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National Oceanic and Atmospheric Administration
National Marine Sanctuaries Conservation Science Series

Stetson Bank Long-Term Monitoring: 2016 Annual Report

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Cover Photo:
Aiolochroia crassa sponge at Stetson Bank with a commonly observed algae species, *Dictyota* sp.
Photo: Marissa Nuttall /NOAA

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Abstract

This report documents study methods and summarizes key findings and field notes from the 2016 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, and supports a diverse benthic community of sponges and coral. Benthic monitoring has been conducted at the site since 1993 and was expanded in 2015 to include monitoring in the mesophotic habitats surrounding the bank crest.

In 2016, bank crest high relief habitat was documented to have higher hydrocoral and sponge cover than low relief habitat, with overall macroalgae cover increasing from 2015 levels. Bank crest fish communities were predominantly small individuals and exhibited an inverted biomass pyramid. In the mesophotic zone, two hardbottom habitats were documented: coralline algae reef and deep reef. Biotic cover on coralline algae reef was predominantly Rhodophyta (red algae) and Astrocoeniidae (stony coral), and deep reefs were dominated by Antipathidae (black coral). Mesophotic fish communities comprised small individuals, like the bank crest, and biomass was predominantly invertivores.

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 within Flower Garden Banks National Marine Sanctuary (FGBNMS). It contains a high latitude coral community, existing at the northern limit of coral community ranges. The area is considered "marginal" in environmental conditions for coral reef development and growth due to varying temperature and light availability. However, Stetson Bank supports a well-developed benthic community of tropical marine sponges, corals, and other invertebrates. 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 from >30% to <1% cover due to bleaching and has not recovered to pre-2005 levels.

In 1993, an annual long-term monitoring program was initiated at Stetson Bank by Gulf Reef Environmental Action Team (GREAT), and later conducted by FGBNMS. The monitoring focused on the bank crest 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 exploration lead to the discovery of mesophotic reefs surrounding Stetson Bank that occur outside of the current sanctuary boundary (Figure I).

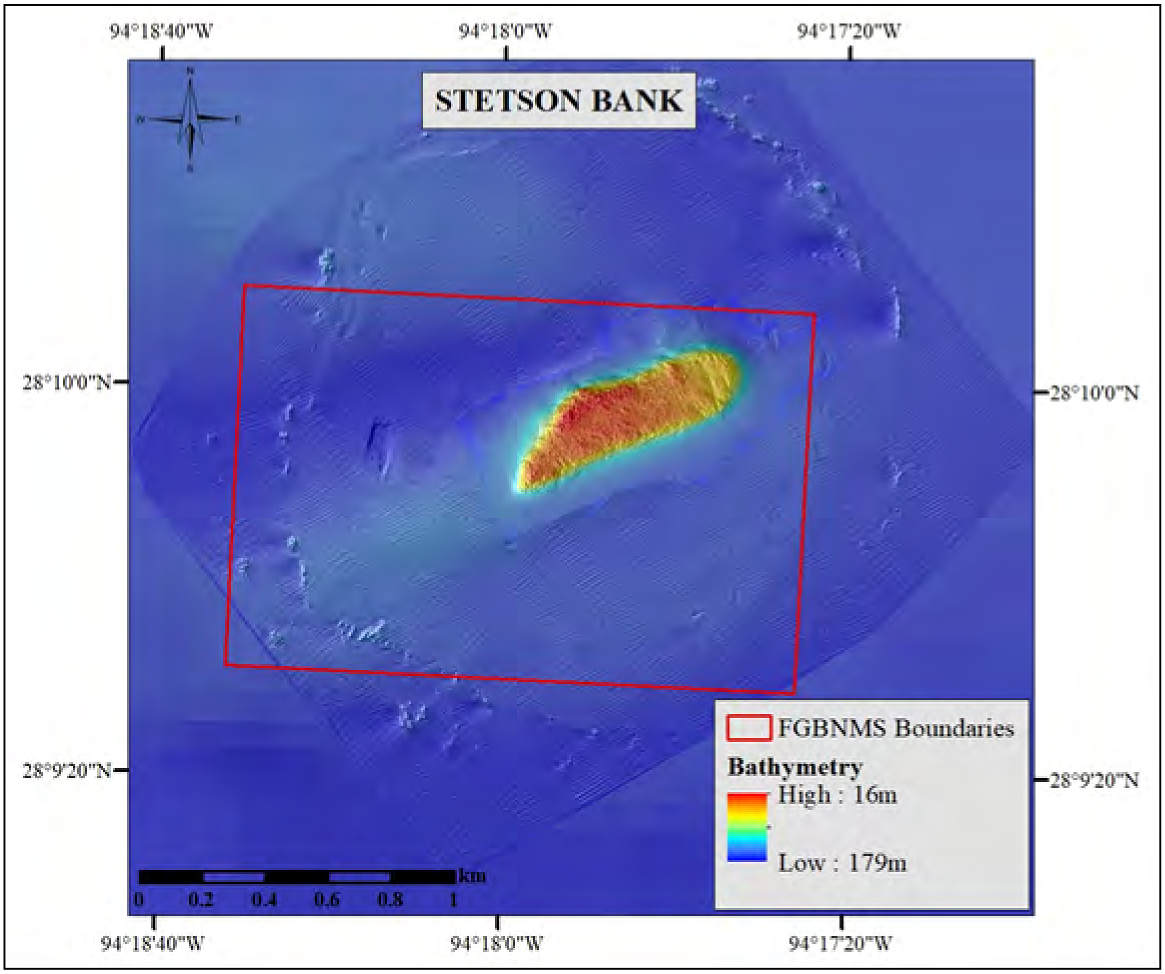


Figure I. Bathymetric map of the topography of Stetson Bank, where red lines indicate sanctuary boundary. Image: NOAA

In 2015, 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 second year of the study are presented in this report. Data were collected on seven cruises throughout the year (Table I).

Table I. Dates and primary tasks of data collection cruises for data summarized in this report.

Date	Main Task
11/2/2015 – 11/5/2015	Water quality: Instrument deployment and algae monitoring
2/17/2016 – 2/18/2016	Water quality: Instrument download and sample collection
2/28/2016 – 2/29/2016	Water quality: Sample collection and algae monitoring
5/19/2016	Water quality: Sample collection
6/7/2016 – 6/10/2016	Reef crest monitoring: Benthic and fish community monitoring
9/11/2016 – 9/15/2016	Mesophotic monitoring: Benthic and fish community monitoring
11/13/2016 – 11/15/2016	Water quality: Instrument download and sample collection

To date, the monitoring program at Stetson Bank represents one of the longest 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 in documenting and tracking their impacts on 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 48 contains a large *Pseudodiploria strigosa* colony along with the hydrocoral *Millepora alcicornis* and multiple sponges. Photo: Ryan J. Eckert, NOAA

Introduction

Permanent photostations have been in place on Stetson Bank since 1993. Locations were selected along high relief hardbottom features at biologically diverse locations by scuba divers, and marked using nails or eyebolts and numbered tags. Initially, 36 permanent photostations were installed. Over time, many of these stations have been lost, and new stations have been established. As of 2016, a total of 59 stations, with 18 of the original stations, were in use. All of these photostations occur on the hardbottom habitat accessible from permanent mooring buoys 1, 2, and 3 (Table 1.1, Figure 1.1). Each station, which is marked by a metal pin or eye-bolt and numbered cattle tag, 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.

Table 1.1. Coordinates and depths of permanent mooring buoys used to access repetitive photostations 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

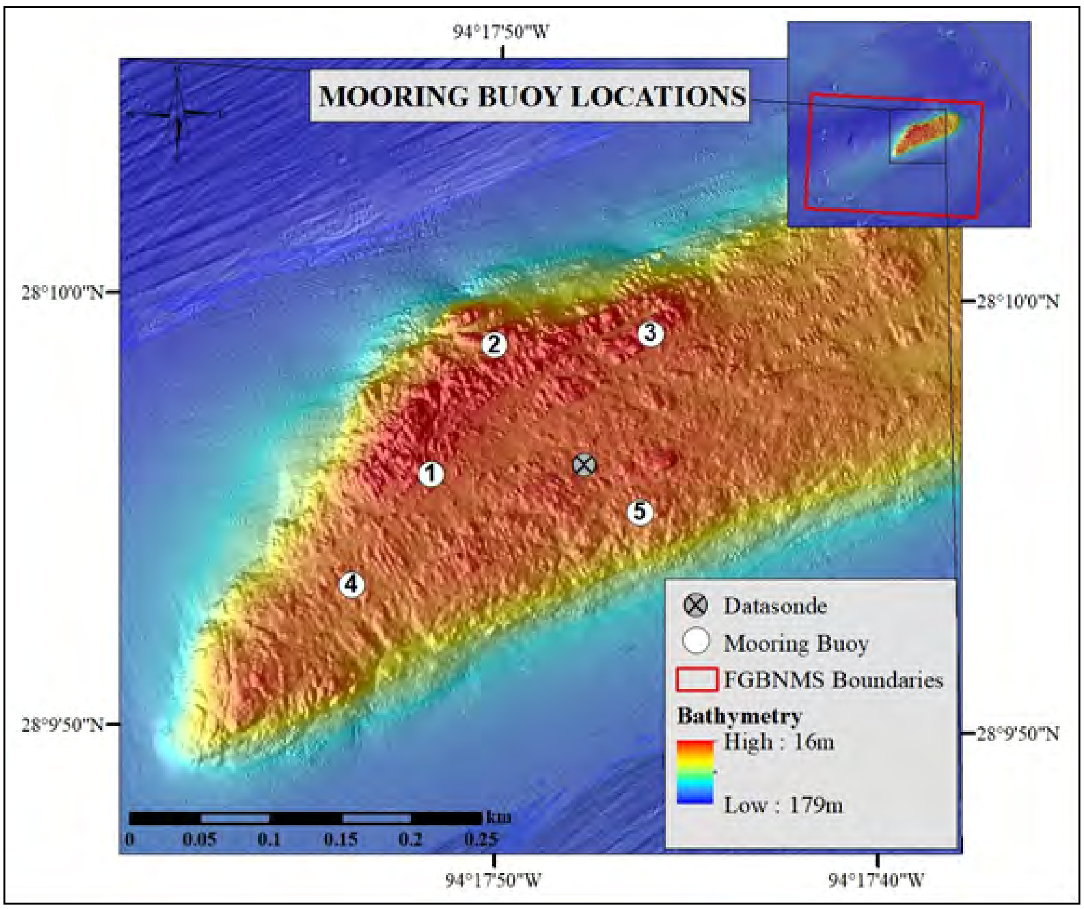


Figure 1.1. Bathymetric map of Stetson Bank showing the seafloor topography and mooring buoy locations. Image: NOAA

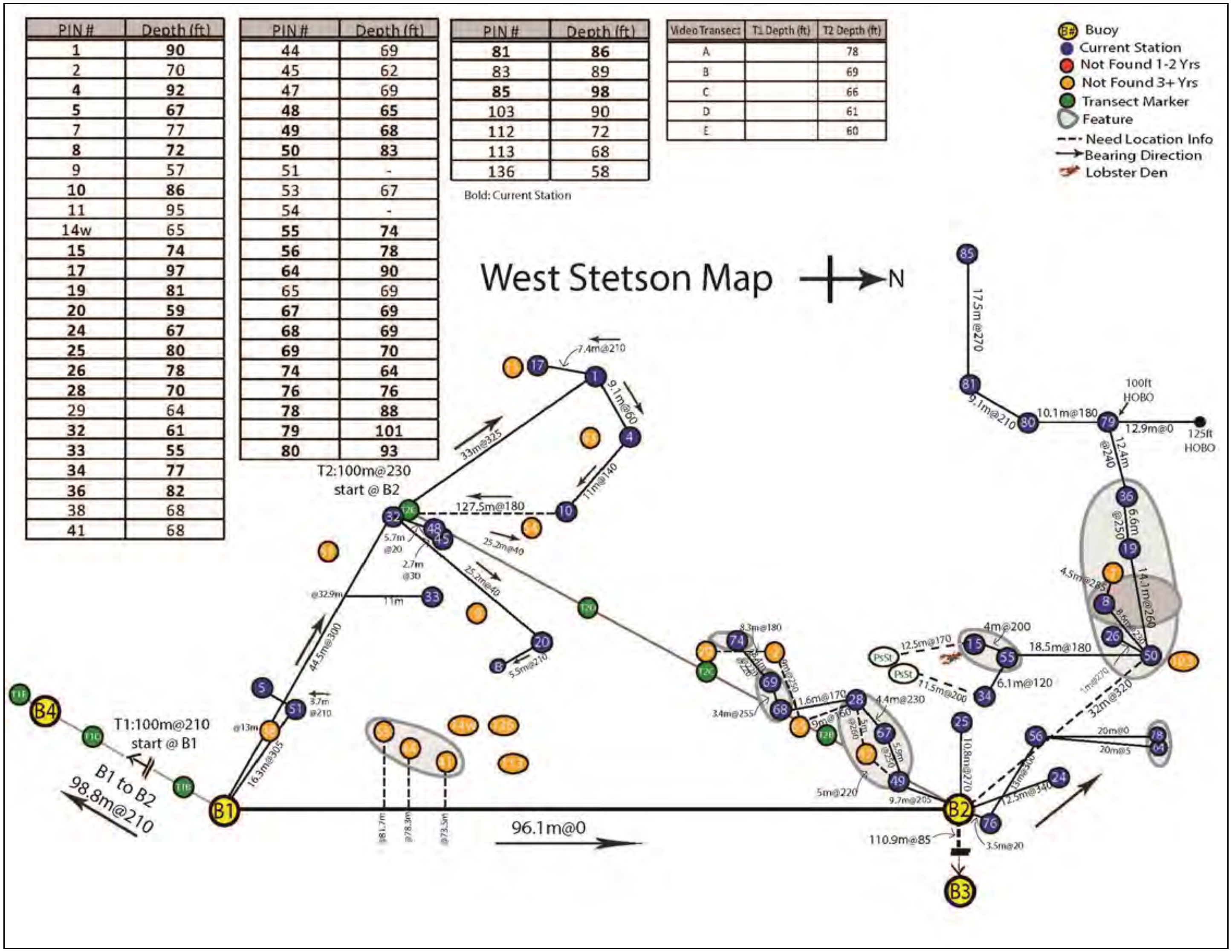
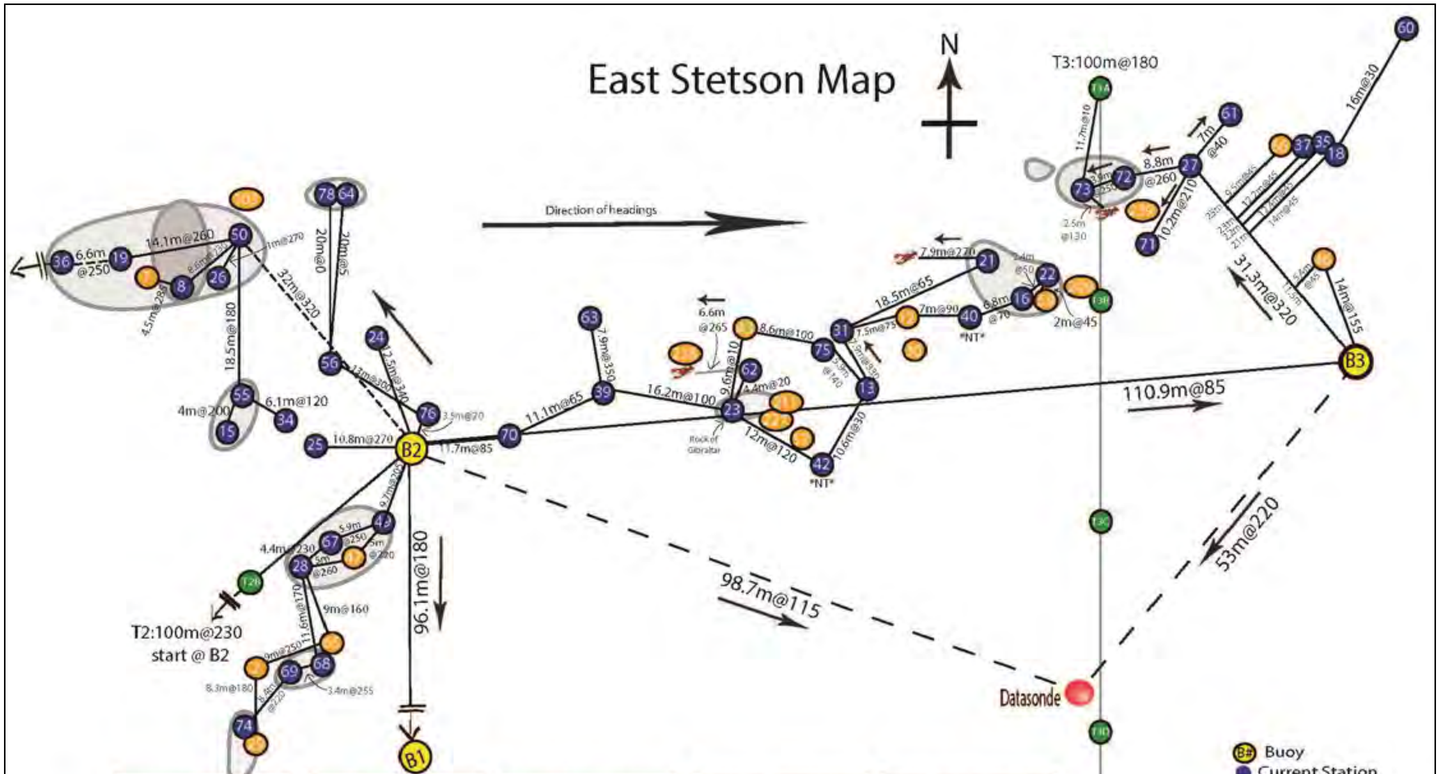


Figure 1.2. West Stetson map, used by divers to locate the repetitive photostations in the study site. Image: NOAA



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	-

Bold: Current Station

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, using floating plastic chains with attached weights. Divers then photographed each station. In 2016, 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 to 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 and images taken in a vertical and northward orientation 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.

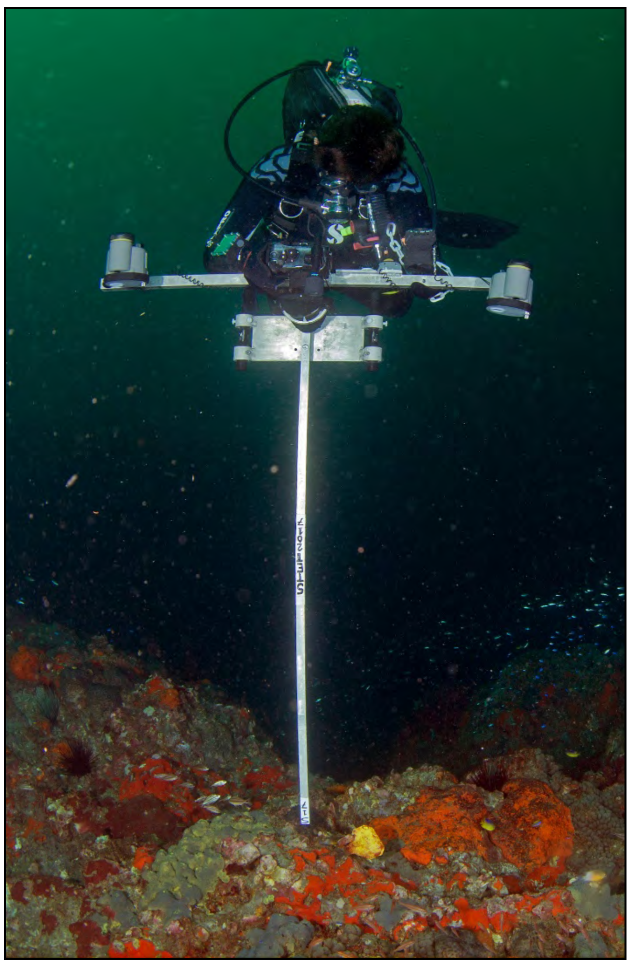


Figure 1.4. T-frame configuration. G11 Fisheye FIX® housing mounted to the frame, set at 1.5 m from the substrate, with two Inon® Z240 strobes, set 1.2 m apart. Photo: George P. Schmahl/NOAA

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 were identified to lowest possible taxonomic group (macroalgae included algae longer than approximately 3 mm and included thick algal turfs); and 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 was recorded as a note with each point. Summary data were grouped into six functional categories: scleractinian coral, hydrocoral, sponge, macroalgae, colonizable substrate, and other biota. Rubble was not presented 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

A total of 59 repetitive photostations were located and photographed, six of which required refurbishment. No new stations were installed in 2016. Depth of the stations ranged from 16.8 - 30.8 m, with an average station depth of 23.0 m.

Mean scleractinian cover was 4.7% (± 1.5 SE), hydrocoral cover was 1.8% (± 0.7 SE), sponge cover was 16.2% (± 1.5 SE), macroalgae cover was 30.7% (± 1.9 SE), colonizable substrate cover was 43.0%. (± 2.5 SE), and other biota cover was 1.7% (± 0.4 SE) (Figure 1.5). Average species richness at each station was 9.0 (± 0.2 SE).

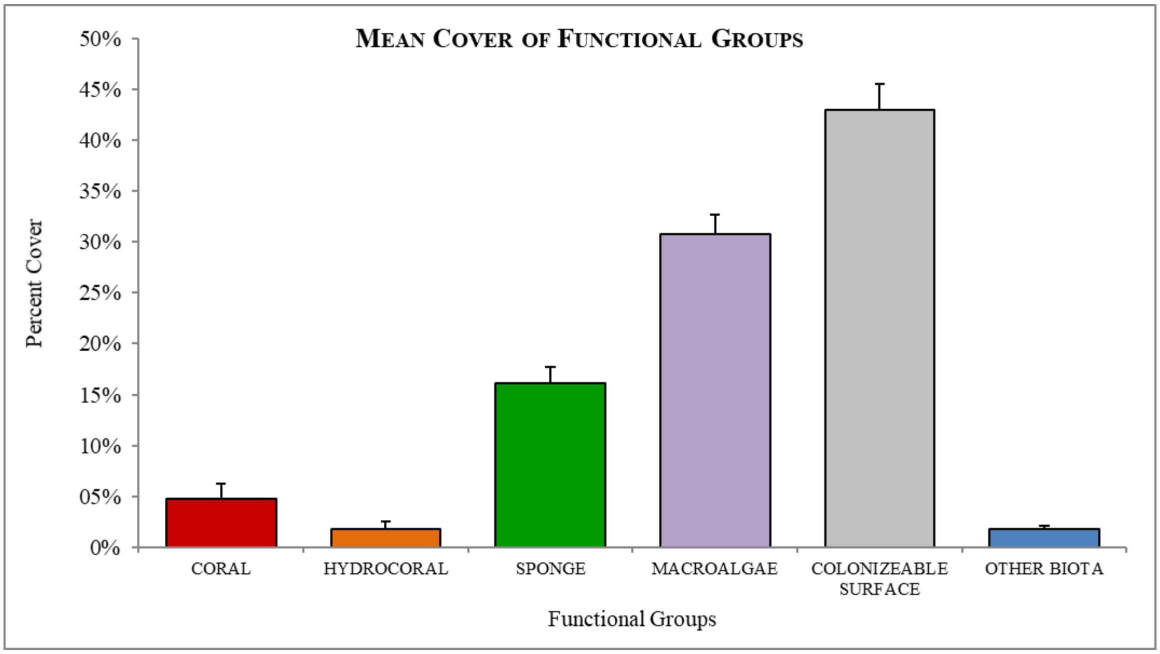


Figure 1.5. Mean functional group percent cover (with standard error bars) in repetitive photostations in 2016.

Of the four species of scleractinian coral ("coral" in graphs) and one species of hydrocoral observed, *Madracis decactis* was the predominant species (2.6% ± 1.1 SE), in repetitive photostations (Figure 1.6).

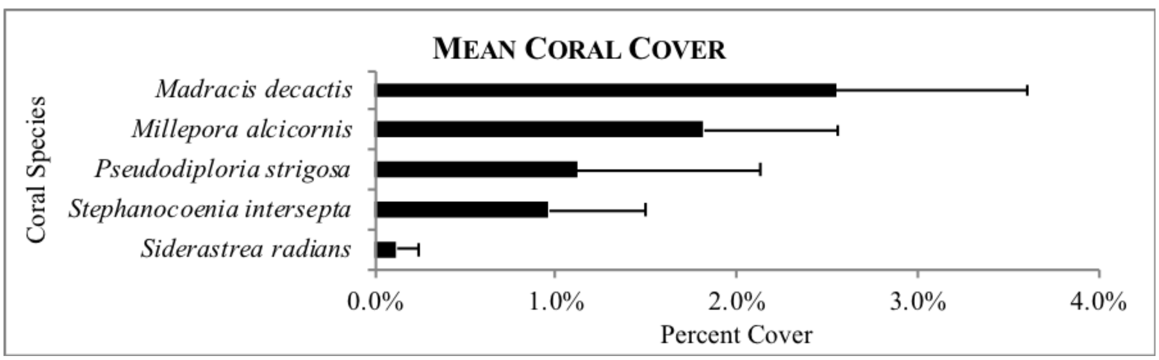


Figure 1.6. Mean coral cover of the observed coral species (with standard error bars) in repetitive photostations in 2016.

Eleven species and five morphospecies of sponge and encrusting sponge were observed, with *Ircinia strobilina* as the predominant species with a mean of 5.5% (± 0.9 SE) cover in repetitive photostations (Figure 1.7).

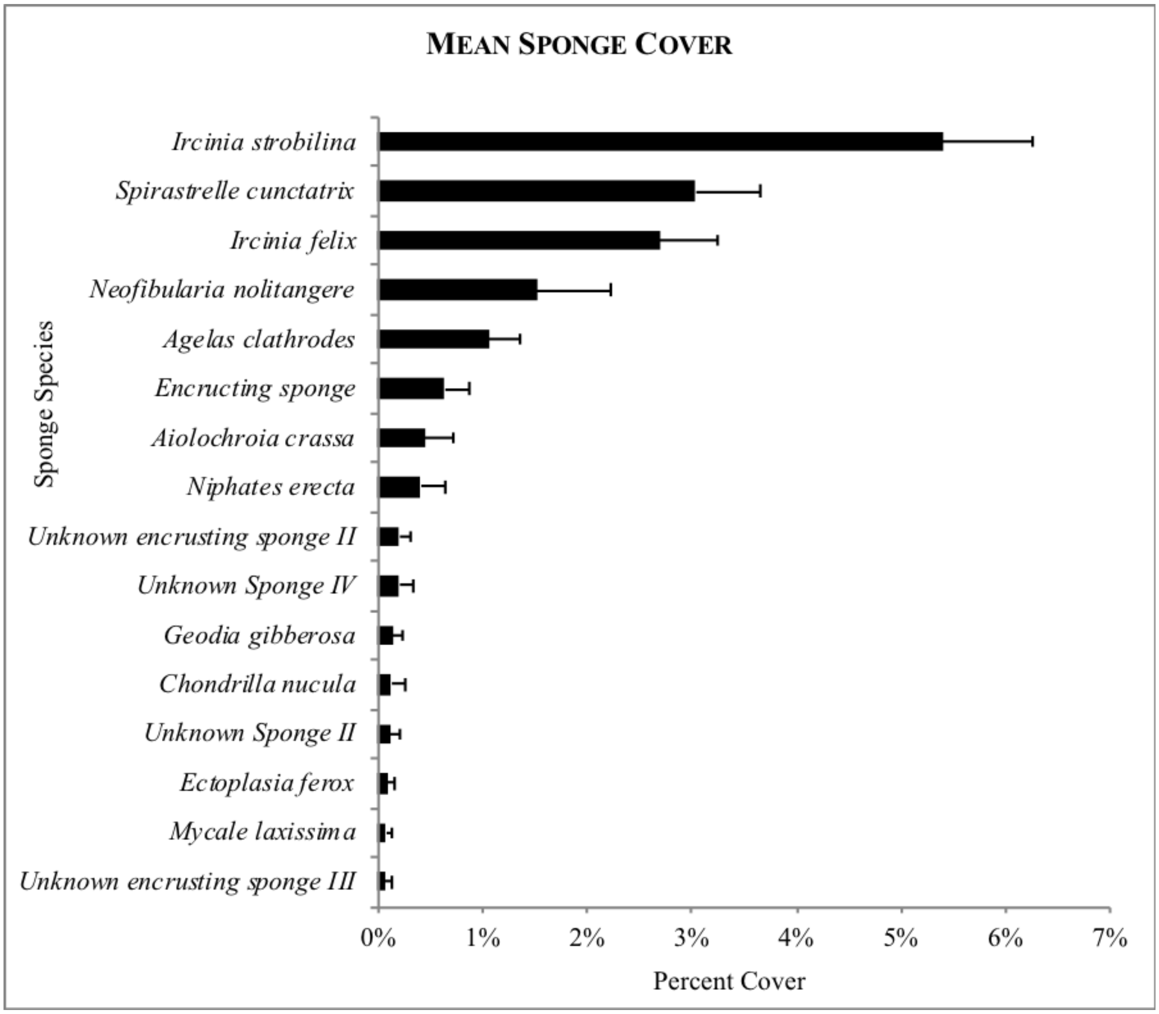


Figure 1.7. Mean sponge cover of the observed sponge species (with standard error bars) in repetitive photostations in 2016.

Qualitative comparisons of stations from 2015 noted complete losses (13 colonies) and wasting (seven colonies) of *I. strobilina* and *Ircinia felix*. One colony of *M. decactis* that exhibited bleaching in 2015 was noted to have recovered, while recent mortality was noted in a different colony in 2016.

Discussion

Percent cover of each functional group varied between years (Figure 1.8). Macroalgae cover has been in decline from a high in 2012 of 72.5% (± 2.30 SE) to a low of 27.9% (± 2.22 SE) in 2015, with 2016 seeing a small increase (2.8%) in macroalgae cover. As macroalgae cover has declined, colonizable substrate cover has increased as more substrate is exposed. However, algal cover can rapidly fluctuate in a short timeframe and causality for macroalgae decline and subsequent colonizable substrate increase is not apparent.

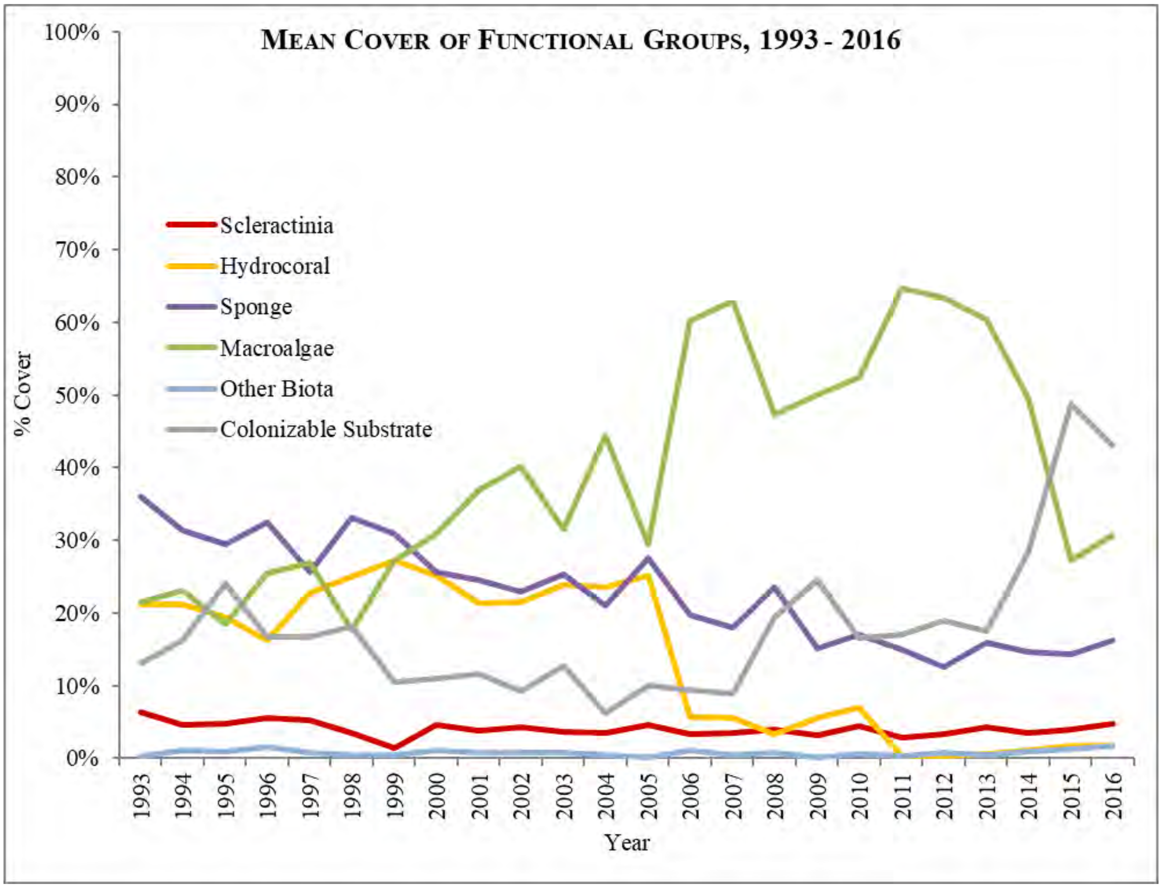


Figure 1.8. Mean percent cover of each functional group from 1993 - 2016 in repetitive photostations.

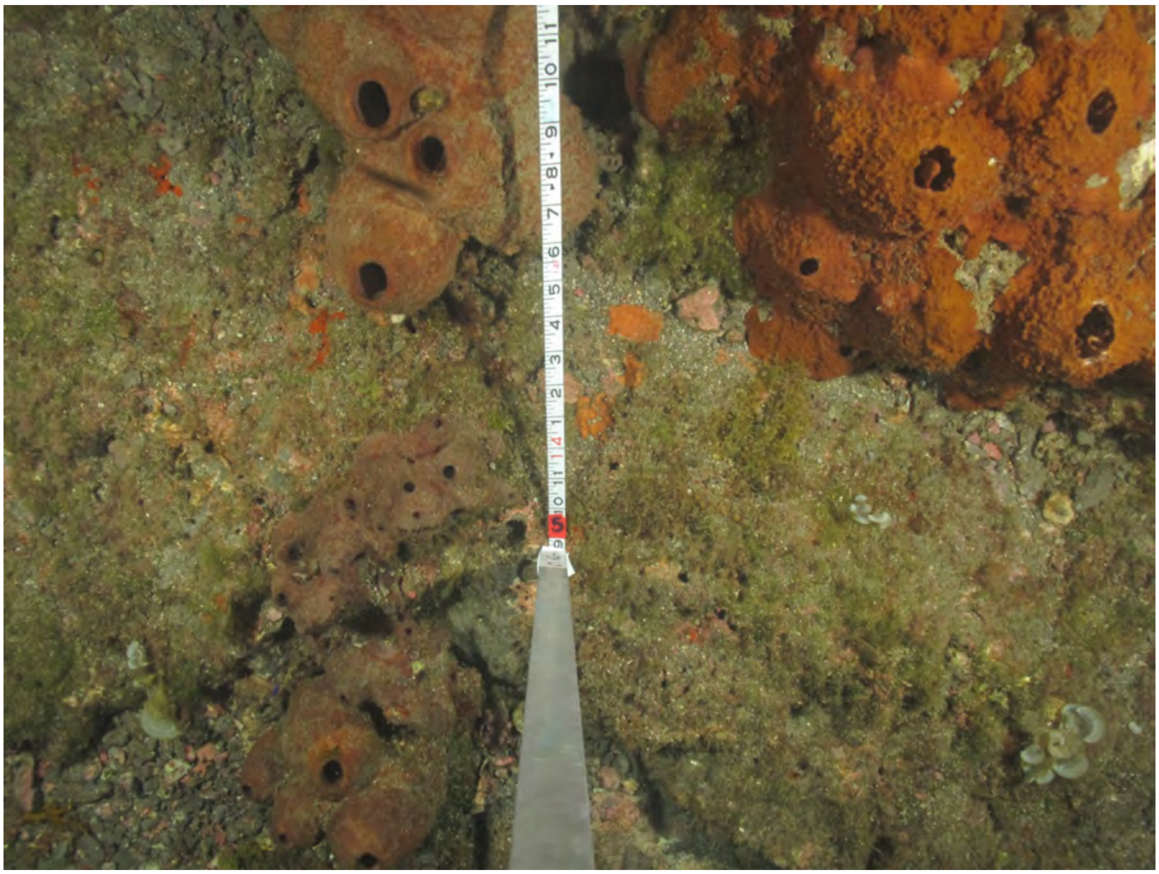
In 2016, the dominant coral species was *M. decactis* and the dominant sponge species was *I. strobilina*. It should be noted that the repetitive photostations do not provide a comprehensive view of the dominant species on the reef, as stations are biasedly placed (see Chapter 1 Methods for details on site selection).

Qualitative comparisons indicate that sponge populations at Stetson Bank are highly dynamic, with some colonies expanding (*Neofibularia nolitangere*) and others declining (*I. strobilina* and *I. felix)*, with overall stability in sponge community cover in recent years following the steady decline observed since the initiation of monitoring in 1993. Coral communities appear low, but stable in recent years, with the observation of the recovery of one paling colony from 2015, of *M. decactis*, and the recent death of a ~20% of a second colony of *M. decactis*.

Challenges and resolutions

- Pin installation at station #45 in 2015 was incorrect.
    - Pin location was corrected in 2016.

CHAPTER 2: RANDOM TRANSECTS



A random transect image shows sponge and macroalgae. Photo: John A. Embesi/NOAA

Introduction

To estimate the areal coverage of benthic components such as corals, sponges, and macroalgae, transect tapes were positioned at random locations within two habitat types to compare them 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) within low relief and high relief habitat on Stetson Bank. Habitat was defined using 1 m^2 resolution bathymetric data. Range (maximum – minimum 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 transects 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 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, were used.

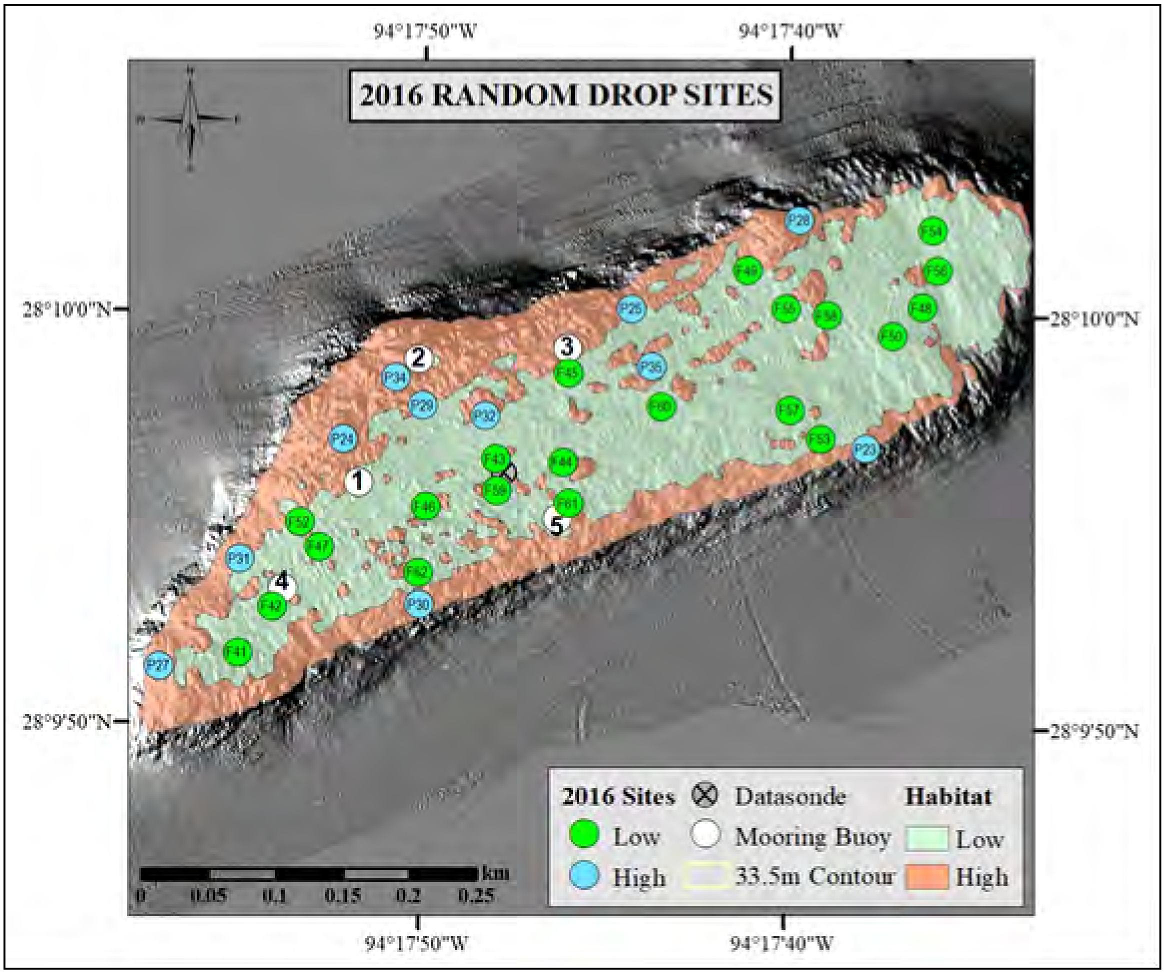


Figure 2.1. Location of random drop sites in 2016, where blue dots denote high relief sites and green dots denote low relief sites. Image: NOAA

Data processing

Percent cover was analyzed using CPCe®. A total of 500 points were randomly overlaid on each transect. Points were equally distributed between the photos that made up each transect. Identifications and data summaries were made in the same manner described in Chapter 1.

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 31 random transects were conducted during this study period: 21 in low relief habitat and 10 in high relief habitat. The depth of the stations ranged from 18.0 – 32.3 m.

Cover on transects in both the low relief and high relief habitat was predominantly macroalgae (thick turfs and fleshy macroalgal species) and colonizable substrate. Scleractinian coral cover was low in both habitats. However, both mean hydrocoral and mean sponge cover were greater in high relief habitat than in low relief habitat.

In low relief habitat, mean scleractinian coral cover was 0.4% (± 0.1 SE), hydrocoral cover was 0.3% (± 0.1 SE), sponge cover was 10.8% (± 1.2 SE), macroalgae cover was 46.1% (± 2.9 SE), and colonizable substrate cover was 27.0%. (± 2.4 SE). In high relief habitat, scleractinian coral cover was 0.4% (± 0.3 SE), hydrocoral coral was 3.0 (± 1.6 SE), sponge cover was 12.5% (± 2.9 SE), macroalgae cover was 53.1% (± 3.1 SE), and colonizable substrate cover was 20.6%. (± 2.8 SE) (Figure 2.2). In low relief habitat, average species richness was 13 (± 0.5 SE), and in high relief habitat, average species richness was 14 (± 0.5 SE).

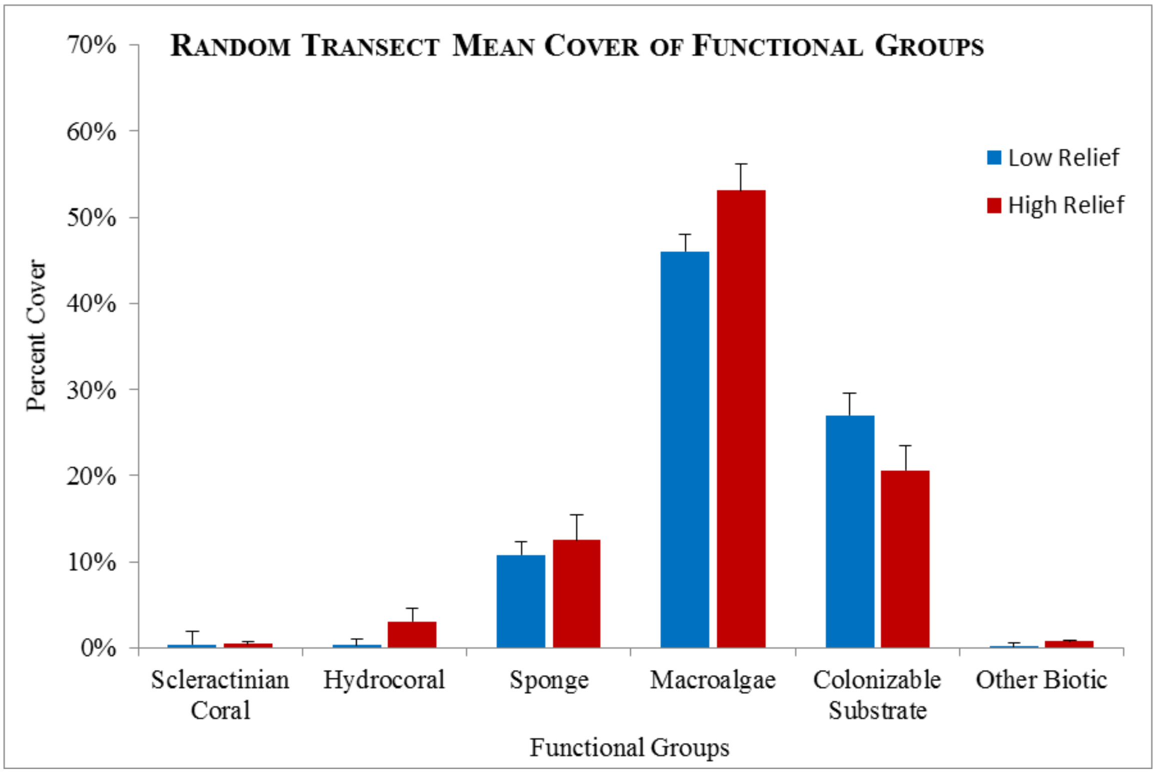


Figure 2.2. Random transect functional group percent cover (with standard error bars) for 2016, where low relief is represented by blue and high relief is represented by red.

Seven species of coral were observed in the surveys, combined. In both low and high relief habitat, *M. alcicornis* had the greatest cover at 0.34% (± 0.12 SE) and 3.04% (± 1.69 SE), respectively (Figure 2.3).

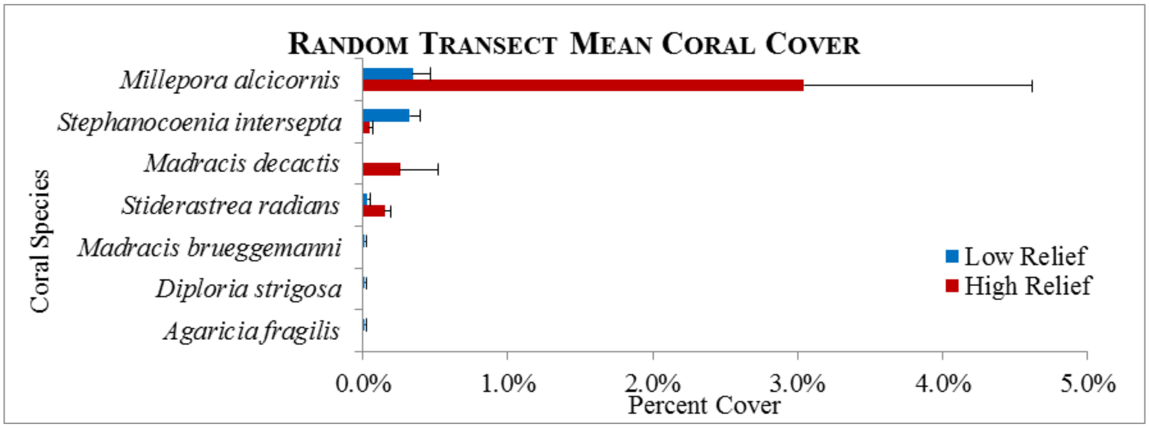


Figure 2.3. Random transect percent cover of each of coral species (with standard error bars) for 2016, where low relief is represented by blue and high relief is represented by red.

Fifteen species of upright sponge, one unknown upright sponge, one species of encrusting sponge, and one unknown encrusting sponge were observed in all surveys. In both the low relief and high relief habitat, *N. nolitangere* was the predominant species, comprising 6.45% (± 0.88 SE) and 5.48% (± 2.22 SE), respectively (Figure 2.4).

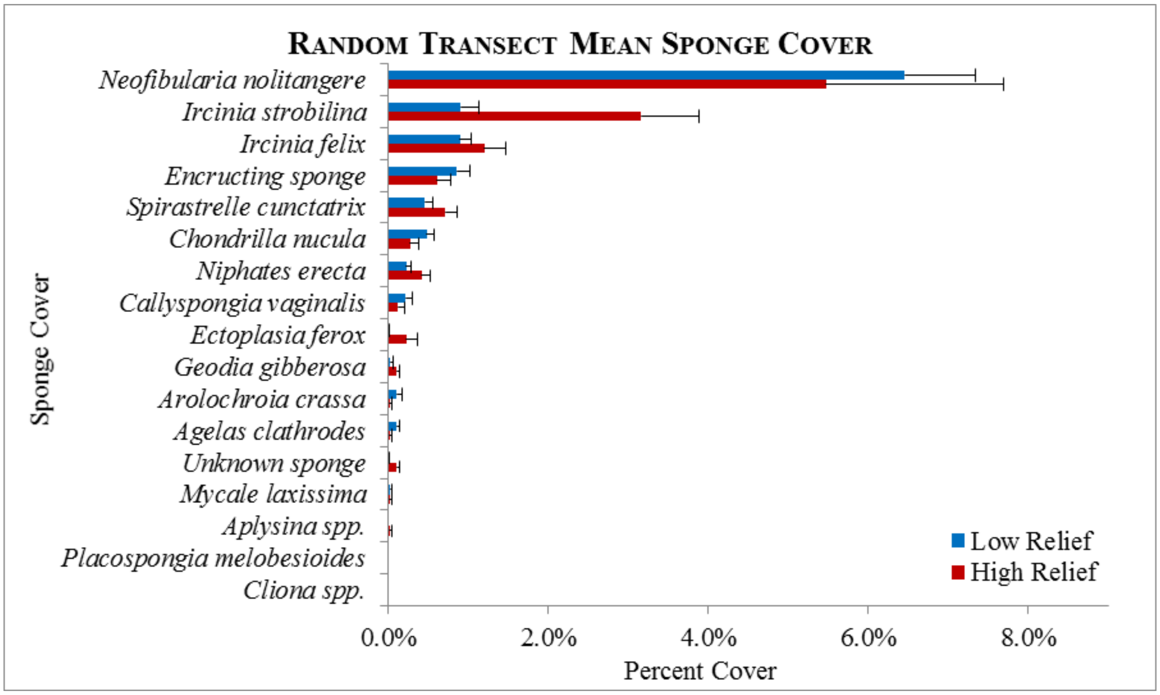


Figure 2.4. Random transect percent cover of each sponge species (with standard error bars) for 2016, where low relief is represented by blue and high relief is represented by red.

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

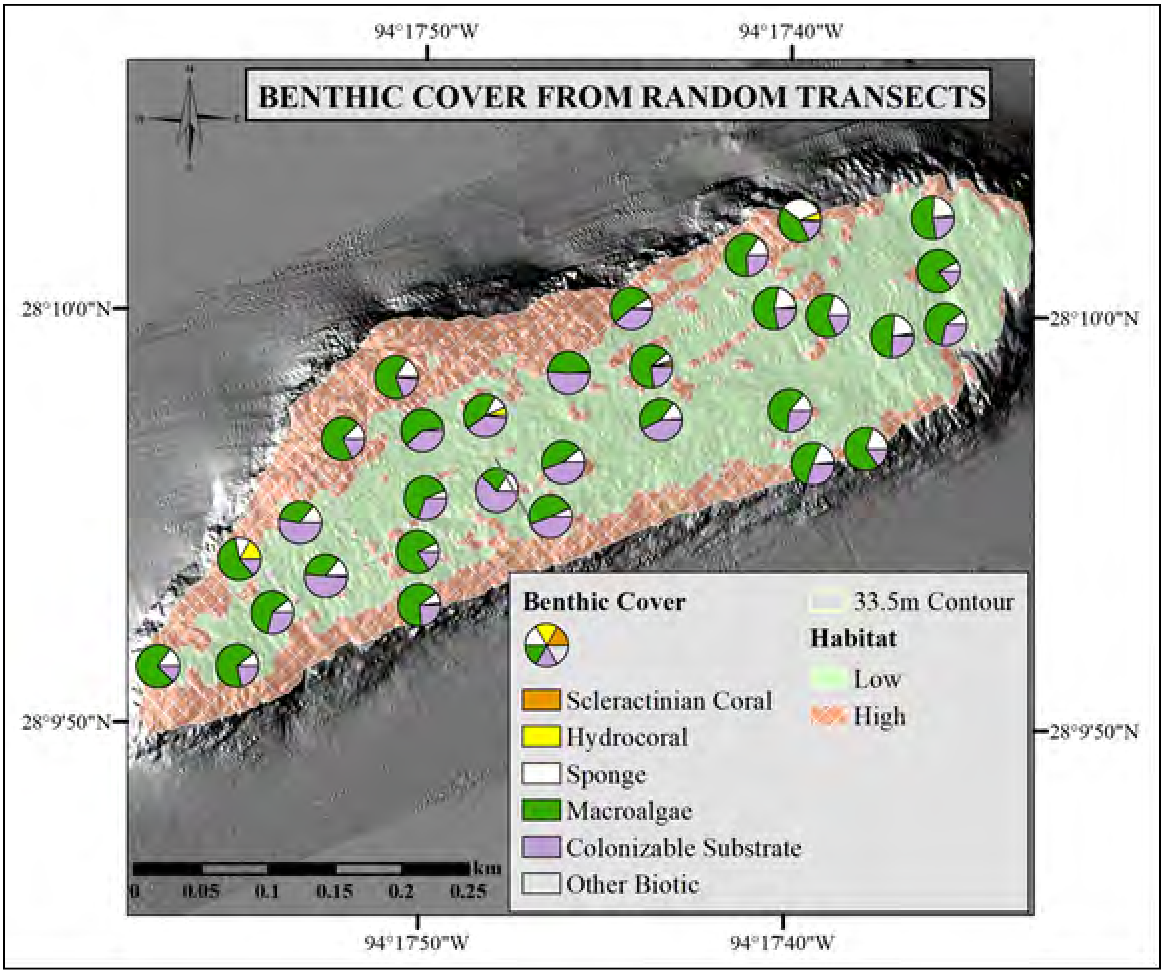


Figure 2.5. Spatial projection of random transect functional group percent cover for 2016. Each pie chart represents the location at which a survey was conducted and the proportion of percent cover represented by each functional group. Image: NOAA

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 extensive long-term dataset, they cannot be used to represent the entire benthic community due to the biased original selection criteria of those sites.

Macroalgae cover is a highly dynamic component of the ecosystem, documented to vary in relation to eutrophication, upwelling, nutrient availability, seasonally, and in relation to the grazer community composition in other reef habitats (Bonaldo and Bellwood 2011; Diaz-Pulido and Garzon-Ferreira 1997; Diaz-Pulido and Garzon-Ferreira 2002; Naim 1993). The high variability of this component of the benthic community often alters estimates for underlying organisms and bottom types. Variations in macroalgae cover at

Stetson Bank were generally inversely proportional to changes in cover of the CTB category, but they had little or no significant effect on cover estimates for corals and sponges. This trend has also been observed in the long-term monitoring study by Johnston et al. (2016) at East and West Flower Garden Banks.

While coral cover was low in both low relief and high relief habitats, in comparison to other Caribbean reefs (Jackson et al. 2014), different species represented the dominant coral in each habitat on Stetson Bank. The dominant coral species in low relief habitat was *S. intersepta* and *S. radians*, whereas high relief habitat, where coral cover is slightly greater, was dominated by the ahermatypic hydrozoan *M. alcicornis* and the scleractinian *S. intersepta*. While sponge cover was marginally lower in low relief habitat, in both habitats the dominant sponge species was *N. nolitangere*, contributing to approximately 6% of benthic cover in both habitats. All of these observations were distinctly different from the observations from repetitive photostations (presented in Chapter 1), where *M. decactis* and *I. strobilina* were the dominant coral and sponge species, respectively.

Challenges and resolutions

- During data collection dives, divers had trouble with selecting camera settings to provide sufficient lighting for images. This was corrected as subsequent dives were conducted.
    - Identify standardized camera settings that can be changed as conditions warrant. In addition, provide divers unfamiliar with the camera equipment time to use the camera in water before data collection begins. Develop instruction sheets for underwater use.
- Random transect P22-2 conducted on high relief site P22 was identified to be low relief habitat by divers.
    - Transect reclassified to low relief habitat for data processing.

CHAPTER 3: FISH SURVEYS

Atlantic Creolefish, *Paranthias furcifer*, school in high abundance at Stetson Bank. Photo: Ryan J. Eckert/NOAA

Introduction

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

Methods

Field methods

Fishes were visually assessed by scuba divers using a modified Bohnsack and Bannerot (1986) stationary visual fish census technique. Observations of fishes were restricted to an imaginary cylinder with a radius of 7.5 m, extending to the surface. All fish species observed within the first five minutes of the survey were recorded as the diver slowly rotated in place. 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, and >35 cm, where each individuals size was recorded. Each survey required 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 location was selected randomly in two habitat types defined by relief (low and high) (see Chapter 2 Methods). A minimum of fifteen surveys are conducted annually: ten in low relief habitat and five in high relief habitat. In 2016, 31 fish surveys were conducted: 20 in low relief and 11 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 manta rays, stingrays, and sharks were removed from biomass analyses because their rare occurrence and large size would obscure patterns of interest in the more commonly observed species.

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 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 31 fish surveys were conducted, 20 of which were in low relief habitat, and 11 of which were in high relief habitat. Total species richness from all surveys was 80, and total family richness from all surveys was 32. Average species richness per survey was lower in low relief habitat than high relief habitat, with 17 (± 0.8 SE) in low relief and 21 (± 1.8 SE) in high relief. Average family richness per survey was similar between habitats, with 12 (± 0.5 SE) in low relief and 12 (± 0.8 SE) in high relief habitats.

Sighting frequency and occurrence

Overall, seaweed blenny (*Parablennius marmoreus*), bluehead (*Thalassoma bifasciatum*), and sharpnose puffer (*Canthigaster rostrata*) had the highest sighting frequencies 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 when habitats were combined.

Table 3.1. Sighting frequency of the 10 most observed fish species in 2016. Bold text indicates species that were among the 10 most frequently seen species in both habitats.

Family Name: Species Name (Common Name - Trophic Guild) Species ID	Sighting Frequency (%)		
	Combined	Low relief	High Relief
Blenniidae: *Parablennius marmoreus* (seaweed blenny-I)	100.0	100.0	100.0
Labridae: *Thalassoma bifasciatum* (bluehead-I)	100.0	100.0	100.0
Tetraodontidae: *Canthigaster callisterna* (sharpnose puffer-I)	100.0	100.0	100.0
Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	90.3	95.0	81.8
Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)	96.8	95.0	100.0
Pomacentridae: *Chromis multilineata* (brown chromis-I)	80.6	80.0	81.8
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish-I)	77.4	70.0	90.9
Pomacentridae: *Stegastes partitus* (bicolor damselfish-H)	61.3	65.0	54.5
Chaenopsidae: *Emblemaria pandionis* (sailfin blenny-PL)	48.4	60.0	27.3
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	54.8	60.0	45.5
Labridae: *Bodianus rufus* (Spanish hogfish-I)	58.1	45.0	81.8
Pomacanthidae: *Pomacanthus paru* (French angelfish-I)	61.3	55.0	72.7
Tetraodontidae: *Sphoeroides spengleri* (bandtail puffer-I)	61.3	60.0	63.6

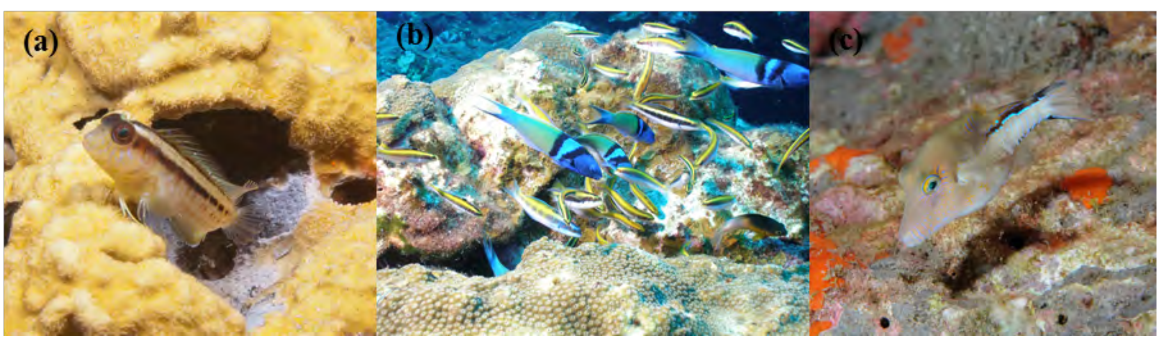


Figure 3.1. Images of the most frequently observed species in 2016. (a) seaweed blenny (Photo: E.L. Hickerson/NOAA), (b) bluehead (Photo: G.P. Schmahl/NOAA), and (c) sharpnose puffer. Photo: George P. Schmahl/NOAA

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, 55 species were characterized as "rare," while 25 species were characterized as "prevalent." Most shark and ray species are considered 'rare' (occur in <20% of all surveys) 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 low relief habitat, with 174 individuals per 100 m^2 (± 31.5 SE). In high relief habitat, density was 162 individuals per 100 m^2 (± 26.4 SE).

When averaged by habitat type, some similarities were observed between the densest species in each habitat type, with eight of the same species occurring in both habitats (Table 3.2). In low relief habitat seaweed blenny (*Parablennius marmoreus*) and in high relief habitat cocoa damselfish (*Stegastes variabilis*), had the greatest average density.

Table 3.2. Average density (individuals/100 m^2) of the 10 densest fish species in 2016. Grouped by habitat type, ± standard error, where bold text indicates species that were among the 10 densest species in both habitats and dashes indicate that the species was not observed in that habitat.

Family Name: Species Name (Common Name - Trophic Guild)	Density (Individuals/100 m^2)		
Species ID	Combined	Low relief	High Relief
Blenniidae: *Parablennius marmoreus* (seaweed blenny-I)	28.7 ± 5.8	24.9 ± 6.0	35.6 ± 12.0
Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)	29.5 ± 5.4	18.4 ± 4.4	49.6 ± 10.7
Labridae: *Thalassoma bifasciatum* (bluehead-I)	21.7 ± 3.6	18.1 ± 2.9	28.3 ± 8.6
Pomacentridae: *Chromis multilineata* (brown chromis-I)	23.2 ± 9.0	12.1 ± 2.8	43.4 ± 24.4
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish-I)	8.1 ± 2.1	7.6 ± 2.3	9.0 ± 4.1
Tetraodontidae: *Canthigaster callisterna* (sharpnose puffer-I)	6.5 ± 0.5	6.8 ± 0.7	6.0 ± 0.8
Chaenopsidae: *Emblemaria pandionis* (sailfin blenny-PL)	4.7 ± 2.1	6.7 ± 3.2	1.1 ± 0.7
Labridae: *Clepticus parrae* (creole wrasse-PL)	5.5 ± 3.3	4.2 ± 4.1	7.9 ± 5.3
Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	4.4 ± 0.9	3.6 ± 1.0	5.8 ± 1.8
Apogonidae: *Apogon pseudomaculatus* (twospot cardinalfish-PL)	2.5 ± 0.8	3.4 ± 1.1	0.9 ± 0.5
Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper-P)	3.7 ± 3.7	-	10.3 ± 10.3
Haemulidae: *Haemulon aurolineatum* (tomtate-I)	4.7 ± 3.2	3.0 ± 2.8	7.7 ± 7.7

Biomass

Average biomass across all surveys was 9417.5 g/100 m^2 (± 6343.1 SE). High relief habitat possessed the greatest average biomass, with 20873.7 g/100 m^2 (± 17806.6 SE) while low relief habitat had 3116.6 g/100 m^2 (± 893.3 SE).

When averaged by habitat type, some similarities were observed between the species contributing the greatest biomass in each habitat type. Table 3.3 shows the 10 species contributing the most to observed biomass in each habitat, and overall. In low relief habitat, horse-eye jack (*Caranx latus*) had the greatest average biomass, with 414.7 g/100 m^2 (± 408.3 SE). In high relief habitat, almaco jack (*Seriola rivoliana*) had the greatest average biomass, with 17954.3 g/100 m^2 (± 10695.1 SE).

Table 3.3. Average biomass of the top 10 fish species in 2016. Grouped by habitat type, ± standard error, where bold text indicates species that were among the 10 densest species in both habitats and dashes indicate that the species was not observed in that habitat.

Family Name: Species Name (Common Name - Trophic Guild)	Biomass (g/100 m^2)		
Species ID	Combined	Low relief	High Relief
Carangidae: *Caranx latus* (horse-eye jack-P)	267.6 ± 263.5	414.7 ± 408.3	0.0 ± 442.3
Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	325.5 ± 69.3	229.6 ± 56.8	499.9 ± 116.3
Kyphosidae: *Kyphosus saltatrix/incisor* (chub (Bermuda/yellow)-H)	309.7 ± 146.3	209.7 ± 141.8	491.4 ± 245.6
Pomacanthidae: *Pomacanthus paru* (French angelfish-I)	237.9 ± 55.9	185.9 ± 51.8	332.4 ± 93.9
Haemulidae: *Haemulon melanurum* (cottonwick-I)	201.2 ± 135.0	182.0 ± 169.4	236.1 ± 226.7
Scombridae: *Scomberomorus maculatus* (Spanish mackerel-P)	97.4 ± 97.4	151.0 ± 151.0	0.0 ± 163.6
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	167.1 ± 43.3	143.3 ± 47.2	210.4 ± 72.7
Blenniidae: *Parablennius marmoreus* (seaweed blenny-I)	49.7 ± 21.4	52.5 ± 26.2	44.6 ± 35.9
Ostraciidae: *Lactophrys triqueter* (smooth trunkfish-I)	44.9 ± 18.6	48.4 ± 27.3	38.5 ± 31.3
Holocentridae: *Holocentrus adscensionis* (squirrelfish-I)	48.0 ± 19.2	40.6 ± 26.7	61.6 ± 32.3
Carangidae: *Seriola rivoliana* (almaco jack-P)	6370.9 ± 6370.9	-	17954.3 ± 10695.1
Carangidae: *Caranx crysos* (blue runner-P)	171.0 ± 171.0	-	481.9 ± 287.1
Carangidae: *Seriola dumerili* (greater amberjack-P)	131.1 ± 131.1	-	369.6 ± 220.1
Sphyraenidae: *Sphyraena barracuda* (great barracuda-P)	124.2 ± 124.2	-	350.1 ± 208.5
Lutjanidae: *Lutjanus griseus* (gray snapper-I)	98.2 ± 46.8	-	276.7 ± 78.5

Trophic Guilds

Richness within trophic guild was calculated overall and for each habitat (Table 3.4). Overall, invertivores possessed the greatest richness, with 43 species and 23 families comprising the guild, and planktivores possessed the lowest richness, with eight species and six families comprising the guild overall. This pattern was also observed when surveys were analyzed by habitat type, except in low relief habitat, where piscivores had the lowest species and family richness (six and four, respectively).

Table 3.4. Fish species and family richness by trophic group in 2016. Grouped by habitat type and combined, with the number in parenthesis representing family richness.

Trophic Guild	Combined	Low relief	High Relief
Herbivore	14 (6)	12 (6)	13 (6)
Planktivore	8 (6)	7 (5)	7 (5)
Invertivore	43 (23)	37 (21)	35 (19)
Piscivore	15 (8)	6 (4)	11 (6)

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 63.4%, and piscivores contributed the least, at 3.9%. This pattern was observed in both habitats. For all surveys combined, piscivores contributed the greatest biomass while planktivores contributed the least (77.9% and 0.6%, respectively). A similar pattern was observed in high relief habitat. However, in low relief habitat, biomass was dominated by invertivores and the lowest contributor to biomass was planktivores (37.2% and 2.3%, respectively).

Table 3.5. Percent contribution of trophic guild to fish density and biomass in 2016.

Trophic Guild	Density (%)			Biomass (%		
	Combined	Low relief	High Relief	Combined	Low relief	High Relief
Herbivore	22.7	26.6	15.0	7.9	27.3	2.6
Planktivore	10.0	6.5	16.9	0.6	2.3	0.1
Invertivore	63.4	66.1	58.3	13.6	37.2	7.2
Piscivore	3.9	0.8	9.8	77.9	33.3	90.1

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.

Table 3.6. Percent contribution of density of the top three fish species by trophic guild in 2016. Grouped by habitat type, where bold text indicates species that were among the three densest species in the trophic guild in both habitats.

Trophic Guild	Family Name: Species Name (Common Name - Trophic Guild) Species ID	% Contribution to Trophic Density		
		Com bined	Low relief	High Relief
H	**Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)**	76.4	70.0	81.4
	Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	11.4	13.8	9.5
	Pomacentridae: *Stegastes partitus* (bicolor damselfish-H)	3.9	6.1	2.2
	Acanthuridae: *Acanthurus tractus* (ocean surgeonfish-H)	2.0	1.5	2.4
I	**Blenniidae: *Parablennius marmoreus* (seaweed blenny-I)**	26.6	29.7	23.5
	Pomacentridae: *Chromis multilineata* (brown chromis-I)	20.1	21.5	18.8
	Labridae: *Thalassoma bifasciatum* (bluehead-I)	21.5	14.4	28.7
P	Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper-P)	55.7	0.0	62.7
	Carangidae: *Caranx crysos* (blue runner-P)	22.6	0.0	25.4
	Epinephelidae: *Mycteroperca phenax* (scamp-P)	5.6	40.0	1.3
	Carangidae: *Caranx latus* (horse-eye jack-P)	3.6	32.5	0.0
	Carangidae: *Caranx bartholomaei* (yellow jack-P)	3.3	0.0	3.8
	Carangidae: *Caranx ruber* (bar jack-P)	1.4	12.5	0.0
PL	**Labridae: *Clepticus parrae* (Creole wrasse-PL)**	32.6	24.8	47.1
	Chaenopsidae: *Emblemaria pandionis* (sailfin blenny-PL)	28.0	39.3	6.8
	Apogonidae: *Apogon pseudomaculatus* (twospot cardinalfish-PL)	14.8	20.0	5.2
	Pomacentridae: *Chromis scotti* (purple reeffish-PL)	9.2	3.5	20.0
	Pomacentridae: *Chromis insolata* (sunshinefish-PL)	12.5	10.7	15.7

Table 3.7. Percent contribution of biomass of the top three fish species from each trophic guild in 2016. 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	Family Name: Species Name (Common Name - Trophic Guild) Species ID	% Contribution to Trophic Biomass		
		Comb ined	Low relief	High Relief
H	**Kyphosidae: *Kyphosus saltatrix/incisor* (chub (Bermuda/yellow)-H)**	41.6	39.8	43.2
	Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	43.8	43.5	44.0
	Acanthuridae: *Acanthurus tractus* (ocean surgeonfish-H)	6.4	7.2	5.8
I	**Pomacanthidae: *Pomacanthus paru* (French angelfish-I)**	18.6	19.6	17.7
	Haemulidae: *Haemulon melanurum* (cottonwick-I)	15.7	19.1	12.6
	Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	13.1	15.1	11.2

Trophic Guild	Family Name: Species Name (Common Name - Trophic Guild) Species ID	% Contribution to Trophic Biomass		
		Combined	Low relief	High Relief
	Lutjanidae: *Lutjanus griseus* (gray snapper-I)	7.7	0.0	14.7
P	Carangidae: *Seriola rivoliana* (almaco jack-P)	86.8	0.0	91.7
	Carangidae: *Caranx crysos* (blue runner-P)	2.3	0.0	2.5
	Carangidae: *Caranx latus* (horse-eye jack-P)	3.6	68.6	0.0
	Carangidae: *Seriola dumerili* (greater amberjack-P)	1.8	0.0	1.9
	Scombridae: *Scomberomorus maculatus* (Spanish mackerel-P)	1.3	25.0	0.0
	Carangidae: *Caranx ruber* (bar jack-P)	0.2	4.7	0.0
PL	Chaenopsidae: *Emblemaria pandionis* (sailfin blenny-PL)	19.1	70.2	0.1
	Ptereleotridae: *Ptereleotris helenae* (hovering dartfish-PL)	4.7	17.2	0.0
	Labridae: *Clepticus parrae* (Creole wrasse-PL)	4.7	4.1	4.9
	Epinephelidae: *Paranthias furcifer* (Atlantic Creolefish-PL)	68.0	0.0	93.3
	Apogonidae: *Apogon pseudomaculatus* (twospot cardinalfish-PL)	1.4	4.5	0.2
	Pomacentridae: *Chromis scotti* (purple reeffish-PL)	1.1	1.7	0.9

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 63.9% and 70.6% 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). Within all habitat types, herbivores, invertivores, and planktivores were dominated by smaller individuals, while piscivores were dominated by larger individuals in low relief habitat and small individuals in high relief habitat.

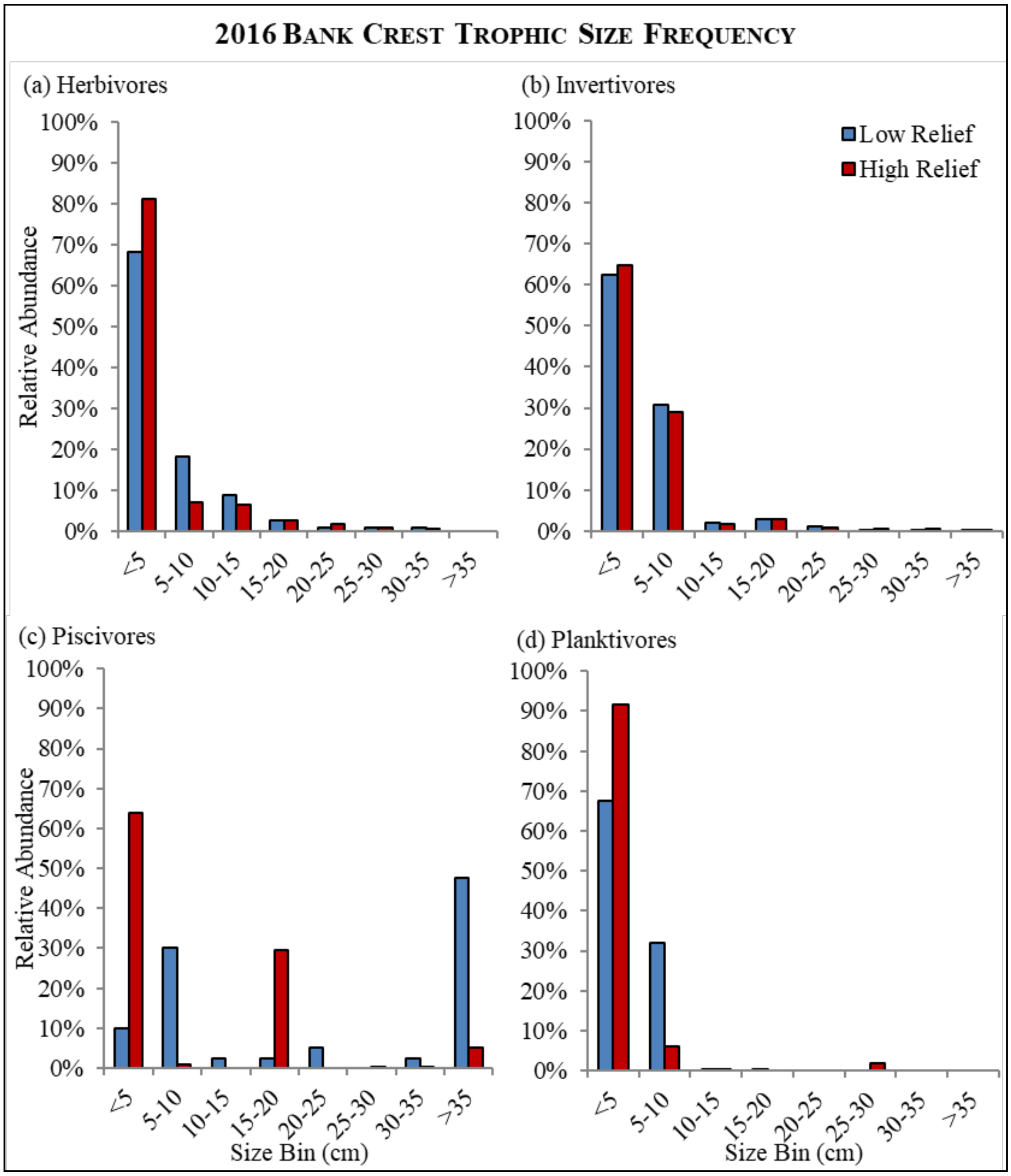


Figure 3.2. Size distribution by trophic guild. Blue columns represent low relief habitat and red columns are high relief habitat in 2016.

Dominance plots

When all samples were combined, the average dominance plot *w* value was slightly positive, at 0.12 (± 0.02 SE). By habitat, all values were close to zero (Table 3.8), indicating that accumulated biomass was evenly distributed between large and small species.

Table 3.8. Mean dominance plot w values by habitat in 2016. Values ± standard error for each habitat and combined.

Low relief	High Relief	Combined
0.13 ± 0.02	0.09 ± 0.04	0.12 ± 0.02

Spatial analysis

When stratified random surveys were projected spatially, additional trends in species distributions were observed (Figure 3.3). During the study period, density of piscivores was low and surveys were dominated in density by invertivores and herbivores.

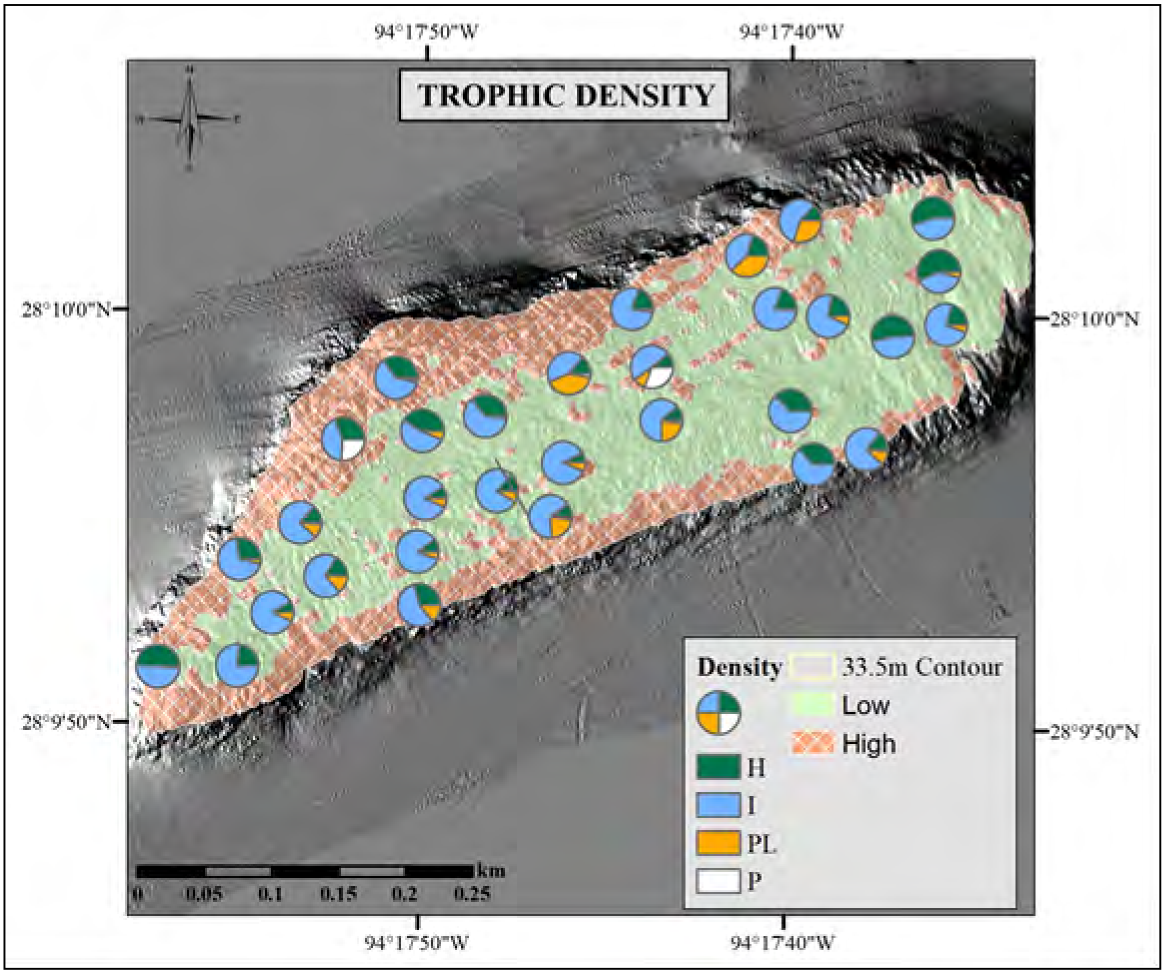


Figure 3.3. Spatial projection of fish trophic group density in 2016. Each pie chart represents the location at which a survey was conducted and the proportion of density represented by each trophic guild. H=Herbivore, I=Invertivore, PL=Planktivore, and P=Piscivore. Image: NOAA

The biomass of each trophic guild at each survey site was also projected (Figure 3.4). During the study period, overall biomass of piscivores was greater in surveys located on the edges of the bank, where the recorded biomass of great barracuda (*Sphyraena barracuda*) and greater amberjack (*Seriola dumerili*) was variable but large at certain locations. Invertivore biomass was higher in the middle of the bank, where the recorded biomass of angelfish, particularly French angelfish (*Pomacanthus paru*), was large.

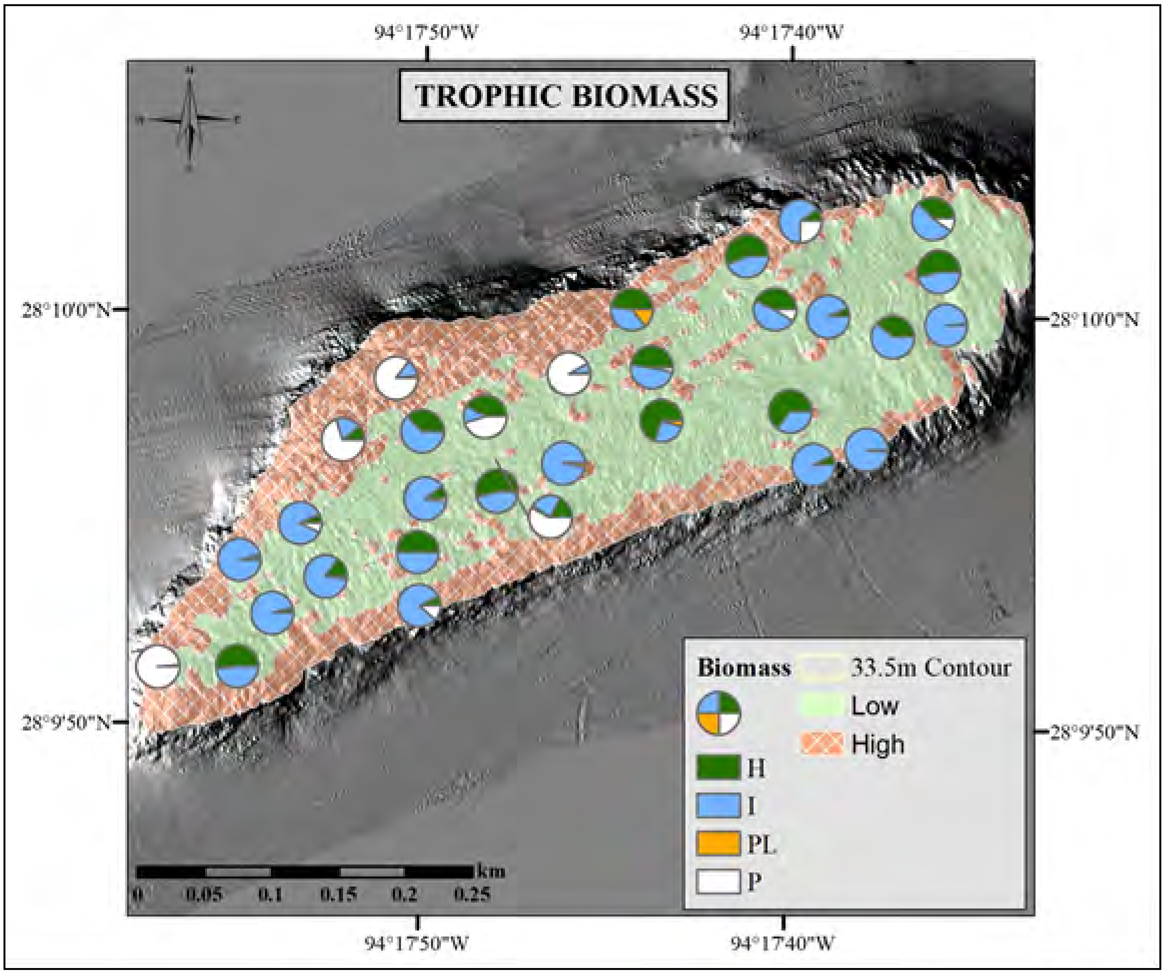


Figure 3.4. Spatial projection of fish trophic group biomass in 2016. Each pie chart represents the location at which a survey was conducted and the proportion of biomass represented by each trophic guild. H=Herbivore, I=Invertivore, PL=Planktivore, and P=Piscivore. Image: NOAA

Discussion

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

Small invertivorous fish dominated density at Stetson Bank. Additionally, the invertivore guild was represented by the most individual species and families, and possessed the greatest overall density of any trophic guild. While this was also true for biomass in low relief habitat, biomass in high relief habitat was predominantly piscivorous fish, due to the presence of dense schools of almaco jack. Due to the schooling behavior of these pelagic fish, while they contributed greatly to biomass estimates when they were observed in a survey, they were infrequently observed (considered rare in sighting frequency calculations and having large standard error values).

In combined surveys, piscivore biomass was greater than herbivore biomass. 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 (DeMartini et al. 2008; Friedlander and DeMartini 2002; 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. However, coral cover at Stetson Bank is low compared to other Caribbean reefs (Jackson et al. 2014), with less than 3% cover. Despite the overall lack of coral cover, high relief habitats on Stetson Bank possess complex habitat, both abiotic and biotic, which provide shelter for prey fishes; such shelter is nearly absent in low relief habitat. The observed inverted biomass pyramid is likely due to the availability of refuges, rapid turnover rates of prey items, slow growth rates of predators, and potential food subsidies from the surrounding pelagic environment (DeMartini et al. 2008; Odum and Odum 1971; Wang et al. 2009). However, when examined by habitat, piscivore biomass dominance is only observed in high relief habitat. The concentration of piscivores in this area may be a result of habitat preference due to the availability of complex habitat for shelter and food.

The density of reef fish at Stetson Bank was dominated by small individuals (<5 cm), which account for >60% of all recorded fishes. However, when density and biomass were analyzed, the fish community at Stetson Bank appears to be well balanced between density and biomass.

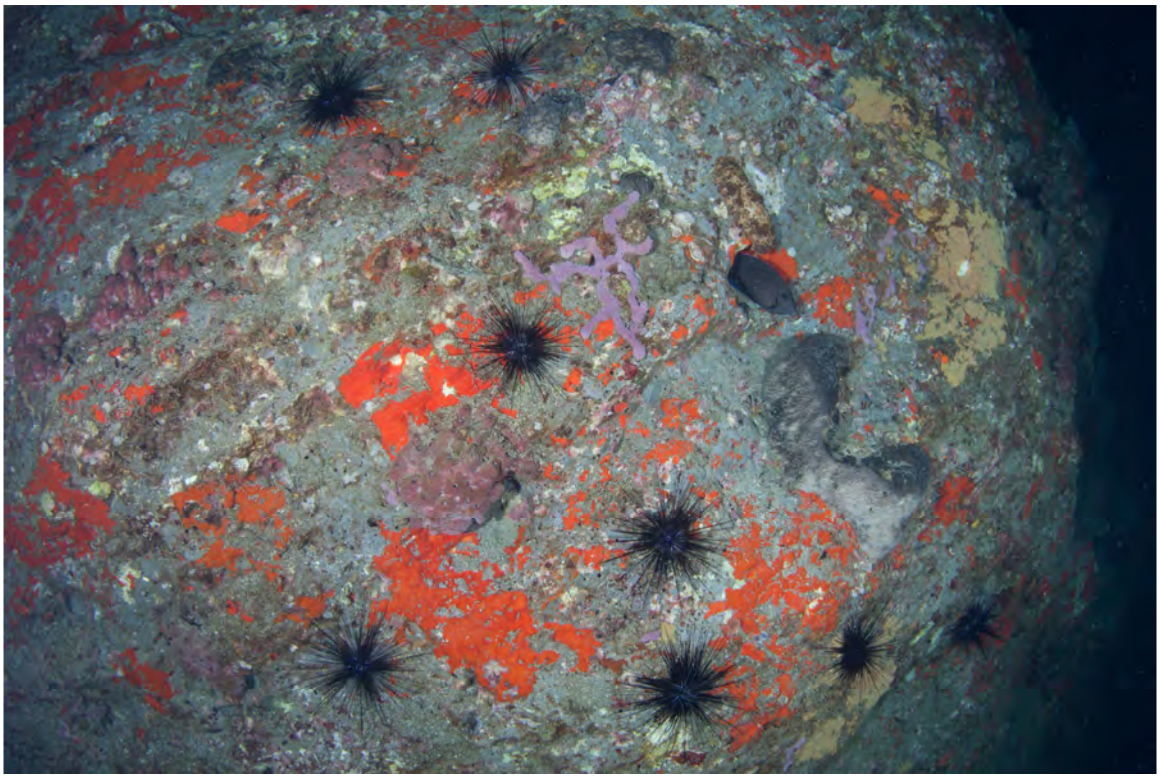
Although lionfish have been reported at Stetson Bank by recreational scuba divers since 2011, only one lionfish observation was recorded in low relief habitat in surveys during this study period. The invasion of this exotic species is of particular concern and continued attention to changes in their population is recommended.

Overall, the fish community suggests a variable fish population, composed of both commercially and recreationally valuable fish species. Additional variation of the fish community at Stetson Bank might be occurring at both the diurnal and seasonal scale. However, continued monitoring of this community is necessary to understand natural variation of the fish community and detect significant changes from the normal variation of the fish assemblage, in addition to documenting potential impacts of invasive species.

Challenges and Resolutions

No problems were encountered in the 2016 field season.

CHAPTER 4: SEA URCHIN AND LOBSTER SURVEYS



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

Introduction

The long-spined sea urchin, *Diadema antillarum*, was an important herbivore on coral reefs throughout the Caribbean until the mid-1980s. Between 1983 and 1984, an unknown pathogen reduced 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 various lobster species (Caribbean spiny lobster [*Panulirus argus*], spotted spiny lobster [*Panulirus guttatus*], and slipper lobster species [Scyllaridae]) at Stetson Bank.

Methods

Field methods

Due to the nocturnal nature of these species, visual surveys were conducted at night, a minimum of 90 minutes after sunset. Two belt transects, 2 m wide and 100 m long, were conducted by diver teams on lines between permanent mooring buoys (between buoy #1 – #2 and #2 – #3). One additional belt transect, 2 m wide and 50 m long (between buoy #3 – repetitive photostation 27) was also conducted. In total, 500 m^2 was surveyed. The abundance of long-spined sea urchin, Caribbean spiny lobster, spotted spiny lobster, and slipper lobster species 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 daylight hours.

Data processing

Density of each species of interest 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 1.3 individuals per m^2 (± 0.42 SE). No Caribbean spiny lobster, spotted spiny lobster, or slipper lobster were observed in surveys conducted in 2016.

Repetitive photostations, which were selectively placed in high relief habitat, had an average density of 2.26 individuals per m^2 (± 0.284 SE). Along random transects, the density of long-spined sea urchins was higher in high relief habitat where the average density was 1.18 per m^2 (± 0.29 SE), than low relief habitat, where the average density was 0.12 individuals per m^2 (± 0.05 SE).

Discussion

Long-spined sea urchin populations at Stetson Bank were different between the survey methods and habitat types, reflecting strong diurnal habitat preferences and behaviors. Average density was higher in daytime repetitive photostations and random transects, where abundance was obtained from image analysis. While night surveys aimed to capture abundance while the species were more active, the number of surveys was limited, limiting power of the data analyses. The lower densities observed during night surveys may be due to the increased feeding activity at night, leading to an expansion of their spatial distribution (they leave shelter areas to feed) and habitat type encountered along the survey lines (while both high relief and low relief habitat is surveyed at night, the coverage of each has not been calculated).

Studies have demonstrated that increasing 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 die-off, limited recovery of long-spined sea urchin populations has been seen in numerous locations throughout the Caribbean, with a regional average density of 0.023 per m^2 (Karmer 2003), far below abundances prior to the die-off. Studies have documented local densities ranging from 0 – 8.9 per m^2 (Carpenter and Edmunds 2006) and a high of 12 per m^2 at Discovery Bay in Jamaica (Edmunds and Carpenter 2001), while East and West Flower Garden Banks in the Gulf of Mexico have documented recent average densities from 0 – 0.13 per m^2 (Johnston et al. 2015). 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 show this trend. 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 2016 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 and a temperature logger collected temperature data every hour at 30 m.

Water column profiles recording depth, temperature, salinity, turbidity, pH, fluorescence, and dissolved oxygen were conducted quarterly throughout the year. With these profiles, water samples were collected each quarter and analyzed by a laboratory for select nutrient levels and ocean carbonate measurements.

Methods

Field methods

Temperature and salinity loggers

At a 24 m depth, the primary instrument for recording salinity, temperature, and turbidity was a Sea-Bird® Electronics, *16plus* V2 CTD with a WET Labs ECO NTUS turbidity meter. 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, 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 was checked. Maintenance and factory service of each instrument were performed annually.

Onset® Computer Corporation HOBO® Pro v2 U22-001 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 the instruments at Stetson Bank from October 8, 2015 to October 7, 2016 for the 24 m station. Due to poor weather conditions during the November 2016 data collection cruise, the 30 m and 40 m station instruments were not collected or exchanged, therefore data presented for the 30 m and 40 m station spans October 8, 2015 to June 7, 2016.

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 dissolved oxygen (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 on 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 18th, June 10th, May 19th, August 12th, and November 15th, 2016.

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 liter Niskin bottles. The carousel was attached to the vessel with a scientific winch cable. The winch cable allows the operator to activate the bottles to sample at specific depths. Six samples were collected each quarter. Two 2.5 liter water samples were collected near the seafloor (approximately 20 m depth), mid-water (10 m depth) and near the surface (1 m depth).

Water samples for chlorophyll-*a* analyses were collected in 1000 ml glass containers with no preservatives. Samples for reactive soluble phosphorous were placed in 250 ml bottles with no preservatives. Ammonia, nitrate, nitrite, and total nitrogen samples were collected in 1000 ml bottles with a sulfuric acid preservative. An additional blind duplicate water sample was taken at one of the sampling depths for each sampling period. Within minutes of sampling, labeled sample containers were stored on ice at 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 collection. Each sample was analyzed for chlorophyll-*a* and nutrients (ammonia, nitrate, nitrite, phosphorous and total nitrogen). In 2016, water samples were obtained on February 18th, May 19th, August 12th, and November 15th.

Water samples for ocean carbonate measurements were collected following methods requested by CCL at TAMU-CC. Samples were collected in Pyrex 250 ml borosilicate bottles with polypropylene caps. Two replicates were collected at each depth. Bottles were filled using a 30 cm plastic tube that connected from the spout of the Niskin. Bottles were rinsed three times using the sample water, filled carefully to reduce bubble formation, and overflowed by at least 200 ml. Following, 100µl of $HgCl_2$ was added to each bottle before inverting vigorously. Samples were then stored at 4°C. Samples and CTD profile data were sent to CCL at TAMU-CC, in Corpus Christi, Texas. Samples were obtained on February 18th, May 19th, August 12th, and November 15th, 2016.

Data processing

Temperature, salinity, and turbidity data obtained from loggers were downloaded and processed each quarter. The 24-hourly readings obtained each day were averaged into one 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, a historical average of data from the previous 10 years (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.

Chlorophyll-*a* and nutrient analyses results were obtained quarterly from A&B Laboratories and compiled into an excel table. Ocean carbonate analyses results were compiled and received as an annual report from the CCL at TAMU-CC.

Results

Temperature and salinity loggers

Slightly cooler temperatures were observed at the deeper stations. Sea-Bird instruments, at the 24 m station, showed the minimum temperature logged during this time frame was 18.5º C, recorded on February 15, 2016. The maximum temperature, recorded on September 28, 2016, was 30.3º C. The minimum temperature logged during this time frame at the 30 m station was 18.1º C and at the 40 m station was 18.0º C, both recorded on February 16, 2016. As the data presented for the 30 m and 40 m stations only runs through June, summer high temperatures are lacking.

Based on daily data from HOBO thermographs, temperature at each station was compared. A maximum temperature difference 0.23º C and a minimum temperature difference of -1.42º C was observed between the 24 m and the 30 m stations. Average temperature difference between these two stations was -0.15º C. A maximum temperature difference 0.33º C and a minimum of -2.61º C was observed between the 24 m and the 40 m station. Average temperature difference between these stations was -0.44º C.

Water temperatures at the 24 m station are compared with averages for that station from the past 10 years in Figure 5.1. Temperatures for the current cycle were warmer than the 10-year average from November 2015 through January 2016, during which a steep decline of almost 2° C was seen over nine days. Temperatures following January 2016 were variable, but similar to the 10-year average through April 2016. Temperatures returned to warmer than the 10-year average from April 2016 through June 2016. Following June 2016, large temperature fluctuations were recorded, with temperatures exceeding the 10-year average at the end of the cycle. The 10-year average record is only available for the 24 m station.

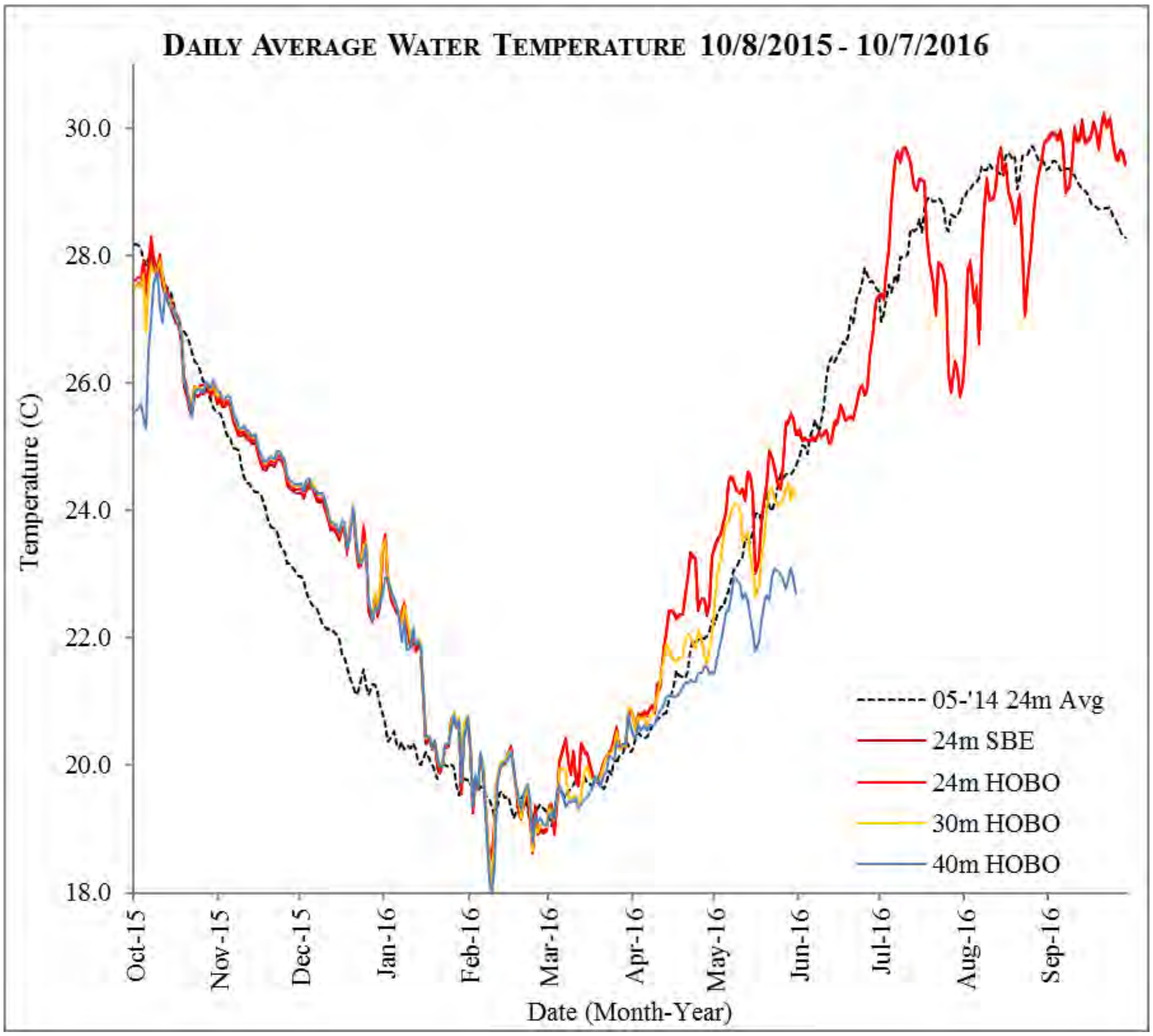


Figure 5.1. Temperature (°C) at Stetson Bank from October 8, 2015, to October 7, 2016. Black dashed line represents 10-year average temperature.

The minimum salinity level recorded (at the 24 m SBE) during this time frame was 32.4 PSU on July 14, 2016. The maximum salinity level was 36.4 PSU on February 19 – 20, 2016. Figure 5.2 shows the salinity recorded at the 24 m station and the average salinity observed over the last five years at this station. Salinity was similar to average over most of the year, but showed greater fluctuation over the summer months. Lower than average salinity (by a maximum of 3.1 PSU) was observed between July 2016 and August 2016.

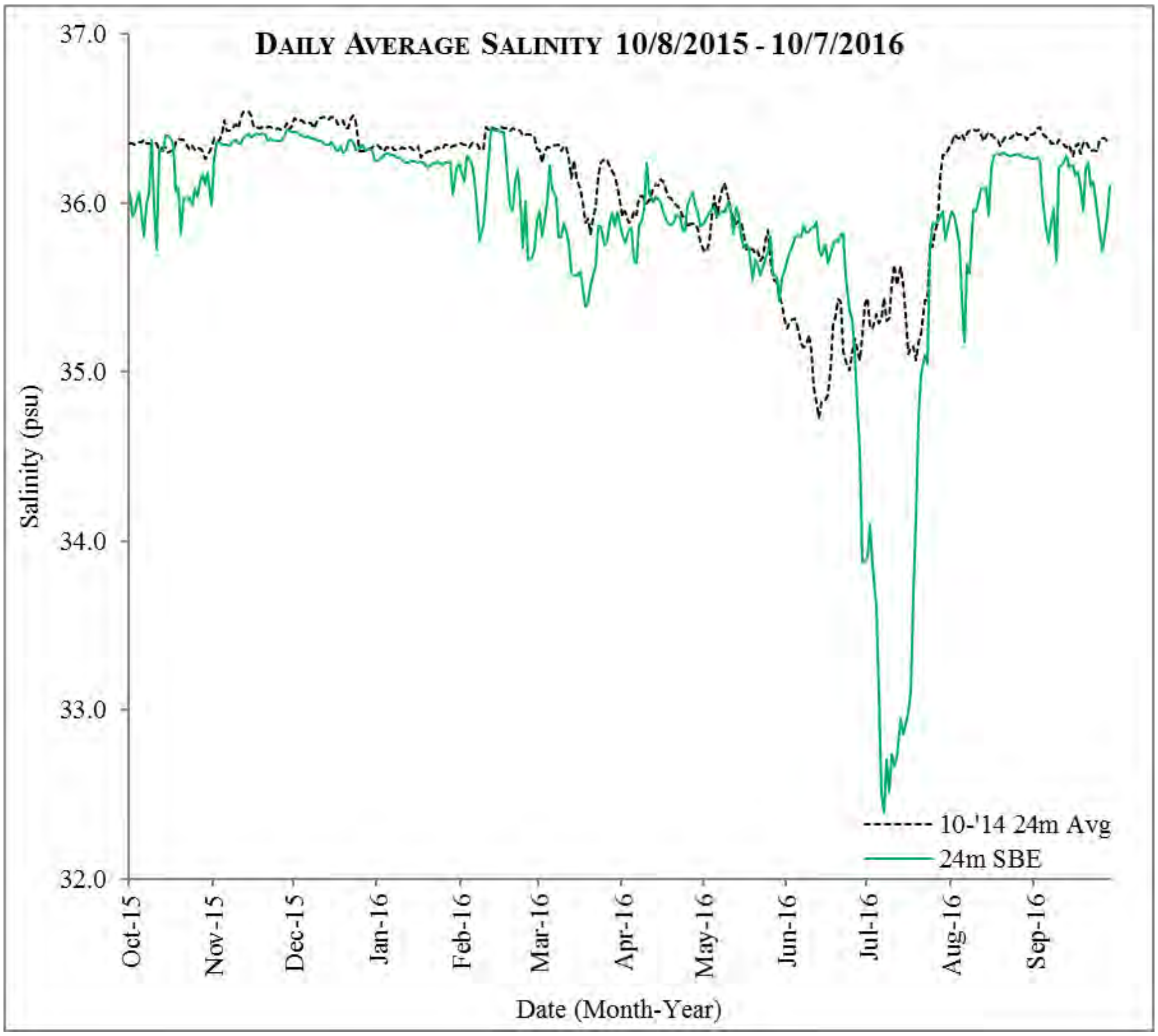


Figure 5.2. Salinity (PSU) on the bank crest from October 8, 2015 to October 7, 2016. Black dashed line represents a five-year average salinity.

The minimum turbidity recorded during this time frame was 0.03 NTU on November 5, 2016. The maximum turbidity was 6.35 NTU on July 25, 2016. Figure 5.3 shows the turbidity recorded at the 24 m station. Greater variation in turbidity was seen between July and August, 2016 (Figure 5.3).

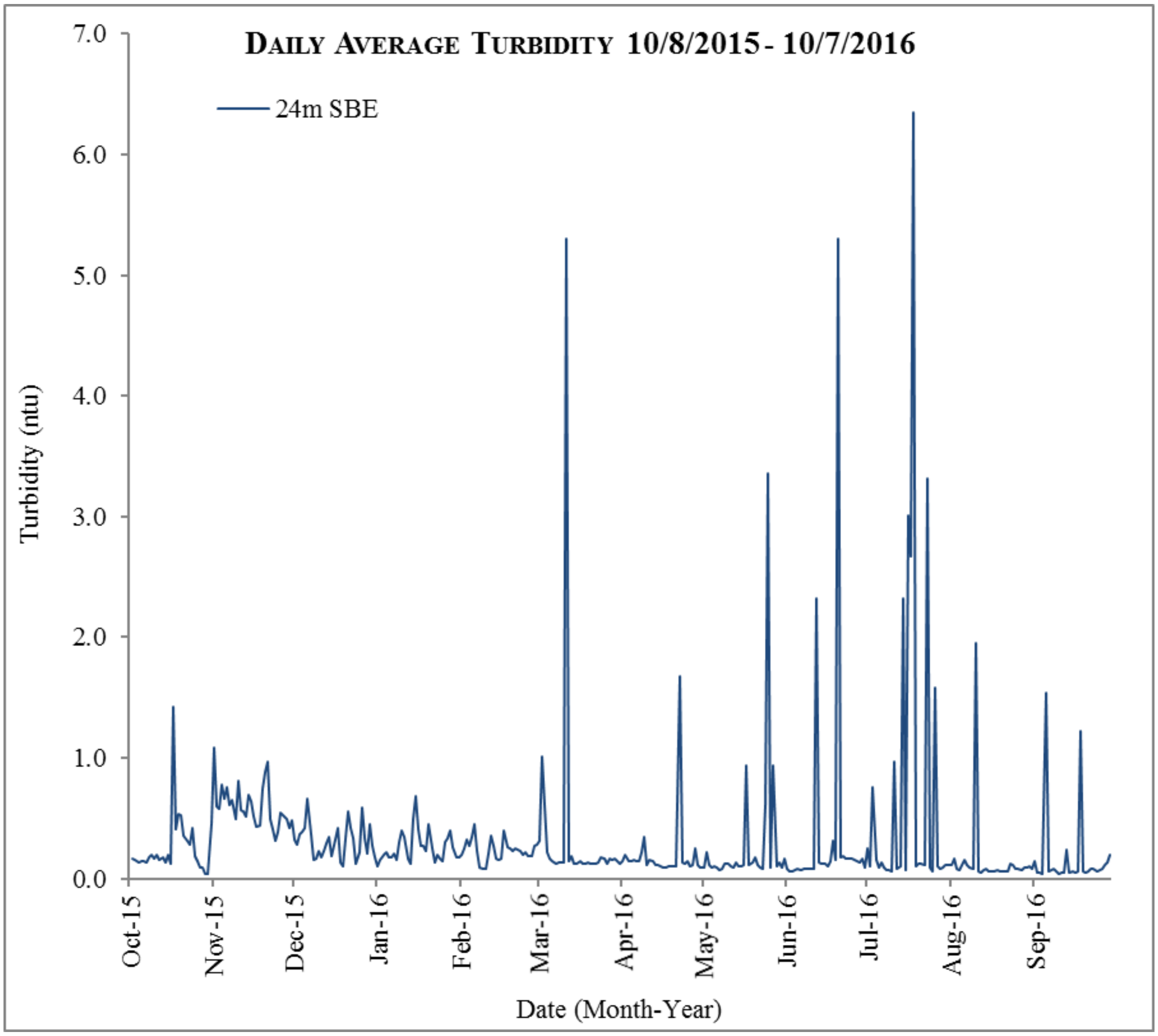


Figure 5.3. Turbidity (NTU) on the bank crest from October 8, 2015 to October 7, 2016.

Water column profiles

In 2016, a total of four temperature profiles were collected: February 18th (Feb 2016), May 19th (May 2016), August 12th (Aug 2016), and November 15th (Nov 2016).

Water temperatures varied throughout the year, and showed only slight variation between the surface and 20 m (Figure 5.4). In May 2016, water temperature gradually declined with increasing depth. In Feb 2016, the water column was at its coolest, <21^{o} C, and in Aug 2016, the entire water column was >30^{o} C.

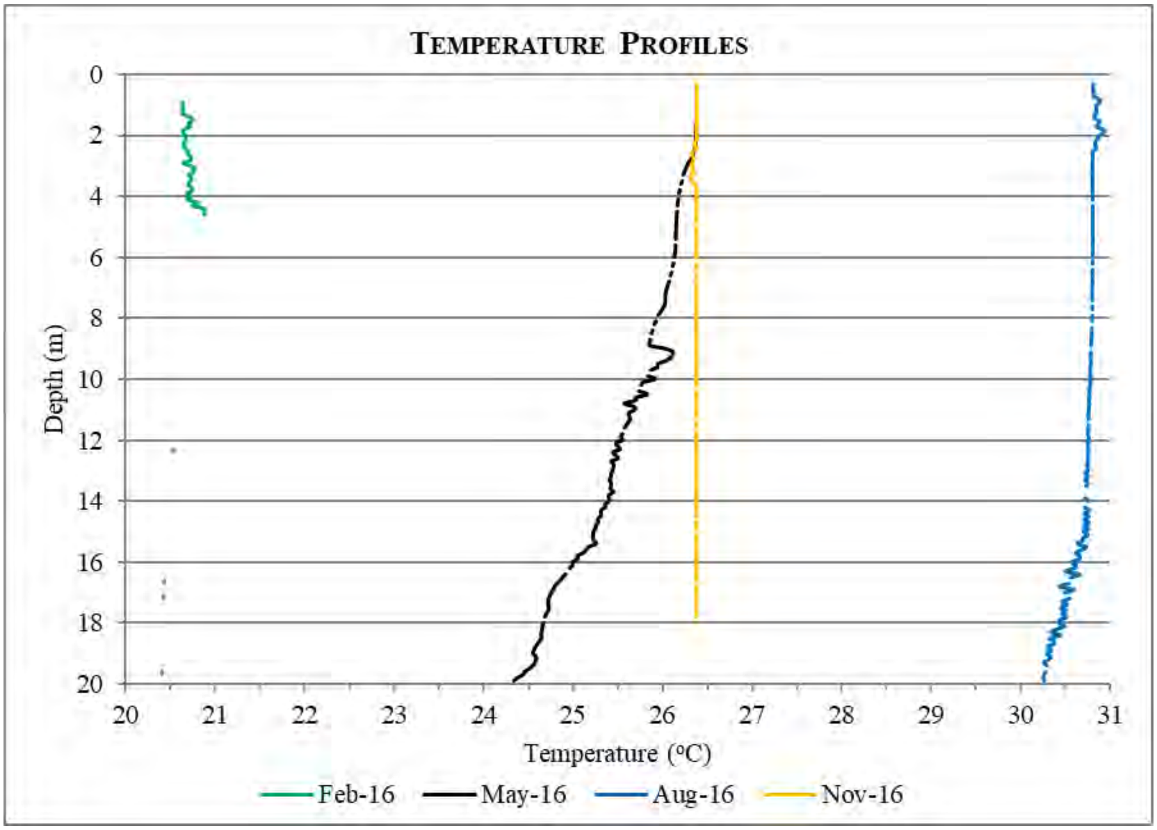


Figure 5.4. Temperature profiles for 2016.

Salinity varied throughout the year, with the lowest salinity recorded in Aug 2016 (Figure 5.5). In both Feb and May 2016, lower salinity was observed in the surface waters, and an increase in salinity observed with increasing depth.

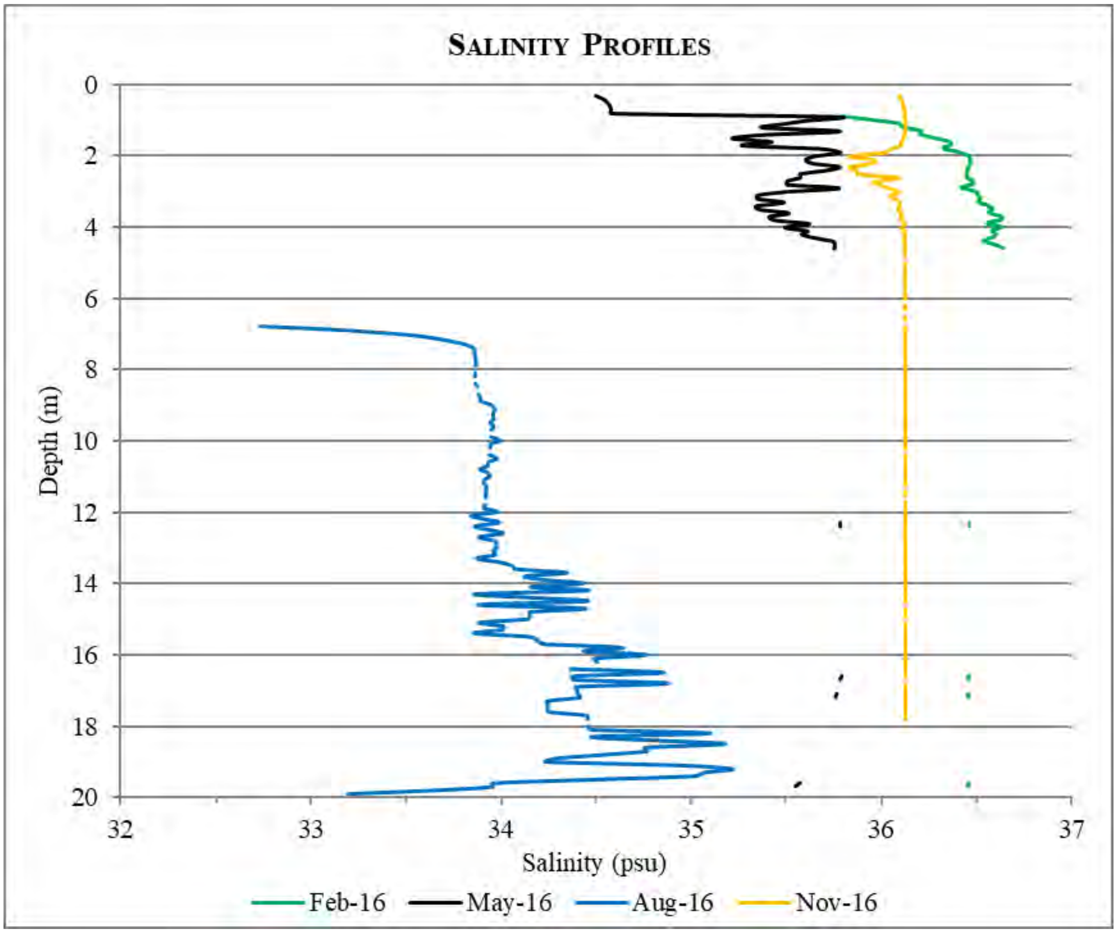


Figure 5.5. Salinity profiles collected in 2016.

Other water profile parameters were graphed in Figure 5.6. Feb and Aug 2016, had slightly lower pH and more stratification near the surface than May and Nov 2016. Turbidity was similar throughout the year at depths >5 m, with surface waters showing more variability. Fluorescence was greatest in Nov 2016, and was stable throughout the water column. The lowest fluorescence level was recorded in May and August. Dissolved oxygen instruments failed in August and November, but remaining profiles were stable with depth, except in water <4 m in February.

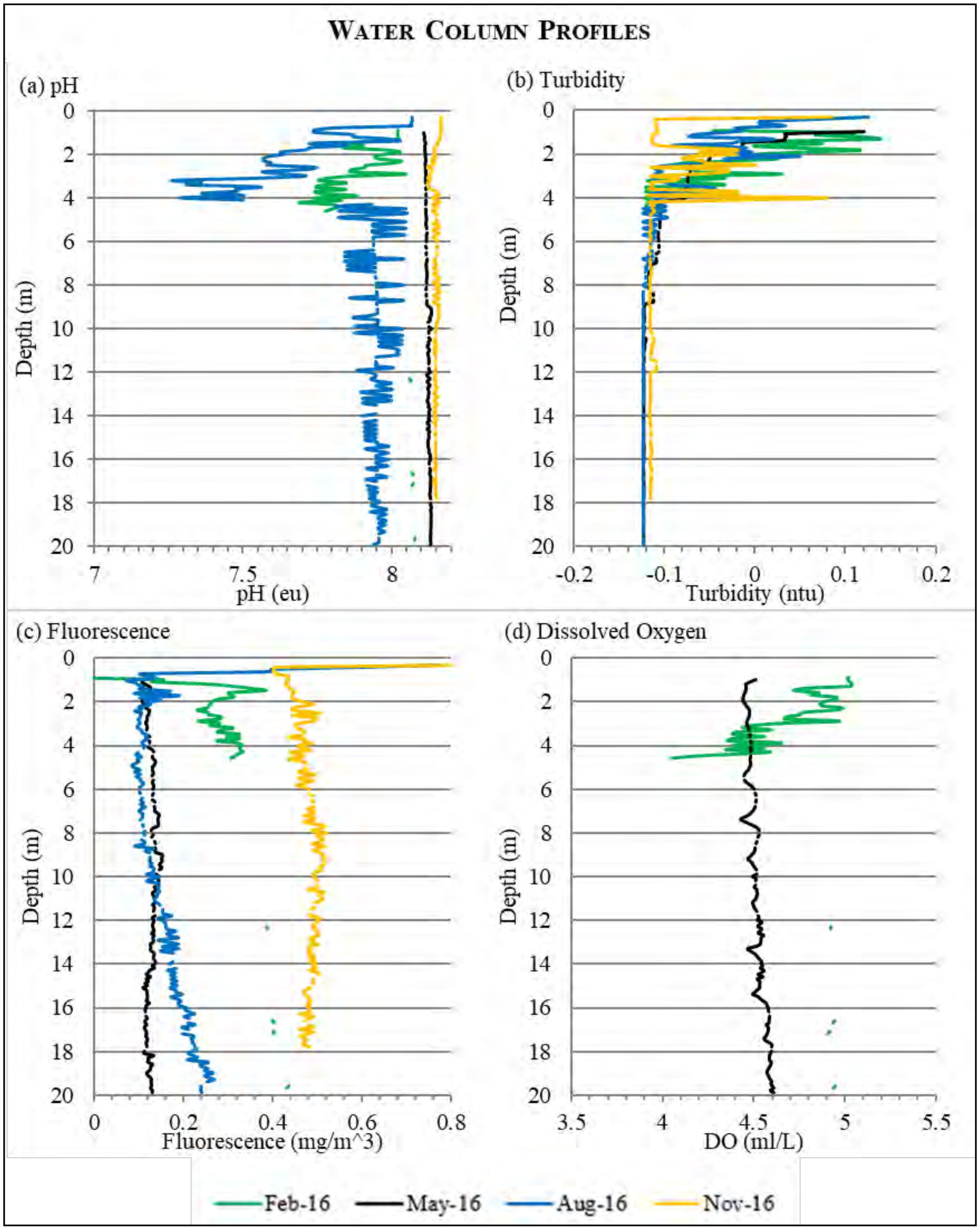


Figure 5.6. pH, turbidity, fluorescence, and DO profiles collected in 2016. (a) shows pH in eu, (b) shows turbidity in NTU, (c) shows fluorescence in mg/m^3, and (d) dissolved oxygen in ml/L.

Water samples

Nutrient analyses indicate that ammonia, chlorophyll-*a*, nitrate, nitrite, phosphorus, and nitrogen levels for all samples in 2016 were below readable levels.

Carbonate samples taken throughout the year included pH, pCO_2, alkalinity, and total dissolved CO_2 (DIC) (Table 5.2). Total pH showed small variations throughout the year. The lowest pCO_2 value, where the air-sea pCO_2 gradient was greatest, was observed in February 2016. The lowest $\Omega_{aragonite}$ values and highest DIC were also observed in February 2016, but aragonite saturation states suggested the seawater was well buffered across all survey times.

Table 5.2. Ocean carbonate sample results for 2016.

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 (‰)
2/18/2016	20	36.64	20.40	8.040	2396.9	2090.6	8.108	3.47	347.1	ND
2/18/2016	10	36.65	20.59	8.040	2398.3	2089.1	8.105	3.47	349.8	ND
2/18/2016	1	36.65	20.65	8.038	2396.9	2087.8	8.103	3.47	351.5	ND
5/19/2016	20	36.16	24.61	8.040	2391.7	2068.8	8.045	3.48	408.6	0.264
5/19/2016	10	36.17	25.93	8.056	2363.4	2052.1	8.042	3.56	411.6	0.062
5/19/2016	1	35.95	26.37	8.059	2339.7	2035.3	8.039	3.52	414.9	-0.042
8/12/2016	20	35.93	30.13	8.072	2380.5	2037.5	7.996	3.77	462.0	ND
8/12/2016	10	35.79	30.76	8.090	2353.6	2024.6	8.005	3.84	453.3	ND
8/12/2016	1	35.66	30.81	8.091	2355.9	2026.6	8.006	3.83	454.6	ND
11/15/2016	20	36.08	26.39	8.065	2411.5	2058.6	8.043	3.70	408.3	ND
11/15/2016	10	36.07	26.38	8.083	2413.2	2057.5	8.062	3.84	389.3	ND
11/15/2016	1	36.07	26.40	8.091	2415.3	2047.4	8.069	3.86	381.2	ND

Discussion

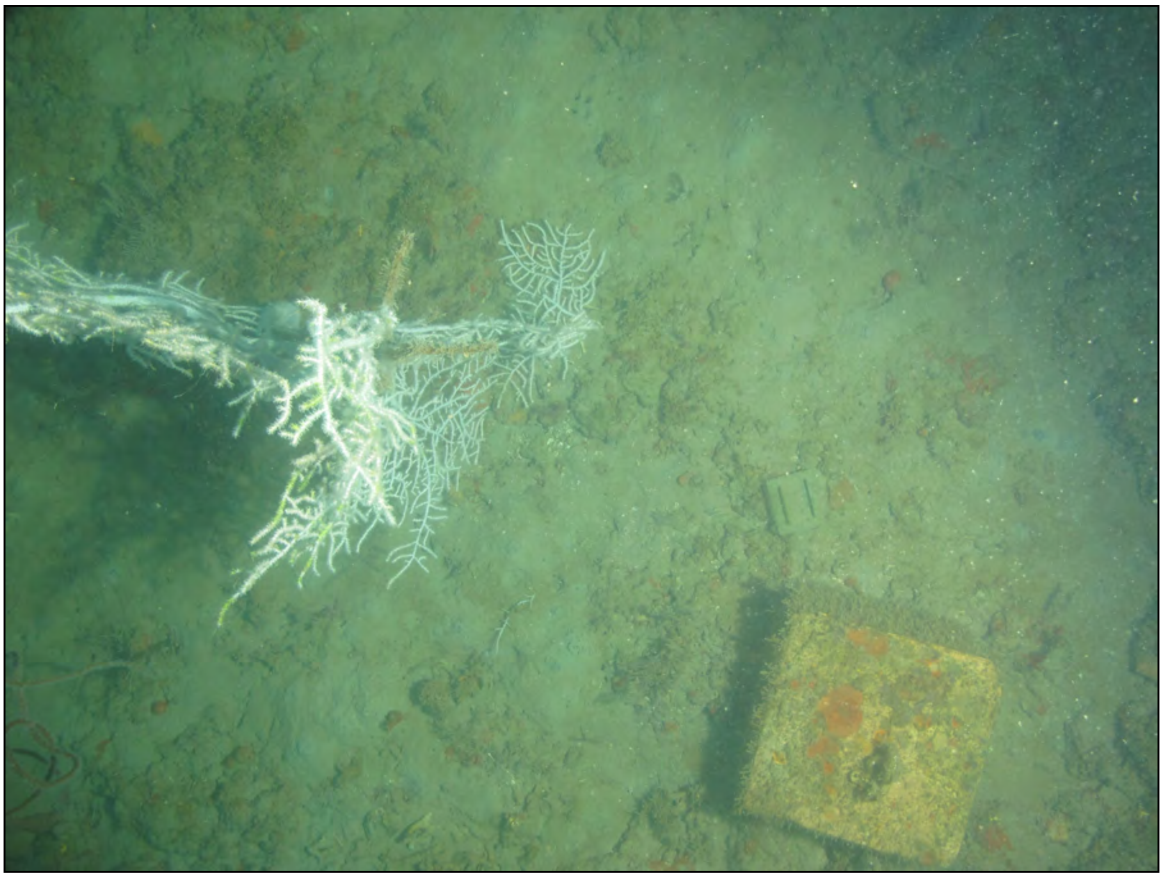
Stetson Bank water temperature readings during this period were initially warmer than average historical data. However, springtime temperatures were similar to the 10-year average from 2005-2014, followed by warming and highly variable temperatures in the summer. Temperatures reached maximum highs of >30ºC for seven days in September of 2016, with four consecutive days above 30ºC. Despite these high temperatures and noted bleaching at the nearby East and West Flower Garden Banks, no bleaching was recorded at Stetson Bank. The observed period of high temperature corresponded with a period of reduced salinity in July 2016, where salinity was reduced by >3 PSU. Typically, the summer months at Stetson Bank see more variable salinity levels, which correlate with months of increased flow rates of the Mississippi and Atchafalaya Rivers, where April is the peak month and flow rates decline gradually through July (Meade 1995).

Water quality parameters indicated minimal water column stratification throughout the year. Laboratory analyses indicated that nutrient levels at Stetson Bank continued to be below detectable levels, indicating low nutrient waters. Carbonate analysis detected lowered salinity recordings in August samples, along with lowest pH and greatest pCO_2 measurement, potentially connected to a significant flood and subsequent runoff event observed in Texas and Louisiana. This also corresponds with SBE measurement of low salinity, high temperature, and high turbidity in mid-July. Overall, data indicate a thermal control on carbonate systems (carbonate saturation state and CO_2 partial pressure, or pCO_2) in this region. After normalization using the annual mean temperature, annual mean of surface seawater $npCO_2$ does not 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 all year round), indicating this cyclic change may correspond to a shift in the balance between respiration and production, but continued field sampling (in conjunction with phytoplankton survey) is needed to test this explanation. 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 2016 demonstrates that seawater in the FGBNMS area (including East Bank, West Bank, and Stetson Bank), despite its proximity to the land, behaved like an oligotrophic open ocean setting (such as the Bermuda Atlantic Time-series Study, or BATS) (Bates et al. 2012) in terms of its annual pCO_2 fluctuation and minimal terrestrial influence. However, significant terrestrial flooding can bring high pCO_2 water and possibly terrestrial organic carbon to the region, causing CO_2 degassing at the sea surface while the freshwater influence lingers. With continuing CO_2 increase in the atmosphere, it is also likely that seawater will further take up CO_2 to lead to long-term acidification. Carbonate chemistry data can be used as a reference for future studies in this region in terms of investigating ocean acidification (due to atmospheric CO2 intrusion) and man-made or naturally occurring petroleum leakage in the northern Gulf of Mexico.

Challenges and resolutions

- Poor weather conditions in the fall of 2016 limited offshore time, preventing the collection of deep temperature thermistors at the 30 m and 40 m stations.
    - These instruments will be collected as soon as possible with weather and cruise schedule. However, battery life and memory on these instruments is greater than one year, so we have little concern about data loss at this time.
- Dissolved oxygen sensors failed in August 2016.
    - Results from this sensor are excluded from this report in August and November 2016. The instrument was returned to Seabird Electronics for repair and calibration.

CHAPTER 6: MESOPHOTIC REPETITIVE QUADRANTS



One of the mesophotic repetitive photostations, M02, was placed near gorgonian sea fans. Photo: NOAA/UNCW-UVP

Introduction

Seven permanent photostations were marked 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). The latitude and longitude of locations were recorded using the navigation system on the ROV (Figure 6.1). All stations were located and photographed in 2016, although obtaining a repeatable image proved challenging.

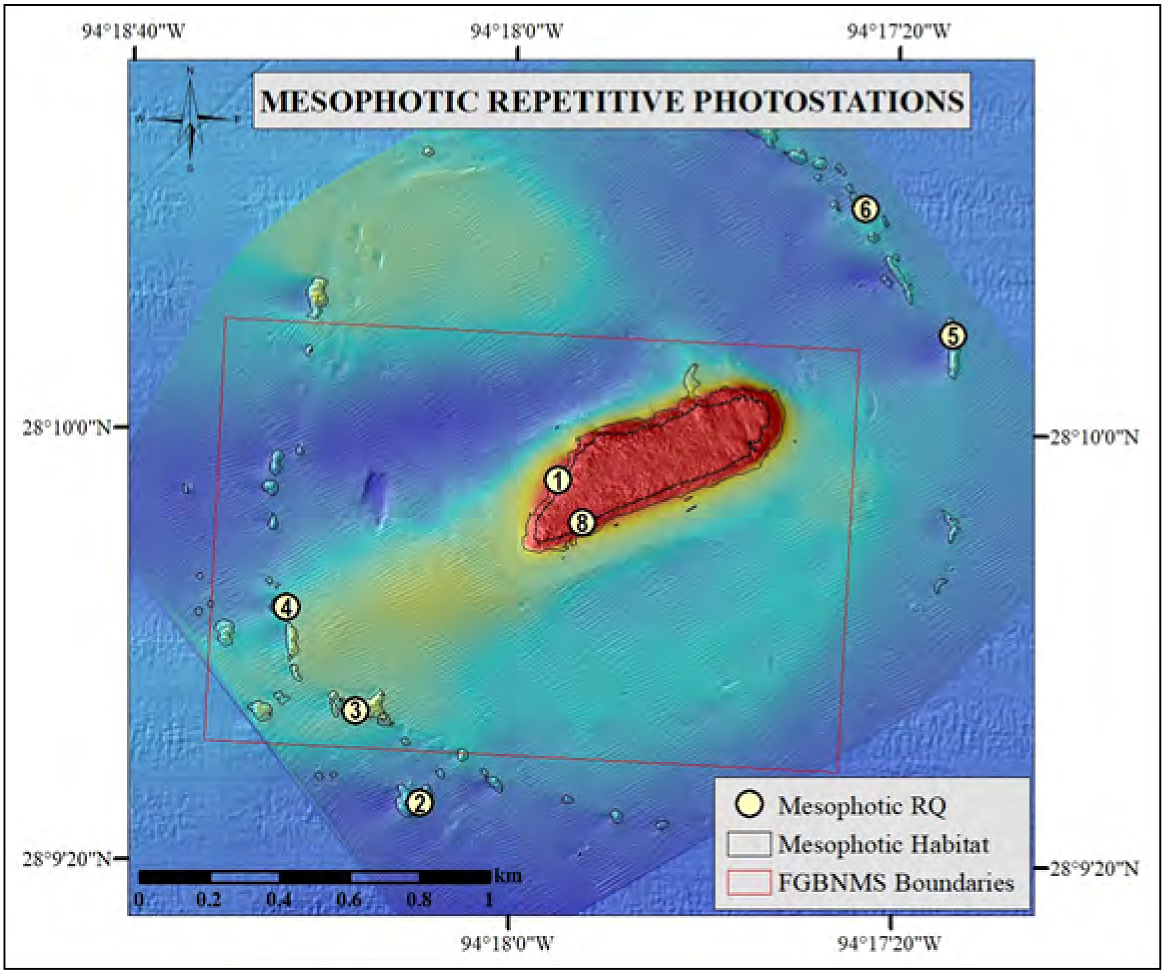


Figure 6.1. Location of mesophotic repetitive photostations at Stetson Bank. Image: NOAA

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 on the location to find the 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 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.

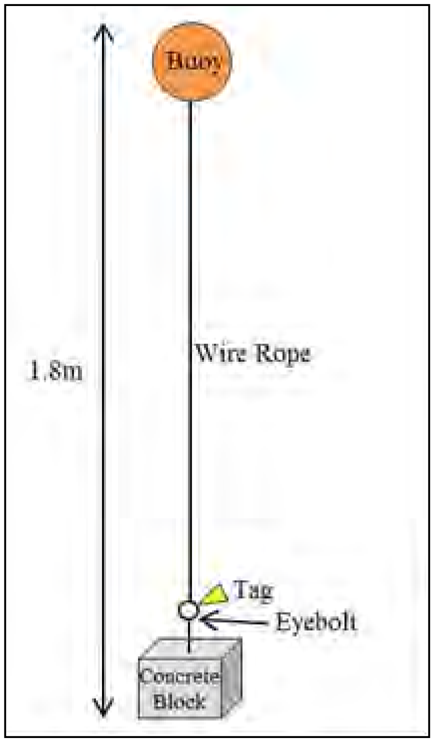


Figure 6.2. Mesophotic repetitive quadrant marker.

Using recorded latitude and longitude overlaid into the ROV navigation system, an ROV was used to locate and photograph 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, where the ROV was positioned directly above the station marker, approximately 1 m above the bottom.

In 2016, a SubAtlantic Mohawk 18 ROV, owned by the National Marine Sanctuary Foundation (NMSF) 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 and two parallel spot lasers set at 30 cm in the video and 10 cm in the still camera frame for use as a scale.

Data processing

Qualitative summaries of still frame image from the high definition video and downward facing still camera were conducted 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 = *Stephanocoenia 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.

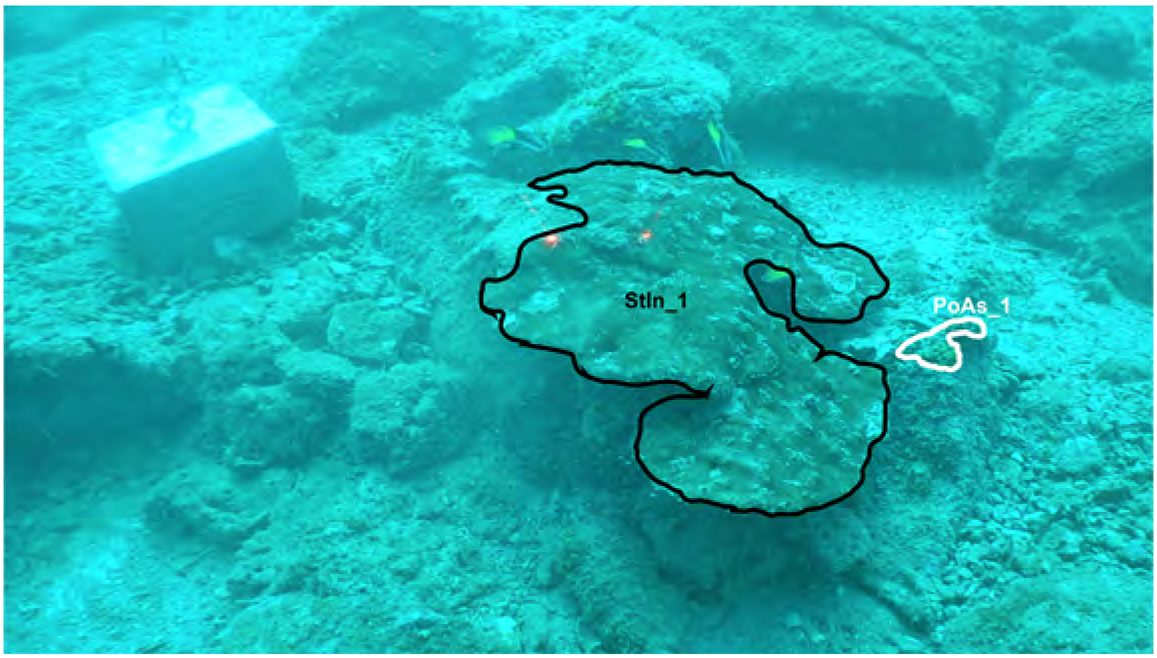


Figure 6.3. Mesophotic photostation M01 in 2015. Key features are outlined and identified.

Results

A total of seven repetitive mesophotic photostations were photographed in 2016. Depth of the stations ranged from 35.8 – 54.7 m. Qualitative summaries of each station were produced (Table 6.1).

Table 6.1. Repetitive photostation M01 - M08 descriptions and change comparisons for 2016.

Station	Depth (m)	Bearing (Deg.)	Latitude (DD)	Longitude (DD)	Site Description	2016 Comp.
M01	39.9	130	28.16542	-94.29867	Coral (StIn_1) *Stephanocoenia intersepta*: 50.3 x 30.4 x 12.4 cm. No bleaching present. (PoAs_1) *Porites astreoides*: 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.	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.	Marker appears to have moved, 10-15 cm.
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.	Marker appears to have moved, 30-35 cm.
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.	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	Sea frost growing on BCSF_1
M08	35.8	225	28.16432	-94.29794	Coral (StIn_1) *Stephanocoenia intersepta:* 58.6 x 48.3 x 4 cm. No bleaching present. (StIn_2) *Stephanocoenia intersepta*: 32.6 x 18.0 x 3 cm. Sponge *Neofibularia nolitangere*. 80% hard bottom covered in macroalgae and rubble.	StIn_1 unsilted edge. More Dictyota growth

Discussion

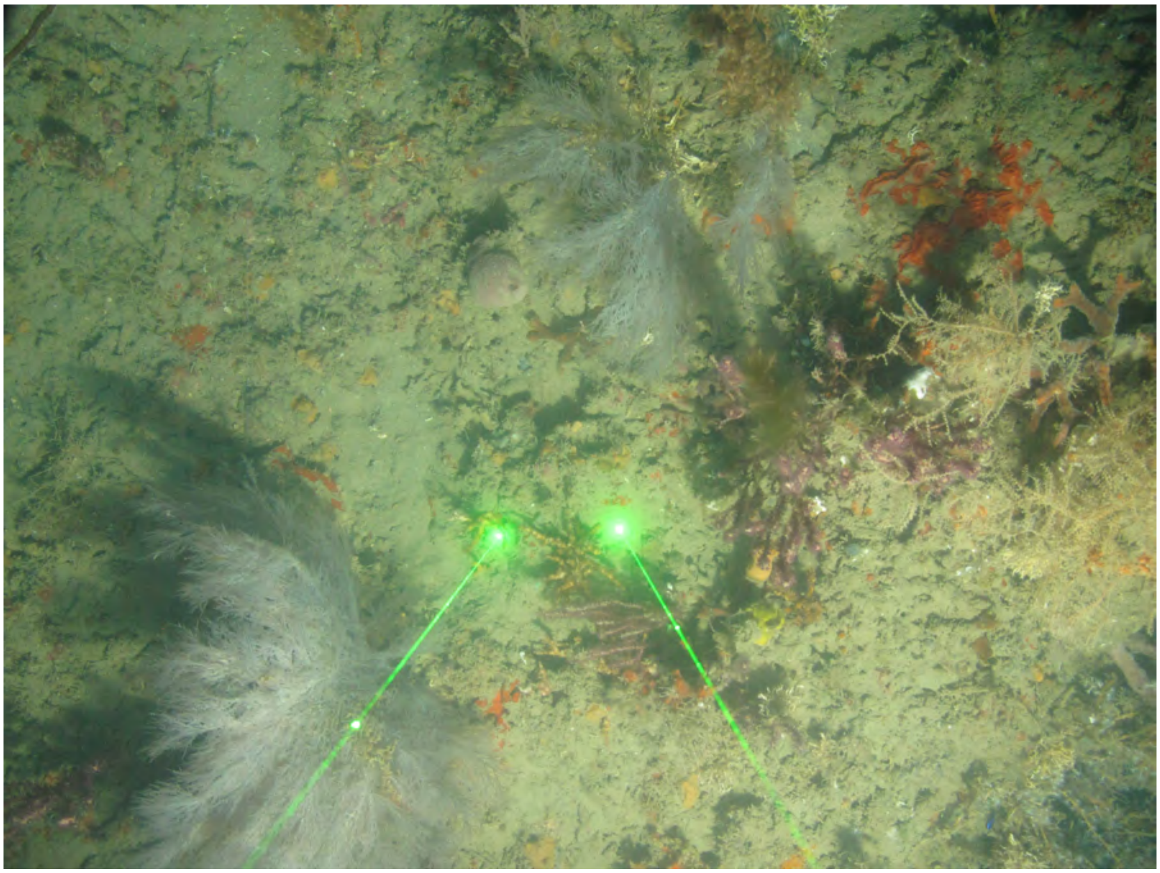
This report presents the second year of mesophotic repetitive photostations in the long-term monitoring program at Stetson Bank. As the ROV was not identically configured between years and some site markers appeared to have moved, collecting replica images of the sites between years was not possible. However, all sites were relocated with minimal effort, despite the loss of sub-surface buoys.

These photostations marked a variety of sites. While comparisons were qualitative in nature 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 2015 and 2016. Qualitative comparisons documented the movement of two markers (M03 and M04), and the growth of sea frost on a black coral sea fan. In addition, the cleaning of silt from a head of *Stephanocoenia intersepta* (M08) and the growth of macroalgae was noted.

Challenges and resolutions

- The sampling skid was not attached to the ROV for sampling in 2016. The lack of the skid meant the angle of the image captured at each site was lower than in 2015, making the benthos captured in 2016 different than 2015, and making images hard to compare.
    - Forward facing still frames were still captured in 2016. However, we also captured downward facing still images for each site and will explore how to make these images comparable between years.
- All repetitive markers lost their subsurface buoys. This is likely due to failure of crimp sleeves.
    - A lack of subsurface markers will make stations difficult to locate. However, this also allowed for downward facing images to be collected. For future deployments, heavy gauge stainless steel wire and stainless steel crimps will be used.
- Due to electrical failure, the sampling skid had to be removed, preventing additional site deployments.
    - No additional sites were deployed in 2016.

CHAPTER 7: MESOPHOTIC RANDOM TRANSECTS



Black corals, octocorals, sponges, hydroids, and bryozoans inhabit the mesophotic reefs surrounding Stetson Bank. Photo: UNCW-UVP

Introduction

A minimum of 15 random transects were 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. These 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 habitat. Two-meter resolution bathymetry raster was imported into ArcMap® and focal statistics calculated for range (minimum – 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 2016, 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 transects would overlap or environmental conditions would have resulted in poor quality data.

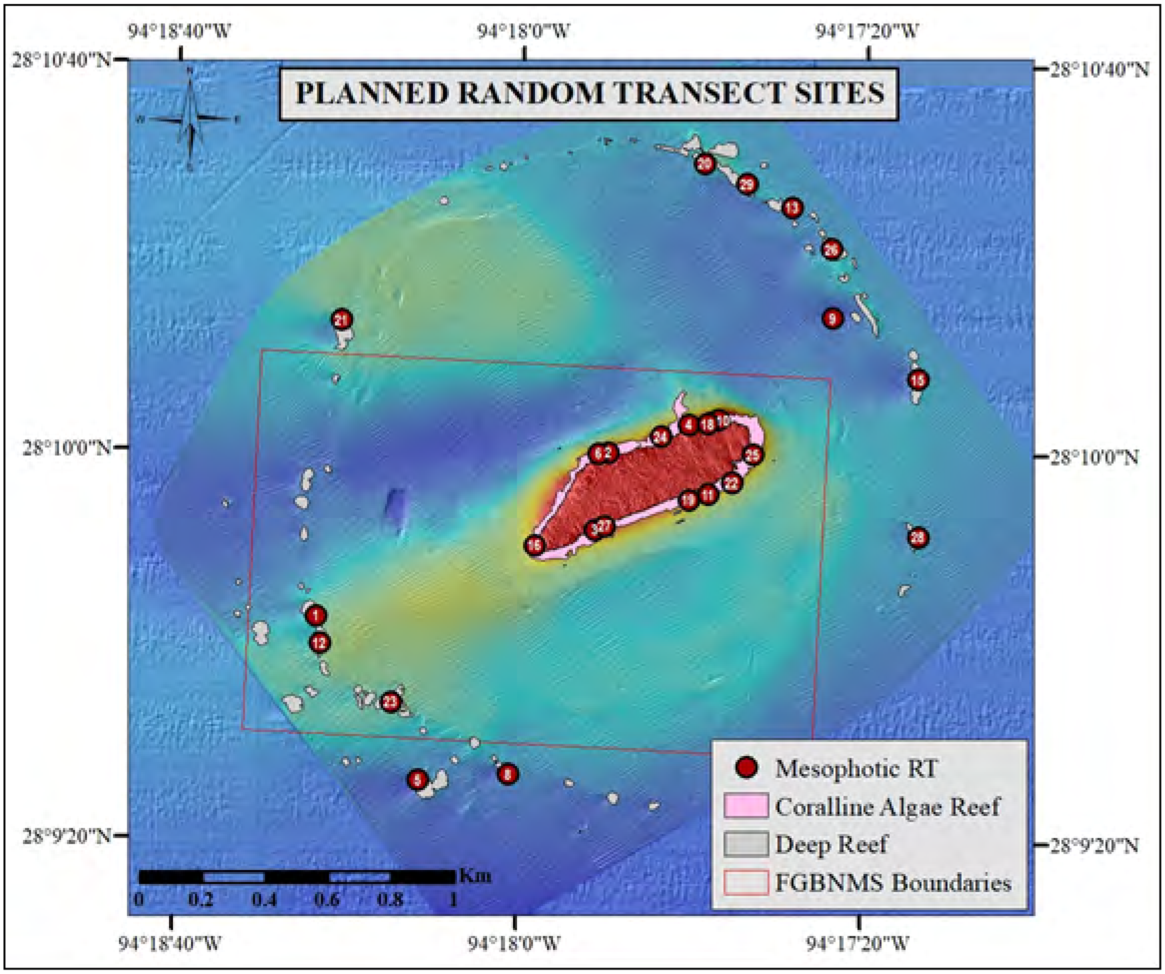


Figure 7.1. Mesophotic random transect locations for 2016. Image: NOAA

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

In 2016, 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

Transects with fewer than nine useable images, following the removal of images that were silted, shadowed, out of focus, or of 100% soft bottom, were removed from analyses. A maximum of 11 images were randomly selected from the remaining images in a transect for processing. 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 within 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, included 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. Families of interest from the cnidarian phylum were expanded to family groupings and summarized. Bleaching, paling, fish biting, and other disease or damage were recorded as "notes," providing additional information for each random point.

In percent cover analysis, as transects differed in area, weighted cover was used in the analysis. To obtain weighted cover, percent cover was multiplied by the area captured in the image. This was then converted to relative 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 2016, 13 in coralline algae habitat and 13 in deep reef habitat. Of those 26, two were removed as, following the removal of silted, shadowed, out of focus, or soft bottom images, fewer than nine useable images were collected. The remaining 24 were processed: 13 in coralline algae reef and 11 in deep reef habitat. Depth of the stations in coralline algae reef habitat ranged from 33.5 to 45.7 m, with an average station depth of 38.8 m, and depth in deep reef habitat, ranged from 51.5 to 58.3 m, with an average station depth of 54.6 m. Results were grouped by habitat type.

Relative 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 2016.

Habitat	Coralline Algae Reef (Relative % Cover)	Deep Reef (Relative % Cover)
Rubble	29.3	3.3
Soft bottom	0.1	37.8
Hard bottom	21.5	37.6
Biota	49.1	21.3

Nine phyla comprised the recorded biota in both habitats (Figure 7.2). Coralline algae reef biota were predominantly Chlorophyta, comprising 36.5% relative cover, primarily due to the abundance of green turf algae in these habitats. Deep reef biota were predominantly Cnidaria, comprising 12.2% relative cover.

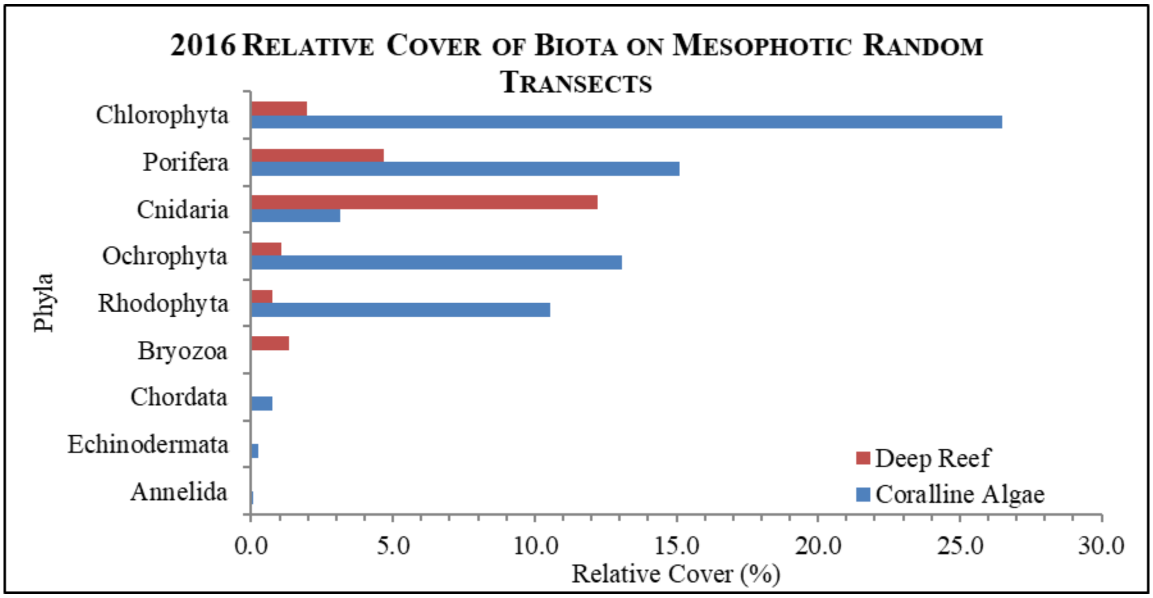


Figure 7.2. Relative percent cover of phyla in mesophotic habitats in 2016.

Of the cnidarian species of interest, species were summed to family level. A major contributor to this phylum in deep reef habitat that was not included in family level analysis is hydroids, comprising ~40% of cnidarians observed. A total of eight families were recorded (Figure 7.3). Coralline algae reef cnidaria were predominantly Astrocoeniidae, at 1.1% relative cover, due to the prevalence of *S. intersepta*. Deep reef cnidaria were predominantly Antipathidae, comprising 3.2% cover, due to the prevalence of a black coral sea fan, potentially *Antipathes atlantica/gracilis*.

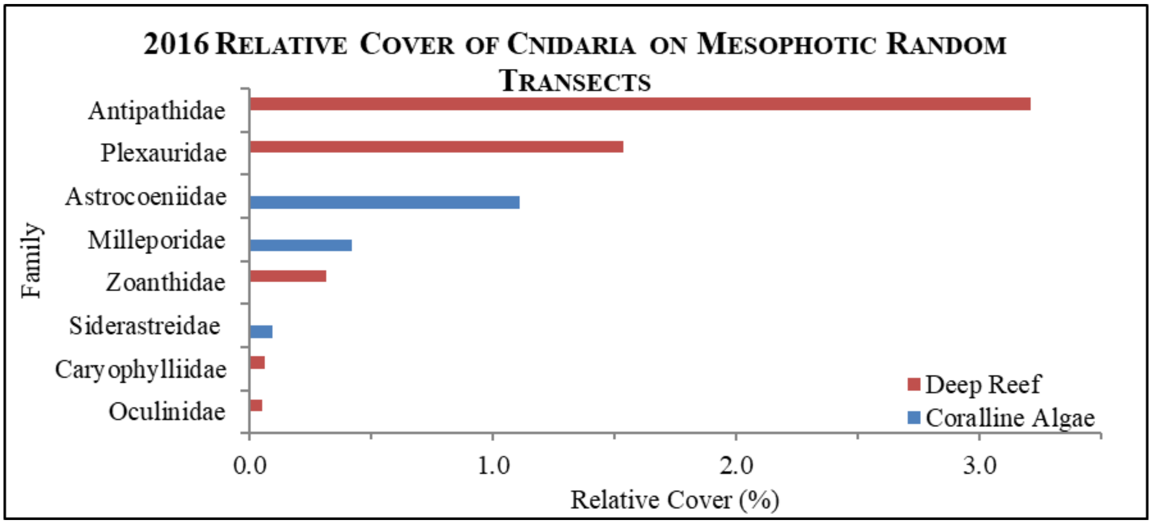


Figure 7.3. Relative percent cover of cnidarian families of interest in mesophotic habitats in 2016.

Density of colonies varied between habitat types, with a total of nine families recorded (Figure 7.4). The densest family in deep reef was Antipathidae with a mean of 2.84 individuals per m^2 (± 0.41 SE), which were entirely absent from coralline algae reefs. The densest colonies in coralline algae reef were Astrocoeniidae at 1.95 individuals per m^2 (± 0.79 SE).

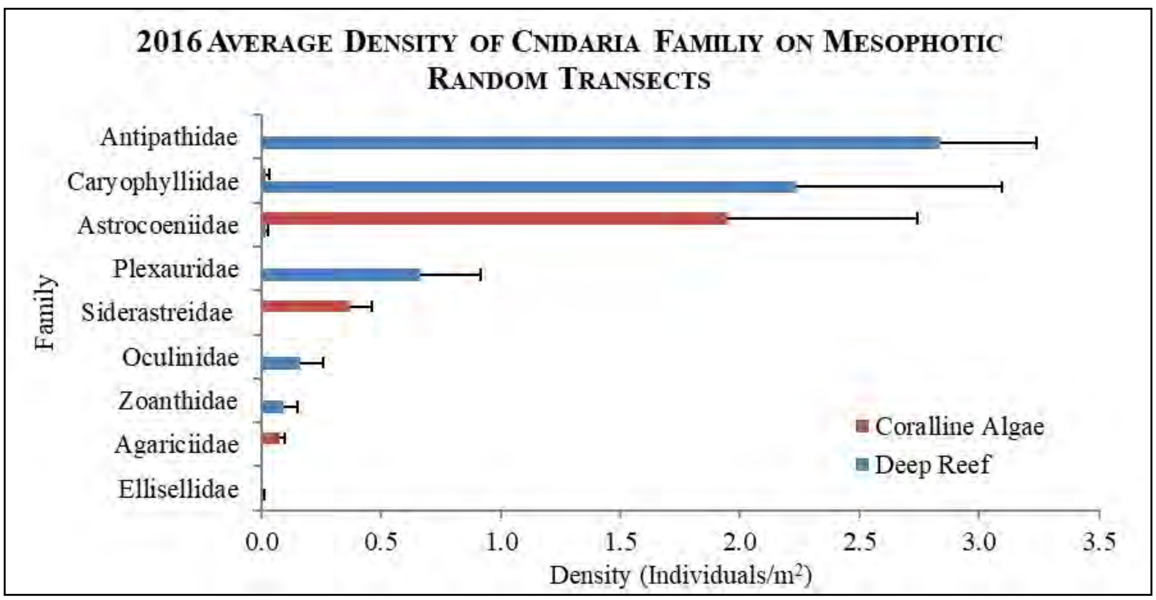


Figure 7.4. Colony density (per 1 m^2) of cnidarian families in mesophotic habitat in 2016.

Density of cnidarian of species of interest (grouped by family) were projected spatially, additional trends were observed (Figure 7.5). Surveys on deep reef habitat were primarily dominated by Antipathidae colonies, though on deep reef patch reefs located on the southwest and northeast of the study site, Plexauridae were also found. In coralline algae habitat, the western portion of the bank crest possessed more Siderastreidae colonies than the east, which was predominantly Astrocoeniidae.

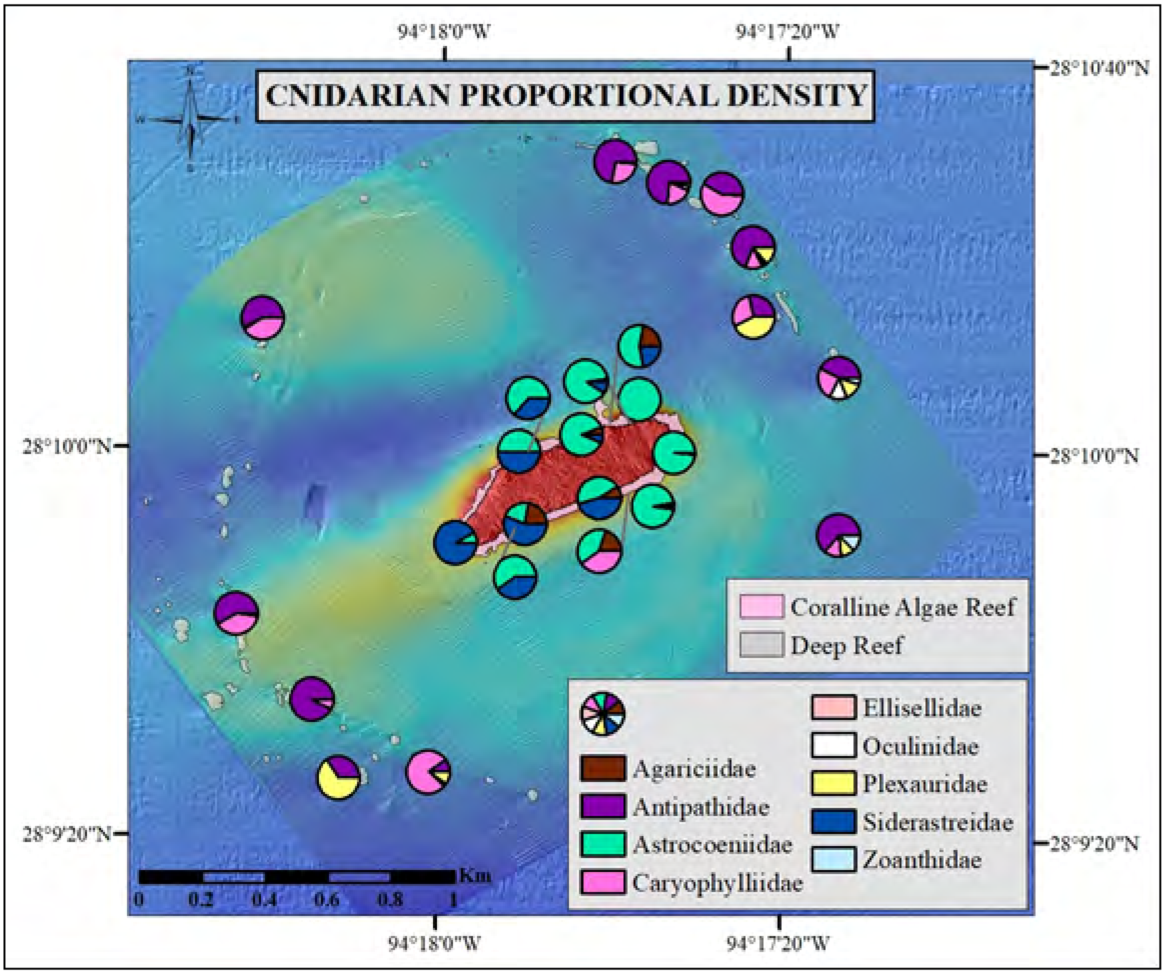


Figure 7.5. Spatial projection of mesophotic cnidarian family density in 2016. Each pie chart represents the location at which a survey was conducted and the proportion of density represented by each family of interest. Image: NOAA

Discussion

Mesophotic ecosystems are a substantial component of Stetson Bank. Two distinct habitat types were encountered in this study, each with different communities. In 2015, coralline algae reef habitat was defined by the presence of abundant crustose coralline algae with Astrocoeniidae as the dominant coral group. Similar to 2015, in 2016 the Astrocoeniidae family comprised the greatest coral density in this habitat. Deep reef habitat cnidarian density was predominantly Antipathidae, primarily due to the abundance of a black coral sea fan, potentially *A. atlantica/gracilis*.

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 – 30 cm and *S. intersepta* colony size ranges are reported from 15 – 76 cm (Humann and Deloach 1992). Therefore, the small colonies observed may represent coral recruits or colonies with stunted growth due to the sub-optimal environmental conditions for coral growth at Stetson Bank.

Challenges and resolutions

No problems were encountered in the 2016 field season. However, 17 random transect sites were revisited in 2016 to conduct benthic surveys using the methods developed by NOAA's Deep Sea Coral Research and Technology Program (DSCRTP) to compare data collected from each method. The DSCRTP methods include capturing a five-minute video transect with scale lasers that is processed for complete coral colony counts.

CHAPTER 8: MESOPHOTIC FISH SURVEYS

Lionfish, big-eye, rock hind, yellowtail reeffish, vermilion snapper, and red snapper use mesophotic reef habitat near a boat anchor and rope. Photo: NOAA/UNCW

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 to <10 cm, ≥10 to <15 cm, ≥15 to <20 cm, ≥20 to <25 cm, ≥25 to <30 cm, ≥30 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 0700), 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 2016 sampling period, 29 fish surveys were conducted.

In 2016, 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 separately mounted laser array, set at 30 cm distance, was used in the field of view 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, utilizing 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 species identifications. Additionally, transects >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 was 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 furthest 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-nine mesophotic fish surveys were conducted in 2016 (Figure 8.1). After removing transects with limited visibility or >50% soft bottom, 19 transects were analyzed. Greater turbidity was observed in the deep reef habitat than in coralline algae reef. Depth of transects ranged from 33.0 – 57.2 m, with an average station depth of 44.1 m. Species richness from all surveys was 60, and family richness from all surveys was 28. Average species richness was 15 (± 1.1 SE), and average family richness was 9 (± 0.6 SE). Average species and family richness were greater in deep reef habitat (17 ± 1.4 SE and 10 ± 0.7 SE, respectively) than coralline algae reef habitat (13 ± 1.4 SE and 8 ± 0.8 SE, respectively).

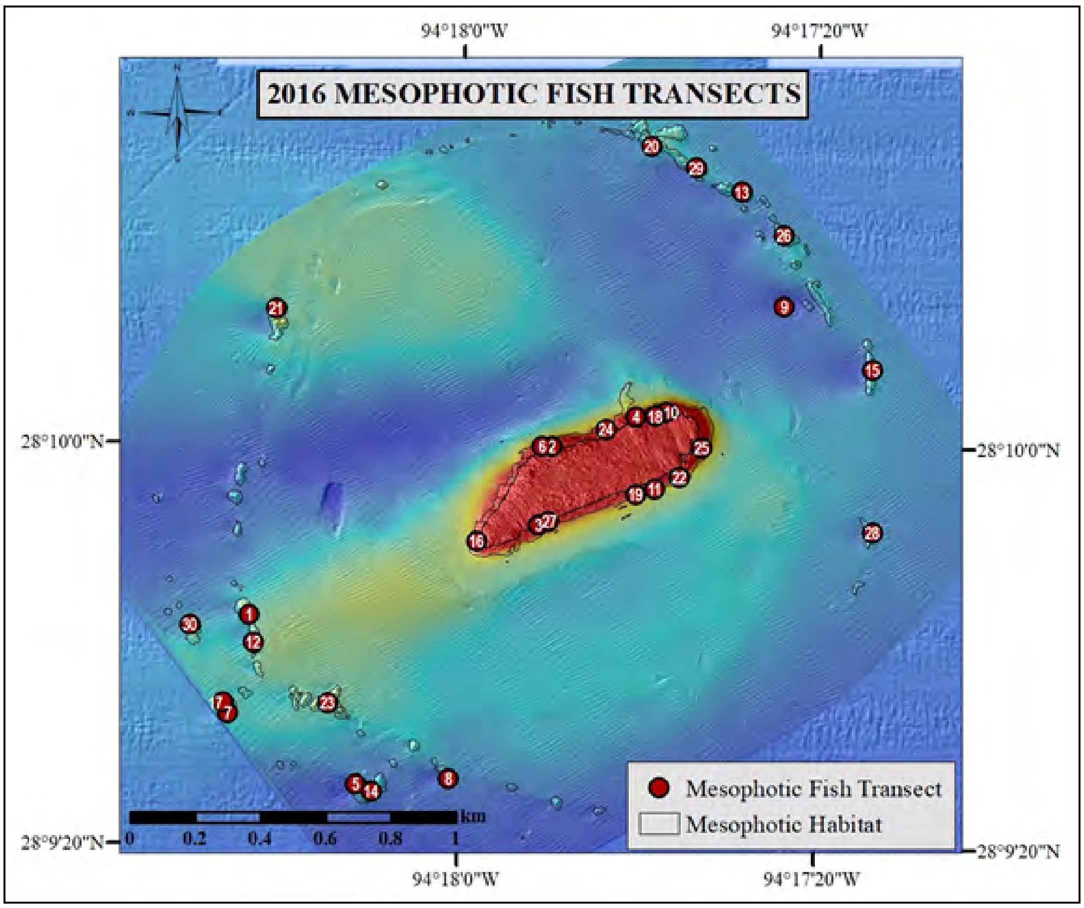


Figure 8.1. Location of mesophotic fish surveys in 2016. Image: NOAA

Sighting frequency and occurrence

The most frequently sighted species in the mesophotic habitat at Stetson Bank in 2016 was yellowtail reeffish (*Chromis enchrysura*). Rank occurrence of the top 10 most frequently sighted species was calculated (Table 8.1).

Table 8.1. Sighting frequency of the 10 most observed mesophotic fish species in 2016. Grouped by habitat, where bold text indicates species that were among the 10 most frequently seen species in both habitats.

Family Name: Species Name (Common Name - Trophic Guild) Species ID	Sighting Frequency (%)		
	Combined	Deep Reef	Coralline Algae Reef
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish-I)	85.7	77.8	91.7
Labridae: *Bodianus pulchellus* (spotfin hogfish-I)	71.4	66.7	75.0
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish-I)	66.7	33.3	91.7
Epinephelidae: *Mycteroperca phenax* (scamp-P)	61.9	33.3	83.3
Pomacentridae: *Chromis insolata* (sunshinefish-PL)	61.9	33.3	83.3
Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)	52.4	11.1	83.3
Tetraodontidae: *Canthigaster rostrata* (sharpnose puffer-I)	52.4	11.1	83.3
Scorpaenidae: *Pterois volitans/miles* (lionfish-P)	52.4	66.7	41.7
Epinephelidae: *Epinephelus adscensionis* (rock hind-I)	52.4	22.2	75.0
Pomacentridae: *Chromis multilineata* (brown chromis-I)	47.6	11.1	75.0
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	42.9	55.6	33.3
Priacanthidae: *Priacanthus arenatus* (bigeye-PL)	33.3	66.7	8.3

Species were considered "rare" if they were recorded in less than 20% of all surveys. "Prevalent" species were recorded in ≥20% of surveys. Over all surveys, 39 species were characterized "rare," while 21 species were characterized "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 62.0 individuals per 100 m^2 (± 17.0 SE). In deep reef habitat, yellowtail reeffish and tomtate (*Haemulon aurolineatum*) had the greatest average density, with 2.9 individuals per 100 m^2 (± 0.9 SE) and 2.7 individuals per 100 m^2 (± 1.7 SE), respectively (Table 8.2). In coralline algae reef habitat, yellowtail reeffish and vermilion snapper (*Rhomboplites aurorubens*) had the greatest average density, with

68.8 individuals per 100 m^2 (± 25.3 SE) and 6.9 individuals per 100 m^2 (± 3.2 SE), respectively.

Table 8.2. Mean density (individuals/100 m^2) of the 10 densest mesophotic fish species in 2016. Grouped by habitat, ± standard error; bold text indicates species that were among the 10 densest species in both habitats and dashes indicate that the species was not observed in that habitat.

Family Name: Species Name (Common Name - Trophic Guild)	Density (Individuals/100m2)		
Species ID	Combined	Deep Reef	Coralline Algae Reef
Pomacentridae: *Chromis enchrysura* (yellowtail reeffish-I)	41.1 ± 16.3	2.9 ± 0.9	68.8 ± 25.3
Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper-P)	4.0 ± 2.0	0.1 ± 0.1	6.9 ± 3.2
Pomacentridae: *Chromis multilineata* (brown chromis-I)	2.8 ± 1.1	2.3 ± 2.3	3.2 ± 0.9
Haemulidae: *Haemulon aurolineatum* (tomtate-I)	2.3 ± 1.2	2.7 ± 1.7	1.9 ± 1.7
Pomacentridae: *Chromis scotti* (purple reeffish-PL)	2.2 ± 0.9	1.2 ± 1.2	2.8 ± 1.3
Pomacentridae: *Chromis insolata* (sunshinefish-PL)	1.4 ± 0.4	0.5 ± 0.5	2.0 ± 0.5
Lutjanidae: *Lutjanus griseus* (gray snapper-I)	1.4 ± 1.1	0.1 ± 0.1	2.3 ± 1.9
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish-I)	1.0 ± 0.4	0.0 ± 0.0	1.6 ± 0.6
Labridae: *Bodianus pulchellus* (spotfin hogfish-I)	0.7 ± 0.2	0.3 ± 0.1	1.0 ± 0.2
Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)	0.7 ± 0.2	<0.1 ± <0.1	1.1 ± 0.3
Sciaenidae: *Pareques umbrosus* (cubbyu-I)	0.1 ± 0.1	0.2 ± 0.2	0.1 ± 0.1
Priacanthidae: *Priacanthus arenatus* (bigeye-PL)	0.1 ± 0.1	0.2 ± 0.0	0.1 ± 0.1
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	0.2 ± 0.1	0.1 ± 0.0	0.3 ± 0.2

Biomass

Average biomass in all surveys was 1825.6 g/100 m^2 (± 602.3 SE). Tomtate and grouper spp. had the greatest average biomass in deep reef habitat, with 1206.3 g/100 m^2 (± 770.6 SE) and 144.2 g/100 m^2 (± 144.2 SE), respectively (Table 8.3). In coralline algae habitat, gray snapper (*Lutjanus griseus*) and tomtate had the greatest average biomass, with 1138.4g/100 m^2 (± 955.7 SE) and 754.1 g/100 m^2 (± 737.3 SE), respectively.

Table 8.3. Mean biomass of the top 10 mesophotic fish species in 2016. Grouped by habitat, ± standard error, where bold text indicates species that were among the 10 densest species in both habitats and dashes indicate that the species was not observed in that habitat.

Family Name: Species Name (Common Name - Trophic Guild Species ID	Biomass (g/100m2)		
	Combined	Deep Reef	Coralline Algae Reef
Haemulidae: *Haemulon aurolineatum* (tomtate-I)	944.5 ± 524.3	1206.3 ± 770.6	754.1 ± 737.3
Lutjanidae: *Lutjanus griseus* (gray snapper-I)	677.5 ± 556.9	43.7 ± 31.7	1138.4 ± 955.7
Pomacanthidae: *Pomacanthus paru* (French angelfish-I)	139.7 ± 94.9	-	241.2 ± 159.8
Muraenidae: *Gymnothorax moringa* (spotted moray-P)	124.9 ± 92.5	-	215.8 ± 157.0
Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	113.1 ± 63.2	73.8 ± 28.9	141.8 ± 108.6
Kyphosidae: *Kyphosus saltatrix/incisor* (Bermuda/yellow chub-H)	90.9 ± 90.9	-	157.0 ± 157.0
Scorpaenidae: *Pterois volitans* (lionfish-P)	83.1 ± 33.8	38.3 ± 14.2	115.6 ± 56.5
Balistidae: *Balistes capriscus* (gray triggerfish-I)	64.4 ± 40.3	-	111.3 ± 67.2
Epinephelidae (grouper spp.-P)	60.7 ± 60.7	144.2 ± 144.2	-
Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper-P)	59.9 ± 54.8	-	103.5 ± 94.2
Carangidae: *Seriola rivoliana* (almaco jack-P)	30.3 ± 22.4	72.0 ± 51.5	-
Lutjanidae: *Lutjanus campechanus* (red snapper-P)	36.5 ± 19.2	43.3 ± 33.6	31.5 ± 23.9
Labridae: *Bodianus pulchellus* (spotfin hogfish-I)	45.3 ± 12.3	25.6 ± 8.3	59.6 ± 19.8
Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper-P)	22.4 ± 10.2	22.6 ± 14.0	22.2 ± 15.0
Chaetodontidae: *Chaetodon sedentarius* (reef butterflyfish-I)	54.2 ± 22.3	1.0 ± 0.6	93.0 ± 34.5

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 eight species (± 0.6 SE) constituting the guild, and herbivores possessed the lowest average species richness overall, with one species (± 0.3 SE) comprising the guild.

Table 8.4. Mean mesophotic fish species richness within trophic guilds in 2016.

Trophic Guild	Combined	Deep Reef	Coralline Algae Reef
Planktivore	2 ± 0.2	1 ± 0.2	3 ± 0.3
Piscivore	3 ± 0.3	2 ± 0.4	3 ± 0.4
Invertivore	8 ± 0.6	6 ± 0.5	11 ± 0.5
Herbivore	1 ± 0.3	0 ± 0.2	2 ± 0.2

The contribution of each trophic guild to the observed density and biomass overall and by habitat was calculated (Table 8.5). In both deep reef and coralline algae habitat, invertivores contributed most to observed density of fishes (78.9 % and 83.5 %, respectively) and herbivores contributed the least (0.1 % and 2.4 %, respectively). Observed biomass in both deep reef and coralline algae reef habitat was primarily composed of invertivores (79.8 % and 77.4 %, respectively).

Table 8.5. Percent contribution of mesophotic fish trophic guild to density and biomass in 2016.

Trophic Guild	Density (% Contribution)			Biomass (% Contribution)		
	Combined	Deep Reef	Coralline Algae Reef	Combined	Deep Reef	Coralline Algae Reef
Planktivore	6.5	16.9	5.7	0.9	1.4	0.8
Piscivore	8.1	4.1	8.5	17.4	18.8	16.9
Invertivore	83.1	78.9	83.5	78.0	79.8	77.4
Herbivore	2.2	0.1	2.4	3.6	<0.1	4.9

The three species contributing the most to observed density (Table 8.6) and biomass (Table 8.7) within each habitat type and from each trophic guild were calculated.

Table 8.6. Percent contribution of mesophotic fish density of the top three species to trophic guild in 2016. Grouped by habitat, where bold text indicates species that were among the three densest species in both habitats.

Trophic Guild	Family Name: Species Name (Common Name - Trophic Guild) Species ID	% Contribution to Trophic Density		
		Combined	Deep Reef	Coralline Algae Reef
H	**Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)**	47.8	57.5	47.7
	Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	15.6	-	15.6
	Kyphosidae: *Kyphosus saltatrix/incisor* (Bermuda/yellow chub-H)	14.1	-	14.2
	Pomacentridae: *Stegastes partitus* (bicolor damselfish-H)	8.2	42.5	8.0
I	**Pomacentridae: *Chromis enchrysura* (yellowtail reeffish-I)**	79.7	32.3	83.4
	Pomacentridae: *Chromis multilineata* (brown chromis-I)	5.4	25.8	3.8
	Haemulidae: *Haemulon aurolineatum* (tomtate-I)	4.4	31.0	2.3
	Lutjanidae: *Lutjanus griseus* (gray snapper-I)	2.6	0.8	2.8
P	**Lutjanidae: *Rhomboplites aurorubens* (vermilion snapper-P)**	80.2	31.2	82.1
	Epinephelidae: *Mycteroperca phenax* (scamp-P)	7.4	17.9	7.0
	Scorpaenidae: *Pterois volitans* (lionfish-P)	4.1	23.8	3.3
PL	**Pomacentridae: *Chromis scotti* (purple reeffish-PL)**	53.5	64.4	50.8
	Pomacentridae: *Chromis insolata* (sunshinefish-PL)	33.9	26.2	35.8
	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish-PL)	3.3	-	4.1
	Priacanthidae: *Priacanthus arenatus* (bigeye-PL)	2.8	8.5	1.5

Table 8.7. Percent contribution of mesophotic fish biomass of the top three species from each trophic guild in 2016. Grouped by habitat, where bold text indicates species that were among the three densest species in both habitats.

Trophic Guild	Family Name: Species Name (Common Name - Trophic Guild) Species ID	% Contribution to Trophic Biomass		
		Combined	Deep Reef	Coralline Algae Reef
H	**Kyphosidae: *Kyphosus saltatrix/incisor* (Bermuda/yellow chub-H)**	86.6	-	149.5
	Acanthuridae: *Acanthurus chirurgus* (doctorfish-H)	10.4	-	18.0
	Pomacentridae: *Stegastes variabilis* (cocoa damselfish-H)	1.5	0.1	2.6
	Pomacentridae: *Stegastes partitus* (bicolor damselfish-H)	0.4	<0.1	0.7
I	**Haemulidae: *Haemulon aurolineatum* (tomtate-I)**	41.9	53.5	33.4
	Lutjanidae: *Lutjanus griseus* (gray snapper-I)	30.0	1.9	50.5
	Pomacanthidae: *Pomacanthus paru* (French angelfish-I)	6.2	-	10.7
	Pomacanthidae: *Holacanthus bermudensis* (blue angelfish-I)	5.0	3.3	6.3
P	Muraenidae: *Gymnothorax moringa* (spotted moray-P)	24.8	0.0	42.9
	Scorpaenidae: *Pterois volitans* (lionfish-P)	16.5	7.6	23.0
	Epinephelidae (grouper spp.-P)	12.1	28.6	-
	Carangidae: *Seriola rivoliana* (almaco jack-P)	6.0	14.3	-
	Lutjanidae: *Lutjanus campechanus* (red snapper-P)	7.2	8.6	6.3
	Epinephelidae: *Mycteroperca interstitialis* (yellowmouth grouper-P)	11.9	0.0	20.6
PL	**Priacanthidae: *Priacanthus arenatus* (bigeye-PL)**	72.1	80.6	66.0
	Epinephelidae: *Paranthias furcifer* (Atlantic creolefish-PL)	17.1	0.0	29.5
	Pomacentridae: *Chromis insolata* (sunshinefish-PL)	6.3	9.6	3.9
	Pomacentridae: *Chromis scotti* (purple reeffish-PL)	2.5	1.4	3.3

Size-frequency

Size frequency, using relative abundance, was calculated for all surveys and for each trophic guild (Table 8.6). In all surveys combined, 68.5 % of individuals were <5 cm. All trophic guilds were predominantly composed of small individuals (<5 cm).

Table 8.6. Relative percent abundance of fish in each size category in 2016.

Size Category (cm)	Combined	Planktivore	Piscivore	Invertivore	Herbivore
<5	68.5	83.9	35.2	71.9	50.0
5-10	11.1	6.7	41.0	7.6	16.3
10-15	3.3	4.0	3.4	3.0	12.5
15-20	1.2	2.4	2.2	1.1	-
20-25	1.7	2.7	4.6	1.3	1.0
25-30	10.0	0.3	4.2	11.3	19.2
30-35	3.6	-	5.0	3.8	1.0
>35	0.5	-	4.2	0.1	-

Dominance plots

When averaged for all samples, dominance plots (abundance-biomass curve) *w* values were near zero, 0.03 (± 0.04 SE) overall. Both deep reef and coralline algae reef habitat had mean *w* statistic close to zero, 0.09 ± 0.07 SE and -0.01 ± 0.05 SE, respectively.

Spatial analysis

When surveys were projected spatially, general trends in trophic distribution were observed. The density of each trophic guild at each survey site was projected (Figure 8.2). During this study period, density of piscivores was patchy in both deep reef and coralline algae reef habitat, primarily due to the density of vermilion snapper. Invertivore density was high throughout the study area, primarily due to the density of yellowtail reeffish.

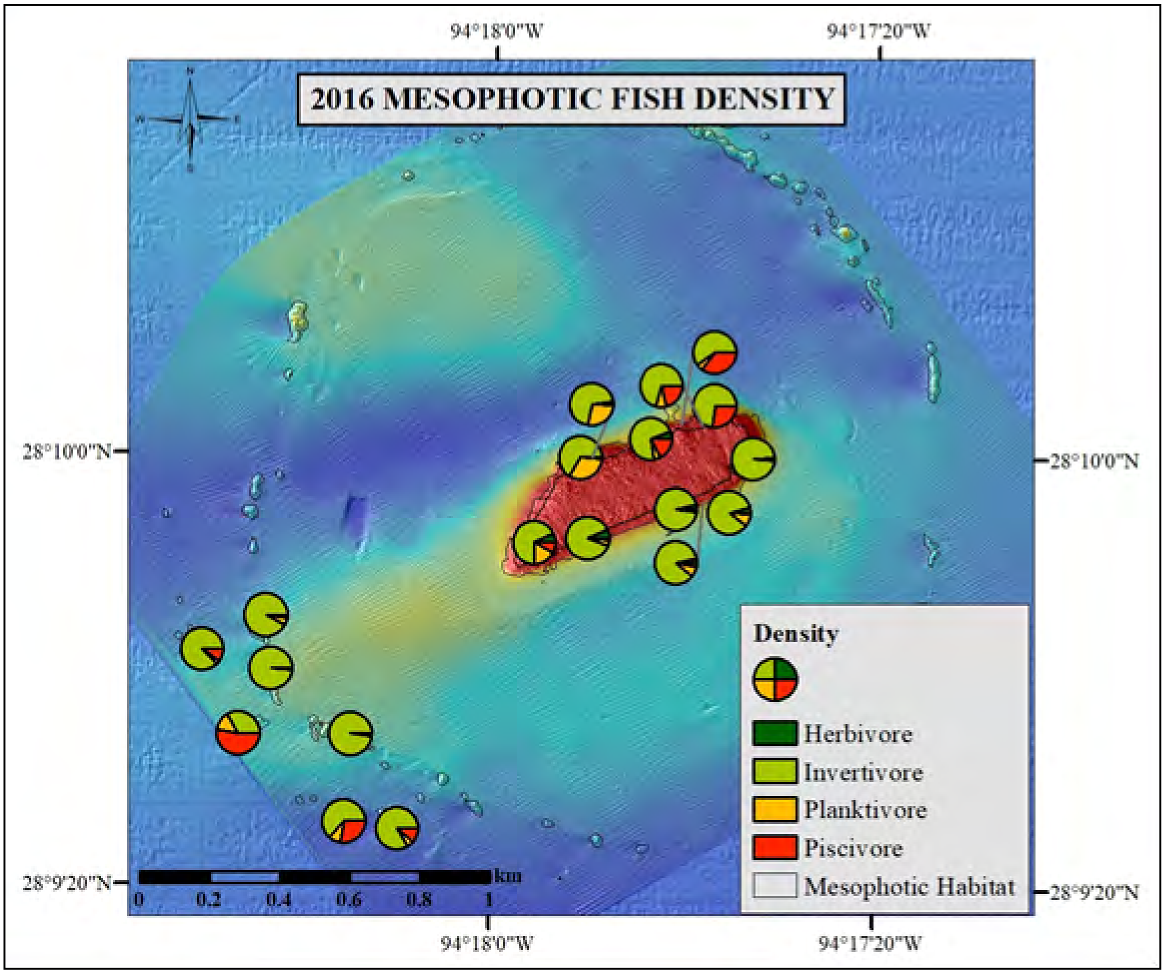


Figure 8.2. Spatial projection of mesophotic fish trophic density in 2016. Each chart represents the location at which a survey was conducted. Image: NOAA

The biomass of each trophic guild at each survey site was also projected (Figure 8.3). During this study period, overall biomass of piscivores was predominant in most surveys, due to the predominance of grouper in deep reef habitat and moray eels in coralline algae reef habitat.

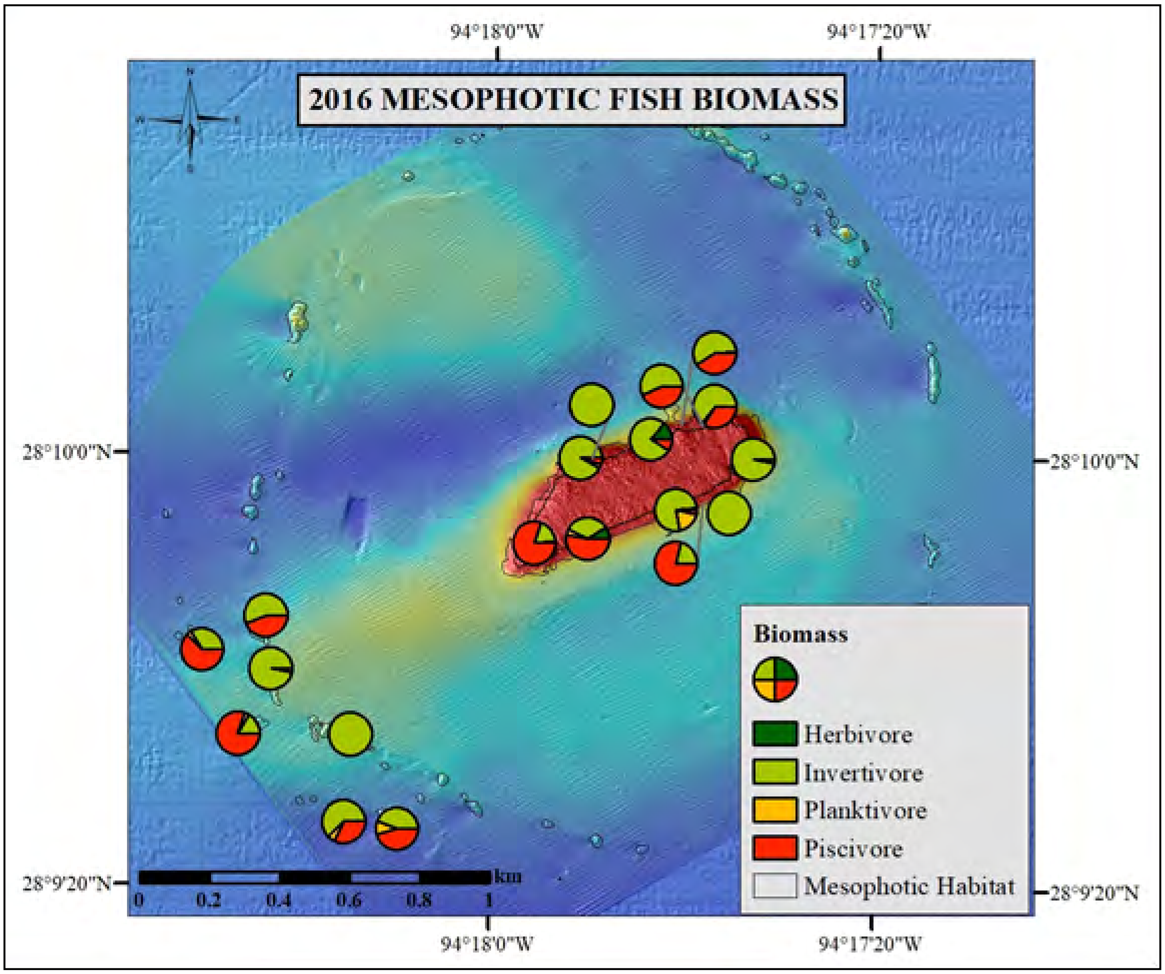


Figure 8.3. Spatial projection of mesophotic fish trophic biomass in 2016. Charts represents the location at which a survey was conducted. Image: NOAA

Discussion

This data collection period represents the second year of quantitative mesophotic fish surveys conducted 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 to shallow bank crest communities. They were dominated by piscivorous fishes and lacking in herbivorous fishes.

Fish in mesophotic habitat at Stetson Bank in 2016 were mostly small individuals, <5 cm. Abundance-biomass comparisons indicated the mesophotic fish community at Stetson Bank appears to be balanced in abundance and biomass in both habitat types.

Spatial analysis highlights the importance of mesophotic habitat for piscivorous fish, although their distribution was somewhat patchy. It also highlights the lack of herbivorous fish found in these habitats.

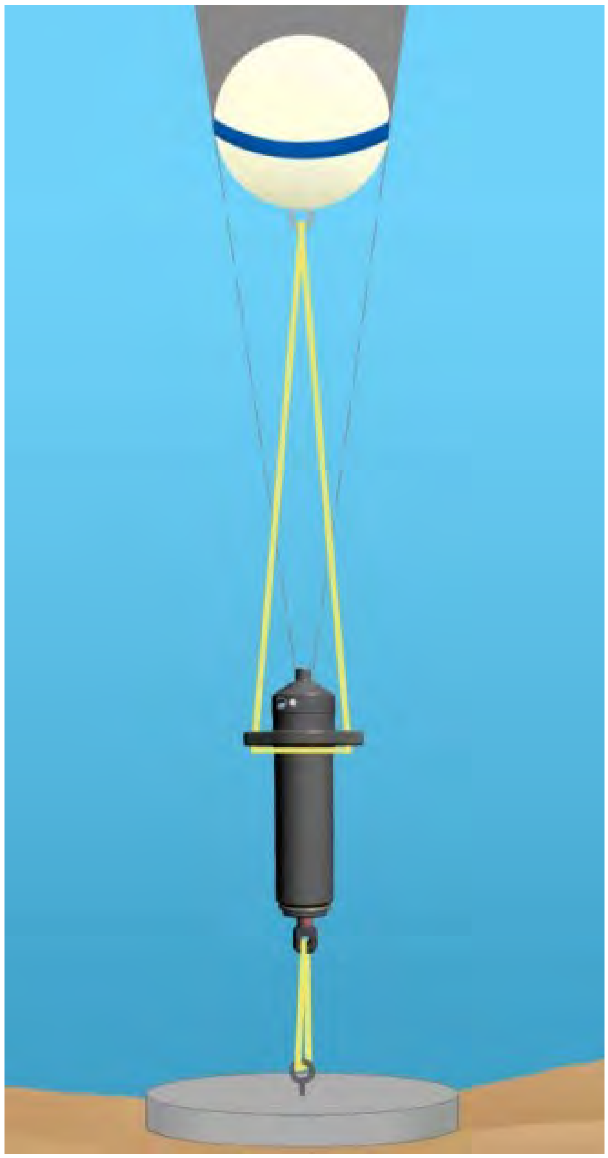
On the bank crest of Stetson Bank, scuba divers have reported lionfish since 2011. Lionfish were first documented in the first mesophotic fish surveys of this study in 2015 and continue to be documented in 2016. The invasion of this exotic species is of particular concern due to their voracious appetite, high fecundity, and apparent lack of predators. The biomass of lionfish in 2016 appeared in the top 10 in both habitat types and the species was the ninth 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 (including the effects of lionfish). Overall, the mesophotic fish community was variable and composed of both commercially and recreationally valuable fish species.

Challenges and resolutions

- Due to electrical failure of the sampling skid on the ROV, forward facing lasers for the video camera were not available at the same time as downward facing lasers for the still camera.
    - A set of lasers used for shallow water photography, set at 30 cm apart, were mounted to the ROV frame in view of the video frame. As the lasers were battery operated, surveys were halted when the batteries died so the ROV could be recovered and batteries replaced. However, for those transects where lasers could not be located in the image frame, field of view area obtained from other surveys on the same dive were averaged and used as estimated field of view.
- Mesophotic fish surveys in deep reef habitat were concentrated in the southwest.
    - Due to poor visibility in other deep reef habitat areas, only surveys conducted in the southwest portion of the bank possessed sufficient visibility to process fish survey data.

CHAPTER 9: MESOPHOTIC WATER TEMPERATURE



VEMCO VR2AR acoustic release system. 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).

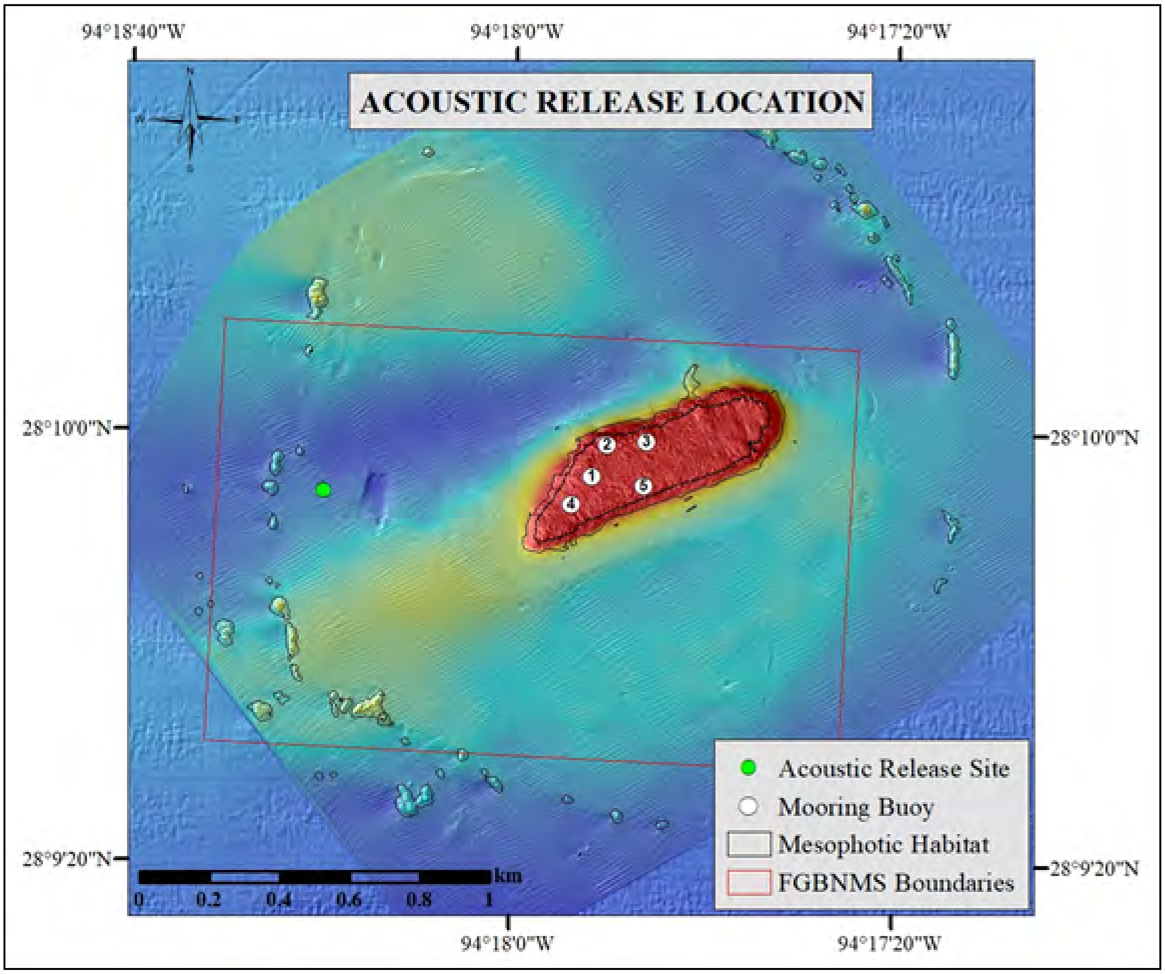


Figure 9.1. Location of the acoustic release system deployed in 2015. System holds instruments at 54 m and 44 m to record water temperature every hour. Image: NOAA

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 and used to record temperature at that depth. A 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 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, it is thought that 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 events.

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, instead lying 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 of the instrument that holds it vertical in the water column and provides the flotation to return the instrument to the surface. As collection in 2016 using an ROV was not possible, we plan to attempt a recovery during the mesophotic cruise in 2017.

CHAPTER 10: VIDEO OBSERVATIONS AND NOTES

Madracis brueggemanni sits atop a black ball sponge, *Ircinia strobilina*, at Stetson Bank. Photo: Ryan J. Eckert/NOAA

Introduction

Three 100 m 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. Each transect was marked using 12-inch 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 were surveyed and will be added to the site maps. Before videoing, a line was laid between the eyebolts to mark the transect.

In 2016, video surveys were recorded along each transect, starting from eyebolt A, and ending at eyebolt E. Video was recorded using a Sony® Handycam® HDR-CX350 HD video camera in a Light and Motion® Stingray G2® housing.

A plumb bob was secured to the front of the camera housing with 2 m of scope between the camera housing and the plumb bob. The diver swam along the transect line, following the line with the plumb bob. The camera was maintained at a 45° angle to the reef during filming.

Mesophotic video transects

None were completed in 2016.

General observations

General observations of interest 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, several Caribbean spiny lobster, and one queen conch. Sponges and corals appeared to be in good health with no notable impacts. Isolated occurrences of fishing line entangled on the reef were noted and for one video transect, a visible thermocline was observed.

No mesophotic video transects were completed in 2016 due to limited time.

General observations on the shallow reef cruise included observations of sandbar sharks (*Carcharhinus plumbeus*), loggerhead sea turtles (*Caretta caretta*), and common octopuses (*Octopus vulgaris*). Algae on the bank crest appeared somewhat more abundant than in 2015. On the mesophotic cruise, researchers observed sandbar sharks and lionfish. Visibility was noted to be variable around the reef, but appeared best in the morning hours.

Discussion

Several interesting observations were made during the 2016 field season. Thermoclines were captured visually in transect video on the bank crest in 2016, showing cold water mixing occurring during the early summer. Of particular note, several Caribbean spiny lobster and a queen conch (*Strombus gigas*) was also captured in video transects. In addition, sharks, not typically documented in fish surveys, were observed, and loggerhead sea turtles were observed. Repeated sighting of these animals throughout the years, while not captured in long-term monitoring datasets, suggest the species maybe persistent at Stetson Bank.

Conclusions

This report summarizes the findings from the annual monitoring conducted at Stetson Bank in 2016. 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-hydrocoral community to algal-sponge community over that time. Data from this study period showed an increase in macroalgae cover since 2014, decreasing the availability of open substrate for potential colonization. This finding was also supported in random transect data. Sponge cover has been in a slow gradual decline since the initiation of monitoring, but has stabilized around 15% since 2013.

Water column temperatures warmed quickly early in the year and documented several consecutive days where water temperatures on the bank crest exceeded 30°C. Salinity declines in July indicate potential runoff events extending to Stetson Bank. While ocean carbonate samples support the potential impact of a runoff event in July 2016, all nutrient samples in 2016 were below detectable limits. Additionally, carbonate chemistry indicates that this area, despite its proximity to the land, more closely resembles an open ocean setting, and acts as a net CO_2 sink.

Mesophotic benthic habitats at Stetson Bank were quantitatively surveyed for the second time in 2016. Two distinct habitats were documented, each with a unique biotic community. While biota 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 dominant species observed in mesophotic habitat at Stetson Bank are commercially and recreationally valuable species.

Several challenges were encountered during this study period, particularly with mesophotic monitoring tasks. The ability to capture repetitive imagery of the repetitive photostations proved to be the greatest challenge in completing field work, with additional images captured in 2016 to attempt to reconcile these issues. The 2017 field season will allow further refinement of these techniques and retrieval of malfunctioning equipment.

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

BATS – Bermuda Atlantic Time-series Study
BSEE – Bureau of Safety and Environmental Enforcement
CCL – Carbon Cycle Laboratory
CPCe – Coral Point Count® with Excel® extensions
CTB – former denotation of colonizable substrate
DIC – total dissolved CO_2
DO – dissolved oxygen
EPA – Environmental Protection Agency
FGBNMS – Flower Garden Banks National Marine Sanctuary
GREAT – Gulf Reef Environmental Action Team
NMSF – National Marine Sanctuary Foundation
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