore dominated biomass indicates that the ecosystem maintains an inverted biomass pyramid, where piscivore dominance is associated with minimal detrimental environmental impacts, particularly from fishing (Friedlander and DeMartini 2002; DeMartini et al. 2008; Knowlton and Jackson 2008; Sandin et al. 2008; Singh et al. 2012). Typically, inverted biomass pyramids are associated with healthy reef systems with high coral cover. Coral cover at Stetson Bank, however, is low, compared to other Caribbean reefs (Jackson et al. 2014), comprising less than three percent of the benthic cover (Jackson et al. 2014). In fact, the bank and its ecological characteristics reflect those of higher latitude, sub-tropical topographic features more than those of a true coral reef (Bright et al. 1985).

Despite the low coral cover, high relief habitats at Stetson Bank provide moderately complex habitat, both geological and biological, that provide potential refuges for prey fishes (Townsend and Bologna 2007; Harborne et al. 2012). Furthermore, the productive and dynamic physical environment in which the bank is situated provides ample food for the high population of fish and invertebrates for which the bank is known. The observed inverted biomass pyramid in the high relief habitat is likely due to the availability of refugia, rapid turnover rates of prey items, slow growth rates of predators, and potential food subsidies from the surrounding pelagic environment (Odum and Odum 1971; DeMartini et al. 2008; Wang et al. 2009). It should be noted, however, that piscivore biomass was only marginally higher than herbivore biomass in low relief habitat, and is potentially the effect of pelagic fish swimming through the habitat and spillover of high densities of small schooling piscivores from high relief habitat.

While density of reef fish at Stetson Bank mostly comprised small individuals (<5cm), which account for >80% of all recorded fish, abundance biomass curves indicate the fish community at Stetson Bank is well balanced between density and biomass, where biomass neither predominately comprised many small individuals nor few large individuals.

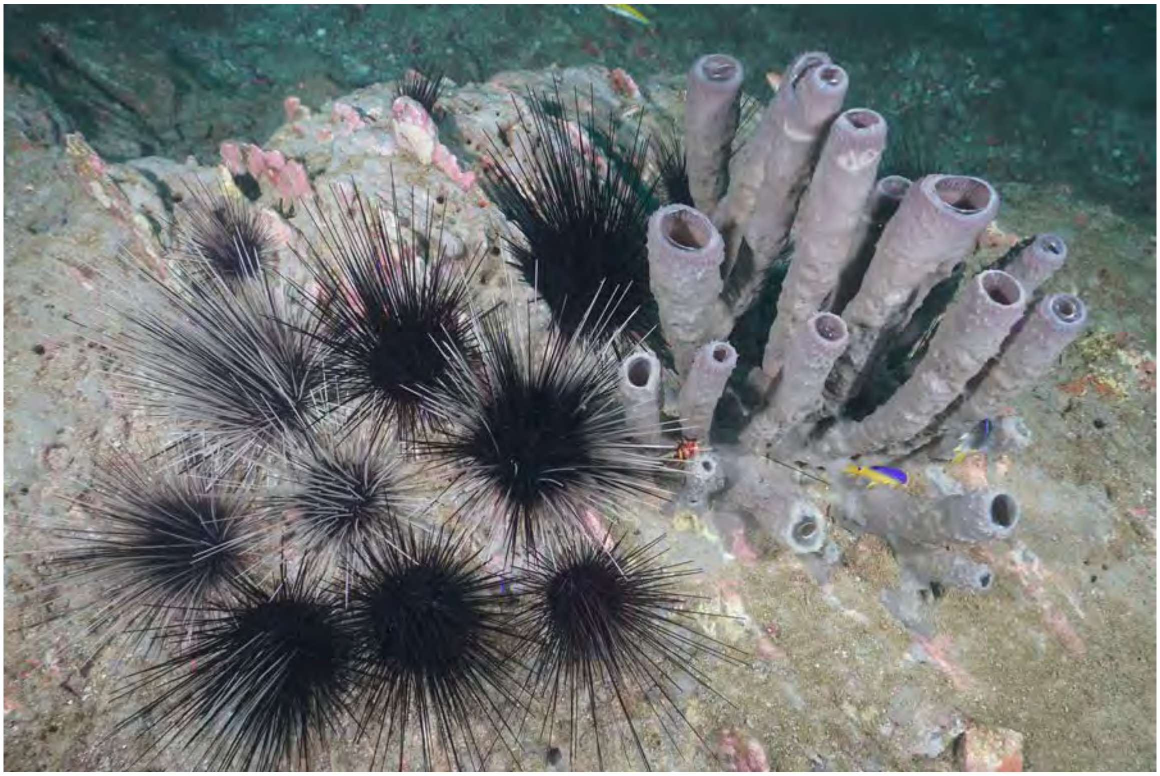
Lionfish have been reported at Stetson Bank by recreational scuba divers since 2011. In 2017 monitoring efforts, five lionfish were observed during surveys in both high and low relief habitats. The invasion of this exotic species is of particular concern and continued attention to changes in their population is recommended.

Overall, the fish community suggests a variable fish population, comprised of both commercially and recreationally valuable juvenile and adult fish species. While not a component of this study, additional variation of the fish community may occur at both the diurnal and seasonal scale at Stetson Bank. Continued monitoring of this community is necessary to understand natural variation of the fish community and detect significant changes of the fish assemblage, in addition to documenting potential impacts of invasive species.

Challenges and Resolutions

No problems were encountered in the 2017 field season.

CHAPTER 4: SEA URCHIN AND LOBSTER SURVEYS



Long-spined sea urchin, *Diadema antillarum*, at Stetson Bank. Photo: G.P. Schmahl/NOAA.

Introduction

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

Methods

Field 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 100 m long, were conducted by dive teams along lines between permanent mooring buoys (from buoy #1 to #2 and #2 to #3). One additional belt transect, 2 m wide and 50 m long (from buoy #3 to repetitive photostation 27) was also conducted. In total, 500 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) were noted.

In addition, sea urchin counts were conducted on both repetitive photostation images and random transect images. The abundance of long-spined sea urchin at each photostation or transect was recorded. These images were captured throughout the day (sunrise to sunset).

Data Processing

Density of each species was calculated as number of individuals per m^2 for each survey type. When multiple surveys were conducted along the same transect line, the surveys were averaged for that transect before processing for density.

Results

On night surveys, the average density of long-spined sea urchins was 1.69 individuals per m^2 (± 35.24 SE). No Caribbean spiny lobster or spotted spiny lobster were observed in 2017 surveys, but one Spanish slipper lobster was observed.

Repetitive photostations, which were selectively placed in high relief habitat, had an average density of 1.32 individuals per m^2 (± 0.16 SE). Along random transects, the density of long-spined sea urchins was greater in high relief habitat, where the average density was 0.57 per m^2 (± 0.24 SE), than in low relief habitat, where the average density was 0.06 individuals per m^2 (± 0.04 SE).

Discussion

Though sea urchin densities at Stetson Bank were different between habitat types, average density was similar in daytime repetitive photostations and night surveys. Densities were lower in random transects, which were conducted during daytime and in places more likely to contain low relief.

The similarity in daytime and night survey counts is likely due to the relative lack of refuge at Stetson Bank compared to more complex coral reef habitats. While there are substantial outcrops that have some complexity, the invertebrates remain visible to divers even when they are within cracks and crevices in the rocks. The nighttime surveys attempted to capture abundance while the species were more active, but the number of surveys was limited, limiting the power of the data analyses. Future sampling may be able to improve power by combining day and night surveys in certain habitats.

Studies have demonstrated that long-spined sea urchin populations reduce macroalgae cover, increasing coral recruitment (Carpenter and Edmunds 2006). Further, modeling studies suggest that reef systems with sea urchin densities >1 per m^2, in addition to a robust grazing fish community, are more resilient than reef systems with lower urchin densities (Mumby et al, 2006; Mumby et al. 2007). Following the 1983-1984 Caribbean-wide die-off, limited recovery of long-spined sea urchin populations has been seen throughout the Caribbean, with a regional average density of 0.023 per m^2 (Kramer 2003). Studies have documented local densities from 0 – 12 per m^2 throughout the Caribbean (Edmunds and Carpenter 2001; Carpenter and Edmunds 2006). East and West Flower Garden Banks in the Gulf of Mexico have documented post-mortality local densities of <0.1 and 0.21 per m^2, respectively (Johnston et al. 2017). Long-spined sea urchin density at Stetson Bank was higher than the regional average for the Caribbean but lower than some observed local maxima.

Lobster densities have historically been low at Stetson Bank, and continue to be. In 2015, dens inhabited by Caribbean spiny lobster around the study area were documented and added to the study area map for potential surveys in the future.

Challenges and Resolutions

No problems were encountered in the 2017 field season.

CHAPTER 5: WATER QUALITY

Water samples are collected for nutrient analyses from the sampling carousel aboard the R/V *Manta*. Photo: NOAA

Introduction

Several water quality parameters were continually or periodically recorded at Stetson Bank. 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 recording, temperature, salinity, pH, turbidity, fluorescence, and dissolved oxygen (DO) were conducted quarterly throughout the year. With these profiles, water samples were collected each quarter and analyzed by an Environmental Protection Agency (EPA) certified laboratory for select nutrient levels (chlorophyll-a, ammonia, nitrate, nitrite, and total nitrogen). Ocean carbonate samples were sent to a university laboratory for measurement of total pH, alkalinity, and total dissolved CO_2 (DIC), from which *in situ* pH and pCO2 were calculated.

Methods

Field Methods

Temperature and Salinity Loggers

The primary instrument for recording salinity, temperature, and turbidity was a Sea-Bird® Electronics, *16plus* V2 CTD (SBE 16*plus*) with a WET Labs ECO NTUS turbidity meter, deployed at a depth of 24 m. The logger was installed on a large railroad wheel, on a low relief surface of the bank crest, in the midsection of the bank (Figure 1.1, Datasonde). The instrument recorded temperature, salinity, and turbidity hourly throughout the year. Each quarter year, the instrument was exchanged by scuba divers for downloading and maintenance. It was immediately exchanged with an identical instrument to avoid any gaps in the data collection. Prior to re-installation, all previous data were removed from the instrument and battery life checked. Maintenance and factory service of each instrument were performed at annual intervals.

Onset® Computer Corporation HOBO® Pro v2 U22-001 (HOBO) thermographs were used to record temperature on an hourly basis. These instruments provide a highly reliable temperature backup for the primary logging instrument at the 24 m station. In addition, one of these loggers was deployed at a 30 m station and a 40 m station to record temperature hourly. The loggers were also downloaded, maintained, and replaced on a quarterly basis. The instruments were either attached directly to the primary instrument at the 24 m station or to eyebolts at the 30 m and 40 m stations. Prior to re-installation, all previous data were removed from the instrument and battery levels were checked.

This chapter presents data from instrumentation at Stetson Bank from October 8, 2016 to October 7, 2017 for the 24 m, 30 m and 40 m stations. The SBE *16plus* deployed at Stetson Bank during the second quarterly water quality cruise experienced software issues which resulted in a loss of data between July 22, 2017 and October 31, 2017. Therefore, data from backup temperature loggers were used to complete data processing and subsequent reporting during this time frame.

Water Column Profiles

Water column profiles were collected quarterly in conjunction with water samples. A Sea-Bird® Electronics *19plus* V2 CTD recorded temperature, salinity, pH, turbidity, fluorescence, and DO every ¼ second. Data were recorded following an initial soaking period, on the up cast phase of each deployment, while the CTD was brought to the surface at a rate <1 m/sec. Table 5.1 details the instruments used to collect each parameter.

Table 5.1. Sensors added to SBE 19*plus* V2 CTD.

Sensor	Parameter Measured
SBE-18	pH
SBE-43	Dissolved oxygen
WET Labs ECO-FLNTUrtd	Fluorescence and turbidity

Profiles containing temperature, salinity, pH, dissolved oxygen, turbidity, and fluorescence were collected on February 1, May 8, August 23, and October 31, 2017.

Water Samples

Water samples were collected each quarter using a sampling carousel equipped with a Sea-Bird® Electronics *19plus* V2 CTD and six OceanTest® Corporation 2.5 l Niskin bottles. In September 2017, the CTD was outfitted with six additional OceanTest® Corporation 2.5 l Niskin bottles to provide a full complement of sampling bottles for the fourth quarter water sampling cruise. The carousel was attached to the vessel with a scientific winch cable that allows activation of the sampling bottles at specific depths from the shipboard wet lab. A total of six nutrient and four carbonate samples were collected each quarter. Three 2.5 l water samples were collected near the seafloor or reef crest (approximately 20 m depth), three mid-water (10 m depth), and four near the surface (1 m depth). An additional blind duplicate water sample was taken at one of the sampling depths for each sampling period.

One sample bottle from each depth was distributed among 3 containers for nutrient analysis: chlorophyll-*a* samples were distributed to 1000 ml glass containers with no preservatives, samples for reactive soluble phosphorous were distributed to 250 ml bottles with no preservatives, and ammonia, nitrate, nitrite, and total nitrogen samples were distributed to 1000 ml bottles with a sulfuric acid preservative. Immediately after sampling, labeled sample containers were stored on ice and maintained at or below 4° C, and a chain of custody was initiated for processing at an EPA certified laboratory. The samples were transported and delivered to A&B Laboratories in Houston, Texas, within 24 hours of being collected. Each sample was analyzed for chlorophyll-*a* and nutrients (ammonia, nitrate, nitrite, phosphorous, and total nitrogen). In 2017, water samples were obtained on February 1, May 8, August 23, and October 31 .

Water samples for ocean carbonate measurements were collected following methods requested by the Carbon Cycle Laboratory (CCL) at Texas A&M University – Corpus Christi (TAMU-CC) from one sample bottle at each depth, with two replicate samples taken near the surface (1 m). Samples were distributed to Pyrex 250 ml borosilicate bottles with glass stoppers using a 30cm plastic tube that connected to the lower spout of the Niskin bottle. Sample bottles were rinsed three times using the sample water, filled with the plastic tube at the bottom of the bottle to reduce bubble formation, and overflowed by at least 200 ml before 100 μl of $HgCl_2$ was added to each bottle. Stoppers were sealed with Apiezon grease and secured with a rubber band and mixed vigorously. Samples were then stored at 4° C. Samples and CTD profile data were sent to CCL TAMU-CC. Samples were obtained on February 1, May 8, August 23, and October 31, 2017.

Data Processing

Temperature, salinity, and turbidity data were downloaded and processed each quarter from one SBE *16plus* and three HOBO thermographs moored at Stetson Bank. The hourly readings obtained were averaged into a single daily value and recorded in a database. Each calendar day was assigned a value in the database. Separate databases were maintained for each type of logger. For temperature data throughout the year, a historical 10-year average (2005-2014) was used for comparison. For salinity data, a historical average of data from the previous five years (2010-2014) was used for comparison. *In situ* pH and pCO_2 were calculated using measured pH and DIC using the carbonic acid dissociation constants in Dickson and Millero (1987).

Chlorophyll-*a* and nutrient analyses results were obtained quarterly from A&B Laboratories and compiled into a single Excel table. Ocean carbonate analysis results were compiled and received as an annual report from the CCL TAMU-CC. pH was calculated in total scale measured at 25˚ C using a spectrophotometric method with purified m-cresol purple dye.

Results

Temperature and Salinity Loggers

Sea-Bird instruments at the 24 m station showed the minimum temperature logged during this time frame was 19.4^{o} C, recorded on February 8, 2017, and the maximum temperature was 29.2^{o} C, recorded on October 8, 2016. Backup HOBO loggers at the 24 m station showed similar results, with a minimum temperature of 19.5^{o} C logged on February 8, 2017, and a maximum temperature of 29.8^{o} C logged on July 31, 2017. The Sea-Bird logger stopped logging on July 23, 2017, and we are therefore missing data through during the time frame when high temperatures from previous years were recorded. At the 30 m station, a minimum temperature of 19.5^{o} C was logged on February 8, 2017, and a maximum temperature of 29.7^{o} C was logged on August 1, 2017. At the 40 m station, a minimum temperature of 19.5^{o} C was logged on February 8, 2017, and a maximum temperature of 29.4^{o} C was logged on July 31, 2017. Throughout this study period, no days with water temperature over 30^{o} C were recorded by the bank crest instrumentation.

Temperature at each station was compared based on daily data from HOBO thermographs. Slightly cooler temperatures were observed at the deeper stations. At the 24 m and 30 m stations, HOBO thermographs recorded maximum temperature differences of 0.3^{o} C warmer and a 3.3^{o} C cooler. Average temperature difference between the 24 m and 30 m stations was 0.4^{o} C cooler. Similarly, a maximum temperature difference of 0.3^{o} C warmer and 5.1^{o} C cooler was observed between the 24 m and 40 m stations, with the average temperature difference 1.1^{o} C cooler.

Water temperatures at the 24 m station are shown and in comparison to a 10-year average in Figure 5.1. From October 2016 through May 2017, temperatures were warmer than average. However, between May and July 2017, less continuity was observed between the SBE *16plus* and the HOBO logger at 24 m (average difference of 1.1^{o} C), indicting drift in the instrument. As the 24 m HOBO data follow a similar pattern observed in the 30 m and 40 m stations, the error is considered to be in the SBE *16plus*, and HOBO data was used for comparison to the 10-year average from May 2017 forward. Temperatures from May to July 2017 were variable but similar to the 10-year average. However, following July 2017 and through the end of this study period, temperatures were below the 10-year average. The 10-year average comparison is only available at the 24 m station.

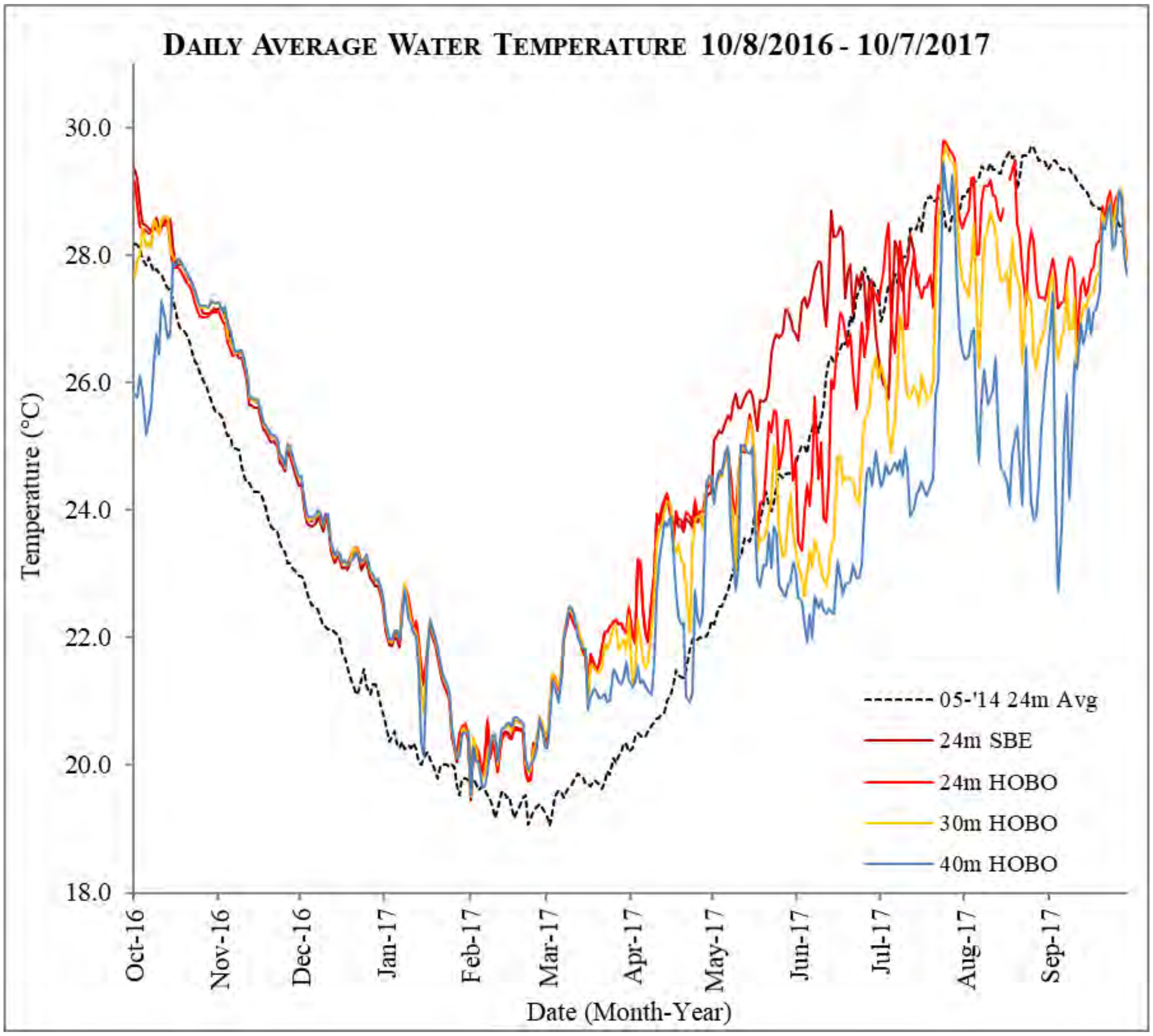


Figure 5.1. Temperature (ºC) at Stetson Bank from 10/8/2016 to 10/7/2017. Black dashed line represents 10-year average temperature.

The minimum salinity level recorded during this time frame was 34.9 psu on April 9, 2017. The maximum salinity level was 36.5 psu on May 30, 2017. Figure 5.2 shows the salinity recorded at the 24 m station and the average salinity observed over a five-year average at this station. Lower than average salinity (by an average of 0.3 psu) was observed between October 2016 and May 2017. Following May 2017, the SBE *16plus* data showed drift and a higher than average salinity (by average of 0.6 psu) through August 2017, which may be an artifact of the drift also observed in the temperature data.

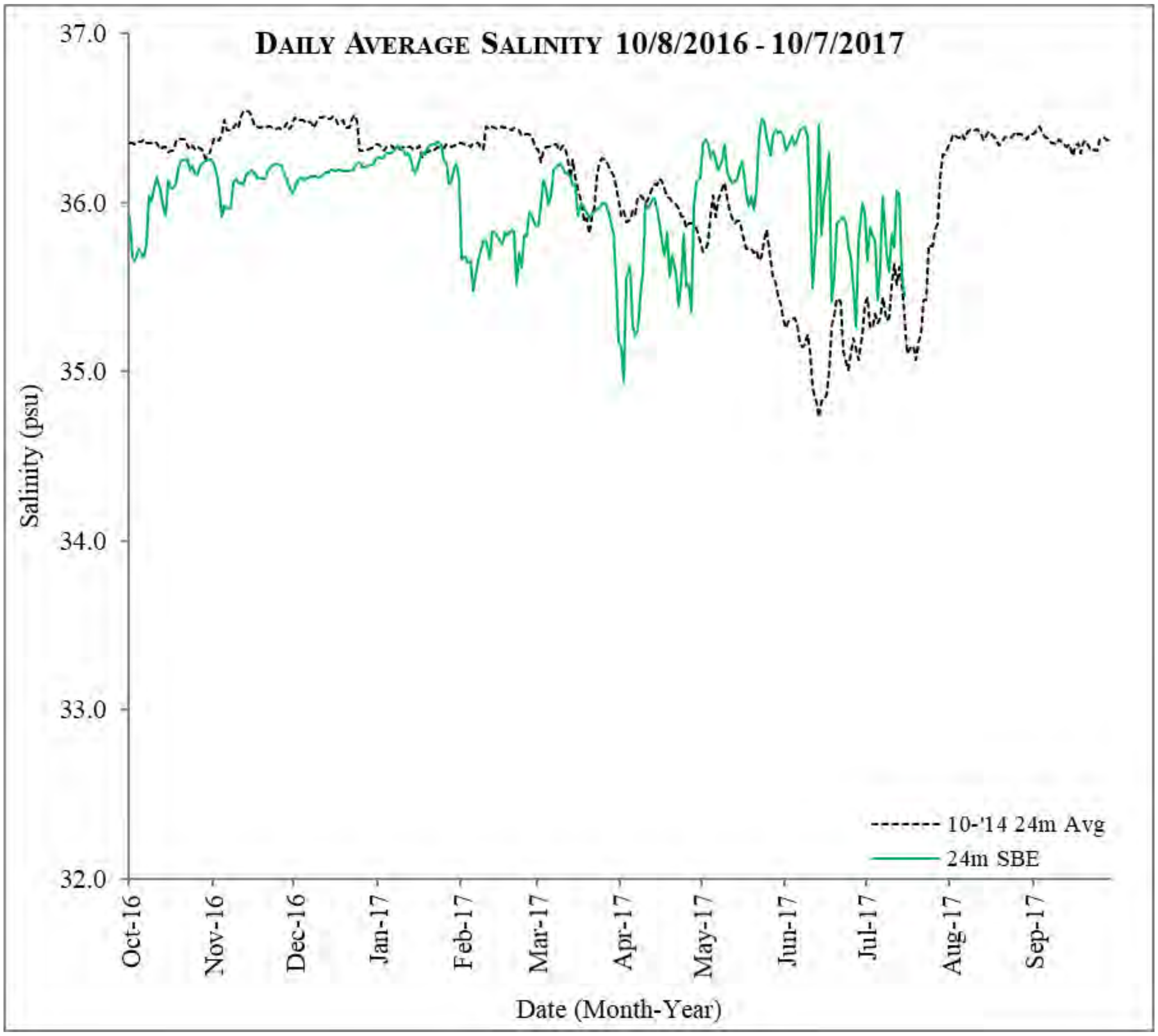


Figure 5.2. Salinity (psu) on the bank crest from 10/8/16 – 10/7/17. Black dashed line represents a five-year average salinity.

Figure 5.3 shows the turbidity recorded at the 24 m station. The minimum turbidity recorded during this time frame was 0.01 ntu on November 5, 2016. The maximum turbidity was 14.73 ntu on January 1, 2017. The greatest variation in turbidity was seen between October and November 2016.

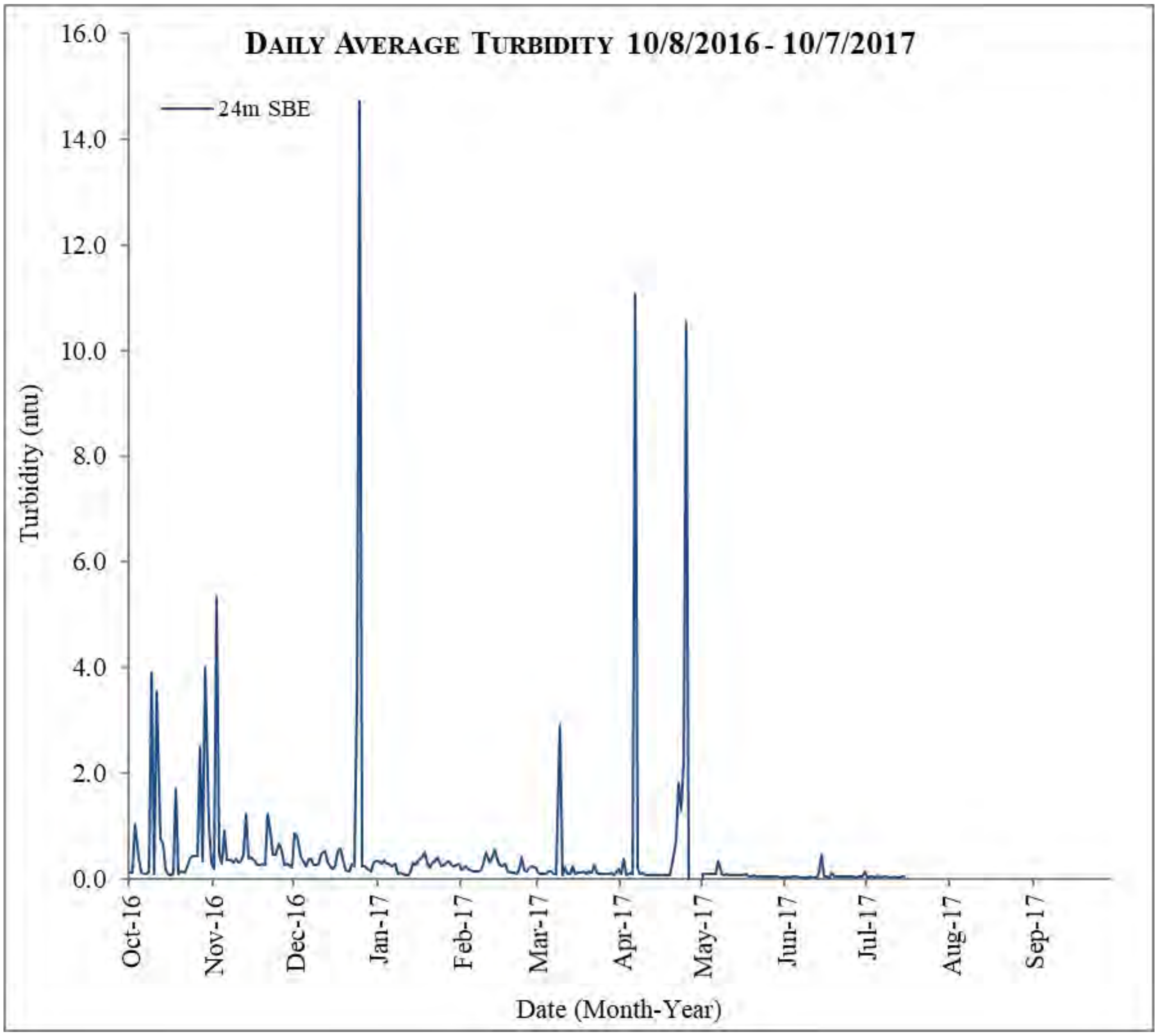


Figure 5.3. Turbidity (ntu) on the bank crest from 10/8/2016 – 10/7/2017.

Water Column Profiles

In 2017, four conductivity, temperature, and density temperature profiles were collected: February 2, May 8, August 23, and October 31, 2017. Henceforth, the dates will be referred to by month and year.

Water temperatures varied throughout the year, and showed only slight variation between the surface and 20 m (Figure 5.4). In August 2017, the water temperature was the warmest recorded, at 30.2^{o} C at the surface, gradually declining with depth. In February 2017, the water column was at its coolest, <21^{o} C, and in May 2017, the water column was isothermal at 24.3^{o} C. There was also little variation in water column temperature during October 2017 when the water temperature was a consistent 26.2^{o} C from the mixing zone at a depth of one meter down to the bank crest at 20 m.

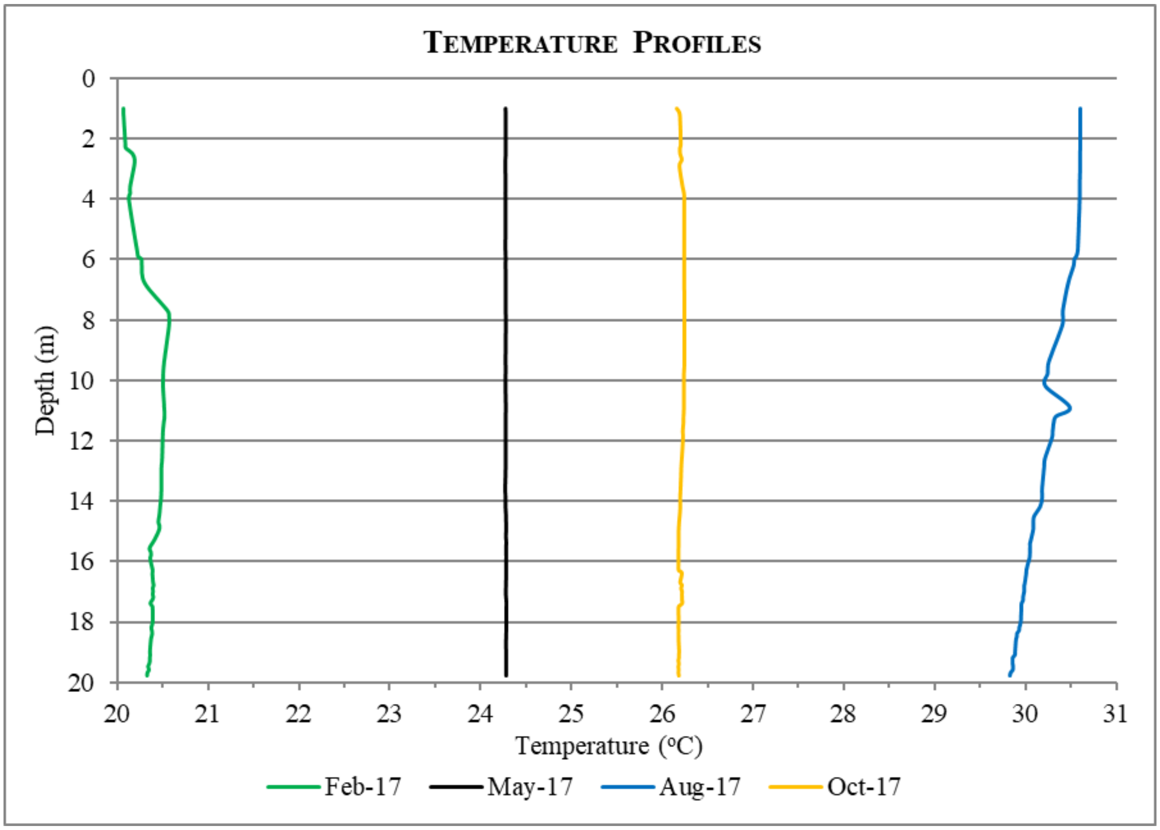


Figure 5.4. Temperature profiles for 2017.

Salinity varied throughout the year, with the lowest salinity recorded in May 2017 (Figure 5.5). In February, August, and October of 2017, lower salinity levels were observed in the upper water column and salinity levels increased with depth.

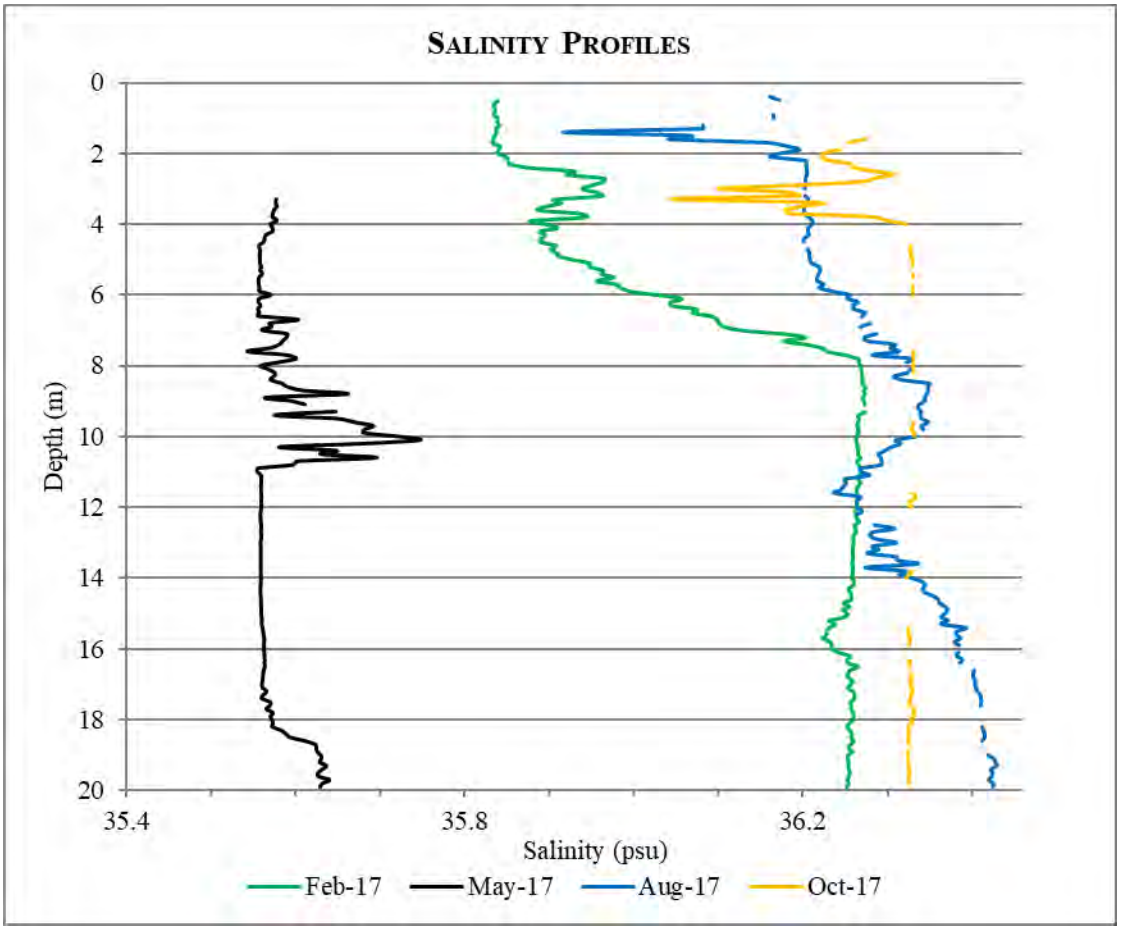


Figure 5.5. Salinity profiles for 2017.

Other water profile parameters, including pH, turbidity, fluorescence, and dissolved oxygen, were recorded during quarterly water sampling and are shown in Figure 5.6. February 2017 exhibited slightly lower pH levels than the May, August, and October 2017 profiles. The October profile demonstrated the most variation in pH by quickly rising 0.4 eu in the top six meters of the water column, stabilizing from four to 16 m and then fluctuating from 16 m to 20 m, just above the bank crest. Turbidity levels were nearly identical in February and May and showed the greatest variability in October.

Fluorescence throughout the water column was greatest in August; however, the upper water column (< 6 m) displayed a similarly high level of fluorescence in February as well. The lowest fluorescence levels were recorded during May and the greatest variability occurred in February and October 2017.

Dissolved oxygen profiles were stable with depth, except in surface water (<4 m) in October. The lowest recorded dissolved oxygen was observed in May and the highest was observed in August and October.

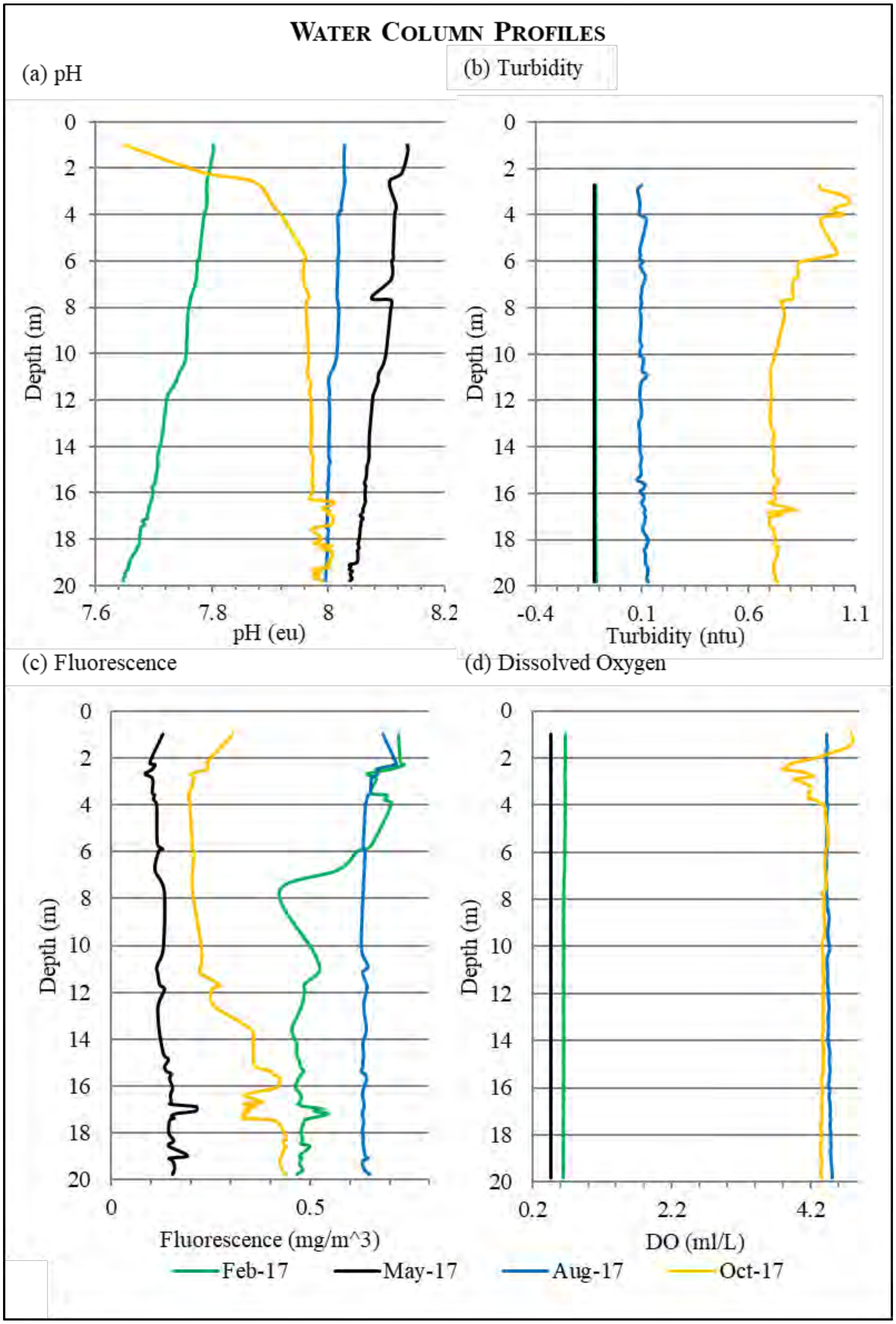


Figure 5.6. pH, turbidity, fluorescence, and DO profiles collected in 2017. (a) pH in eu, (b) turbidity in ntu, (c) fluorescence in mg/m^3, and (d) dissolved oxygen in ml/L.

Water Samples

Nutrient analyses indicate that ammonia, chlorophyll-*a*, nitrate, nitrite, phosphorus, and nitrogen levels for all samples in 2017 were below detectable levels.

Carbonate samples taken throughout the year included pH, alkalinity, and total DIC from which *in situ* pH and pCO_2 were calculated (Table 5.2). Total pH showed small variations throughout the year. The lowest pCO_2 value, when the air-sea pCO_2 gradient was greatest, was observed in February 2017. The lowest $\Omega_{aragonite}$ values were also observed in February 2017, but aragonite saturation states suggested the seawater was well buffered across all survey times. The highest DIC values were observed in May 2017.

Table 5.2. Carbonate sample results for 2017.

Sample Date	Depth (m)	Salinity (ppt)	Temp (ºC)	pH Total	Alkalinity (µmol/kg)	DIC (µmol/kg)	pH *in situ*	$\Omega_{aragonite}$	pCO_2 (µatm)	δ13C (‰)
2/2/2017	21	36.34	20.32	8.051	2401.6	2086.1	8.120	3.53	335.9	0.82
2/2/2017	11	36.33	20.53	8.056	2403.9	2082.3	8.122	3.57	334.1	0.82
2/2/2017	2	35.99	20.09	8.062	2403.4	2082.1	8.136	3.60	322.9	0.68
5/8/2017	20	35.64	24.27	8.055	2409.5	2090.8	8.065	3.62	392.1	ND
5/8/2017	11	35.57	24.28	8.057	2408.6	2090.1	8.067	3.63	390.4	ND
5/8/2017	2	35.64	24.29	8.058	2412.0	2087.6	8.068	3.64	389.2	ND
8/23/2017	21	36.29	29.75	8.083	2403.0	2067.1	8.013	3.96	445.8	1.11
8/23/2017	11	36.25	30.42	8.088	2409.7	2068.8	8.008	4.02	452.6	1.11
8/23/2017	4	36.23	30.59	8.090	2410.2	2064.2	8.007	4.03	453.4	0.98
10/31/2017	22	36.40	26.18	8.083	2408.6	2066.7	8.065	3.87	387.8	ND
10/31/2017	12	36.41	26.18	8.086	2408.0	2063.0	8.068	3.89	384.3	ND
10/31/2017	3	36.44	26.24	8.088	2406.4	2063.3	8.070	3.91	383.0	ND

Discussion

Stetson Bank water temperature readings during this period were initially warmer than average historical data. However, beginning in June, temperatures were below the historical averages and highly variable throughout the summer months. Moored instrument water temperature recordings never exceeded 30º C, with the maximum high of 29.8º C recorded on July 31, 2017.

Salinity levels at Stetson Bank were below the historical averages until May 2017 when they surpassed the historical averages but generally followed the historical trend. While variable salinity levels were observed during this study period, values were within the tolerance limits for coral reefs located in the Western Atlantic (31–38 PSU; Coles and Jokiel 1992). Typically, the summer months at Stetson Bank see more variable salinity levels, which correlates with months of increased flow rates of the Mississippi and Atchafalaya rivers, with April being the peak month and flow rates declining gradually through July (Meade 1995).

Water quality parameters indicated minimal water column stratification throughout the year and nutrient levels continued to be below detectable levels. The lowest pH and greatest pCO_2 measurements were observed in August 2017. Overall, data indicate a thermal control on carbonate systems (carbonate saturation state and CO_2 partial pressure) in this region. Surface seawater $npCO_2$ does not appear to significantly deviate from the atmospheric value, but appears to have a seasonal pattern with a peak $npCO_2$ occurring in late winter to early spring (February-March) and lowest $npCO_2$ in late summer (August-September). Typically, the region observes minimal terrestrial influence (as reflected by high salinity year-round). The distribution of ΔpCO_2 on an annual basis suggested that this area had a small net air-sea CO_2 flux. Seasonal and spatial distribution of seawater carbonate chemistry in 2017 demonstrates that seawater in the FGBNMS area (including East Flower Garden Bank, West Flower Garden Bank, and Stetson Bank), despite its proximity to the land, behaved like an oligotrophic open ocean setting (compare to the Bermuda Atlantic Time-series Study, or BATS; Bates et al. 2012) in terms of its annual pCO_2 fluctuation and minimal terrestrial influence.

On August 29, 2017, Hurricane Harvey passed within 26 km of Stetson Bank. At that time, Harvey was rated as a tropical storm with 72 to 80 kph winds. While physical damage to the bank crest was not observed (see Repetitive Photostations, Discussion), how the hurricane influenced water quality on the bank is unknown as instruments were not operational during the time of the hurricane passage. Water column profiles taken shortly before the hurricane show surface water temperatures below 30^{o} C to approximately 16 m. Coastal runoff from massive rainfall events, like that associated with Hurricane Harvey, has reached offshore to the area of Stetson Bank in previous years (notably 2005 in association with Hurricane Rita) (DeBose et al. 2012). However, two months following the hurricane, water column profiles show increased turbidity throughout the water column while salinity remained high (with the exception of a slight reduction between two and four meters). Additionally, nutrient and ocean carbonate sampling were within expected ranges. While this presents only a one day snapshot of the water column at Stetson Bank following Hurricane Harvey, it suggests water associated with coastal runoff was not present at that time.

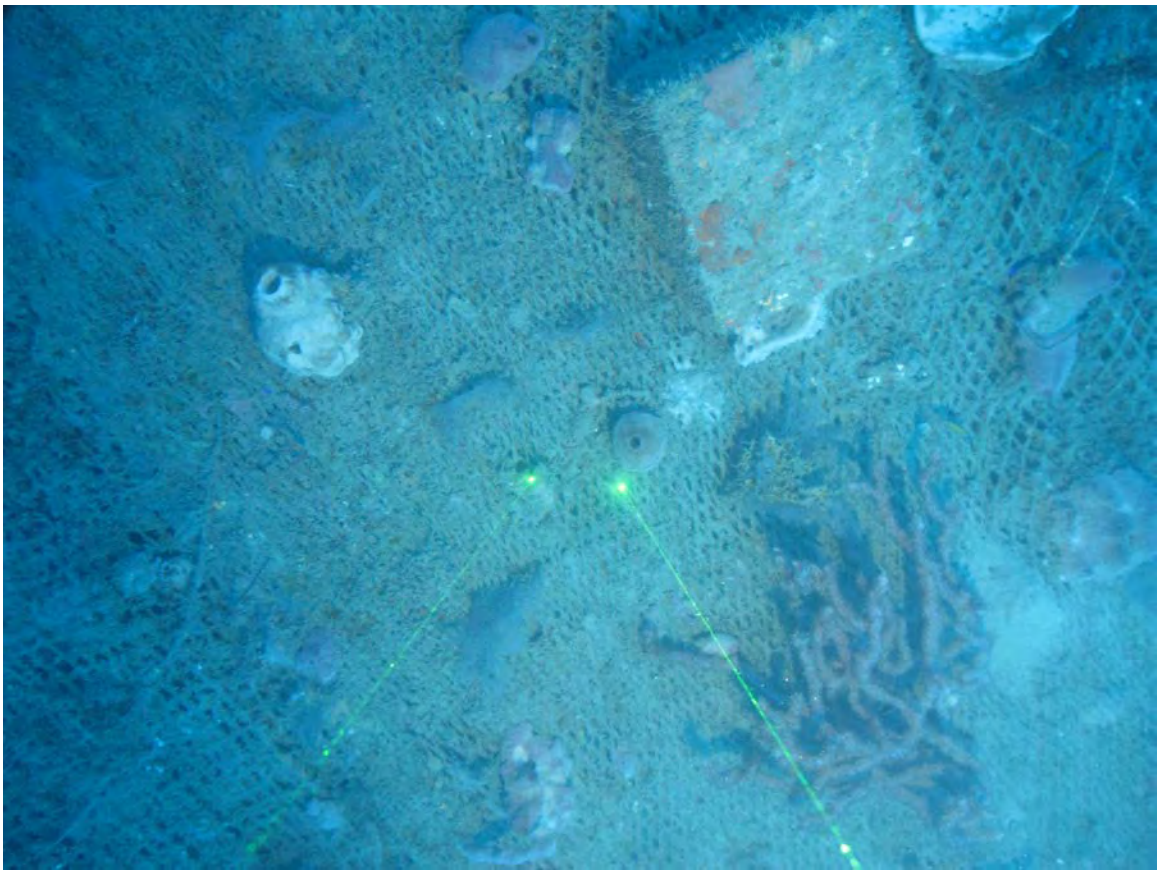
Challenges and Resolutions

- Divers failed to locate and collect the 24 m instruments on a September water quality cruise due to strong currents, high waves, and low water visibility.
    - A second cruise was conducted in early October 2017 and used two dive teams, one to locate and mark the instrument, and one to change it out. In sub-optimal conditions in the future, this technique will be used.
- No data were recorded on the SBE *16plus* between August 3 and November 8, 2017.
    - An issue with the configuration file used to set up the SBE *16plus* for this deployment resulted in erroneous data. Additional training in the proper

setup, assessment, and evaluation of configuration files for new staff is essential and will be conducted at the next available training.

- The SBE *16plus* deployed on May 7, 2017, showed a drift in temperature readings immediately following deployment and suspended recording altogether on July 23, 2017.
    - An unknown issue occurred with the instrument. We have followed up with SeaBird Electronics to address the issue and determined data correction is not possible.

CHAPTER 6: MESOPHOTIC REPETITIVE QUADRANTS



An example of one of the mesophotic repetitive photostations, M03, which was placed atop a high relief outcropping entombed in fishing net. Photo: NOAA/UNCW-UVP

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 remotely operated vehicle (ROV). Their latitude and longitude were recorded using the navigation system on the ROV (Figure 6.1). In 2017, five of the seven stations were located and photographed. While the majority of key features at each station were captured in the images, thee images are not identical between years.

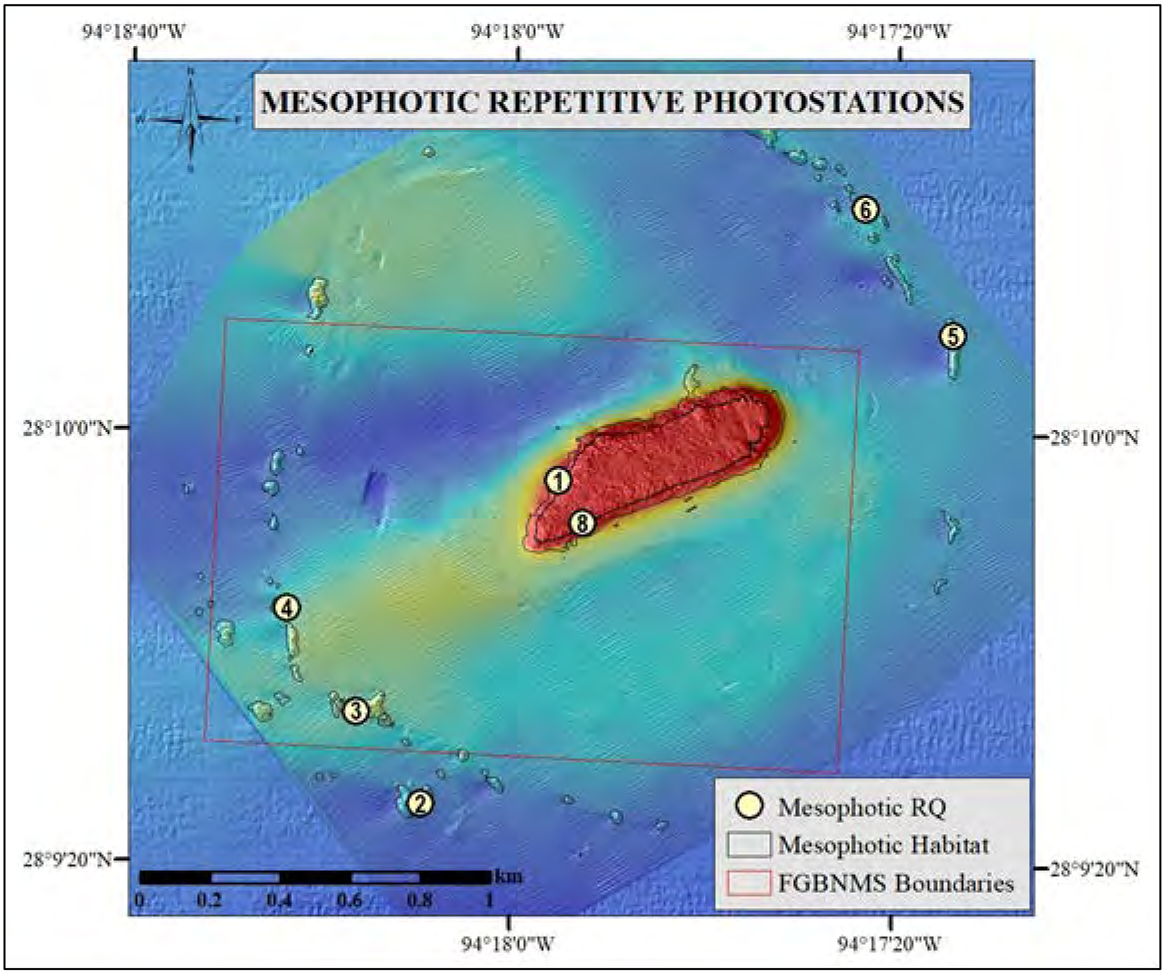


Figure 6.1. Locations of mesophotic repetitive photostations at Stetson Bank. Image: NOAA

Methods

Field Methods

Historical ROV surveys and notable sites (high coral or sponge densities or marine debris) observed during random transects were used to compile a list of potential repetitive photostation locations. The ROV was deployed to find each feature of interest and allow the topside science team to visually assess the feasibility of deploying a marker at the site. Factors considered included visibility (sufficient visibility to operate the ROV safely and capture an image of the feature of interest) and habitat (sufficient low relief habitat on which to deploy the marker). Once an appropriate location was found, a marker was deployed (Figure 6.2).

Markers consisted of a concrete block (25.4 cm x 25.4 cm x 15.2 cm) weighing 25 kg in air (9 kg in saltwater). An eyebolt was embedded into the concrete block, to which a cattle tag with a station ID number and 1.8 m of wire rope was attached via a shackle and thimble. A small 20 cm hard trawl float (3.15 kg buoyancy) was attached to the wire rope using crimping sleeves.

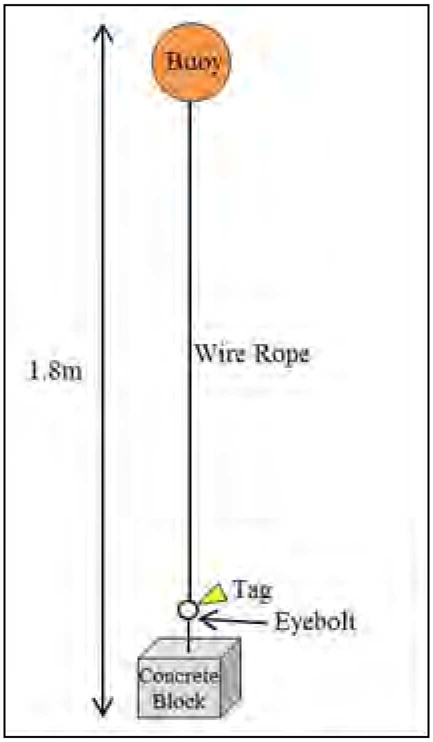


Figure 6.2. Mesophotic repetitive quadrant marker. Image: NOAA

Using recorded latitude and longitude overlaid into the ROV navigation system, an ROV located and photographed each station. To create a repeatable image, each station was assigned a heading from which the ROV collected high definition video imagery of the site, with the marker in view. Still frames for each repetitive station were extracted from the high definition video feed. Starting in 2016, 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 2017, 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 (UNCW-UVP), was used. The ROV was equipped with an Insite Pacific Mini Zeus II HD video camera with two Deep Sea Power & Light 3100 LED lights, a tool skid with an ECA Robotics five-function all-electric manipulator, and two parallel spot lasers set at 10 cm in both the video and the still camera frames for scale.

Data Processing

Qualitative summaries of still frame images from the high definition video and downward facing still camera were made using ImageJ and Microsoft® Excel®. In 2015, key features were identified in each image and outlined using a color-coded key in Adobe Illustrator (Figure 6.3). Key biological features were assigned a code using the first two letters of the genus and species name, along with a unique number for the image (for example, StIn_1 = *S. intersepta* colony 1). Measurements of key stony coral, octocoral, and black coral specimens were made using ImageJ and the reference scale lasers. Key features were compared between subsequent years, when possible. Comparisons documented the loss, reduction, or expansion of key features and changes in general condition.

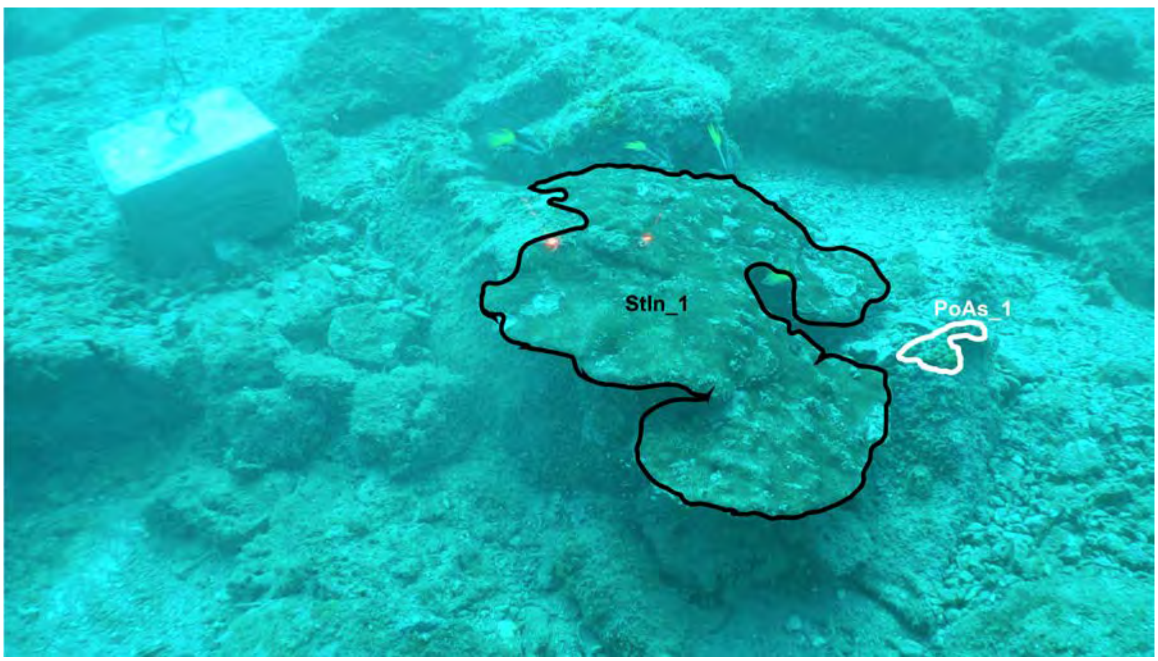


Figure 6.3. Mesophotic photostation M01 in 2015. Key features are outlined and identified. Photo: NOAA/UNCW-UVP

Results

Five out of seven repetitive mesophotic photostations were photographed in 2017. Depth ranged from 35.8 to 54.7 m; average station depth was 47.0 m. Qualitative summaries of each station were produced (Table 6.1).

Table 6.1. Repetitive photostation M01 - M08 descriptions and comparisons for 2017.

Station	Depth (m)	Bearing (Deg.)	Latitude (DD)	Longitude (DD)	Site Description	2016 to 2017 Comp.
M01	39.9	130	28.16542	-94.29867	Coral (StIn_1) *S. 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.	No change apparent
M02	54.7	90	28.15705	-94.30259	Octocoral (HyW_1) white *Hypnogorgia* sp.: 50 x 96 cm. Black coral (Stic_1-2) sea whips. Poor visibility. 100% hard bottom.	Low visibility. No change apparent
M03	51.2	0	28.15942	-94.30448	Sponges (IrW_1-4) white *Ircinia* sp. (IrB_1-12) brown *Ircinia* sp., and (NiEr_1-4) *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.	Complete loss of one colony of *Niphates erecta* (colony not recorded in 2015 site description)
M04	52.4	225	28.16207	-94.30652	Sponges (IrW_1) white *Ircinia* sp.: 25 x 7 x 8 cm, (IrW_2) white *Ircinia* sp.: 16 x 8 x 4 cm. (IrB_1-2), and brown *Ircinia* sp. Black coral sea fan (BCSF_1). 100% hard bottom.	Not found
M05	53.6	0	28.16922	-94.28722	Octocorals (HyW_1-2) white *Hypnogorgia* sp. (HyR_1) red *Hypnogorgia* sp.: 28 cm in height. (HyG_1) gold *Hypnogorgia* sp. Black coral sea whip (Stic_1). 100% hard bottom.	Low visibility. No change apparent
M06	49.1	270	28.17248	-94.28982	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	Not found
M08	35.8	225	28.16432	-94.29794	Coral (StIn_1) *S. intersepta:* 58.6 x 48.3 x 4 cm. No bleaching present. (StIn_2) *S. intersepta*: 32.6 x 18.0 x 3 cm. Sponge *N. nolitangere*. 80% hard bottom covered in macroalgae and rubble.	No change apparent

Discussion

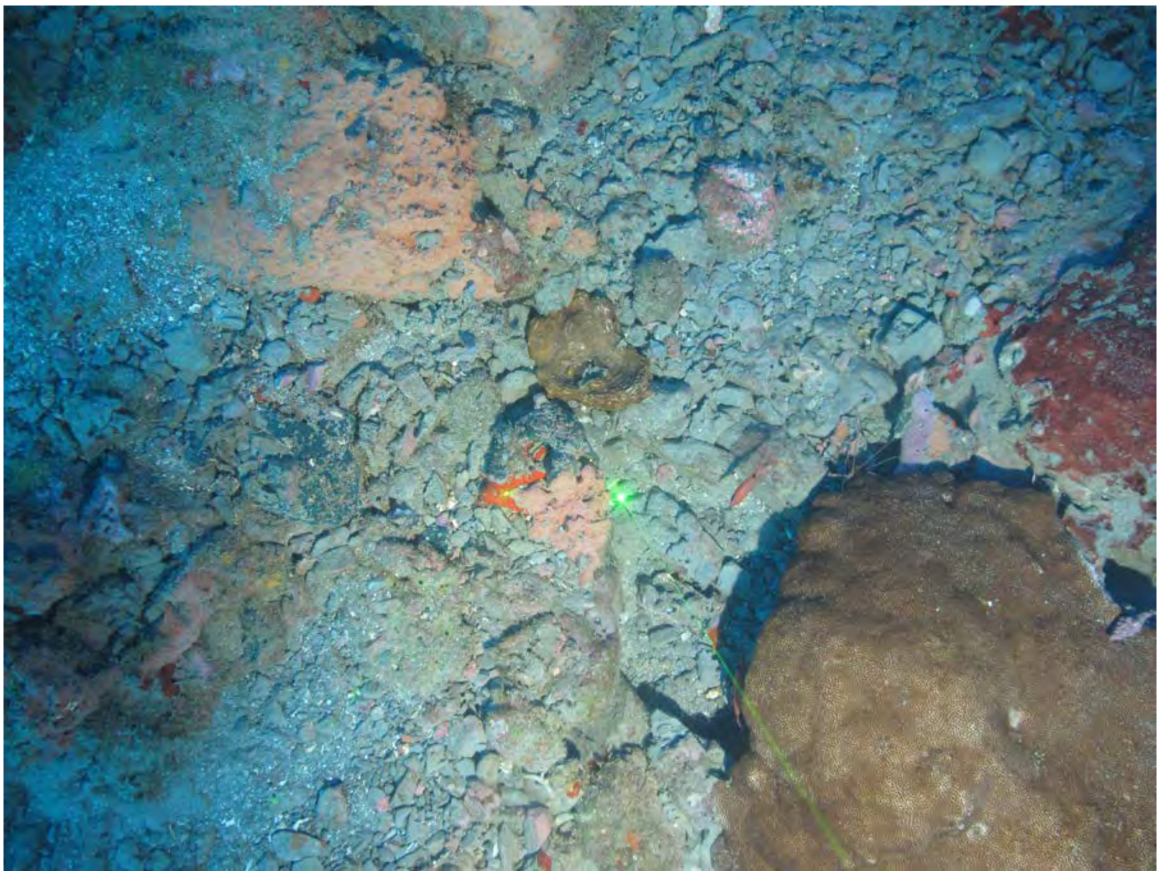
This report presents the third year of mesophotic repetitive photostations in the monitoring program at Stetson Bank. In 2016, collection of repetitive images proved challenging as the ROV was not configured with the tool skid. In 2017, the ROV was configured in the same manner as the 2015 cruise with the tool skid. However, only five of the seven sites were found due to low visibility and marker overgrowth.

These photostations marked a variety of sites. While comparisons were qualitative between years due to the complications of capturing the same image, key biological features, including stony corals, octocorals, black corals, and sponges, did not appear to undergo major changes between 2016 and 2017. However, the loss of a sponge colony (M03) and bleaching on the margin of a *S. intersepta* (M08) was documented.

Challenges and Resolutions

- Not all sites were located.
    - Poor visibility due to heavily silted water combined with markers overgrown by hydroids made locating markers difficult in 2017. In addition, later analysis of the tracking data showed the Hypack ROV position feed was off by ±4.7 m, due to a processing error, affecting our search for a target. This error has been corrected.

CHAPTER 7: MESOPHOTIC RANDOM TRANSECTS



S. intersepta and sponges in coralline algae reef habitat found on the flanks of the main feature at Stetson Bank. Photo: NOAA/UNCW-UVP

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 an ROV. The transects were analyzed to assess community composition and coral density.

Methods

Field Methods

Bathymetric data was processed in Esri's ArcGIS® to highlight potential mesophotic reef habitat. Two meter resolution bathymetry raster was imported into ArcMap® and focal statistics 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. Area shallower than 33.5 m was removed. The raster was then converted to a polygon feature.

Two habitats were identified in 2015: coralline algae reef and deep reef. In 2017, a total of 30 surveys (15 in each habitat) were randomly distributed within the polygon 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 conducted at all sites if sites appeared too close to allow unique surveys or environmental conditions would have resulted in poor quality data.

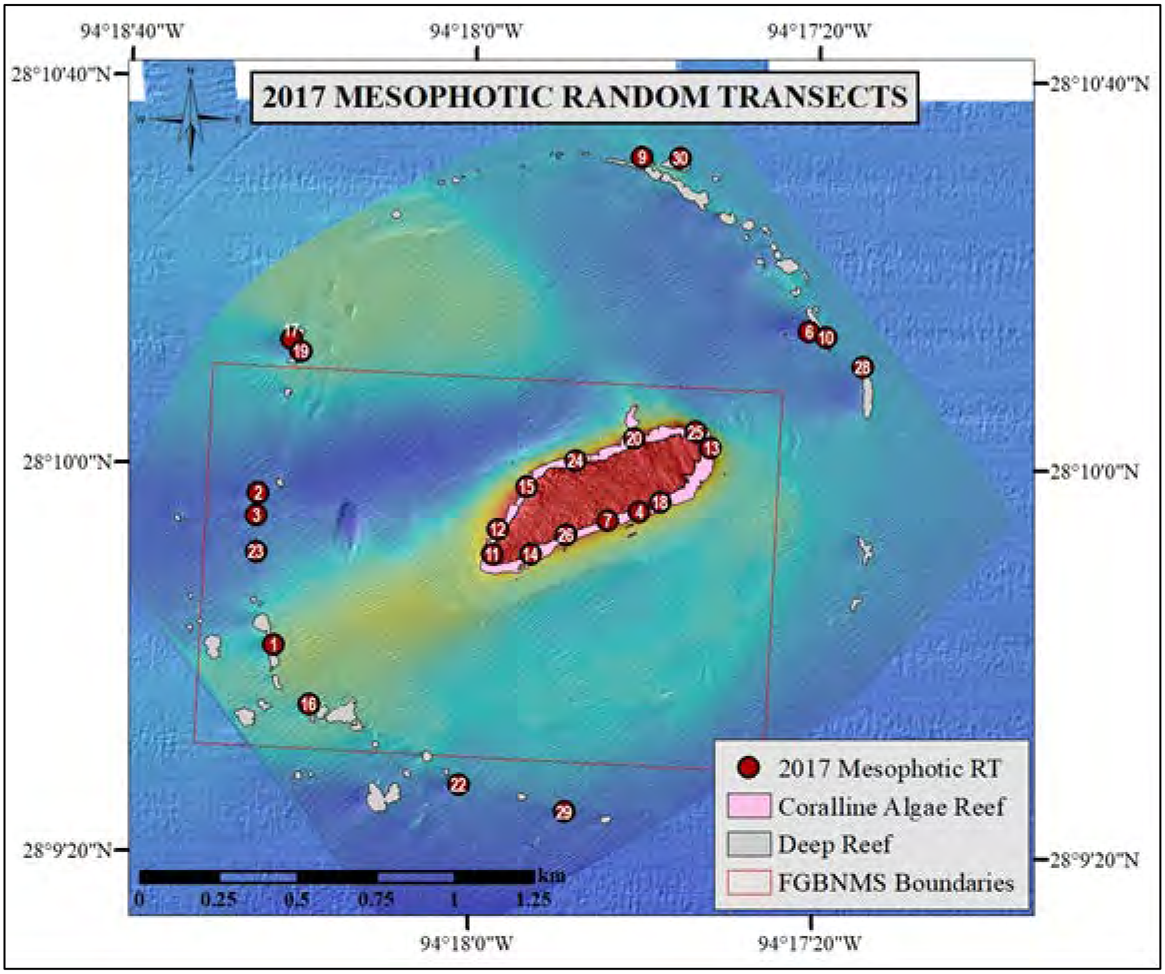


Figure 7.1. Mesophotic random transect locations in 2017. Image: NOAA

Surveys were conducted using an 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 at one meter above the bottom, at a speed of 1 kph, taking downward facing still images every 30 seconds during the transect.

In 2017, the same ROV system as described in Chapter 6 Methods was used. 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.

Data Processing

Images were processed to remove silted, shadowed, out of focus, or soft bottom images. From the remaining images, a minimum of nine and a maximum of 11 images were randomly selected for processing. If a transect did not have at least nine useable images, it was removed from the analysis. The size of each image was calculated in ImageJ and recorded in Microsoft® Excel®. Colony counts for cnidarian species of interest (stony corals, octocorals, black corals, and soft corals) were conducted for each image and recorded. Colony counts were calculated for each species, summed across transects, divided by the transect area, and presented as density per 100 m^2.

Percent cover of the images was analyzed using CPCe. A total of 500 points were randomly overlaid on each transect, with an equal number of points on each photo of the transect. The benthic species lying under these points were identified. Microsoft® Excel® spreadsheets were created automatically via CPCe using customized coral code files pertinent to the benthic species in the mesophotic zone in this region.

Organisms positioned beneath each random point were identified to lowest possible taxonomic group for Cnidaria, Porifera, and macroalgae (algae longer than approximately 3 mm, including thick algal turfs). Other organisms were identified to the phylum level. Substrate was characterized as rubble, soft bottom, fine turfs, and bare rock. Summary data were grouped into substrate or phylum level categories. Cnidarians were further summarized by family. Bleaching, paling, fish biting, and other disease or damage were recorded as notes, providing additional information for each random point.

Because transects differed in area, weighted cover was used in percent cover analysis. To obtain weighted cover, percent cover was multiplied by the area captured in the image, then scaled again to percentages to obtain an adjusted percent cover for data, summarized by habitat.

Cnidarian density data were projected spatially as pie charts following the Methods in Chapter 2.

Results

A total of 26 mesophotic random transects were conducted in 2017. Depth of the stations ranged from 33.4 m to 56.5 m, with an average station depth of 46.8 m. Two distinct habitats were observed: mesophotic reefs with coralline algae (coralline algae reef) and mesophotic reefs without coralline algae (deep reef) (Figure 7.1). Results were grouped by habitat type.

Adjusted percent cover in both habitats was dominated by bare substrate in the form of rubble, soft bottom, or hard bottom habitat (Table 7.1). However, rubble was seen more frequently in coralline algae reef habitat than deep reef habitat, and soft bottom was seen more frequently in deep reef habitat than coralline algae reef habitat.

Table 7.1. Relative percent cover of substrate and biota in mesophotic habitats in 2017.

Habitat	Coralline Algae Reef (Relative % Cover)	Deep Reef (Relative % Cover)
Biota	15.7	21.8
Hard bottom	30.0	55.0
Rubble	54.3	1.6
Soft bottom	0.0	21.6

A total of nine phyla comprised the recorded biota in both habitats (Figure 7.2). Coralline algae reef biota were predominately Chlorophyta, comprising 8.3% relative cover, primarily due to the abundance of green turf algae in these habitats. Deep reef biota were predominately Cnidaria, comprising 15.5% relative cover.

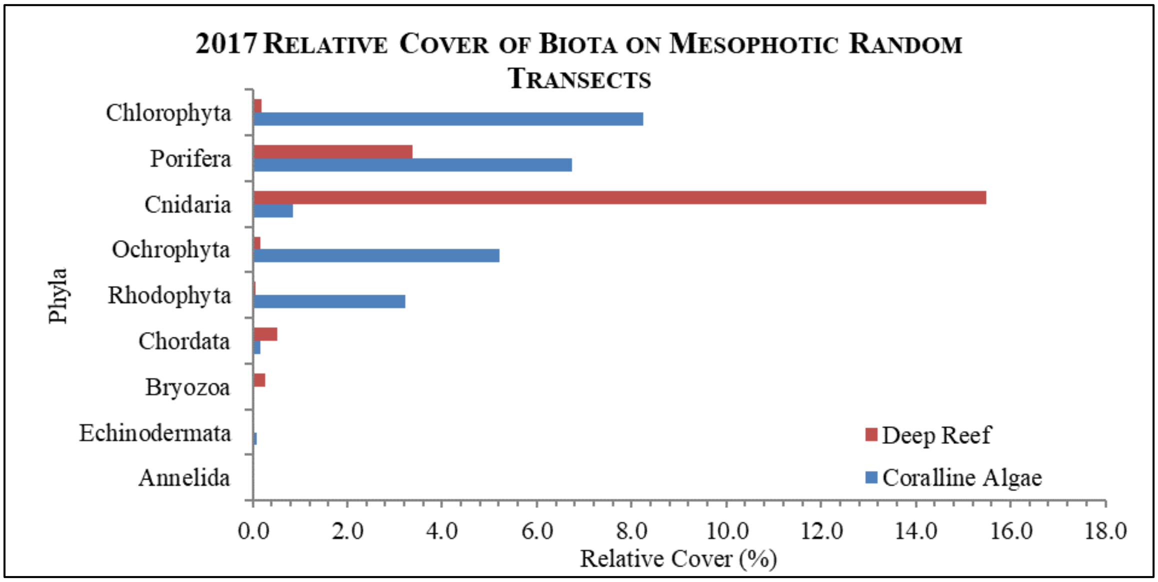


Figure 7.2. Relative percent cover of phyla in mesophotic habitats in 2017.

The cnidarian species of interest were summed to family level. A major contributor to this phylum in deep reef habitat that were not included in family level analysis were hydroids, constituting approximately 50% of cnidarians observed. A total of nine families were recorded (Figure 7.3).

Cnidarians in coralline algae habitat were predominately Astrocoeniidae, at 0.5% relative cover, due to the prevalence of *S. intersepta*. Deep reef cnidarians were predominately Antipathidae, constituting 3.6% cover, due to the prevalence of a black coral sea fan, potentially *Antipathes atlantica/gracilis*.

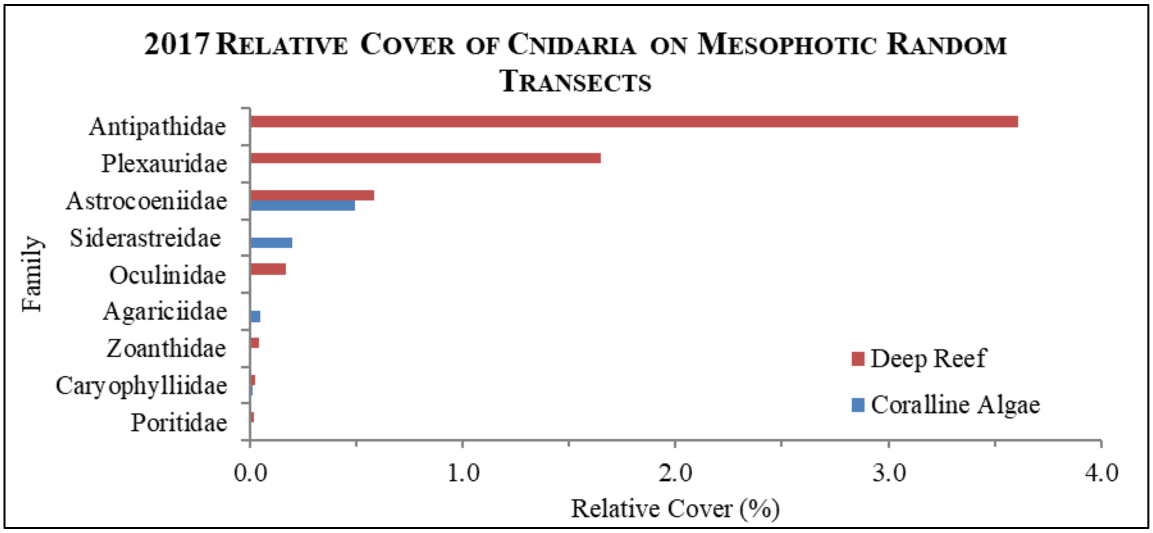


Figure 7.3. Adjusted percent cover of cnidarian families of interest in 2017.

Density of colonies varied between habitat types, with a total of nine families recorded (Figure 7.4). The densest family in deep reef, Caryophylliidae, with a mean of 8.21 individuals per m^2 (± 5.17 SE), was absent from coralline algae reefs. The densest colonies in coralline algae reef was Astrocoeniidae at 1.00 individuals per m^2 (± 0.38 SE).

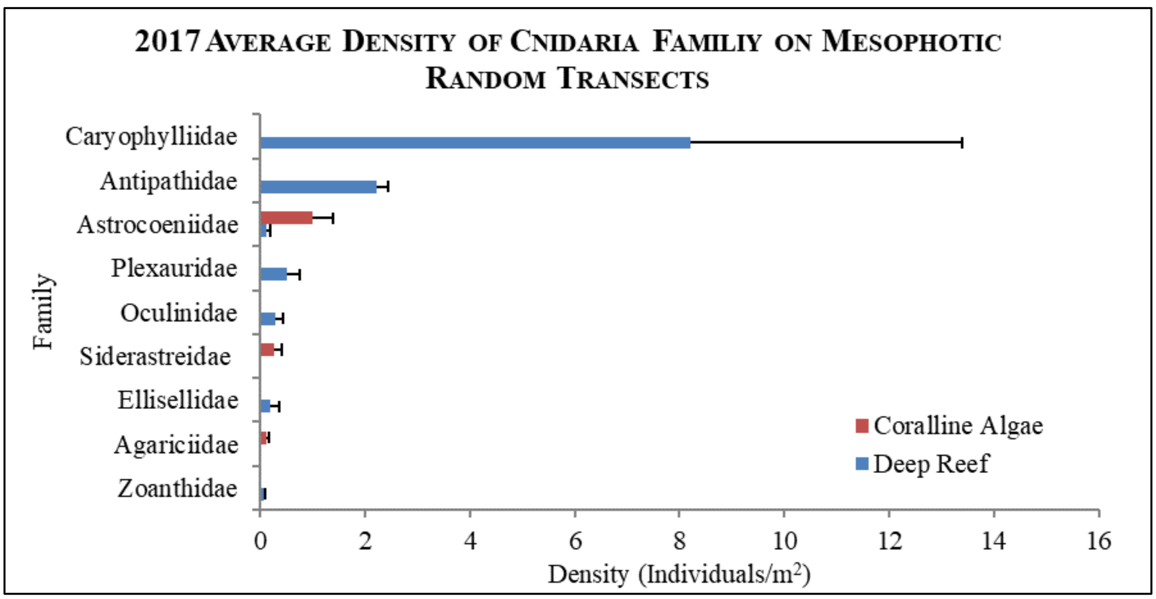


Figure 7.4. Family colony density in number per 100 m^2.

When colony density (grouped by family) was projected spatially, additional trends were observed (Figure 7.5). Surveys in coralline algae reef habitat showed that the southern edge of the bank possessed higher densities of Agariciidae. Surveys on deep reef habitat were predominately Antipathidae colonies, though some differences were evident to the northeast where greater densities of Plexauridae colonies were found.

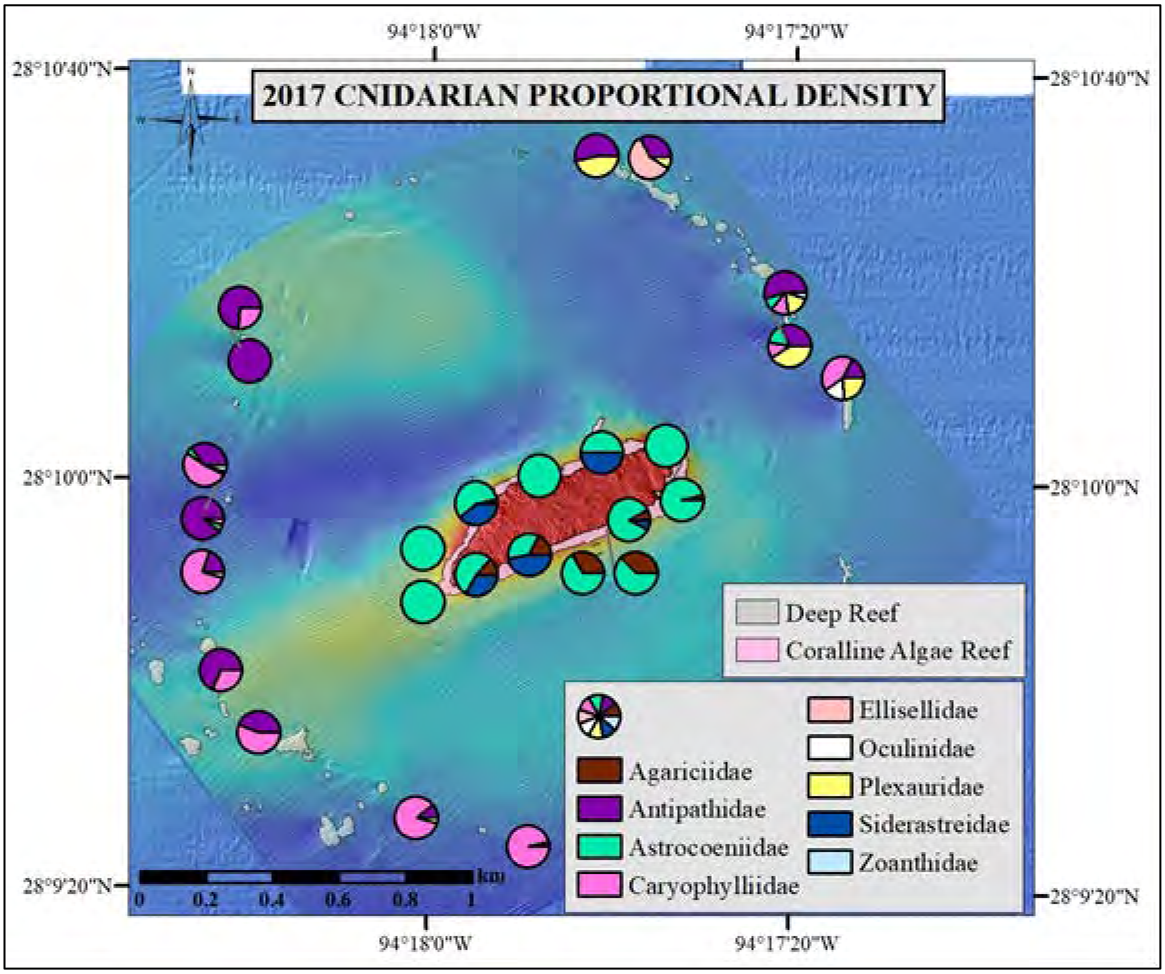


Figure 7.5. Spatial projection of mesophotic cnidarian family density. Each pie chart represents the location at which a survey was conducted and the proportion of density represented by each family of interest. Image: NOAA

Discussion

Mesophotic ecosystems are a critical component of Stetson Bank. Two habitat types were encountered at Stetson Bank, each with a distinct community. Coralline algae reef habitat was defined by an abundance of light dependent, crustose coralline algae, principally Rhodophyta, which were not present in the deep reef habitat. Cnidarians in coralline algae habitat rank as the fifth phyla by benthic cover. Within the cnidarians, the Astrocoeniidae family constituted the highest cover and greatest density. Predominate biota in deep reef habitat were Cnidaria, of which cover was mostly Antipathidae due to an abundance of a black coral sea fan (potentially *A. atlantica/gracilis*). However, density in deep reef habitat was predominately Caryophylliidae, principally solitary cup corals.

Interesting spatial trends were observed within coralline algae reef habitat. Agariciidae was documented only on the southern edge of the central bank feature, whereas other transects in this habitat contained Astrocoeniidae and Siderastreidae. Notes from these observations identified that *S. intersepta* and *M. brueggemanni* contributed the most to Astrocoeniidae densities and *S. radians* contributed most to Siderastreidae densities.

In deep reef habitat, the northeastern area exhibited higher densities of octocorals from the Plexauridae family. The observed spatial differences in benthic community are potentially due to different local conditions, such as turbidity and currents.

It was noted that most *S. radians* and *S. intersepta* colonies observed in the coralline algae reef habitat were small in size (<5 cm). In other parts of the Caribbean region, *S. radians* colony size ranges are reported from 10 cm to 30 cm and *S. intersepta* colony size ranges are reported from 15 cm to 76 cm (Humann and Deloach 1992). The small colonies may represent coral recruits or colonies with stunted growth due to sub-optimal environmental conditions for coral growth.

Challenges and Resolutions

No problems were encountered in the 2017 field season.

CHAPTER 8: MESOPHOTIC FISH SURVEYS

Red snapper schools were observed on dives to the ring of mesophotic habitat surrounding the main feature at Stetson Bank. Photo: NOAA/UNCW-UVP

Introduction

To examine fish community composition and changes over time, belt transect visual fish censuses were conducted at random locations in the mesophotic habitat surrounding Stetson Bank, in conjunction with mesophotic random transects. These surveys were used to characterize and compare fish assemblages.

Methods

Field Methods

Fishes were visually assessed by ROV using belt transect methods discussed in Chapter 7 Methods. Observations of fishes were restricted to the field of view of the ROV's high definition video camera. All fish species observed were recorded, counted, and sized using mounted scale lasers in the field of view of the ROV. Fork length was 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, where each individual's size was recorded. 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 Methods). A minimum of 15 surveys are conducted annually. However, during the 2017 sampling period, 28 fish surveys were conducted.

In 2017, the same ROV system described in Chapter 6 Methods was used. This ROV was also 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.

Data Processing

Fish survey data were entered into a Microsoft® Excel® database by the surveyor in real time. Entered data were later checked for quality and accuracy prior to processing by a second person, using high definition video of the survey. Data were processed using the same methods described in Chapter 3.

Transects where visibility was restricted to <3.5 m in the lateral field of view were removed from analysis. These transects exhibited low species richness and may not be representative of the habitat due to the limited visibility preventing observations and species identifications. Additionally, transects with >50% soft bottom habitat were removed from analyses.

Area of each survey was calculated by importing ROV track data, recorded every two seconds, into ArcMap®. The line data were smoothed using PAEK algorithm and a smoothing tolerance of 10 m. Line length was then calculated in WGS83 UTM15 for the 10-minute transect. Distance was multiplied by the maximum horizontal distance in the field of view, where field of view was determined using forward facing dual lasers, measured at the farthest point in the field of view. Measurements were calculated using ImageJ.

Statistical Analyses

See statistical analyses outlined in the Methods of Chapter 3.

Results

Twenty-eight mesophotic fish surveys were conducted in 2017 (Figure 8.1). After removing transects with limited visibility or >50% soft bottom, 21 transects were analyzed. Greater turbidity was observed in the deep reef habitat than in coralline algae reef. Depth of transects ranged from 33.4 m to 56.5 m, with an average station depth of 44.9 m. Total species richness from all surveys was 56, and total family richness from all surveys was 26. Average species richness was 11 (± 1.3 SE), and average family richness was 8 (± 0.7 SE). Both average species and family richness was greater in coralline algae reef habitat (15 ± 1.2 SE; 10 ± 0.6 SE) than deep reef habitat (6 ± 0.7 SE; 6 ± 0.6 SE).

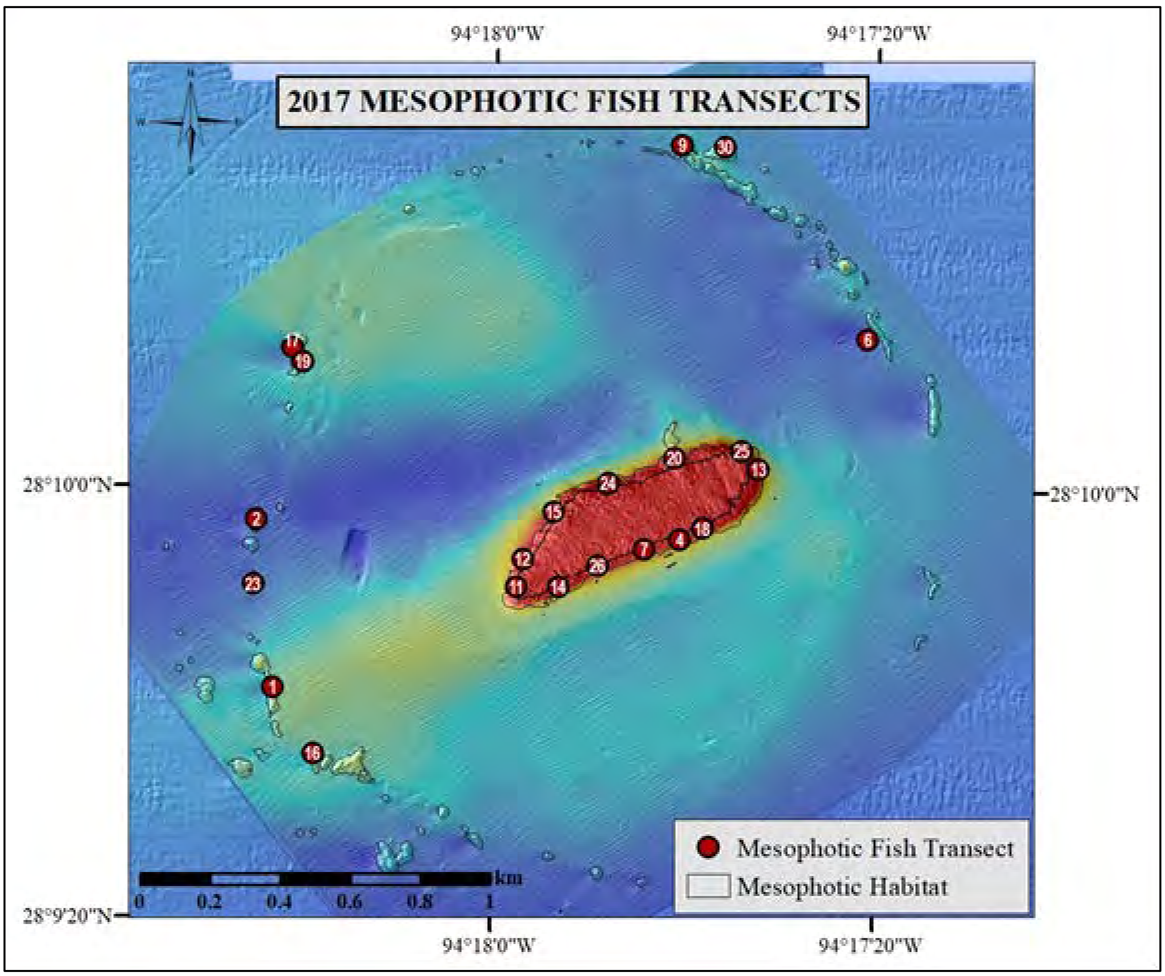


Figure 8.1. Location of mesophotic fish surveys. Image: NOAA

Sighting Frequency and Occurrence

The most frequently sighted species in the mesophotic habitat at Stetson Bank in 2017 was yellowtail reeffish (*Chromis enchrysura*). Sighting frequencies for the top 10 most frequently observed species are shown in Table 8.1.

Table 8.1. Sighting frequency of the 10 most observed mesophotic species in each habitat. Of these, species indicated in bold were among the 10 most frequently observed in both habitats.

Species ID Family Name: Species Name (Common Name - Trophic Guild)	Sighting Frequency (%)		
	Combined	Deep Reef	Coralline Algae Reef
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish - I)	85.7	66.7	100.0
Lutjanidae: *Lutjanus campechanus* (red snapper - P)	71.4	77.8	66.7
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish - I)	66.7	66.7	66.7
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish - I)	66.7	44.4	83.3
Labridae: *Bodianus pulchellus* (spotfin hogfish - I)	66.7	22.2	100.0
Scorpaenidae: *Pterois volitans* (red lionfish - P)	61.9	55.6	66.7
Pomacentridae: *Chromis insolata* (sunshinefish - PL)	61.9	11.1	100.0
Pomacanthidae: *Pomacanthus paru* (French angelfish - I)	47.6	0.0	83.3
Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper - P)	47.6	22.2	66.7
Epinephelidae: *Epinephelus adscensionis* (rock hind - I)	42.9	0.0	75.0
Haemulidae: *Haemulon aurolineatum* (tomtate - I)	38.1	88.9	0.0
Lutjanidae: Rhomboplites aurorubens (vermilion snapper - P)	38.1	33.3	41.7
Holocentridae: Holocentrus adscensionis (squirrelfish - I)	38.1	0.0	66.7
Priacanthidae: *Priacanthus arenatus* (bigeye - PL)	28.6	55.6	8.3
Tetraodontidae: *Sphoeroides spengleri* (bandtail puffer - I)	23.8	33.3	16.7

Species were considered “rare” if they were recorded in less than 20% of surveys. “Prevalent” species were recorded in ≥20% of surveys. Over all surveys, a total of 38 species were characterized as rare, while 18 species were characterized as prevalent. No sharks or rays were observed in mesophotic fish surveys at Stetson Bank during this study period.

Density

Average fish density for all surveys was 31 individuals per 100 m^2 (± 5.6 SE). In deep reef habitat, tomtate (*Haemulon aurolineatum*) and red snapper (*Lutjanus campechanus*) had the greatest average density, with 3.5 individuals per 100 m^2 (± 1.6 SE) and 3.0 individuals per 100 m^2 (± 1.2 SE), respectively (Table 8.2). In coralline algae reef habitat, yellowtail reeffish and juvenile vermilion snapper (*Rhomboplites aurorubens*) had the greatest average density, with 19 individuals per 100 m^2 (± 3.4 SE) and 7 individuals per 100 m^2 (± 2.9 SE), respectively.

Table 8.2. Average density (individuals/100 m^2) of the 10 densest mesophotic species, ± standard error, in each habitat. Of these, species indicated in bold were among the 10 densest species in both habitats. Dashes indicate that the species was not observed.

Species ID	Density (Individuals/100 m^2)		
Family Name: Species Name (Common Name - Trophic Guild)	Combined	Deep Reef	Coralline Algae Reef
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish - I)	11.1 ± 2.8	0.6 ± 0.4	19.0 ± 3.4
Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper - P)	4.7 ± 1.8	1.4 ± 0.9	7.2 ± 2.9
Pomacentridae: *Chromis insolata* (sunshinefish - PL)	3.1 ± 1.2	<0.1 ± 0.0	5.5 ± 1.8
Lutjanidae: *Lutjanus campechanus* (red snapper - P)	2.6 ± 0.6	3.0 ± 1.2	2.4 ± 0.7
Haemulidae: *Haemulon aurolineatum* (tomtate - I)	1.5 ± 0.7	3.5 ± 1.6	-
Labridae: *Bodianus pulchellus* (spotfin hogfish - I)	1.2 ± 0.4	0.1 ± 0.0	2.1 ± 0.5
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish - I)	0.7 ± 0.3	0.3 ± 0.1	1.0 ± 0.5
Apogonidae: *Apogon affinis* (bigtooth cardinalfish - I)	0.6 ± 0.6	-	1.0 ± 1.0
Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper - P)	0.4 ± 0.1	0.1 ± 0.1	0.6 ± 0.2
Pomacentridae: *Chromis scotti* (purple reeffish - PL)	0.4 ± 0.2	-	0.6 ± 0.3
Priacanthidae: *Priacanthus arenatus* (bigeye - PL)	0.4 ± 0.2	0.8 ± 0.4	<0.1 ± 0.0
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish - I)	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Scorpaenidae: *Pterois volitans* (red lionfish - P)	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Chaetodontidae: *Chaetodon ocellatus* (spotfin butterflyfish - I)	0.1 ± 0.1	0.2 ± 0.1	<0.1 ± 0.0

Biomass

Average biomass in all surveys was 1141.2g/100 m^2 (± 151.6 SE). Red snapper and tomtate had the greatest average biomass in deep reef habitat, with 670.3g/100 m^2 (± 282.0 SE) and 104.2g/100 m^2 (± 54.9 SE), respectively (Table 8.3). In coralline algae habitat, red snapper and French angelfish (*Pomacanthus paru*) had the greatest average biomass, with 483.0g/100 m^2 (± 157.8 SE) and 191.0 g/100 m^2 (± 65.6 SE), respectively.

Table 8.3. Average biomass of the top 10 mesophotic species, ± standard error, in each habitat. Of these, species indicated with bold text were among the top 10 biomass contributors in both habitats. Dashes indicate that the species was not observed.

Species ID	Biomass (g/100 m2)		
Family Name: Species Name (Common Name - Trophic Guild	Combined	Deep Reef	Coralline Algae Reef
Lutjanidae: *Lutjanus campechanus* (red snapper - P)	563.3 ± 147.9	670.3 ± 282.0	483.0 ± 157.8
Pomacanthidae: *Pomacanthus paru* (French angelfish - I)	109.2 ± 42.4	-	191.0 ± 65.6
Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper - P)	107.4 ± 50.9	53.3 ± 38.0	148.1 ± 84.3
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish - I)	70.0 ± 26.3	89.8 ± 47.1	55.1 ± 30.6
Haemulidae: *Haemulon aurolineatum* (tomtate - I)	44.7 ± 25.5	104.2 ± 54.9	-
Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper - P)	32.7 ± 14.8	63.1 ± 32.3	9.9 ± 4.7
Labridae: *Bodianus pulchellus* (spotfin hogfish - I)	26.3 ± 11.8	1.3 ± 1.1	45.1 ± 19.2
Carangidae: *Seriola rivoliana* (Almaco jack - P)	21.4 ± 15.8	36.2 ± 36.2	10.2 ± 6.9
Scorpaenidae: *Pterois volitans* (red lionfish - P)	18.9 ± 8.4	12.6 ± 6.1	23.6 ± 14.1
Sphyraenidae: *Sphyraena barracuda* (great barracuda - P)	17.4 ± 12.9	-	30.5 ± 22.2
Epinephelidae: Epinephelus adscensionis (rock hind - I)	17.3 ± 5.1	-	30.3 ± 6.7
Priacanthidae: *Priacanthus arenatus* (bigeye - PL)	17.2 ± 8.0	37.9 ± 16.5	1.7 ± 1.7
Epinephelidae: Paranthias furcifer (Atlantic creolefish - PL)	13.7 ± 9.7	-	23.9 ± 16.6
Chaetodontidae: Chaetodon sedentarius (reef butterflyfish - I)	12.0 ± 4.5	4.1 ± 1.8	18.0 ± 7.5
Chaetodontidae: *Chaetodon ocellatus* (spotfin butterflyfish - I)	4.7 ± 3.5	9.1 ± 8.2	1.4 ± 1.1

Trophic Guilds

Species richness within trophic guilds was calculated overall and by habitat type (Table 8.4). Invertivores possessed the greatest average species richness overall, with seven species (± 0.8 SE) comprising the guild, and herbivores possessed the lowest average species richness overall, with one species (± 0.3 SE) comprising the guild.

Table 8.4. Average mesophotic fish species richness within trophic guilds.

Trophic Guild	Combined	Deep Reef	Coralline Algae Reef
Herbivore	1 ± 0.3	0 ± 0.1	1 ± 0.4
Invertivore	7 ± 0.8	4 ± 0.5	10 ± 0.7
Piscivore	3 ± 0.3	2 ± 0.2	3 ± 0.5
Planktivore	2 ± 0.2	1 ± 0.2	2 ± 0.3

The contribution of each trophic guild to the observed density and biomass overall and by habitat was calculated (Table 8.5). In deep reef habitat, invertivores and piscivores contributed most to observed density of fishes (48.1 % and 44.1 %, respectively). In coralline algae reef habitat, invertivores contributed the most to observed density (57.6 %). For both deep reef and coralline algae reef habitat, herbivores contributed the least (0.3% and 2.5 %, respectively). Observed biomass in both deep reef and coralline algae reef habitat was primarily piscivores (77.2 % and 60.7 %, respectively).

Table 8.5. Percent contribution of mesophotic fish trophic guild to density and biomass.

Trophic Guild	Density (% Contribution)			Biomass (% Contribution)		
	Combined	Deep Reef	Coralline Algae Reef	Combined	Deep Reef	Coralline Algae Reef
Herbivore	2.2	0.3	2.5	1.1	<0.1	1.8
Invertivore	56.1	48.1	57.6	28.7	19.4	35.1
Piscivore	27.3	44.1	24.1	67.4	77.2	60.7
Planktivore	14.5	7.5	15.8	2.8	3.5	2.4

The three species contributing the most to observed density and biomass within each habitat type from each trophic guild are shown in Tables 8.6 and 8.7, respectively.

Table 8.6. Percent contribution of density of the top three mesophotic species in each habitat and trophic guild. Of these, species indicated in bold were among the three densest species in both habitats.

Trophic Guild	Species ID Family Name: Species Name (Common Name)	% Contribution to Trophic Density		
		Combined	Deep Reef	Coralline Algae Reef
H	**Pomacentridae: *Stegastes variabilis* (cocoa damselfish)**	35.0	33.3	35.1
	Acanthuridae: *Acanthurus chirurgus* (doctorfish)	18.2	-	19.1
	Pomacentridae: *Pomacentridae* (damselfish spp.)	17.5	11.5	15.0
I	**Pomacentridae: *Chromis enchrysura* (yellowtail reeffish)**	63.9	10.9	71.9
	Haemulidae: *Haemulon aurolineatum* (tomtate)	8.6	65.6	-
	Labridae: *Bodianus pulchellus* (spotfin hogfish)	7.0	1.3	7.9
	Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish)	4.2	6.2	3.8
	Pomacanthidae: Holacanthus bermudensis (blue angelfish)	1.8	6.6	1.1
P	**Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper)**	57.6	29.0	67.4
	Lutjanidae: *Lutjanus campechanus* (red snapper)	32.2	61.5	22.1
	Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper)	4.6	2.1	5.5
	Scorpaenidae: *Pterois volitans* (red lionfish)	3.6	6.1	2.7
PL	**Pomacentridae: *Chromis insolata* (sunshinefish)**	72.4	3.6	78.5
	Pomacentridae: *Chromis scotti* (purple reeffish)	8.3	-	9.0
	Priacanthidae: *Priacanthus arenatus* (bigeye)	8.2	96.4	0.3
	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish)	5.7	-	6.2

Table 8.7. Percent contribution of biomass of the top three mesophotic species in each habitat and trophic guild. Of these, species indicated in bold were among the three greatest biomass contributors in both habitats.

Trophic Guild	Species ID (Family Name: Species Name (Common Name)	% Contribution to Trophic Biomass		
		Combine d	Deep Reef	Coralline Algae Reef
H	Acanthuridae: *Acanthurus chirurgus* (doctorfish)	44.9	-	45.9
	Acanthuridae: *Acanthurus*. (surgeonfish spp.)	44.7	-	45.6
	Pomacentridae: *Stegastes variabilis* (cocoa damselfish)	4.9	2.2	4.9
	Pomacentridae: *Pomacentridae* (damselfish spp.)	2.4	97.8	0.4
I	Pomacanthidae: *Pomacanthus paru* (French angelfish)	33.3	-	108.5
	Pomacanthidae: *Holacanthus bermudensis* (blue angelfish)	21.4	42.7	31.3
	Haemulidae: *Haemulon aurolineatum* (tomtate)	13.6	49.5	-
	Chaetodontidae: *Chaetodon ocellatus* (spotfin butterflyfish)	1.4	4.3	0.8
P	**Lutjanidae: *Lutjanus campechanus* (red snapper)**	73.2	79.9	67.4
	Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper)	14.0	6.4	20.7
	Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper)	4.2	7.5	1.4
	Sphyraenidae: *Sphyraena barracuda* (great barracuda)	2.3	-	4.3
PL	**Priacanthidae: *Priacanthus arenatus* (bigeye)**	53.6	100.0	6.2
	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish)	42.5	-	85.9
	Pomacentridae: *Chromis insolata* (sunshinefish)	2.5	-	5.1

Size-Frequency

Size frequency, using relative abundance, was calculated for all surveys and for each trophic guild (Table 8.2). In all surveys combined, 63.6% of individuals were <5 cm. All trophic guilds had at least a plurality of small individuals (<5 cm) in coralline algae reef. However, deep reef piscivores and planktivores were predominately medium sized individuals (15 cm to 30 cm).

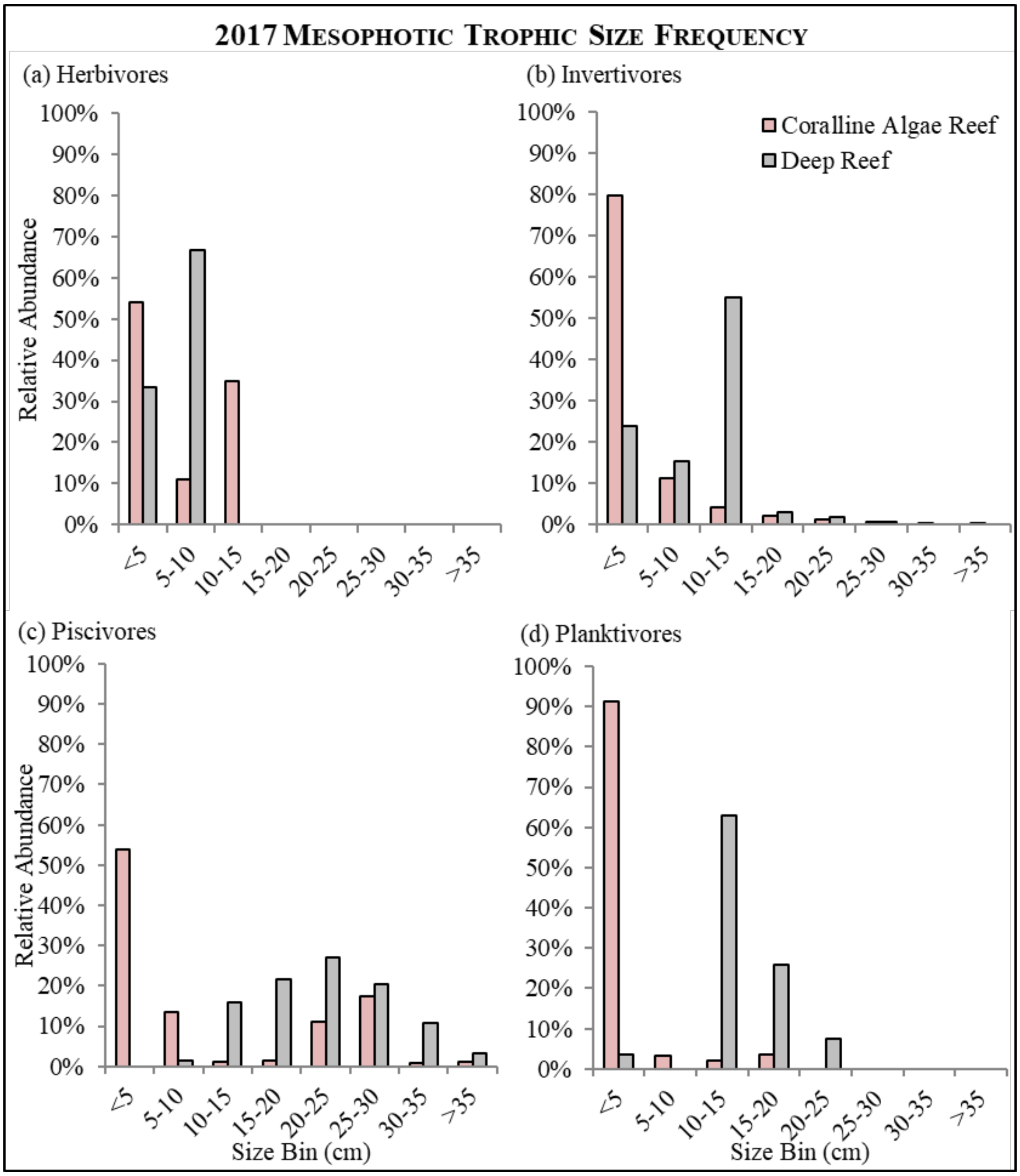


Figure 8.2. Size distribution by trophic guild. Pink columns represent coralline algae reef and gray columns are deep reef.

Dominance Plots

When averaged for all samples, dominance plots (abundance-biomass curve) *w* values were slightly positive, 0.14 (± 0.03 SE). Coralline algae reef habitat had mean *w* statistic close to zero, while deep reef habitat was slightly positive (0.07 ± 0.02 SE; 0.22 ± 0.07 SE).

Spatial Analysis

When surveys were projected spatially, general trends in species distributions were observed. The density of each trophic guild at each survey site was projected (Figure 8.3). During this study period, density of piscivores was noticeably greater in the deep reef habitat surrounding the main feature of Stetson Bank, primarily due to the density of red snapper. Conversely, invertivore density was higher around the main feature of the bank in coralline algae habitat due to the density of yellowtail reeffish.

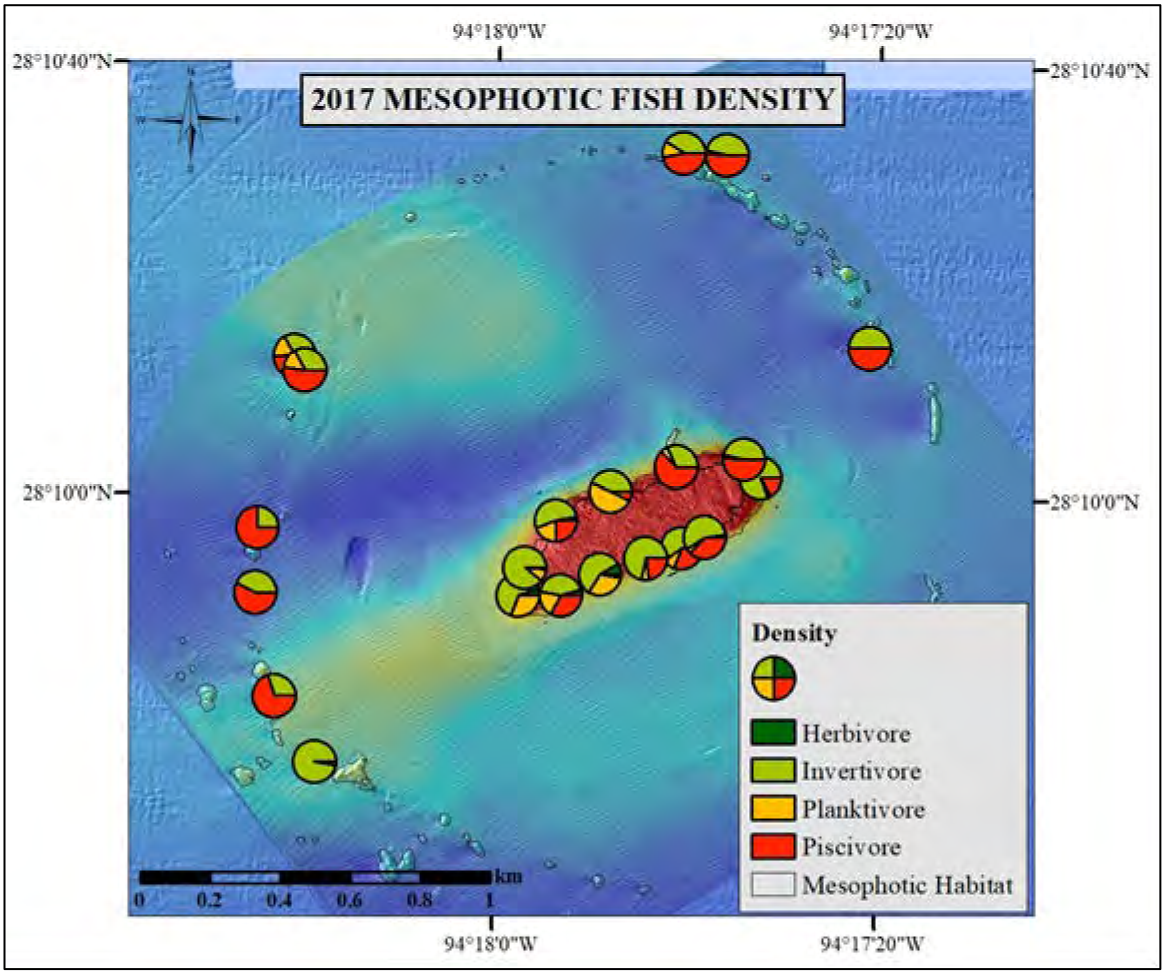


Figure 8.3. Spatial projection of mesophotic fish trophic density. Each chart represents the location at which a survey was conducted. Image: NOAA

The biomass of each trophic guild at each survey site was also projected (Figure 8.4). During this study period, piscivores predominated biomass in most surveys, due to the density of red snapper in both habitats.

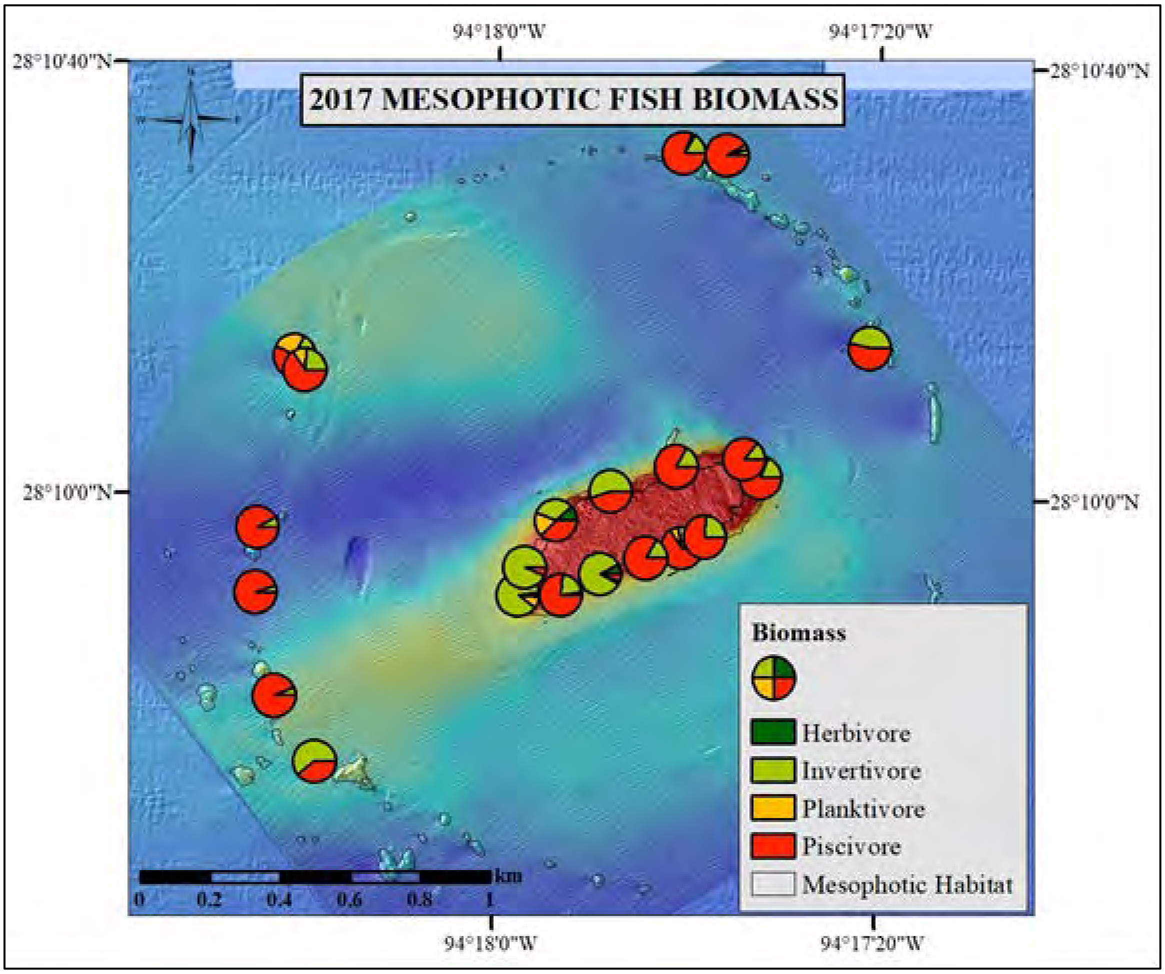


Figure 8.4. Spatial projection of mesophotic fish trophic biomass. Charts represents the location at which a survey was conducted. Image: NOAA

Discussion

This data collection period represents the third year of quantitative mesophotic fish surveys at Stetson Bank. Fish communities are considered an important component in monitoring programs as they can be indicators of ecosystem health (Sale 1991). The addition of mesophotic fish communities to this monitoring program will enable researchers and managers to better understand, monitor, and track changes in these deeper communities.

While direct comparison is not possible due to the different methods employed, these deeper communities were notably different than shallow bank crest communities. The mesophotic fish community was variable and composed of both commercially and recreationally valuable fish species. They were heavily predominated by piscivorous fishes and lacked herbivorous fishes.

Fish in mesophotic habitat at Stetson Bank in 2017 were mostly comprised of small individuals, <5 cm. Abundance-biomass comparisons indicated the mesophotic fish community at Stetson Bank appears to be equally balanced between abundance and biomass in coralline algae reef habitat but deep reef habitat is slightly biomass predominant.

Spatial analysis highlights the importance of mesophotic patch reefs for piscivorous fish, with biomass in both deep reef and coralline algae reef habitats predominantly piscivores. However, density in both habitats was mostly invertivores (primarily yellowtail reeffish).

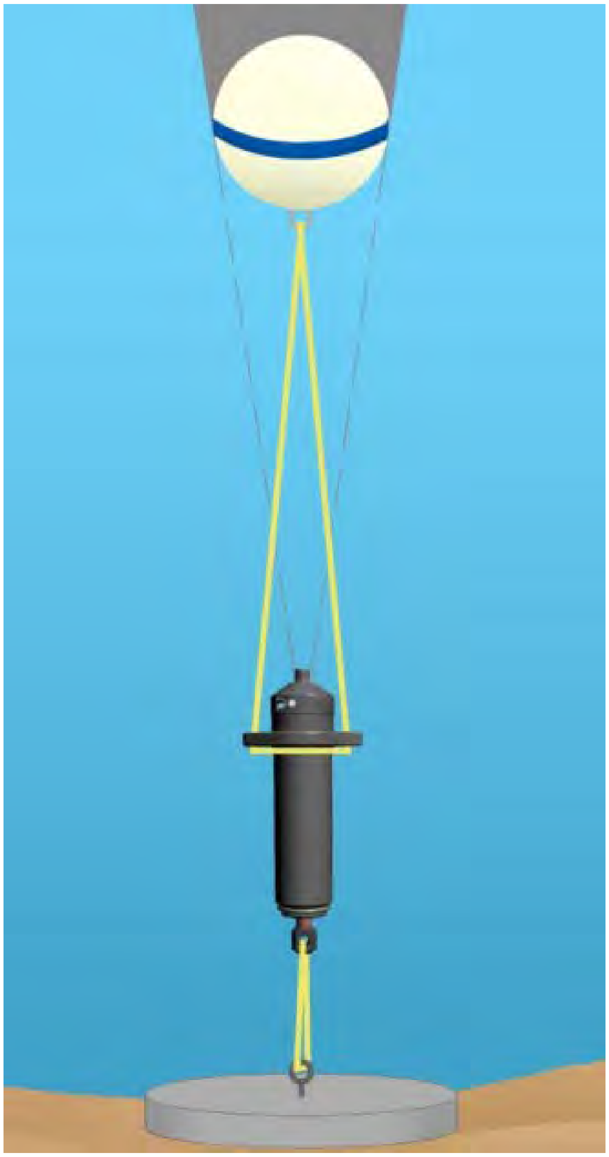
On the bank crest of Stetson Bank, scuba divers have reported lionfish since 2011. Lionfish were first documented in the first mesophotic fish surveys of this study in 2015 and continue to be documented in 2017. The invasion of this exotic species is of particular concern due to their voracious appetite, high fecundity, and apparent lack of predators. The biomass and density of lionfish in 2017 appeared in the top 10 in both habitat types and the species was the sixth most frequently sighted species on all surveys.

Continued monitoring of fish communities at Stetson Bank will help establish the degree of natural variation occurring in the community, allowing for more sensitive analysis to detect significant changes from the normal variation of the fish assemblage.

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.
    - Previous years established a minimum field of view of 5 m to consider the visibility sufficient. For 2017, this minimum was reduced to 3 m, increasing the number of usable surveys in deep reef habitat from two to nine.

MESOPHOTIC WATER TEMPERATURE



VEMCO acoustic release system setup. Image: VEMCO

Introduction

Water temperature loggers were deployed at Stetson Bank in July 2015 to collect water temperature data every hour. Two instruments were deployed on a single acoustic release system, one at 54 m and one at 44 m (Figure 9.1).

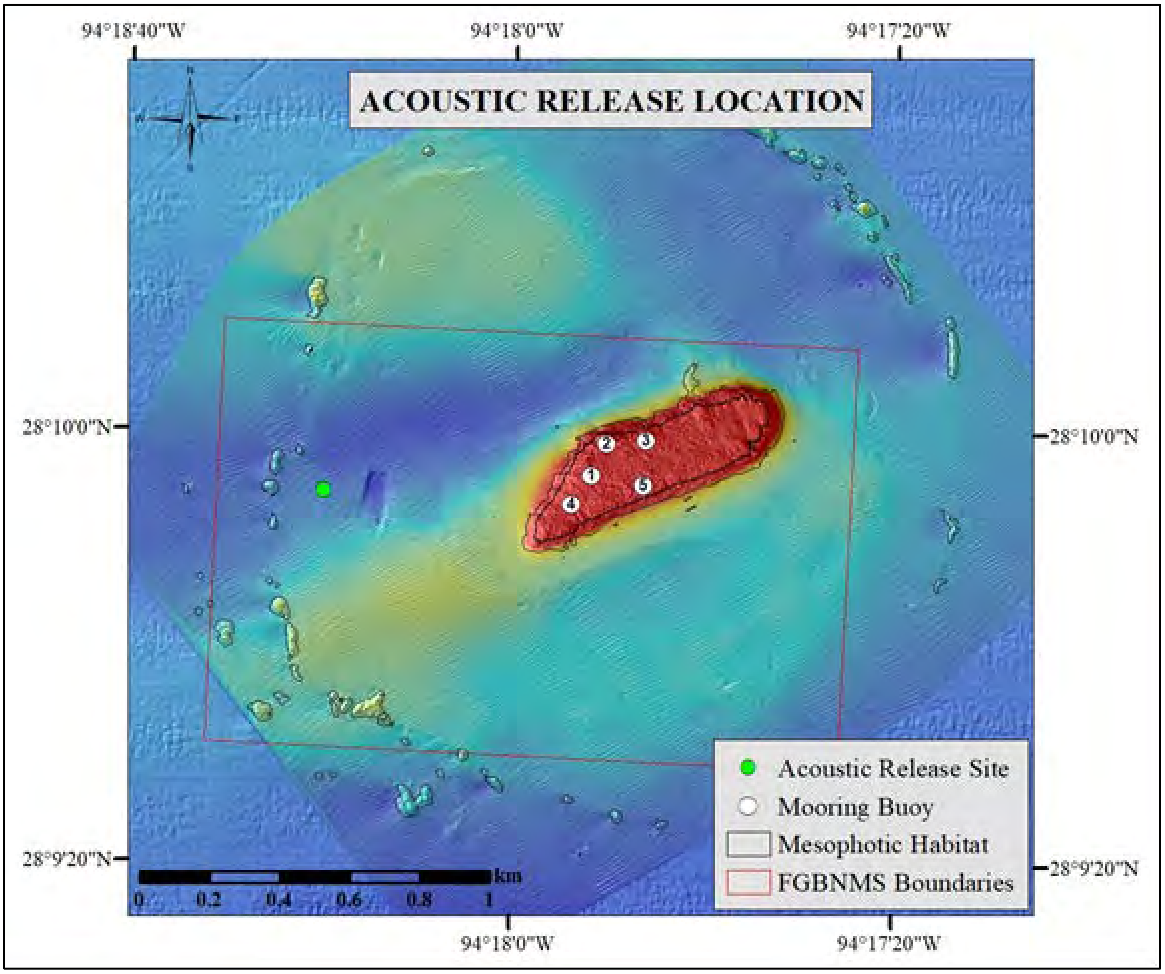


Figure 9.1. Location of the acoustic release system. System holds instruments at 54 m and 44 m to record water temperature every hour. Image: NOAA

Methods

Field Methods

Acoustic Release System

Both instruments were deployed on an acoustic release system to allow easy deployment and retrieval, without the need for an ROV. A VEMCO VR2AR, in conjunction with a VR100 receiver, was used as the acoustic release system. In addition to the acoustic release system, the instrument can record and log water temperature. The VR2AR was deployed using a concrete block (approximately 18 kg) connected to the releasing lug on the VR2AR. A hard trawl float (8 kg buoyancy) was connected to the receiver of the VR2AR via 10 m of wire rope.

Temperature Loggers

The VEMCO VR2AR was deployed at 54 m to record temperature at that depth. An Onset® Computer Corporation HOBO® Pro v2 U22-001 thermograph was attached to the wire rope 10 m above the VR2AR. Both instruments were set to record temperature hourly. Every six months the instrument will be collected, downloaded, maintained, and redeployed.

Data Processing

Temperature data obtained from loggers were downloaded and processed every six months. The 24 hourly readings obtained each day were averaged into one daily value and recorded in a database. Separate databases were maintained for each type of logger.

Results

No data are available at this time.

Discussion

Water temperature is one of many factors that can affect species composition and health. Generally, temperature stability increases with depth. Divers deploy reef-based instruments to a maximum depth of 40 m. These mesophotic instruments expand the temperature array off the main reef feature at Stetson Bank to a maximum depth of 54 m. Temperature fluctuations at these sites will help researchers better understand the mesophotic environment at Stetson Bank and observe potential upwelling or other events that affect ecosystem processes.

Challenges and Resolutions

- When instrument retrieval was attempted on November 3, 2015, surface communication with the system indicated that the instrument was no longer vertical in the water column, but laying horizontally on the seafloor. A release was attempted, and executed by the instrument, but the instrument did not rise to the surface. In July 2016, a plan to recover the unit using an ROV was unsuccessful due to the failure of the sampling skid on the ROV.
    - It is presumed something has happened to the flotation on the instrument, which both holds it vertical in the water column and provides the flotation to return it to the surface. As collection in 2017 using an ROV was not possible, we plan to attempt a recovery during the mesophotic cruise in 2018.

VIDEO OBSERVATIONS, NOTES, AND OTHER RESEARCH

A pair of unicorn filefish, *Aluterus Monoceros*, at Stetson Bank. Photo: G.P. Schmahl/NOAA

Introduction

Permanent video transects 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

Field Methods

Bank Crest Video Transects

Three 100 m permanent transects were installed at Stetson Bank in 2015. Each transect 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 area available on the site maps. Before recording on video, 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 swam along the transect line, following the line with the plumb bob. The camera was maintained at a 45^{o} angle to the reef during filming.

Mesophotic Video Transects

None were completed in 2017.

General Observations

General observations were recorded throughout the field work. Observations of biology, geology, marine debris, and operations were made and recorded as notes on each transect.

Data Processing

Notes and observations were made from each transect and recorded in Microsoft® Excel®. Notes were reviewed for interesting or important information.

Results

Bank crest video transects captured moderate densities of long-spined sea urchins and three queen conch (*Lobatus gigas*). Sponges and corals appeared to be in good health with no notable impacts. Green turbid water was present during the survey on all transects and two transects had notably higher cover of *Dictyota* sp. algae on the seafloor.

No mesophotic video transects were completed in 2017 due to limited time.

General observations on the shallow reef cruise included observations of multiple jellies, including Atlantic sea nettles (*Chrysaora quinquecirrha*) and warty sea wasp (*Carybdea marsupialis*); spinner sharks; studded sea stars (*Mithrodia clavigera*); unicorn filefish (*Aluterus monoceros*); reticulated cowry helmet (*Cypraecassis testiculus*); and dense schools of juvenile grunts (likely tomtate and/or cottonwick) and juvenile vermilion Snapper. Algae on the bank crest appeared much more abundant than in 2016.

Discussion

Several interesting observations were made during the 2017 field season. The presence of green water was captured visually in transect video on the bank crest with divers noting an abundance of jellies in the upper water column and *Dictyota* sp. on the seafloor. Divers also noted more queen conch on the bank crest compared to previous years, and some unusual echinoderm (studded sea star) and fish species (unicorn filefish).

Other Research

1. In 2017, a team led by Dr. Santiago Herrera of Lehigh University conducted work in the mesophotic habitats at Stetson Bank. The team collected samples of the gorgonian *Hypnogorgia/Muricea pendula* for a study entitled “Population connectivity of deep-water coral in the northern Gulf of Mexico,” funded by the NOAA RESTORE Act Science Program.
2. Sound trap deployments, led by Dr. Jenni Stanley of Woods Hole Oceanographic Institution in collaboration with NOAA’s Office of National Marine Sanctuaries, continued at Stetson Bank in 2017.
3. Ron Eytan of Texas A&M University at Galveston collected sailfin blennies at Stetson Bank in 2017 for a study entitled “Genetic connectivity of blenny populations, cryptic endemism, and genetics of hybrid breakdown in coral reef fishes in the Gulf of Mexico and greater Caribbean.”
4. NOAA Fisheries SEAMAP Reef Fish project conducted assessments at Stetson Bank in 2017. Surveys conducted included camera array deployments, bandit reel collections, and CTD profiles.

Conclusions

This report summarizes the findings from the annual monitoring conducted at Stetson Bank in 2017. Both bank crest and mesophotic habitat were surveyed in this study period.

The bank crest of Stetson Bank has been monitored for over 20 years. While repetitive photostations do not capture the entire reef community, this form of benthic monitoring has been conducted annually on the reef since 1993, and documented a significant shift from sponge-coral community to algal community over that time. Data from this study period showed a continued increase in macroalgae cover since 2014, decreasing the availability of open substrate for colonization. This finding was also supported in random transect data. Interestingly, multiple colonies of sponges, from the two primary sponge species observed on the bank, disappeared from repetitive photostations between the 2016 and 2017 monitoring period. The cause is unknown.

Water column temperatures were warmer than average for most of the study period, but cooler than average in the summer months. No days were documented with water temperatures on the bank crest over 30ºC. Salinity was higher than average through spring and early summer, and while divers noted green water during the reef crest monitoring cruise, low salinity was not recorded by the instrument at depth. All nutrient samples in 2017 were below detectable limits and carbonate chemistry indicates that this area, despite its proximity to the land, more closely resembles an open ocean setting, and acts as a small net CO_2 sink.

Hurricane Harvey impacted the region in late August 2017. Before the hurricane, divers reported green water at Stetson Bank. The hurricane passed within 26km of Stetson Bank as a tropical storm. No mechanical damage was observed on the bank crest, but turbid water was observed in the water column in the months following the hurricane. While the available data do not indicate freshwater of coastal origin was present at the bank during sampling periods, continuous water quality monitoring instruments were not functional through the fall of 2017. Therefore, whether low salinity water was present on the bank crest following the event is unknown.

Mesophotic benthic habitats at Stetson Bank were quantitatively surveyed for the third time in 2017. Two distinct habitats were documented, each with a unique biotic community. While cover was low on mesophotic reefs in general, density of select small stony coral species was high on mesophotic reefs within coralline algae reef habitat, and density of black coral species was high on mesophotic reefs in deep coral habitat.

While a direct comparison is not possible due to the different methods used, fish communities between the bank crest and mesophotic habitat appear to be very different. The mesophotic habitat appears to be an important location for piscivorous fishes while the bank crest supports a greater proportion of invertivorous fishes. The predominant species observed in mesophotic habitat at Stetson Bank are commercially- and recreationally-valuable species and the juvenile stage of some of these species were seen in high abundance on the bank crest. Lionfish were documented on both the reef crest and mesophotic habitats, and continued to appear in greater densities in mesophotic habitat in 2017 than in previous years.

Several challenges were encountered during this study period, particularly with mesophotic monitoring tasks and water quality instrumentation. The ability to capture repetitive imagery of the mesophotic repetitive photostations proved again to be the greatest challenge in completing field work, with two repetitive sites not located. Poor visibility made locating site markers difficult and conducting fish surveys challenging. In addition, due to cruise shortening for foul weather, the mesophotic thermistors were not collected. On the bank crest, SeaBird instrumentation drifted and then failed in the summer, missing temperature, salinity, and turbidity data collection through the fall.

To date, this monitoring program represents one of the longest running monitoring efforts of a northern latitude coral community. An ongoing monitoring program at Stetson Bank is essential to monitor the drivers of ecosystem variation and change in the northern Gulf of Mexico. Sustained monitoring will continue to document changes in the condition of the reef and will be useful for management decisions and future research.

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Glossary of Acronyms

BSEE – Bureau of Safety and Environmental Enforcement
CCL – Carbon Cycle Laboratory
CPCe – Coral Point Count® with Excel® extensions
CTD - Conductivity, temperature, and depth
EPA – Environmental Protection Agency
FGBNMS – Flower Garden Banks National Marine Sanctuary
GREAT – Gulf Reef Environmental Action Team
NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration
ROV – Remotely Operated Vehicle
TAMU-CC – Texas A&M University – Corpus Christi
TAMUG – Texas A&M University at Galveston
UNCW-UVP – University of North Carolina at Wilmington - Undersea Vehicle Program

National Marine Sanctuaries

America's Underwater Treasures