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Benthic Invertebrate Communities and Habitat Characterization of the Pourtalès Terrace, Florida with Analysis of the Deepwater Coral Habitat Areas of Particular Concern and the East Hump Marine Protected Area

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By

Jana K. Ash

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I. Abstract

The Pourtalès Terrace is a gently curved, narrow triangular platform that parallels the Florida Keys for 213 km running from southern Key Largo to between Key West and the Marquesas Keys. The main Terrace surface begins in 200 m and dips gently to approximately 450 m, where the Pourtalès Escarpment slopes steeply to the deep floor of the southern Straits of Florida. The Terrace platform exhibits a wide variety of Neogene-age geological features, including high-relief ledges, mounds, sinkholes and deep-water biogenic build-ups called bioherms. Previous research revealed dense and diverse benthic assemblages dominated by stylasterid hydrocorals, octocorals and sponges.

Many Terrace features also represent popular, long-term fishing targets. Due to concerns about resource sustainability, (National Oceanic and Atmospheric Administration (NOAA) and the South Atlantic Fishery Management Council (SAFMC) included the Terrace in the Comprehensive Ecosystem-Based Amendment 1 (CE-BA 1, June 2010) that protects deep-water Coral Habitat Areas of Particular Concern (CHAPCs) along the southeastern U.S continental margin by prohibiting use of a variety of potentially damaging bottom fishing gear. NOAA also established the East Hump Marine Protected Area (MPA) as a Type II MPA, permanently closed to fishing for and possession of snapper and grouper species.

To develop a more robust database on Terrace habitats and resources, a research cruise (September 2011) used ROV *Kraken 2* to survey 14 sites both inside and outside the CHAPC and MPA for biological diversity, density, and distribution, with a focus on deep-sea coral and sponge assemblages. The surveys resulted in 58

h of videotape, 2,866 images, and collected 150 specimens of benthic invertebrates. All dive sites were mapped with multibeam sonar.

This project used Coral Point Count with Excel extensions (CPCe)©, PRIMER 6.1.10 beta, JMP© statistical software, and Environmental Systems Research Institute (ESRI) ArcMap 10.3 Geographic Information Systems (GIS) to quantitatively analyze transect images and video from the ROV transects. This information was used to characterize dive sites in terms of benthic invertebrate faunal communities, depth, and topography; and compare results relative to protected versus unprotected sites.

Of the 14 sites surveyed 10 were analyzed and split into 42 transects of approximately 30 m^2 based on five depth and location bin classes. Each site was initially separated into habitat types based on qualitative geomorphologic features for statistical analysis (i.e., mound slope, mound wall, mound top, deep mound, valley, *Lophelia* mound, sinkhole), using methods established by Reed *et al*. (2011; 2014). In initial analysis, depth and location were found to be superior to geomorphology as an indicator of what was driving differences in communities among transects. As a result each transect was placed into one of five depth and location bin classes based on depth (m) of each image and location relating to CHAPC/MPA area borders: West 150-300 m (12 transects), North Central 150-250 m (14), Central 250-300 m (8), South 450-500m (5) and South 500-550 m (3).

Distinct differences in communities of each depth and location bin class in relation to percent cover and organism density were apparent. Communities vary strongly among bins with some similarities: e.g., West 150-300, North-Central 150-

250, and Central 250-300 all included *Stylaster miniatus* (Stylasteridae): South 450-500 and South 500-550 included *Paramuricea* sp. 3 among their most dominant species. Also similar species were found within similar depth ranges. Protection status (within CHAPC, CHAPC/MPA, or No Protection) did not affect differences in communities, suggesting protection regulations have not been implemented long enough to show significant differences between protected and unprotected sites. Several new geologic features were found e.g., the southernmost *Lophelia pertusa* coral mound in U.S. waters. Some important features were described that lie outside of CHAPC/MPA borders, suggesting new borders should be designated.

Results showed a strong relationship between depth and location in forming deep-water communities, and that these factors could be used as proxies for creating habitat maps in unmapped areas. These results will also provide managers and scientists with a valuable baseline for assessing benthic invertebrate communities, their changes over time, and the effectiveness of protected areas on the Pourtalès Terrace.

Key Words: Pourtalès Terrace, habitat characterization, Coral Habitat Areas of Particular Concern, Marine Protected Areas, Comprehensive Ecosystem-Based Amendment 1

II. Introduction

A. History of the Pourtalès Terrace

Investigations of the Straits of Florida began in 1850 when Louis Agassiz was contracted by the U.S Coast Survey to take the first depth soundings off the Florida Keys to improve navigation. Louis Francois de Pourtalès and Henry Mitchell, assistants of the U.S Coast Survey, began exploring the Straits in 1867 aboard the surveying ships *Corwin* and *Bibb.* They reached a maximum depth of 850 fathoms (1554 m) between Florida and Cuba (Agassiz, 1888). Their work discovered what is now known as the Pourtalès Terrace, as well as the first records of deep-sea fauna under the Gulf Stream. This research was followed by more extensive hydrographic and biological operations of the U.S Coast and Geodetic Survey ship *Blake* in 1878 (Agassiz, 1888).

In honor of Pourtalès' discoveries in the Straits of Florida, Alexander Agassiz (1888) named this feature the Pourtalès Plateau. Jordan and Stewart (1961) proposed the current name Pourtalès Terrace instead (Jordan et al., 1964).

Details of Terrace geology remained unknown until Jordan (1954), using the Coast and Geodetic Survey Ship *Hydrographer* described a series of submarine topographic zones 25 miles off the Florida Keys reefs, including a large escarpment and large sinkholes, three at a depth of 900 m. Jordan interpreted these sinkholes as evidence that the submerged tip of the Florida Peninsula once stood above sea-level. However, Land and Paull (2000) claimed the sinkholes were never exposed above sea level due to water depths too great for exposure. In examining the continental slope off southwest Florida, Jordan and Stewart (1959) determined that the escarpment borders the west Florida Continental terrace along the full length of the peninsula. They also described other topographic features including faults, ridges, and fracture. Siegler (1959) referred to the Terrace as an "old coral reef" based on echosounding in 275 to 500 m. Recently Reed *et al*. (2005) described the biology and geology of the deep-water sinkholes on the Terrace from manned submersible dives.

Following publication of detailed bathymetry of the northern Straits of Florida (Jordan & Stewart, 1961; Jordan, 1962), Jordan *et al*. (1964) and Hurley (1964) published detailed bathymetric maps of the southern Straits of Florida and Pourtalès Terrace based on combinations of soundings and precision depth recorder echograms, plus continuous seismic surveys showing sub-bottom profiles. These were followed by a detailed bathymetric map and seismic profile of the entire straits by Malloy and Hurley (1970).

As a result of these studies, the Pourtalès Terrace can now be characterized as a gently curved, narrow triangular platform that parallels the Florida Keys for 213 km, starting from southern Key Largo and ending between Key West and the Marquesas Keys. The main upper boundary begins in 200 m and dips gently to approximately 450 m, where the Pourtalès Escarpment slopes steeply to the deep floor of the southern Straits of Florida (Jordan *et al*. 1964; Reed *et al*. 2005).

Also during the 1960s, the University of Miami carried out extensive dredging and trawling operations in the Straits aimed at better understanding the diversity and distribution of benthic invertebrates and fishes. The collections contributed to numerous taxonomic papers on a wide range of organisms (e.g., Holthuis, 1971, 1974 [Crustacea]; Meyer et al., 1978 [Crinoidea]; Quinn, 1979 [Gastropoda]; Cairns, 1979 [Scleractinia]; Cairns, 1986 [Stylasterdae].

The human occupied vehicles (HOVs) *Aluminaut*, *Ben Franklin*, and *Alvin* first surveyed the deep Straits in the late 1960s focusing chiefly on geology and hydrography. All of them explored the northern Straits (e.g., Neumann and Ball, 1970; Ballard and Uchupi, 1971); none ventured onto the Pourtalès Terrace. More recent research with HOVs and remotely operated vehicles (ROVs) on deep ecosystems and geology of the Straits of Florida, in particular deep coral habitats and lithoherms, have also been carried out primarily in the northern Straits, especially on the Miami Terrace and Bahama Island slopes (e.g., Neumann et al., 1977; Mullins and Lynts, 1977; Mullins and Neumann, 1977; Mullins, 1983; Messing et al., 1990; Anselmetti *et al.,* 2000; Messing, 2004; Grasmueck *et al.* 2006, 2007; Correa *et. al.* 2012a, 2012b). Submersible surveys by Reed et al. (2005) focused on the southern Straits (refer to Previous Biogeographic Work section) whereas Reed et al. (2006) and Reed et al. (2013) surveyed and mapped deep-sea coral ecosystem habitat (DSCE) off the entire eastern coast of Florida. However, as the study of deep-water coral environments has increased, so has the realization that conservation is critical for preserving these habitats as they represent important biological and commercial resources, as well as essential fish habitat for a variety of commercially important species, and an enormous reservoir of largely unknown biodiversity.

B. Previous Biogeographic Work

Recent HOV and ROV dives have revealed dense and diverse benthic assemblages dominated by stylasterid hydrocorals, octocorals and sponges on the

Pourtalès Terrace (Reed *et al*., 2005). Whereas our understanding of deep-water reefs first relied upon dredging and trawling surveys, which could impact live bottom habitat, recent detailed acoustic mapping and ROV techniques have come into widespread use only in the last two decades (Roberts et al., 2005). Reed et al. (2005) used a submersible to characterize benthic and fish resources in eight previously unexplored areas of the Terrace, including the Naples, Jordan and Marathon deep-water sinkholes, and five bioherms. The Jordan sinkhole had the greatest depth and area of any known sinkholes. They identified 42 fish taxa, including several of commercial importance, 66 Porifera taxa, and 21 Cnidaria species.

Additional knowledge is limited and largely restricted to geology. Ross and Nizinski (2007) noted that the most established and extensive deep-sea coral reefs in U.S waters occur off the southeastern continental margin, where extensive rough topography appears to favor development of coral mounds and coral ecosystems. Substantial work is needed in these areas for better resource management. Deep reefs support their own fish populations and great but poorly known invertebrate diversity.

National Oceanic and Atmospheric Administration (NOAA) and the Regional Fishery Management Council publish a report to Congress biennially about the Deep-Sea Coral Research and Technology Program, established in 2006*,* under Section 408 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The goal of the program is to report research activities and results, including identifying, monitoring, and protecting cold and deep-water reefs. In 2011 the

NOAA Deep Sea Coral Research and Technology program funded Harbor Branch Oceanographic Institute's Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) to conduct a research cruise (Reed *et al.* 2012) to the Pourtalès Terrace aboard NOAA ship *Nancy Foster* on 23-30 September 2011 in which the data for this thesis was collected. The cruise mapped ten sites on the Terrace with high-resolution multibeam sonar for the first time. Previously, only low-resolution NOAA regional bathymetric charts were available. The new maps exposed features in far greater detail than previously known, and revealed new topographic features, deep-water sinkholes, and the southernmost known deep-water *Lophelia* coral mound in U.S waters (Reed *et al*. 2012).

The 2014 Deep Sea Coral Research and Technology Program report to Congress covered 2012 and 2013 NOAA research activities. The program explored many U.S regions and found deep-sea corals off every coast below the photic zone. Huge steps have been made in identifying deep- sea coral locations and characterizing those sites.

Based on data from the September 2011 research cruise Reed *et al.* (2014) used density counts and percent cover to analyze and characterize benthic habitat and fish communities for geomorphology, substrate, depth and slope. They found that depth, followed by geomorphology and substrate were the factors contributing to variations in fish communities. Protection status did not affect fish community diversity. Several new geologic features were described that lie outside of Coral Habitat Areas of Particular Concern (CHAPC) and Marine Protected Area (MPA) borders, suggesting new borders be designated (Reed *et al*. 2014).

C. Conservation

Deep-sea coral ecosystems (DSCEs) have proven to be important habitat for numerous fish species, invertebrates, and other organisms, and essential fish habitat for some commercially important species. Not only do DSCEs provide habitat but they are of significant importance for chemical and biological research; e.g., research on bamboo corals (Isididae) has shown they may be used for bone grafts (Lumsden *et al.* 2007), and the polyketide leiodermatolide discovered from a deep-water sponge found on the Pourtalès Terrace shows potent antitumor activity in a model of pancreatic cancer (Paterson *et al*. 2011). In addition, Aphrocallistin (Wright *et al.* 2009) is derived from the deep-water sponge *Aphrocallistes beatrix* which was discovered on deep-water Lophelia reefs in the Straits of Florida, and has selective activity against cancer cells with defined mutations and may have utility in treating melanoma and triple negative breast cancers. The microsclerodermins (Guzmán et al. 2015) are also found in deep-water sponges and shown substantial activity against pancreatic cancer cells through inhibiting the transcription factor nuclear factor kappa B and are under investigation as potential cancer therapeutic agents. Nortopsentin a (Alvarado *et al.* 2013) from the deep-water sponge *Spongosorites* has potent activity against the malaria parasite, *Plasmodium falciparum.*

Human impact on DSCE habitat around the world has been extensive. Deep-water reefs [also called cold-water reefs, as they may occur in relatively shallow water at high latitudes (Rogers, 1999)] were only first discovered in the 1950s (Teichert, 1958), but human impacts have been accumulating for a long time due to lack of knowledge about these reefs or their locations (Rogers, 1999; Stetson *et al.*

1962). Human impacts include fishing and energy production, although commercial bottom fishing appears to be the main source of disturbance, via overfishing and destruction of reef framework by fishing gear such as bottom trawls. Also, communication cables may destroy habitat. Deep-sea oil exploration in the Gulf of Mexico and northern Great Britain could affect coral habitats and organisms by generating problems that are not yet well understood (Rogers, 1999). In 2010 President Barack Obama proposed permitting offshore drilling in Florida as close as 50 miles to the shore, but the idea perished in the Senate (Leary, 2010).

As an example of the longer-term effects bottom trawling had on deep reef habitats, Reed et al. (2007) compared submersible image surveys of deep-water *Oculina varicosa* coral reefs off eastern Florida between 1975-1977 and again in 2001. The extensive populations of grouper and snapper found in the earlier surveys had been decimated by 2001 (Koenig *et al*. 2005), when coral destruction due to bottom trawling for rock shrimp was also documented. From 1975 to 2001, six reef sites had nearly complete destruction of live coral but the two sites within the original 325-km^2 *Oculina* Habitat of Particular Concern (OHAPC) established in 1984 were not impacted by fishing (Brooke *et al*. 2006; Reed *et al*. 2007).

The deep-water scleractinian coral *Lophelia pertusa*, several species stylasterid hydrozoan corals, and numerous octocorals and sponge species occur on the Terrace and create extensive complex habitats for many species (Reed *et al.* 2005). Many of the prominent geological features on the Terrace represent popular, long-term fishing targets due to their being natural spawning, feeding, and nursery grounds for a variety of species. The *Oculina* reefs off the central eastern Florida coast provide a useful case history background for managing resources on the Pourtalès Terrace. Though the OHAPC was established in 1984, there were indications that illegal fishing continued and, in 2003, the South Atlantic Fishery Management Council (SAFMC) passed an amendment requiring commercial vessels such as rock shrimp boats to carry a vessel monitoring system (VMS), as well as the proper permits. Though enforcement of such rules is difficult the Florida Fish and Wildlife Conservation Commission (FWC) does patrol the reef areas for illegal fishing practices (Brooke *et al*. 2006).

In June 2010, due to concerns about the sustainability of both its pelagic and benthic resources, NOAA and the SAFMC included the Pourtalès Terrace when they implemented the Comprehensive Ecosystem-Based Amendment 1 (CE-BA 1) to protect deep-water Coral Habitat Areas of Particular Concern (CHAPCs) along the southeastern U.S continental margin. This amendment prohibits fishing vessels from using a variety of damaging bottom fishing gear including: bottom longline, trawl, dredge, pot or trap, and anchor (SAFMC, 2009a). Currently only three fisheries are allowed to function in this area: wreckfish (*Polyprion americanus*), golden crab (*Chaceon fenneri*), and royal red shrimp (*Pleoticus robustus*). This amendment allows these fisheries to operate within certain areas of the CHAPCs (NOAA, 2009). In addition, NOAA established the East Hump Marine Protected Area (MPA) as a Type II MPA. This area is currently closed to fishing for and possession of snapper and grouper species, but trolling for pelagic fish species is allowed (SAFMC, 2009b). Surveillance of these areas for illegal practices is difficult because they cover large areas and are easily accessible to fishers from the coast (Reed, 2002).

In 2012 the SAFMC proposed Comprehensive Ecosystem-Based Amendment 3 (CE-BA 3), of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), aiming to improve quantifying by catch/mortality rates and discard data methods. Improving data collection on fishing mortality increases ability to track annual limits to then reduce the occurrence of overages. Fisheries affected by CE-BA 3 include wahoo (*Acanthocybium solandri)*, snapper (Lutjanidae), grouper, golden crab and migratory species. As of this thesis, approval of CE-BA 3 by the Council is still under discussion (SAFMC, 2014).

In 2013 the SAFMC proposed Comprehensive Ecosystem-Based Amendment 8 (CE-BA 8) of the MSA. This amendment was prompted by two major deep-water coral site discoveries outside current CHAPC boundaries. This amendment has been approved by the SAFMC, NOAA fisheries and the Secerteray of Commerce and will be published soon (NOAA, 2014). It will double the size of the OHAPC off eastern Florida and add to the CHAPCs off northern Florida and North Carolina, protecting an additional 843 square miles protecting from bottom contact fishing gear.

D. Hypotheses

In addition to the descriptive component of the project, i.e., benthic invertebrate and assemblage distribution, and mapping, the project will address two primary hypotheses:

Hypothesis 1_0: No significant difference exists in benthic invertebrate communities among the ten sites relative to depth, topography, habitat, and available hydrographic data.

Hypothesis 1_a: Significant differences exist in benthic invertebrate communities among the ten sites relative to depth, topography, habitat, and available hydrographic data.

Hypothesis 2_o: No significant difference exists in benthic invertebrate communities based on protected sites: defined as being between the two sites within both the East Hump MPA and CHAPC, and the six sites that are solely within the CHAPC; versus the two non-protected sites.

Hypothesis 2_a: Significant differences exist in benthic invertebrate communities based on protected sites: defined as being between the two sites within both the East Hump MPA and CHAPC, and the six sites that are solely within the CHAPC; versus the two non-protected sites.

Hypothesis two will be used to compare and contrast these sites: protected sites within CHAPC only, and within both CHAPC and MPA; verses unprotected sites outside MPA and CHAPC. Whereas MPA sites are closed to all bottom fishing (hook and line as well as trawling and traps), the only restriction in the CHAPC is the prohibition of bottom trawling and traps. Although it is probably too soon to see significant differences between the sites based on closure, these data can be used to provide baseline data for each of these sites. Therefore H2 will provide data on whether the 3 types of sites (MPA/CHAPC, CHAPC, non-protected) are intrinsically different in habitat, depth, or community, or not.

II. Methods

A. Data Collection

NOAA and CIOERT of Harbor Branch Oceanographic Institute at Florida Atlantic University conducted a research cruise to the Pourtalès Terrace aboard NOAA ship *Nancy Foster* on 23-30 September 2011. Using the University of Connecticut's ROV *Kraken 2*, 14 sites were surveyed, which covered an area of 16 km^2, at depths ranging from 154 to 838 m. The ROV recorded 58 hours of dive videotape with audio annotations made every one to five minutes coded with date, time, coordinates, and depth. Audio commentary included geology, habitat and biota. Digital still Images taken by the ROV totaled 2,866, including 118 images of collected specimens, 358 general habitat images, and 2,253 quantitative transect images. The *in situ* images were taken with the ROV still camera oriented perpendicular to the substrate with parallel scaling lasers 10 cm apart, enabling calculation of image areas. In addition, video transects were used for studies of the fish populations but are not part of this thesis.

The NOAA survey crew mapped ten sites on the Terrace with high-resolution multibeam sonar for the first time. Previously, only low-resolution NOAA regional bathymetric charts were available. The multibeam maps revealed features in far greater detail than previously known, and revealed new topographic features, such as deep-water sinkholes, and the southernmost deep-water *Lophelia* coral mound in U.S waters.

B. Data Preparation

All video and still photographic image data were initially reviewed, incorporating audio annotations. A library of benthic macroinvertebrate images was compiled in advance from both video and digital still images to ensure that taxon identification remained consistent throughout analyses. Final sets of images were assembled for CPCe quantitative analyses after elimination of blurred, dark, distant or otherwise unusable images (e.g., turbidity). Partially shadowed images were cropped. Image contrast and clarity were enhanced in the lab when necessary using Photoshop© or similar software. For CPCe analysis, overlapping images were also removed.

The area of each image used to determine transect surveying area for CPCe analysis was calculated by converting image length and width from pixels to centimeters using the distance between the ROV's parallel scaling lasers as calibration. However, sites were unequally surveyed, as more pictures were taken in some areas than others. Although the height off the bottom for the image transect was ~1.3 m, it was not exact over the rough topography. As a result, the areas of the various images varied somewhat thus the surveyed areas were independent of the number of images. Once equivalent areas surveyed were determined, a common surveyed area of approximately 30 m^2 was chosen that maximized the number of usable sites versus a large sample area. This allowed analysis of 42 transects. A random subset of between six and 48 images per transect was chosen to equal the 30 m^2 standard area, and 829 images were analyzed. Sites with too few images or insufficient area were discarded due to significant outliers in the analyses.

Habitat characterizations of each transect included ROV dive track data (Table 1), which includes depth, longitude, latitude, total distance, and bottom time.

Table 1. Dive track data: site number, dive number, bottom time, total distance, latitude, longitude, and depth.

Site Number	Dive Number	Bottom Time (min)	Total Distance (km)	Latitude (On Bottom)	Longitiude (On Bottom)	Latitude (Off Bottom)	Longitude (Off Bottom)	Depth Ramge (m)
201109231	13	276	0.54	24°19.8057'N	81°41.0539'W	24°19.5988'N	81°41.0817'W	60-285
201109251	16	237	1.55	24°29.5248'N	80°40.4337'W	24°30.0718'N	80°39.9631'W	242-286
201109252	17	213	1.34	24°30.4161'N	80°38.4527'W	24°30.8627'N	80°38.1918'W	200-255
201109261	18	245	1.26	24°43.9444'N	80°28.1576'W	24°44.3720'N	80°27.7402'W	177-207
201109262	19	205	1.23	24°44.8350'N	80°25.2704'W	24°45.2032'N	80°25.1402'W	225-226
201109281	22	251	1.14	24°25.3198'N	80°45.2225'W	24°25.6258'N	80°45.1883'W	154-298
201109282	23	197	1.4	24°24.9404'N	80°43.6936'W	24°25.3221'N	80°43.2504'W	283-306
201109291	24	239	1.33	24°15.4407'N	80°54.2753'W	24°15.7462'N	80°53.7192'W	487-489
201109292	25	213	1.31	24°14.3178'N	80°54.8882'W	24°14.7589'N	80°54.6950'W	468-547
201109301	26	195	0.95	24°20.8432'N	81°51.6737'W	24°20.1985'N	81°51.7227'W	185-230

Of the 14 sites surveyed 10 were analyzed (Figure 1) and initially separated into habitat types based qualitatively on geomorphologic features for statistical analysis (i.e., mound slope, mound wall, mound top, deep mound, valley, *Lophelia* mound, sinkhole), using methods established by Reed *et al.* (2011; 2014).

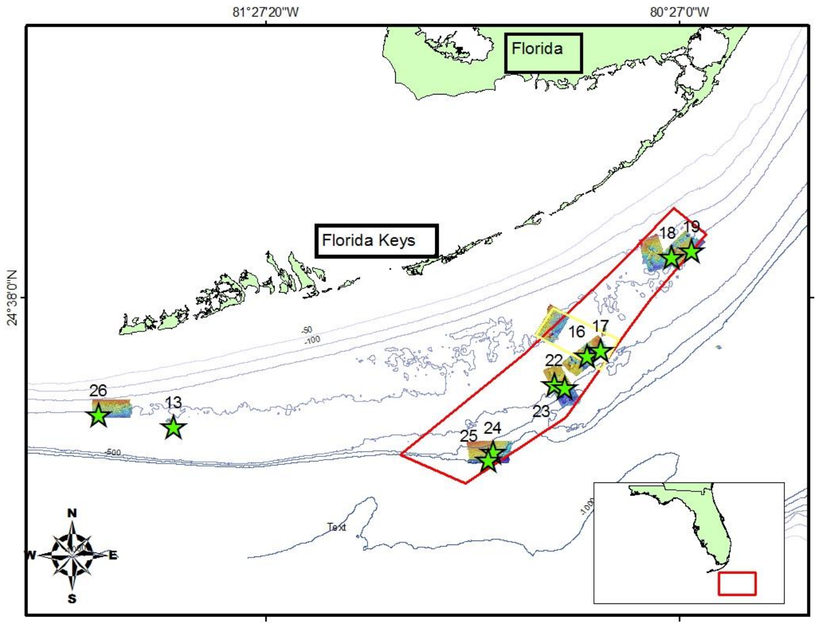

Figure 1. GIS map of the Pourtalès Terrace showing CHAPC border in red, MPA border in yellow with dive sites distinguished by green stars. Dives used in this thesis 13, 16-19, and 22-26.

In initial analysis, depth and location were found to be superior to geomorphology as an indicator of what was the dominant factor for the differences in communities among transects. As a result transects were placed into one of five depth and location bin classes based on depth (m^2) of each image and location (inside versus outside of CHAPC/MPA area borders; i.e., protected sites vs. non-protected sites). Figure 2 shows the five depth and location bin classes on a GIS map. The number of transects within each bin class depended on depth and location: West 150-300 m (12 transects), North Central 150-250 m (14), Central 250-300 m (8), South 450-500 m (5) and South 500-550 m (3). Appendix 1, Table 1 includes transect name, transect by geomorphology, transect by depth and location bin class, image range, number of images, area per m^2 of each transect, mean depth (mean depth of all images per transect), and protection status.

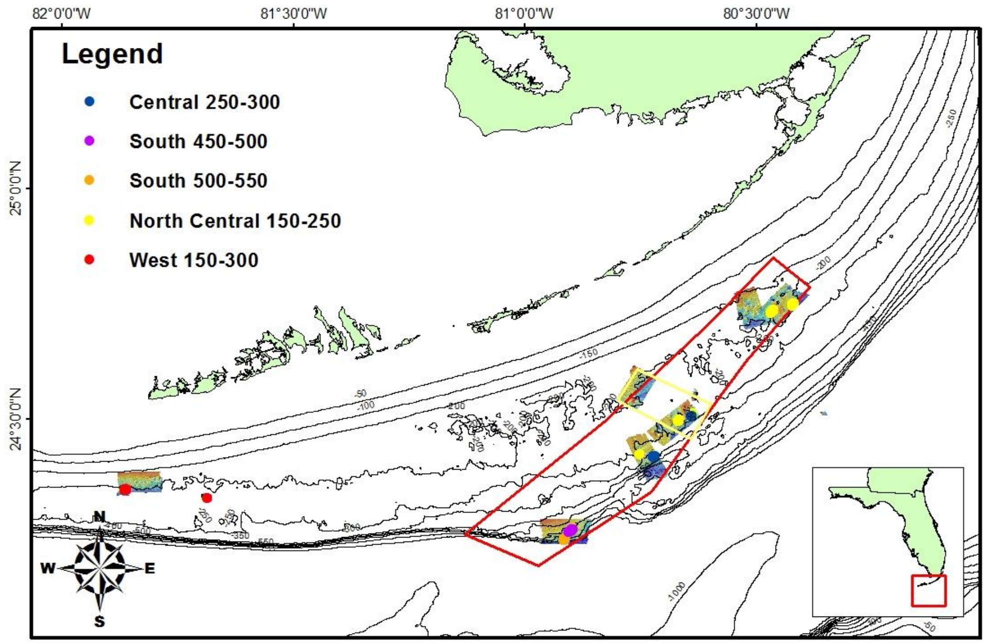

Figure 2. GIS map of the Pourtalès Terrace showing CHAPC border in red, MPA border in yellow, with five depth and location bin classes represented by colored circles.

C. Data Analysis

Using Coral Point Count with Excel extensions (CPCE)© (Kohler and Gill, 2006) 829 images were analyzed for percent cover following protocols established by Reed *et al*. (2011; 2014) for the NOAA/CIOERT Cruise Report (Reed *et al.* 2012), as well as by Messing *et al.* (2011) and Vinick *et al.* (2012) for similar surveys carried out on the nearby Miami Terrace. Fifty random points per image were characterized for percent substrate cover using 16 major benthos and substrate categories; non-living substrates included hard bottom, sediment-veneered hard bottom, and sediment. Living benthos in images were identified to lowest general taxonomic levels possible, primarily within the Phyla Cnidaria, Porifera, and Echinodermata and Appendix 2 shows major categories used for percent cover analysis and CPCe results.

To determine organism density, images were analyzed by counting all visible organisms larger than approximately 3 cm across, identifying them to the lowest taxonomic level possible, and calculating their density from the image area that was determined by CPCe ARA analysis. A library of benthic macroinvertebrate images was compiled in advance from both video and digital still images to ensure that taxon identification remained consistent throughout analyses; some taxa could only be identified to higher taxonomic categories due to difficulty in identification without a specimen. Appendix 2 lists organism density results and the taxonomic list used in analysis.

After images were analyzed, multivariate statistics (PRIMER 6.1.10 Bray-Curtis similarity indices) were used to evaluate similarities and differences among sites, in particular, to identify community differences based on geomorphology, depth/location, and protection status (as defined above under Hypotheses). To understand the relationships among transects, Analysis of Similarities (ANOSIM), Species Accumulation and Species Analysis (SIMPER), Cluster analysis with Dendrogram, and non-metric multi-dimensional scaling (MDS) were used. A univariate ANOVA analysis was conducted using JMP© statistical software to determine whether significant differences existed between sites by depth and location to determine if depth was driving the differences in communities.

The purpose of an MDS plot is to represent the population of samples as points in two dimensions, with the distance between the points relating to the similarity or dissimilarity of the fauna within each site. Therefore points that are close together are more similar in community, and points that are far apart are more dissimilar (Clark and Gorley 2006). Percent cover and density data with geomorphology, protection status and location/depth as factors were square-root transformed, averaged and plotted using Bray-Curtis Similarity indices. Cluster analysis of percent cover data produced a dendrogram for each factor, in which sample size decreased as similarity increased (Clark and Gorley 2006). Cluster dendrograms with transects 1-42 on the x-axis and similarity on the y-axis illustrated similarities based on geomorphology, protection status and depth and location bin classes. Using the dendrogram plots, levels of similarity were observed for each factor and clusters were overlain on MDS plots.

A one-way ANOSIM is based on a resemblance matrix and tests for the null hypothesis, resulting in R statistics and pairwise comparisons. An R statistic is used which ranges from zero to one. Negative R-values are not uncommon and may be due to an outlier or deemed irrelevant due to dissimilarity greater within samples than among (Chapman & Underwood 1999). R-values closer to zero represent no dissimilarities (more similar) those closer to one represent complete dissimilarity. P values are significant when closer to zero (Clarke & Gorley 2006).

Species Accumulation and Species Analysis (SIMPER) was used to analyze organism density count data to determine which species based on location and depth as the factor contributed most to the Bray–Curtis dissimilarity. Groups with higher values had similar communities.

Hillshaded bathymetric maps created by Stephanie Farrington (Harbor Branch Oceanographic Institute at Florida Atlantic University (HBOI)) using Geographic Information Systems (ArcGIS 10.3) software were used for visually interpreting the seafloor slope in the bathymetric data. Cruise field notes describing habitats were plotted in GIS as points overlaying the bathymetry. Geomorphologic features that coincided with the different habitats in the ROV field notes were outlined as separate polygons in GIS using a predetermined minimum mapping unit. Regional geomorphology was evaluated to determine any large-scale cross-shelf trends that might indicate habitat differences. The surveyed sites were plotted in GIS and statistical analyses were performed to test, community similarities among the visually interpreted habitats.

Using ArcGIS software and maps created by Reed *et al.,* 2012 maps were modified to display each transect location based on depth and location bin classes. Each transect track is linked with the images used in analysis; each track consists of round circles representing a photo per circle, with each transect distinguished by color. Appendix 3 shows GIS maps with a smaller map of the Pourtalès Terrace.

IV. Results

The following sections discuss percent cover and density results and multivariate statistical analysis of the similarities and differences among the benthic communities based on geomorphology, depth/location, and protected status of the various transects.

A. Community Analysis by Geomorphology

Percent cover and organism density count data with geomorphology as the factor were square root transformed, averaged and plotted using Bray-Curtis Similarity indices. A cluster analysis produced a dendrogram of percent cover with transects 1-42 on the X-axis and similarity on the Y-axis illustrating similarities based on geomorphology with main groups clustering at 75% similarity (Figure 3; red lines indicate statistically similar groups). Figure 4 shows corresponding MDS plot with five clusters at 75% similarity. Transects 30 and 31, *Lophelia* Mound clustered away from others. The remaining geomorphic factors (Mound-Slope, Deep-Mound, Sinkhole, Valley, Mound-Top, and Mound Wall) were scattered among the remaining clusters.

Cluster dendrogram of density count with transects 1-42 on the X-axis and similarity on the Y-axis illustrating similarities based on geomorphology with main groups clustering at 28% similarity, exhibiting weak similarity (Figure 5). Figure 6 shows corresponding MDS plot with similarity level of 28%. All sinkhole transects clustered together with the *Lophelia* mound cluster overlapping. Mound-slope transects generally clustered near each other or together. Mound-top transects clustered with Mound-slope and Mound-Wall. Deep-mound transects clustered together with Valley, Mound-top, and Mound-slope transects.

Percent cover and organism density analyses data were analyzed using a one-way Analysis of Similarities (ANOSIM) with geomorphology as the factor. ANOSIM of percent cover (Table 2) found significance between groups clustered by geomorphology (p=0.001) but with a low R value (R=0.329) indicating that the community data were weakly related to the qualitative geomorphology categories. Deep Mound/*Lophelia* Mound had the R statistic closet to 1 (R=0.956, p=0.008) followed by Sinkhole/*Lophelia* Mound (R=0.918, p=0.018), and Mound Slope/*Lophelia* Mound (R=0.864, p=0.001). Valley/Mound Top were closest to 0 (R=0.119, p=0.198) followed by Valley/Mound-Slope (R=0.135,p=0.014), and

Mound-Wall/Deep-Mound (R=0.135, p=0.013). Valley/Mound-Wall, Mound-Slope/Mound-Wall, and Mound-Slope/Deep-Mound had negative R statistic values possibly indicating an outlier in the data.

Table 2. ANOSIM percent cover results, using pair-wise testing to analyze geomorphology. Bold groups indicate significance (<0.05).

Groups	R Statistic	P value
Valley, Mound-Slope	**0.135**	**0.014**
Valley, Mound-Top	0.119	0.198
Valley, Mound-Wall	-0.167	0.743
Valley, Deep-Mound	0.201	0.115
Valley, Sinkhole	**0.606**	**0.008**
Valley, Lophelia Mound	**0.796**	**0.029**
Mound-Slope, Mound-Top	**0.399**	**0.008**
Mound-Slope, Mound-Wall	-0.007	0.407
Mound-Slope, Deep-Mound	-0.072	0.806
Mound-Slope, Sinkhole	**0.549**	**0.001**
Mound-Slope, Lophelia Mound	**0.864**	**0.001**
Mound-Top, Mound-Wall	0.046	0.411
Mound-Top, Deep-Mound	**0.419**	**0.02**
Mound-Top, Sinkhole	**0.32**	**0.008**
Mound-Top, Lophelia Mound	0.497	0.054
Mound-Wall, Deep-Mound	**0.135**	**0.013**
Mound-Wall, Sinkhole	**0.733**	**0.018**
Mound-Wall, Lophelia Mound	0.667	0.10
Deep-Mound, Sinkhole	**0.812**	**0.003**
Deep-Mound, Lophelia Mound	**0.956**	**0.008**
Sinkhole, Lophelia Mound	**0.918**	**0.018**

ANOSIM analysis of density count (Table 3) found significance between groups clustered by geomorphology (p=0.002) but with a low R value (R=0.271) indicating again the community was weakly related to the qualitative geomorphology categories. Valley/Sinkhole (p=0.008), Valley/*Lophelia* Mound (p=0.029), Mound-Top/*Lophelia* Mound (p=0.018), and Mound-Wall/*Lophelia* Mound (p=0.1) all equaled R=1, suggesting that community structure relative to geomorphology was entirely dissimilar (different). *Lophelia* Mound found in all groups entirely dissimilar (R=1) signifying its difference from the other geomorphic groups. Mound-Slope/Deep-Mound were closest to 0 (R=0.181, p=0.031) followed by Mound-Slope/ Sinkhole (R=0.205, p=0.054), and Valley/Deep-Mound (R=0.262,p=0.07). Valley/Mound-Slope, Mound-Slope/ Mound-Top, and Mound-Slope/Mound-Wall groups had negative values and perhaps indicate an outlier in the data.

Table 3. ANOSIM density count results, using pair-wise testing to analyze by geomorphology. Bold groups indicate significance (<0.05).

Groups	R Statistic	P value
Valley, Mound-Slope	-0.044	0.564
Valley, Mound-Top	0.281	0.103
Valley, Mound-Wall	0.296	0.114
Valley, Deep-Mound	0.262	0.07
Valley, Sinkhole	**1**	**0.008**
Valley, Lophelia Mound	**1**	**0.029**
Mound-Slope, Mound-Top	-0.011	0.492
Mound-Slope, Mound-Wall	-0.063	0.604
Mound-Slope, Deep-Mound	**0.181**	**0.031**
Mound-Slope, Sinkhole	0.205	0.054
Mound-Slope, Lophelia Mound	**0.563**	**0.002**
Mound-Top, Mound-Wall	0.067	0.304
Mound-Top, Deep-Mound	**0.478**	**0.011**
Mound-Top, Sinkhole	**0.964**	**0.008**
Mound-Top, Lophelia Mound	**1**	**0.018**
Mound-Wall, Deep-Mound	**0.433**	**0.042**
Mound-Wall, Sinkhole	**0.979**	**0.018**
Mound-Wall, Lophelia Mound	1	0.1
Deep-Mound, Sinkhole	**0.906**	**0.001**
Deep-Mound, Lophelia Mound	**0.956**	**0.008**
Sinkhole, Lophelia Mound	**0.928**	**0.018**

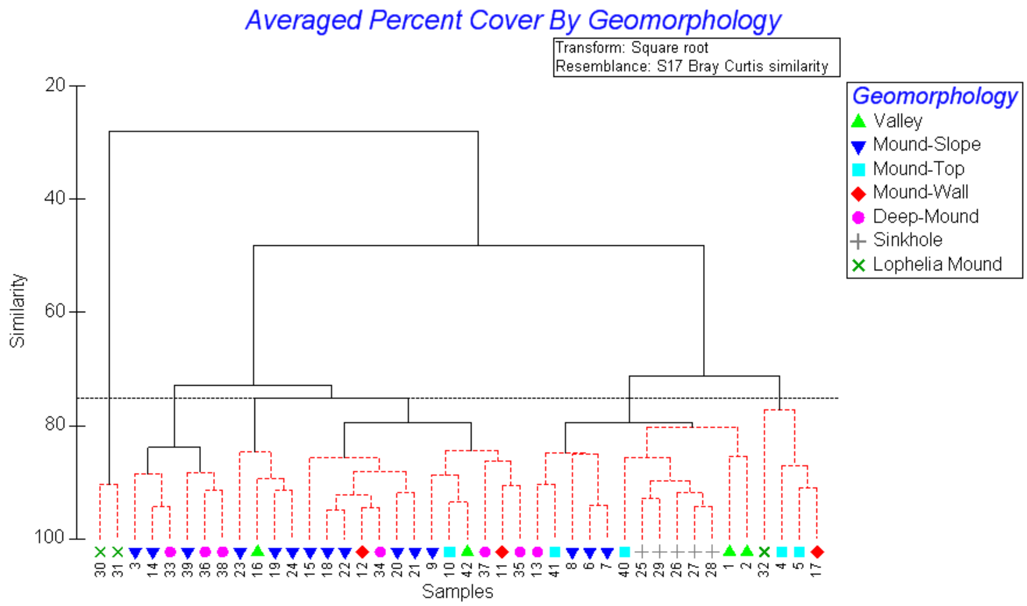

Figure 3. Cluster analysis dendrogram of averaged percent cover by geomorphology with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 75% similarity.

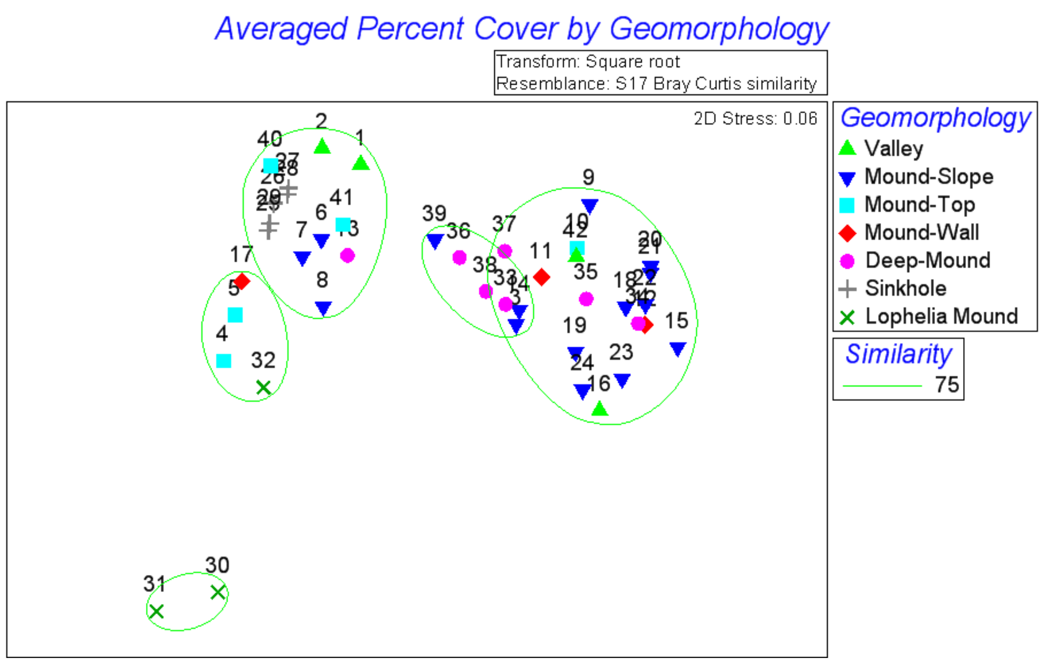

Figure 4. MDS plot from cluster analysis of percent cover by geomorphology with similarity of 75%. Labeled by transect number.

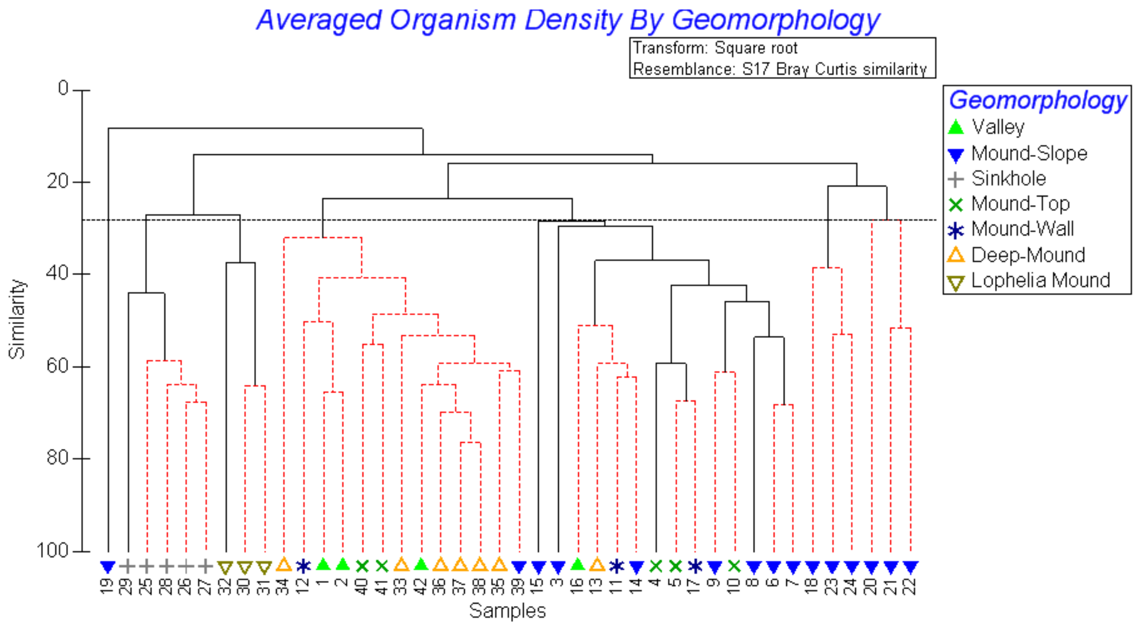

Figure 5. Cluster analysis dendrogram of averaged organism density count by geomorphology with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 28% similarity.

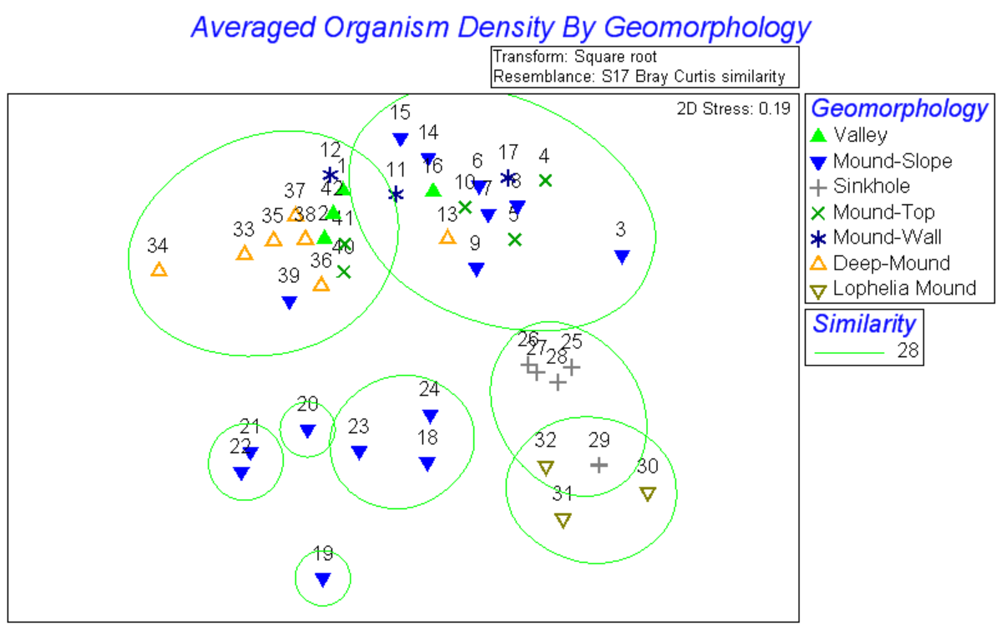

Figure 6. MDS plot from cluster analysis of organism density by geomorphology with similarity of 28%. Labeled by transect number.

B. Community Analysis by Depth and Location

In initial analysis, depth and location were found to be superior to geomorphology as an indicator of what was the dominant factor for the differences in communities among transects. To determine if depth and location were driving significant differences in benthic invertebrate communities transects were placed into 1 of 5 bin classes, and analyzed. Figure 7 shows mean depth of each image within the five depth and location bin classes with North Central 150-250 shallowest (211.45 m) followed by West 150-300 (238.27 m), Central 250-300 (290.37m), South 450-500 (484.76m), and South 500-550 (510.04 m).

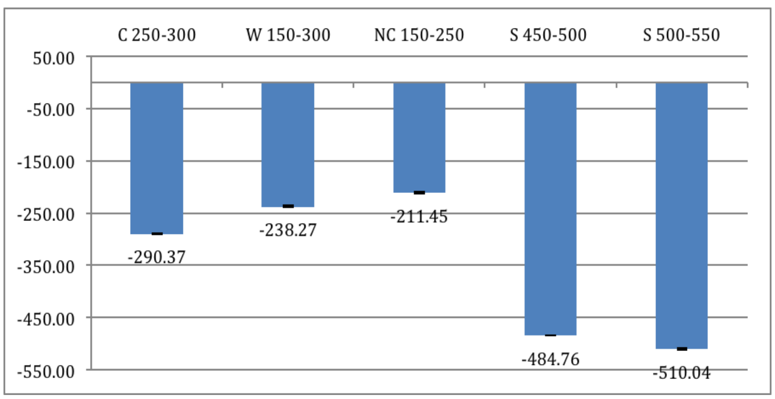

Figure 7. Mean depth of five depth and location bin classes with standard deviation error bars (C=Central 250-300; W=West 150-300; NC=North Central 150-250; S=South 450-500; S=500-550).

A one-way ANOVA (JMP© statistical software) using depth data of each bin class found that all 5 differed significantly from each other by depth and location ($p<0.0001$*) (Figure 8).

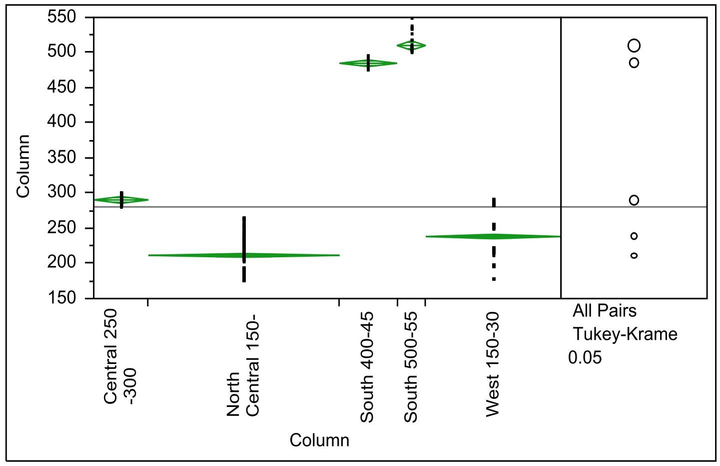

Figure 8. ANOVA one-way analysis results of five habitat bin classes.

Percent cover and organism density data with depth and location as the factor were square root transformed, averaged and plotted using Bray-Curtis Similarity indices. A cluster dendrogram of percent cover with transects 1-42 on the X-axis and similarity on the Y-axis illustrating similarities based on depth and location with main groups clustering at 75% similarity (Figure 9). Figure 10 shows corresponding MDS plot with five clusters at 75% similarity. Again transects 30 and 31 *(Lophelia* Mound) in the South 500-550 habitat bin class plotted away from other clusters indicating dissimilarity. West 150-300, North Central 150-250 and Central 250-300 transects plotted near each other. All South 450-500 transects plotted together with some North-Central 150-250 and West 150-300 transects.

A cluster dendrogram of density count with transects 1-42 on the X-axis and similarity on the Y-axis illustrates similarities based on depth and location with main groups clustering at 28% similarity, exhibiting weak similarity (Figure 11). Figure 12 shows corresponding MDS plot with similarity level of 28%. This percentage at which the main groups separated reflects their relatively low level of similarity. All North Central 150-250 transects clustered together overlapping clusters with West 150-300 and South 450-500. All South 450-500 transects clustered together, and all South 500-550 clustered together, overlapping the South 450-500 cluster. Central 250-300 transects clustered together or near each other. West 150-300 transects clustered together with overlapping with North Central 150-250 cluster. Transects of the same depth and location bin class clustered together indicating similar benthic invertebrate communities were based on depth and location.

Percent cover and organism density analyses results were analyzed using a one-way Analysis of Similarities (ANOSIM) with depth and location as the factor. ANOSIM of percent cover (Table 4) found significance between groups clustered by depth and location (p=0.001) but the low R-value (R=0.306) indicated that depth and location was correlated highly with the community. Central250-300/South500-550 had the closest R statistic to 1 at (R=0.97, p= 0.006) followed by South450-500/South500-550 (R=0.918, p=0.018), and West150-300/South500-550 (R=0.874, p=0.002), which reflects significant dissimilarities. West150-300/North Central150-250 were closest to 0 (R=0.052 and p=0.128) followed by North Central150-250/Central250-300 (R=0.073, p=0.15), and North Central150-250/South450-500 (R=0.188, p=0.069). Pairwise groups that showed significant similarity or dissimilarity had similar depth ranges.

Table 4. ANOSIM percent cover results, using pair-wise testing to analyze by depth and location. Bold groups indicate significance (<0.05).

Groups	R Statistic	P value
West150-300, North Central150-250	0.052	0.128

West150-300, Central250-300	**0.247**	**0.033**
West150-300, South450-500	**0.345**	**0.013**
West150-300, South500-550	**0.874**	**0.002**
North Central150-250, Central250-300	0.073	0.15
North Central150-250, South450-500	0.188	0.069
North Central150-250, South500-550	**0.608**	**0.001**
Central250-300, South450-500	**0.829**	**0.002**
Central250-300, South500-550	**0.97**	**0.006**
South450-500, South500-550	**0.918**	**0.018**

ANOSIM analysis of density (Table 5) found significance between bins clustered by depth and location (p=0.001) and the high R value (R=0.753) indicating that depth and location was correlated highly with the community. All groups had p values that shown significance (<0.05). West 150-300/ South 500-550 showed significance (p=0.002) with a high R-value (R=1) indicating complete dissimilarity followed by West150-300/South450-500 (R=0.995, p=0.001) and North Central150-250/South500-550 (R=0.961, p=0.001). Central 250-300/South 450-500 had the closest R statistic to 0 (R=0.433, p=0.008) followed by Central250-300/South500-550 (R=0.563, p=0.006), and West150-300/North Central150-250 (R=0.712, p=0.001). All R statistic values showed significant dissimilarity among groups indicating location and depth maybe driving differences in communities.

Table 5. ANOSIM density count results, using pair-wise testing to analyze by depth and location. Bold groups indicate significance (<0.05).

Groups	R Statistic	p value
West150-300, North Central150-250	**0.712**	**0.001**
West150-300, Central250-300	**0.732**	**0.001**
West150-300, South450-500	**0.995**	**0.001**
West150-300, South500-550	**1**	**0.002**
North Central150-250, Central250-300	**0.609**	**0.001**
North Central150-250, South450-500	**0.812**	**0.001**
North Central150-250, South500-550	**0.961**	**0.001**
Central250-300, South450-500	**0.433**	**0.008**
Central250-300, South500-550	**0.563**	**0.006**
South450-500, South500-550	**0.928**	**0.018**

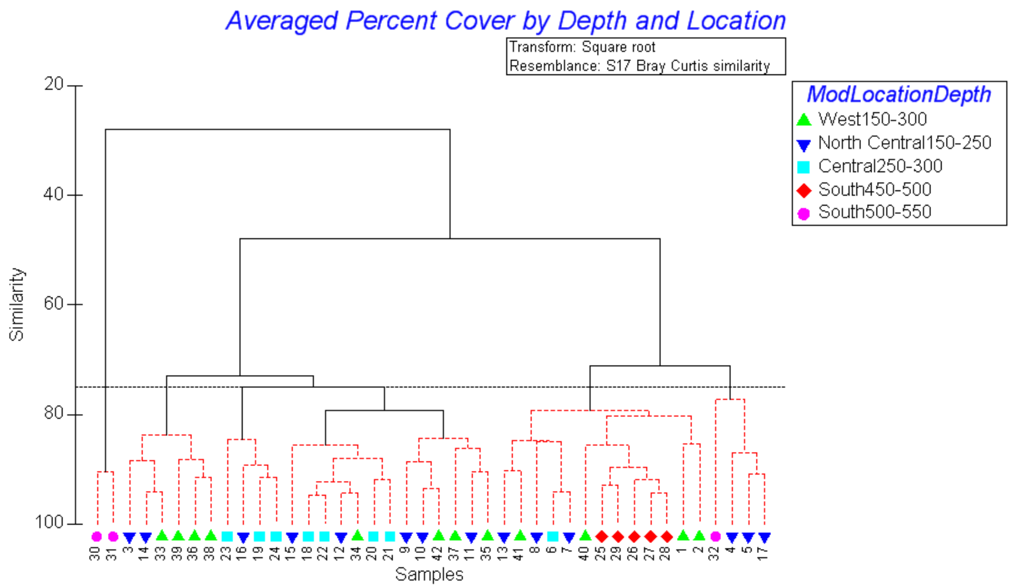

Figure 9. Cluster analysis dendrogram of averaged percent cover by depth and location with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 75% similarity.

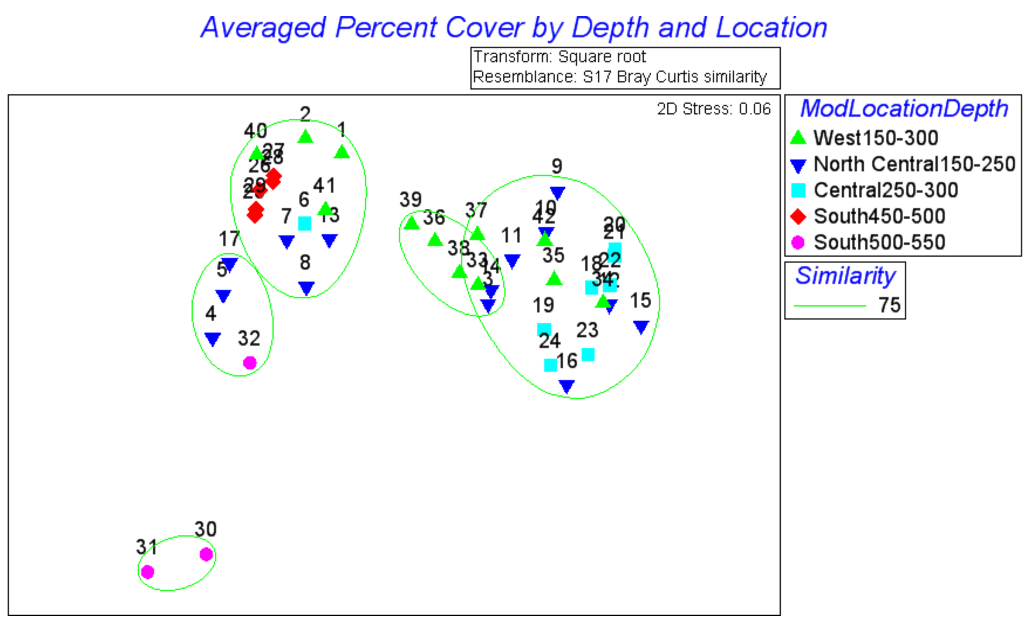

Figure 10. MDS plot from cluster analysis of percent cover by depth and location with similarity of 75%. Labeled by transect number.

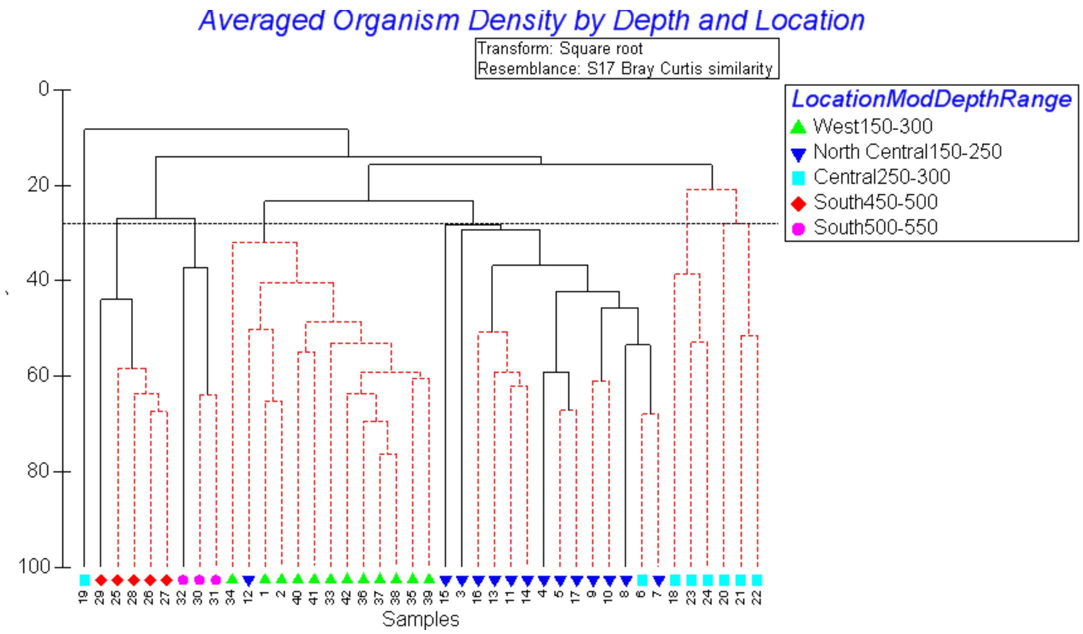

Figure 11. Cluster analysis dendrogram of averaged organism density count by depth and location with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 28% similarity.

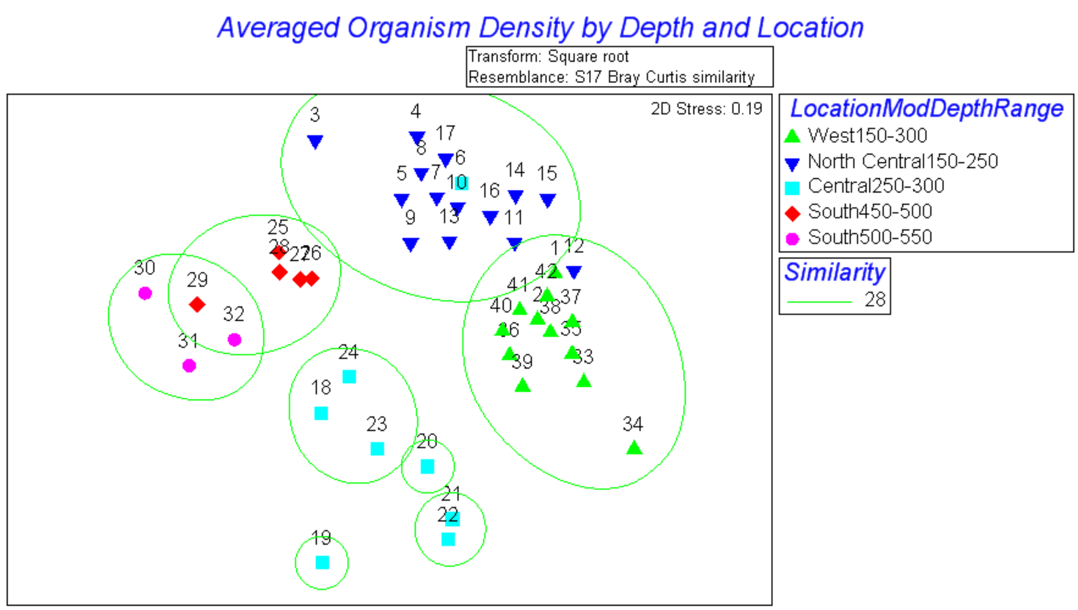

Figure 12. MDS plot from cluster analysis of organism density by depth and location with similarity of 28%. Labeled by transect number.

C. Community Analysis by Protection Status

Percent cover and organism density count data with protection status as the factor were square root transformed, averaged and plotted using Bray-Curtis Similarity indices. A cluster dendrogram of percent cover with transects 1-42 on the x-axis and similarity on the y-axis illustrates similarities based on protection status with clustering at 75% similarity (Figure 13). Figure 14 shows corresponding MDS plot showing 5 clusters with 75 % similarity. Transects 30 and 31 (*Lophelia* Mound) under CHAPC protection plotted away from others. CHAPC transects overlapped another cluster composed mostly of No Protection. Clusters plotted near each other regardless of protection status, indicating that it had a small impact on driving community differences.

A cluster dendrogram of density count with transects 1-42 on the x-axis and similarity on the y-axis illustrates similarities based on protection status with main groups clustering at 28% similarity, exhibiting weak similarity (Figure 15). Figure 16 shows corresponding MDS plot with 28% similarity. Transects with no protection clustered together overlapping a cluster with CHAPC, and MPA/CHAPC. Transects with CHAPC protection clustered together or near each other, with one CHAPC cluster including all MPA/CHAPC transects.

Percent cover and organism density analyses results were analyzed using a one-way Analysis of Similarities (ANOSIM) with protection status as the factor. ANOSIM of percent cover (Table 6) found that groups clustered by protection status weren't correlated significantly with the community ($p=0.471$, $R=-0.002$). The large p value reflects a lack of significance and combined with the negative R-value (R=-

0.002) indicates an outlier in the data. The No Protection, MPA/CHAPC pairwise group had the closest R statistic to 1 (R=0.329, p=0.009). MPA/CHAPC, CHAPC had the closest R statistic to 0 (R=0.008, p=0.393) and No Protection/CHAPC returned a negative R statistic (R=-0.051. p=0.775), perhaps indicating an outlier in the data.

Table 6. ANOSIM percent cover results, using pair-wise testing to analyze by protection status. Bold groups indicate significance (<0.05).

Groups	R Statistic	p value
No Protection, MPA/CHAPC	**0.329**	**0.009**
No Protection, CHAPC	-0.051	0.775
MPA/CHAPC, CHAPC	0.008	0.393

ANOSIM of density (Table 7) found significance between groups clustered by protection status (p=0.002), but the low R-value (R=0.21) indicating the factor only had small effect on organism density count data based on protection status. Not protected, MPA/CHAPC pairwise group had the R statistic closest to 1 (R=0.945, p=0.001) showing significant dissimilarity among communities. Not Protected/CHAPC had the closest R statistic closest to 0 (R=0.224, p=0.009) showing communities to be significantly similar. MPA/CHAPC, CHAPC had a negative R statistic (R=-0.024) and high p value (p=0.558) indicating a possible outlier in the data.

Table 7. ANOSIM density count results, using pair-wise testing to analyze by protection status. Bold groups indicate significance (<0.05).

Groups	R Statistic	p value
Not Protected, MPA/CHAPC	**0.945**	**0.001**
Not Protected, CHAPC	**0.224**	**0.009**
MPA/CHAPC, CHAPC	-0.024	0.558

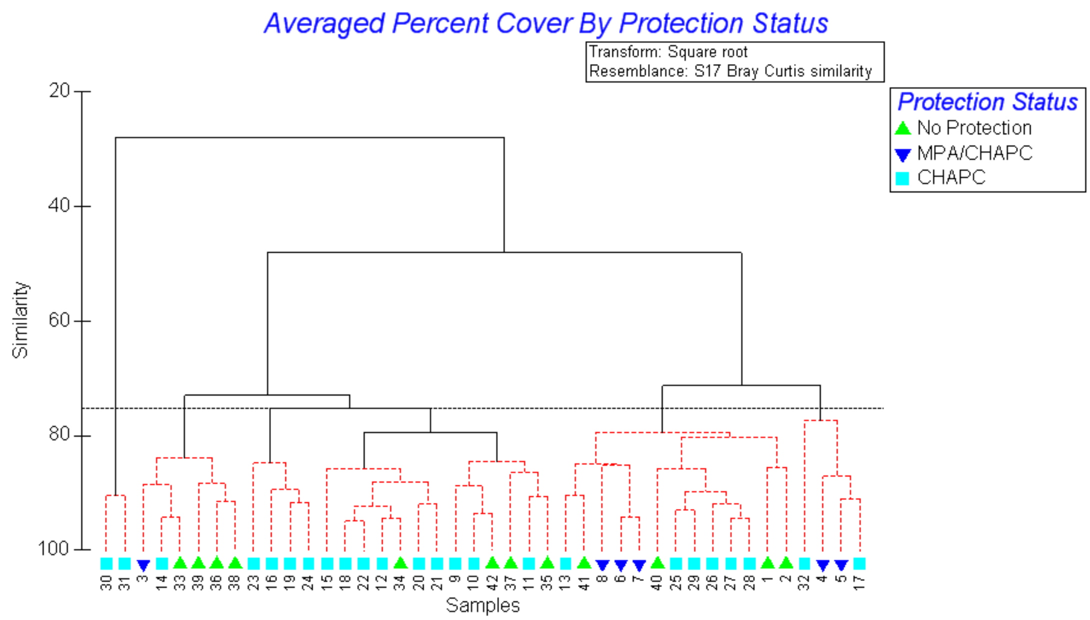

Figure 13. Cluster analysis dendrogram of averaged percent cover by protection status with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 75% similarity.

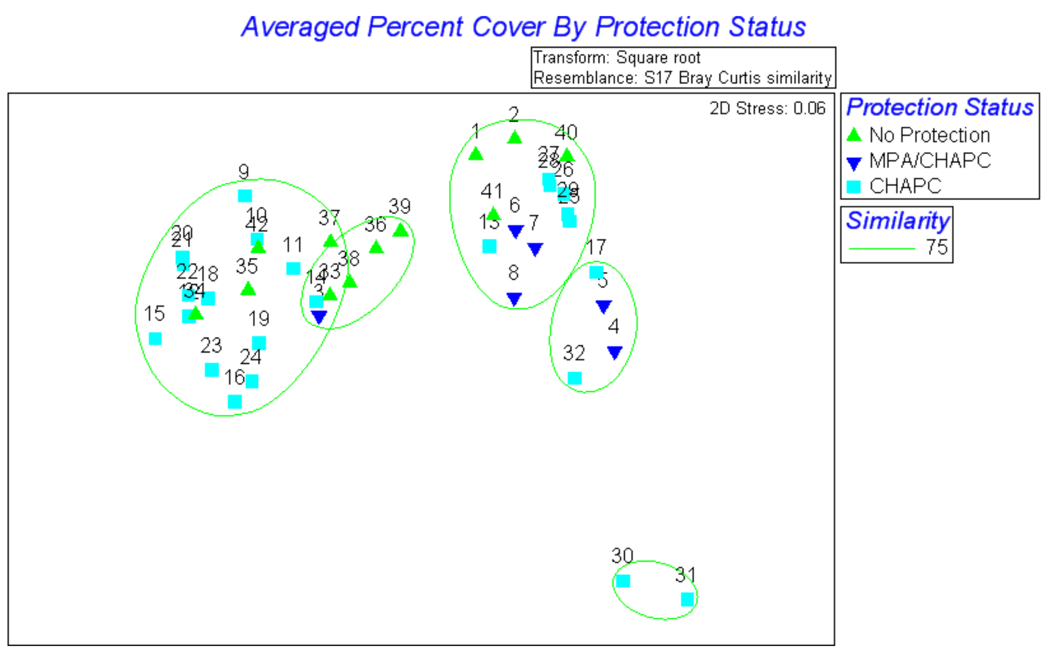

Figure 14. MDS plot from cluster analysis of percent cover by protection status with similarity of 75%. Labeled by transect number.

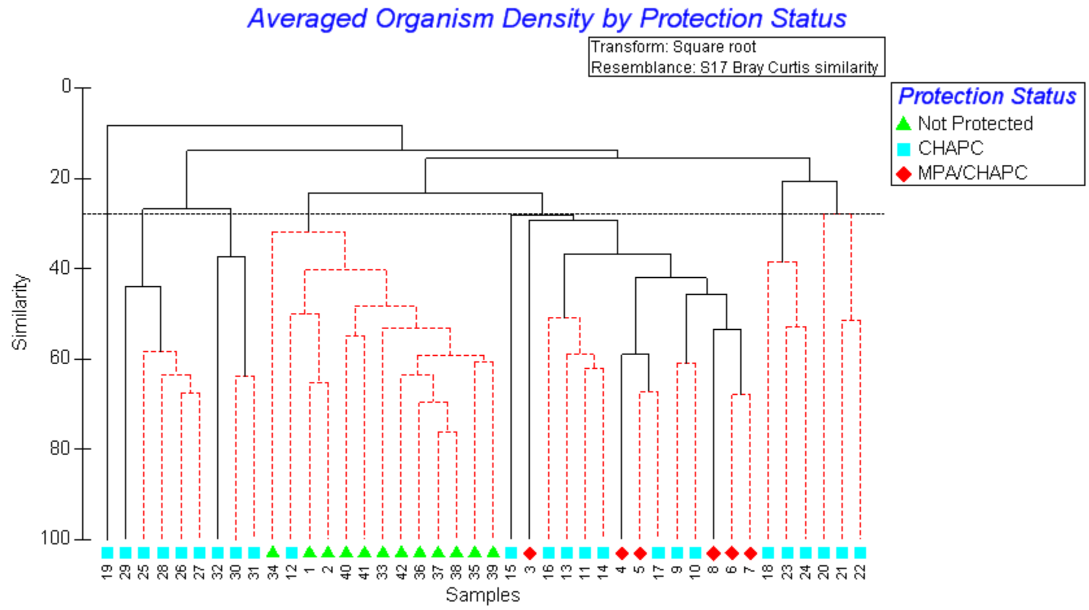

Figure 15. Cluster analysis dendrogram of averaged organism density count by protection status with transects 1 through 42 on the X-axis and similarity on the Y-axis; dashed line representing 28% similarity.

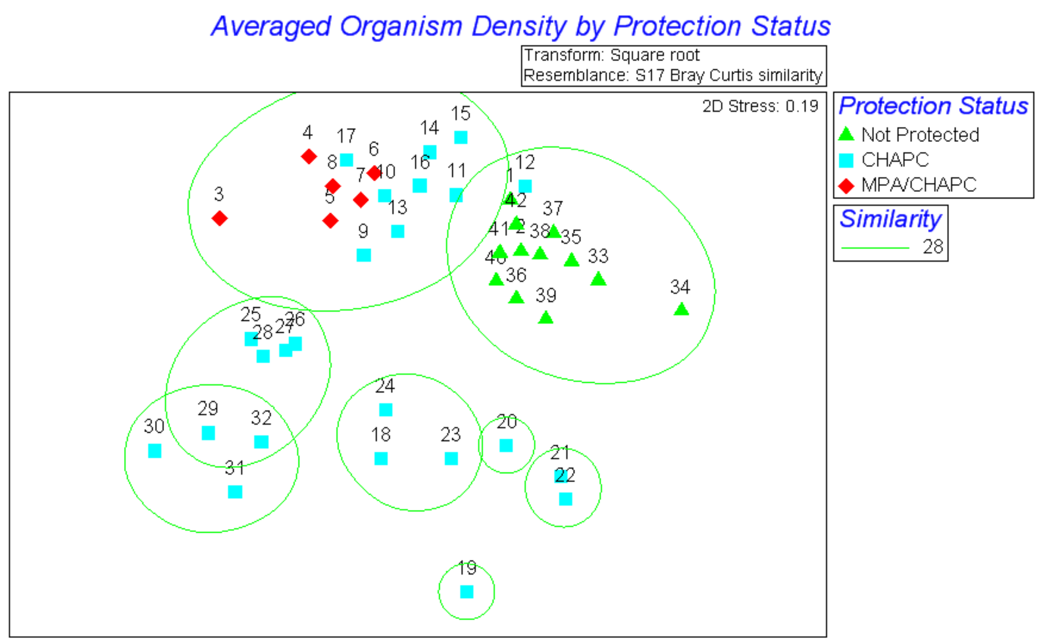

Figure 16. MDS plot from cluster analysis of organism density by protection status with similarity of 28%. Labeled by transect number.

D. Depth and Location Bin Class Characterization

Transects were classified into one of five depth and location bin classes based on depth measured in meters squared for each image and location in relation to CHAPC/MPA area borders (Figure 3). The number of transects within each bin class depended on depth and location. The following sections briefly characterize transects within each depth and location bin class (see Appendix 3).

West 150-300 (12 transects, 217 images analyzed)

This depth and location bin class region is under no protection and is located west of the CHAPC and MPA area borders at depths between 150-300 m. Transects 1 and 2 were run during dive 13 of the cruise, transects 33-42 were run during dive 26 (Table 1, Figure 1). Figure 1 (Appendix 3) displays transects 1 and 2 with the closest isobath contour at 250 m. Figure 2 (Appendix 3) shows transects 33-42 with the closest isobath contour at 200 m.

North Central 150-250 (14 transects, 614 images analyzed)

Transects 3, 4, 5, 7 and 8 are under MPA and CHAPC protection and transects 9-17 are under CHAPC protection. These transects are located centrally and north inside the MPA and CHAPC borders and have at depths between 150-250 m. Transects 3, 4, and 5 were run during dive 16; 7-8 during dive 17; 9-12 during dive 18; 13-16 during dive 19; and 17 during dive 22 (Table 1, Figure 1).

Figure 3 (Appendix 3) shows transect 3, 4, and 5 with the closest isobath contour at 200 m. Figure 3. (Appendix 3) shows transects 6, 7, and 8; however transect 6 is located under depth and location bin class Central 250-300 and will be discussed under it. The isobath contour closest to transects 7 and 8 is 250 m. Figure

5 (Appendix 3) includes transects 9- 12; the map shows no contour lines. Figure 6 (Appendix 3) shows transects 14-16 with the closest isobath at 200 m. Figure 7 (Appendix 3) shows transect 17 with an isobath at 250 m.

Central 250-300 (8 transects, 126 images analyzed)

Transect 6 is located under MPA and CHAPC protection, and transects 18-24 under CHAPC protection. Central bin class transects are located centrally under the MPA and CHAPC borders with a depth range between 250-300 m. Transect 6 was run during dive 17, and 18-24 under dive 23 (Table 1, Figure 1). Figure 4 (Appendix 3) shows transect 6 with the closest isobath contour at 250 m. Figure 8 (Appendix 3) shows 18-24, the closest isobath at 300 m.

South 450-500 (5 transects, 102 images analyzed)

Transects 25-29 are located under CHAPC protection south of the CHAPC and MPA borders at a depth range of 450-500 m. Transects 25- 29 were run during dive 24 (Table 1, Figure 1). Figure 9 (Appendix 3) shows transects 25-29 with the closest isobath at 450 m.

South 500-550 (3 transects, 51 images analyzed)

Transects 30-32 are located under CHAPC protection and located south under the CHAPC and MPA borders at a depth range between 500-550 m. Transects 30-32 were run during dive 25 (Table 1, Figure 1). Figure 10 (Appendix 3) shows transects 30-32 with the closest isobath at 500 m.

E. Percent Cover Analysis

Appendix 2, Table 1 lists the 16 major categories used for percent cover analysis as well as CPCe analysis results in percentages.

West 150-300

Hard bottom substrate dominated (61.83% of cover) followed by sediment veneered hard bottom (SVHB) (31.95%), soft bottom substrate (3.25%), Cnidaria, Non Scleractinia (anemones, soft corals, hydroids, Zoanthids, Ceranthids) (2.10%) and Coral (0.59%) (Figure 17).

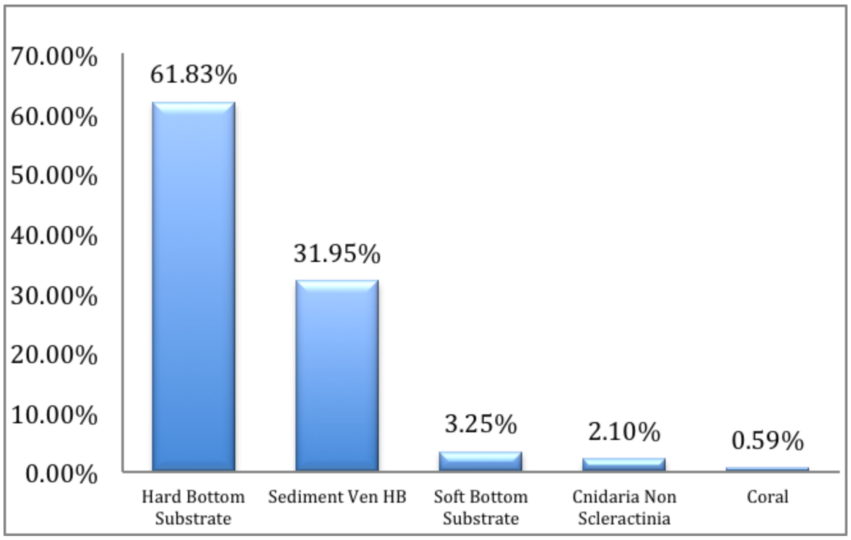

Figure 17. West 150-300. CPCe analysis results showing percent cover of the five most important 16 major substrate and benthos categories. Sediment Ven HB=Sedimentveneered hardbottom.

North Central 150-250

Hard bottom substrate dominated (47.23% of cover) followed by SVHB (35.20%), soft bottom substrate (5.71%), Coral (5.63%), and Porifera (3.15%) (Figure 18).

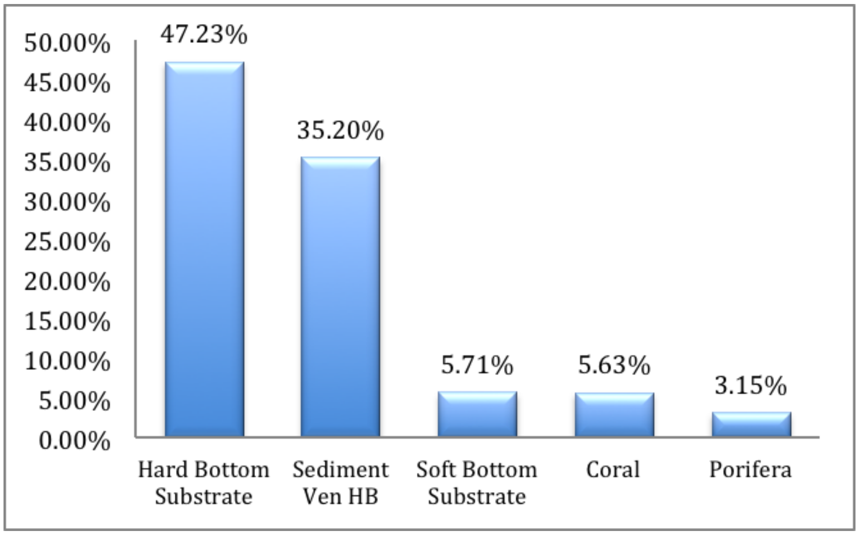

Figure 18. North Central 150-250. CPCe analysis results showing percent cover of the five most important 16 major substrate and benthos categories. Sediment Ven HB=Sediment-veneered hardbottom.

<u>Central 250-300</u>

SVHB dominated (62.51% of cover) followed by hard bottom substrate (29.61%), soft bottom substrate (5.60%), Cnidaria Non Scleractinia (0.94%), and Porifera (0.62%) (Figure 19).

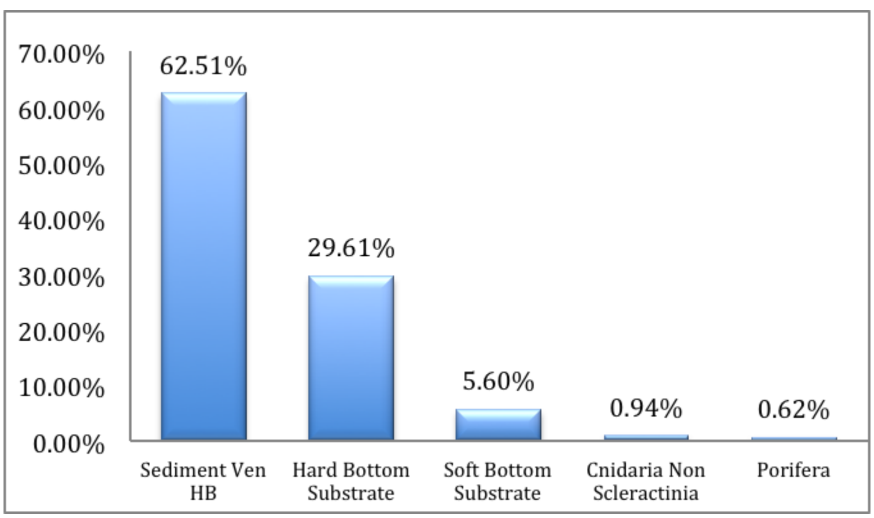

Figure 19. Central 250-300. CPCe analysis results showing percent cover of the five most important 16 major substrate and benthos categories. Sediment Ven HB=Sediment veneered hardbottom.

South 450-500

Hard bottom substrate dominated (93.27% of cover) followed by, Cnidaria Non Scleractinia (2.85%), Porifera (1.72%), Coral (1.56%), and Echinodermata (0.58%) (Figure 20).

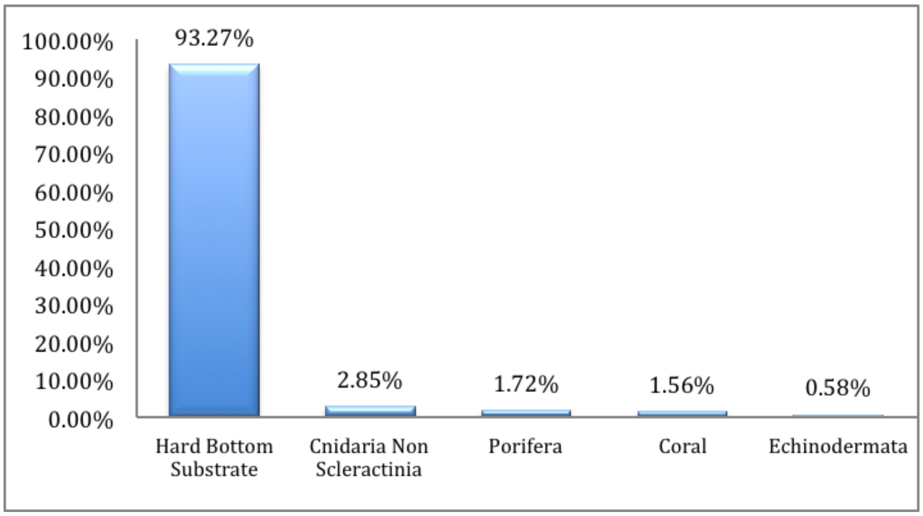

Figure 20. South 450-500. CPCe analysis results showing percent cover of the five most important 16 major substrate and benthos categories.

South 500-550

Coral dominated (76.19% of cover) followed by, Hard bottom substrate (22.46%), Cnidaria Non Scleractinia (0.52%), Porifera (0.49%), and Chordata (0.27%) (Figure 21).

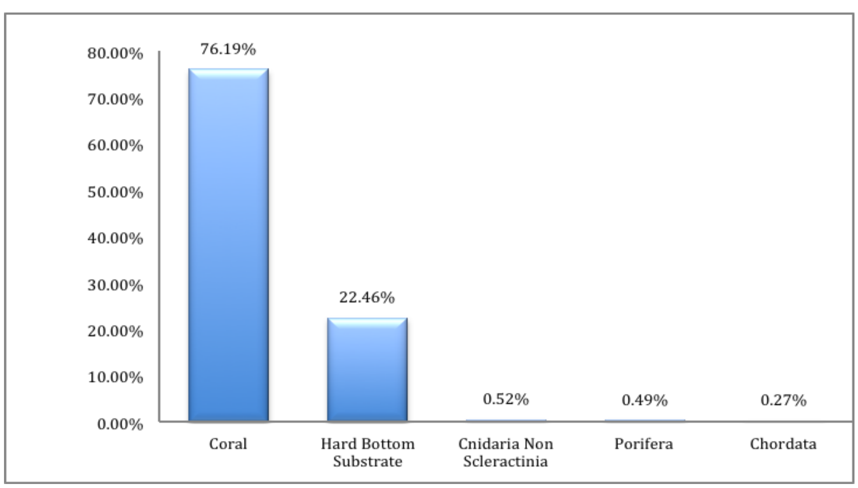

Figure 21. South 500-550. CPCe analysis results showing percent cover of the five most important 16 major substrate and benthos categories.

F. Organism Density Count Analysis

Appendix 2, table 2 shows organism density count results, the taxonomic list used in analysis and results of each transect. For every species on the taxonomic list all transects within each depth and location bin class were totaled and the 5 densest taxa determined for that bin class.

West 150-300

The five taxa with greatest densities were Sagartiidae (Actiniaria) (24.81 m^{-2}) followed by four Stylasteridae (Hydrozoa) taxa: *Stylaster miniatus* (18.31 m^{-2}), Stylasteridae unid. sp. 1 (5.00 m^{-2}), *Pliobothrus echinatus* (2.93 m^2), and Unidentified Stylasteridae (2.14 m^{-2}) (Figure 22).

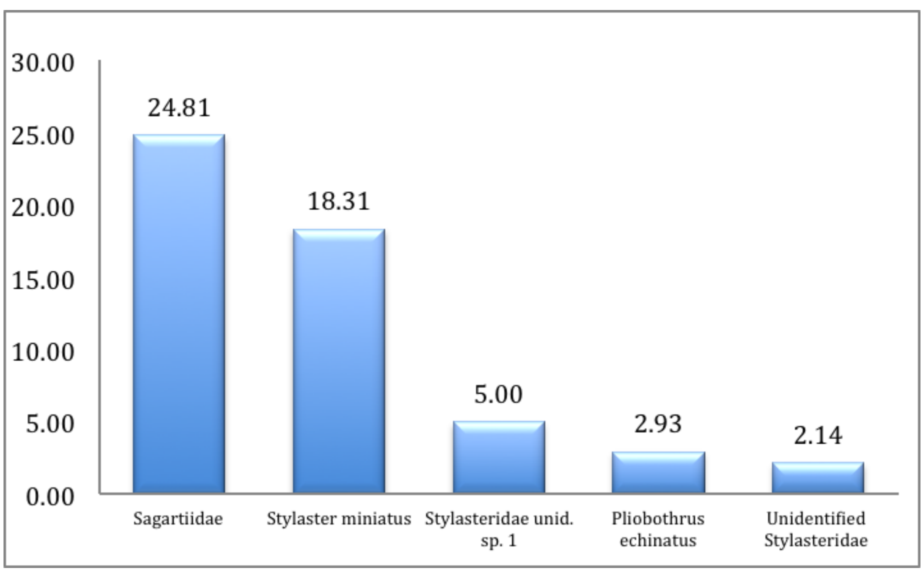

Figure 22. West 150-300. Five most dense benthic taxa m^{-2}.

North Central 150-250

The five taxa with greatest densities were *Stylaster miniatus* (31.29 m^{-2}) followed by *Plumarella* unid. sp. 1 (Octocorallia) (25.25 m^{-2}), *Chondrosia* sp.

(Demospongiae) (11.97 m^{-2}), *Stylaster filogranus* (Stylasteridae) (11.68 m^{-2}), and Petrosiidae unid. sp. (Demospongiae) (4.81 m^{-2}) (Figure 23).

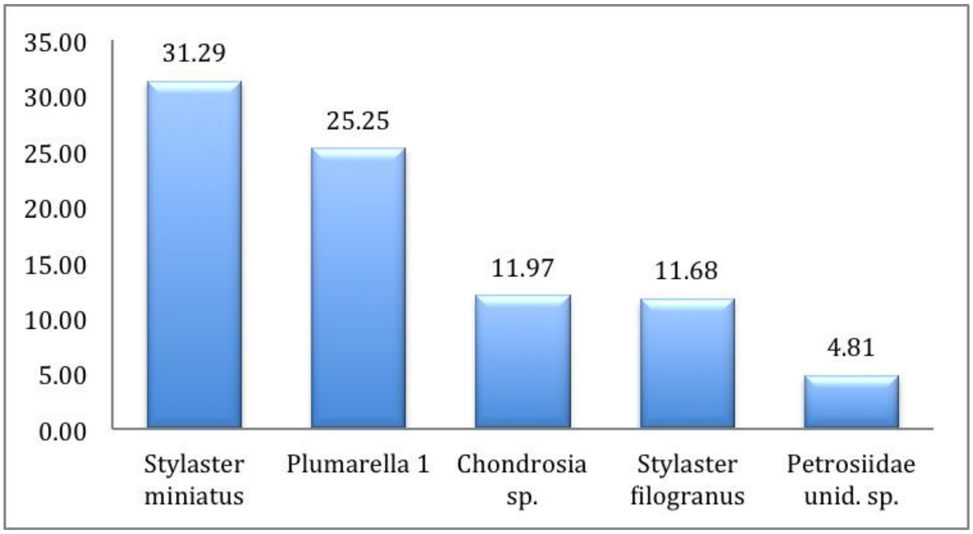

Figure 23. North Central 150-250. Five most dense benthic taxa m^{-2}.

<u>Central 250-300</u>

The six taxa with greatest densities were Hydroida unid. sp. (Hydrozoa) (5.51 m^{-2}) followed by Isididae unid. sp. 2 (Octocorallia) (2.12 m^{-2}), *Stylaster miniatus* (1.74 m^{-2}), Octocorallia unid. sp. 3 (Octocorallia)(1.4 m^{-2}), Astrophorina unid. sp. 4 (Demospongiae) (0.84 m^{-2}), and Hexactinellida unid. sp. 1 (Hexactinellida) (0.84 m^{-2}) (Figure 24).

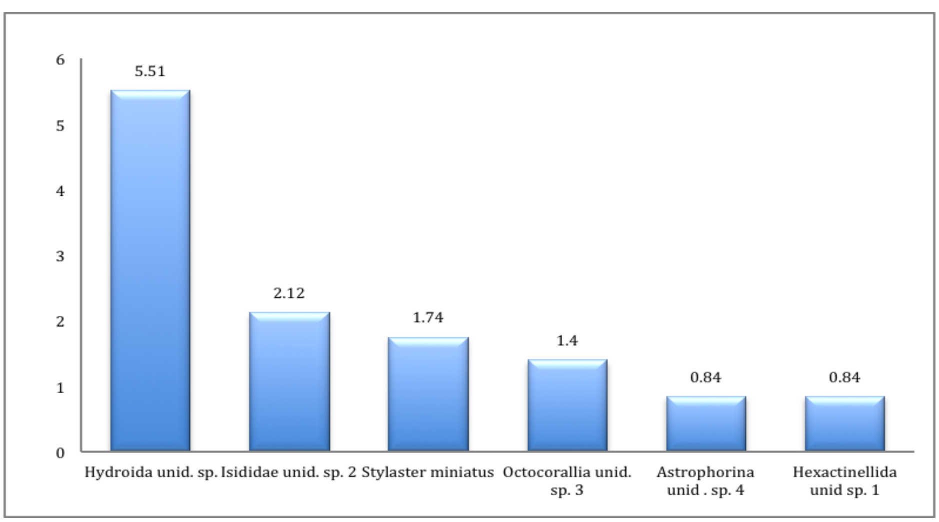

Figure 24. Central 250-300. Six most dense benthic taxa m-^{2}.

South 450-500

The five taxa with greatest densities were *Paramuricea* unid. sp. 3 (Octocorallia) (7.06m^{-2}) followed by Octocorallia unid. sp. 7 (Octocorallia) (4.95m^{-2}), *Comatonia cristata* (Crinodea) (1.64m^{-2}), *Plumarella* unid. sp. 1 (1.54m^{-2}), and Astrophorina unid. sp. 4 (1.5m^{-2}) (Figure 25).

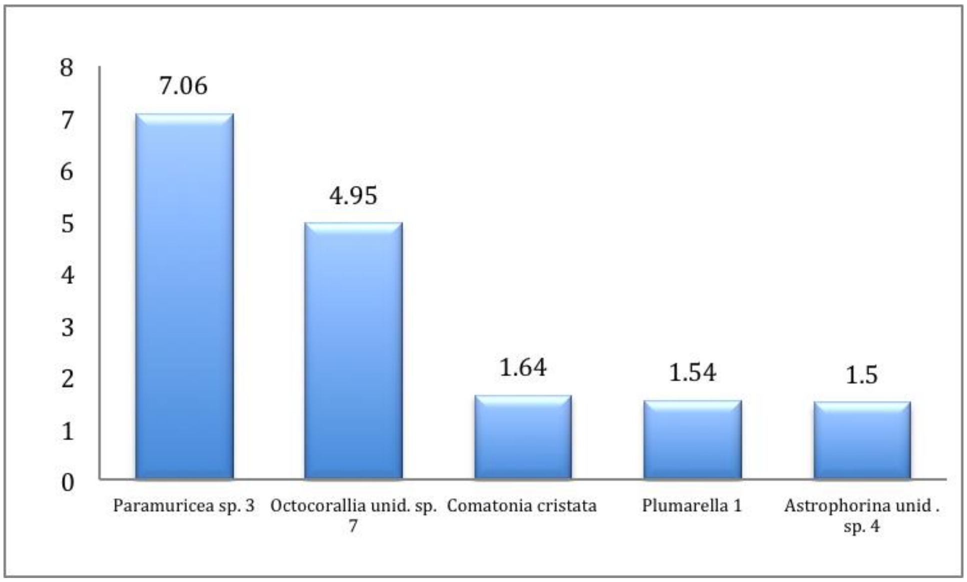

Figure 25. South 450-500. Five most dense benthic taxa m-^{2}.

South 500-550

The five taxa with greatest densities were *Lophelia pertusa* (Scleractinia) (3.9 m^{-2}) followed by *Plumarella* unid. sp. 2 (Octocorallia) (0.84 m^{-2}), *Paramuricea* unid. sp. 3 (0.64 m^{-2}), Isididae unid. sp. 2 (0.37 m^{-2}), and Ophiuroidea (Ophiuroidea) (0.37 m^{-2}) (Figure 26).

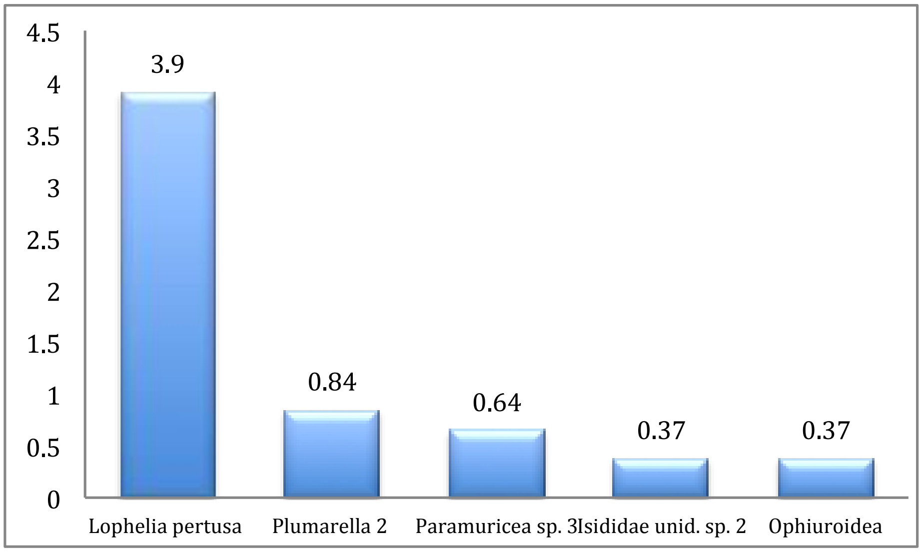

Figure 26. South 500-550. Five most dense benthic taxa m-2.

G. SIMPER Organism Density Analysis by Depth and Location

Organism density results were analyzed using Species Accumulation and Species Analysis (SIMPER) to determine which species based on location and depth as the factor contributed most to the Bray–Curtis dissimilarity. Groups with higher values have similar communities.

Table 8 lists average similarity percentages for the five depth and location bin classes. Transects within South 500-550 had the highest similarity (41.77%) and those within Central 250-300 had the lowest (12.44%).

Table 8. SIMPER results, average similarity for five depth and location bin classes.

Groups	Average Similarity
West 150-300	41.58
North Central 150-250	27.96
Central 250-300	12.44
South 450-500	43.96
South 500-550	41.77

West 150-300

West 150-300 bin had an average similarity of 41.58% with four taxa contributing at least 5% (total 88.34%) to community differences (Table 9). The most significant taxa were Sagartiidae (50.53%) followed by *Stylaster miniatus* (26.30%), Stylasteridae unid. sp. 1 (6.77%), and *Pliobothrus echinatus* (4.74%).

Table 9. West 150-300 SIMPER results, four contributing benthic taxa.

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum.%
Sagartiidae	2.07	21.01	1	50.53	50.53
Stylaster miniatus	1.53	10.93	1.02	26.3	76.83
Stylasteridae unid. sp. 1	0.42	2.82	1.01	6.77	83.6
Pliobothrus echinatus	0.24	1.97	0.92	4.74	88.34

North Central 150-250

North Central 150-250 bin had an average similarity of 27.96% with 10 taxa contributing at least 2% (total 90.24%) to community differences (Table 10). The most significant taxa were *Stylaster miniatus* (53.67%) followed by *Plumarella* unid. sp. 1 (8.76%), and *Chondrosia* sp. (4.93%).

Table 10. North Central 150-250 SIMPER results, ten contributing benthic taxa.

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum.%
Stylaster miniatus	2.34	15.01	1.43	53.67	53.67
Plumarella 1	1.92	2.45	0.27	8.76	62.44
Chondrosia sp.	0.87	1.38	0.51	4.93	67.36
Astrophorina unid. sp. 4	0.34	1.28	0.58	4.57	71.94
Unidentified Demospongiae	0.22	1.21	0.89	4.34	76.27
Stylaster filogranus	0.84	1.14	0.38	4.09	80.37
Pliobothrus echinatus	0.14	0.76	0.74	2.7	83.07
Hexactinellida unid sp. 1	0.24	0.55	0.27	1.97	87.27
Unidentified Hexactinellida	0.09	0.41	0.34	1.48	88.76
Iphiteon panicea	0.12	0.41	0.37	1.48	90.24

Central 250-300

Central 250-300 bin had an average similarity of 12.44% with 10 taxa contributing at least 2% (total 90.40%) to community differences (Table 11). The most significant taxa were *Calocidaris micans* (Echinoidea) (27.54%) followed by *Hydroida* unid. sp. (12.62%) and *Isididae* unid. sp. 2 (11.55%).

Table 11. Central 150-250 SIMPER results, ten contributing benthic taxa.

Species	Av. Abund	Av. Sim	Sim/SD	Contrib%	Cum.%
Calocidaris micans	0.70	3.43	0.68	27.54	27.54
Hydroida unid. sp.	0.69	1.57	0.47	12.62	40.16

Isididae unid. sp. 2	0.27	1.44	0.29	11.55	51.71
Stylaster miniatus	0.22	0.84	0.43	6.79	69.18
Goniasteridae	0.02	0.75	0.27	6.02	75.2
Unidentified Demospongiae	0.08	0.57	0.6	4.58	79.78
Octocorallia unid. sp. 3	0.18	0.41	0.19	3.26	83.04
Stylasteridae unid. sp. 1	0.04	0.39	0.23	3.1	86.14
Unidentified Hexactinellida	0.05	0.34	0.23	2.77	88.91
Desmacellidae (blue morphology)	0.02	0.19	0.46	1.49	90.4

South 450-500

South 450-500 bin had average similarity of 43.96% with 13 taxa contributing at least 2% (total 90.17%) to community differences (Table 12). The most significant taxa were *Paramuricea* sp. 3 (24.76%) followed by Octocorallia unid. sp. 7 (16.40%), and *Comatonia cristata* (8.90%).

Table 12. South 450-500 SIMPER results, thirteen contributing benthic taxa.

Species	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Paramuricea sp. 3	1.41	10.89	1.19	24.76	24.76
Octocorallia unid. sp. 7	0.99	7.21	2.65	16.4	41.17
Comatonia cristata	0.33	3.91	1.44	8.9	50.06
Rochinia crassa	0.24	3.42	2.62	7.77	57.84
Astrophorina unid. sp. 4	0.3	3.14	1.44	7.15	64.99
Lophelia pertusa	0.21	2.89	1.7	6.58	71.57
Plumarella 1	0.31	2.65	1.24	6.03	77.6
Raspailliidae sp. 2	0.13	1.25	0.7	2.84	80.44
Stylaster erubescens	0.15	1.1	1.04	2.51	82.95
Calocidaris micans	0.14	0.91	2.62	2.08	85.02
Unidentified Demospongiae	0.12	0.86	1.04	1.95	86.97
Isididae unid. sp. 1	0.23	0.76	0.58	1.73	88.7
Stylasteridae unid. sp. 1	0.04	0.64	1.02	1.47	90.17

South 500-550

South 500-550 bin had average similarity of 41.77% with 5 taxa contributing at least 3% (total 92.38%) to community differences (Table 13). The most significant taxa were *Lophelia pertusa* (58.85%) followed by *Plumarella* 2 (19.37%) and *Paramuricea* sp. 3 (6.66%).

Table 13. South 500-550 SIMPER results, five contributing benthic taxa.

Species	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Lophelia pertusa	1.3	24.56	2.37	58.8	58.8

Plumarella 2	0.28	8.09	7.9	19.37	78.17
Ophiuroidea	0.12	2.78	0.99	6.66	84.83
Astrophorina unid. Sp. 3	0.08	1.98	1.4	4.74	89.57
Paramuricea sp. 3	0.21	1.17	8.57	2.81	92.38

V. Discussion

A. Community Analysis

Multivariate analysis of percent cover and density by depth and location revealed that these two factors provide the largest impact on driving differences among the benthic communities. The MDS plot for percent cover shows the 500-550 transects clustered away from the others (with 75% similarity). South 450-500 transects clustered together, whereas transects in the West 150-300, North Central 150-250 and Central 250-300 were mixed between clusters. The organism density plot for depth and location showed five distinct clusters (with 28% similarity); all depth/location bin transects within each bin class were clustered together. Cluster analysis of depth and location based on organism densities showed the clearest distinction among transects based on this factor. A one-way Analysis of Similarities (ANOSIM) on percent cover and organism density using depth and location as the factor were significant (p=0.001; p=0.001) but with differing R values. A low R-value (R=0.306) suggested that percent cover had a small impact on communities, whereas a high value (R=0.753) indicated density by depth and location was a good indicator of what drives the differences in benthic communities. To further support depth is significantly correlated with differences in communities a one-way ANOVA showed significant difference (p-Value was <. 0001*) among the five depth and location bin classes.

Multivariate analysis of percent cover and density data by geomorphology found that it wasn't correlated significantly with the community. MDS plots showed Transect 30 and 31 (the *Lophelia* Mound under CHAPC protection) clustered away from the others in both plots. The percent cover plot showed that all other clusters were a mix of the remaining geomorphologic factors (Mound-Top, Mound-Slope, Deep-Mound, Valley, and Sinkhole) at 75% similarity. The organism density plot shown transects with the same geomorphology clustered together or near each other at 28% similarity. A one-way Analysis of Similarities (ANOSIM) on percent cover and organism density using geomorphology as the factor found significant differences (p=0.001, p=0.002) but low R-values (R=0.329; R=0.271), indicating that geomorphology has a small impact in driving differences in communities.

Multivariate analysis of percent cover and density count data by protection status as the factor found that it had a small impact on driving differences among communities. The MDS plot for percent cover with 75% similarity showed protection statuses mixed among clusters. The organism density plot with 28% similarity shows, unprotected transects clustered together: CHAPC transects clustered near each other and within MPA/CHAPC transects and MPA/CHAPC transects clustered together. A one-way ANOSIM based on protection status showed that percent cover is insignificant (p=0.471) with a negative R value (R=-0.002), indicating protection status did not affect communities and may indicate an outlier in the data. A significant result (p=0.002) but a low value for organism density (R=0.21) suggests that protection status has only a small impact on community structure.

Based on data from the September 2011 Reed *et al*. (2014) compared fish communities in relation to the benthic factors of geomorphology, substrate, depth, slope and protection status. They found that depth was the most important factor contributing to variations in fish communities followed by geomorphology and substrate. Reed *et al.* (2014) analyzed 13 dives with 4 factors (geomorphology, substrate, depth, slope and protection status), whereas this thesis separated dive sites into 42 transects based on finer depth and location intervals giving a higher resolution. They compared two depth ranges (150-300 m and 450-850 m) whereas this thesis used 5 depth and location bin classes (West 150-300, North Central 150-250, Central 250-300, South 450-500, and South 500-550).

B. Community Characterization

SIMPER density analysis and organism density results were consistent among bin classes and helped determine which taxa were driving differences in depth and location. Four of the five depth and location bin classes (West 150-300, Central 250-300 and South 450-500) were overwhelmingly dominated by bare hard bottom substrates (Hard Bottom plus Sediment-Veneered Hardbottom (SVHB)), that accounted for 92.12 to 93.78% of cover and supported a diverse assemblage of hard-substrate-dependent biota. Bare hard substrates accounted for 82.43% in the North-Central bin class. However, dominant organisms varied substantially, e.g., sagartiid anemones (SIMPER contributing 50.53%) and at least four stylasterids (SIMPER 37.81%) at West 150-300 (SIMPER average similarity 41.58%); stylasterids (SIMPER 53.67%), the octocoral *Plumarella* unid. sp. 1 (SIMPER 8.76%) and demosponges (*Chondrosia* sp. ((SIMPER 4.93%)) and

Petrosiidae) at North-Central 150-250 (SIMPER 27.96%); non-scleractinian Cnidaria (e.g., unidentified Hydroida (SIMPER 12.62%), Isididae (SIMPER 11.55%), Octocorallia, *S. miniatus*) and sponges at Central 250-300 (SIMPER 12.44%), and some different non-scleractinian Cnidaria (e.g., *Paramuricea* sp. 3 ((SIMPER 24.76%)), unidentified Octocorallia ((SIMPER 16.40%)), and *Plumarella* unid. sp. 1), the crinoid *Comatonia cristata* (SIMPER 8.90%), and Porifera (unidentified Astrophorina) at South 450-500 (SIMPER 43.96%). Among these bin classes, sediment contributed the most (5.60%) at Central 250-300. By contrast, South 500-550 (SIMPER 41.77%) were dominated by Coral (chiefly *Lophelia pertusa*, 76.19%) (SIMPER 58.85%) with bare Hard bottom contributing only 22.46%. The most abundant other species were chiefly octocorals: *Plumarella* unid. sp. 2 (SIMPER 19.37%), *Paramuricea* unid. sp. 3 (SIMPER 6.66%), and unidentified Isididae.

The following summarizes the similar results reported in Reed *et. al*. (2012) and this thesis. During dive 26 Reed *et al.* (2012) found predominantly hard bottom dominated by Cnidaria including Stylasteridae and Sagartiidae. This is consistent with this thesis in which transects in the West 150-300 depth and location bin (dive 26) were 93.78% hard bottom with dominant taxa including sagartiid anemones and at least four stylasterids. For dives 17-19 and 22, Reed *et al*. (2012) reported predominately hard bottom dominated by Cnidaria and Porifera, again consistent with results found in this thesis; transects in the North-Central 150-250 bin class (dives 17-19, and 22) were 82.43% hard bottom dominated taxa including stylasterids, *Plumarella* unid. sp. 1 and demosponges (*Chondrosia* sp. and Petrosiidae)). Dives 17 and 23 were predominantly hard bottom dominated by

Cnidaria and Porifera (Reed *et al.* 2012), similar to transects in the Central 250-300 bin class (one transect under dive 17 and the others dive 23): 92.12% hard bottom with dominant taxa including non-scleractinian Cnidaria and sponges. During dive 24 Reed *et al.* (2012) found predominately hard bottom substrate (97.16%) dominated by Cnidaria and Porifera species with Cnidaria species having the most diverse population. Similarly the South 450-500 bin class (dive 24) 93.27% hard bottom with dominant taxa including non-scleractinian Cnidaria, the crinoid *Comatonia cristata*, and Porifera. During dive 25 Reed *et al*. (2012) found predominantly hard bottom dominated by Cnidaria (*Lophelia pertusa*) and Porifera, consistent with results found in this thesis, which found South 500-550 bin class transects (dive 25) to have 76.19% Coral and 22.46% Hard Bottom with dominant taxa including *L pertusa* and octocorals.

The results support null hypothesis 1 that significant differences exists in communities relative to percent cover and organism densities. Communities differed strongly between bins with the following similarities: West 150-300, North-Central 150-250, Central 250-300 all included *Stylaster miniatus* among the five dominant species also suggesting depth as a driving factor, because all three bins fall between 150 and 300 m. South 450-500 and South 500-550 both included *Paramuricea* unid. sp. 3 among the five dominant species, also suggesting depth and location as possible driving factors.

Observations made during this cruise during dive 25 over a depth range of 468-547 m revealed the southernmost *Lophelia pertusa* coral mound in U.S waters (Reed *et. al.* 2012, 2014). This record is well within the known depth range for

Lophelia habitat along the east coast of Florida (e.g., Grasmueck *et. al.* 2006; Reed, 2002a; Reed *et al.* 2006; Messing *et. al.* 2008). However Ross *et al*. (2015) more recently found living *L. pertusa* colonies off northeastern Florida at depths between 180 and 250 m that maybe maintained at such shallow depths by upwelling cold and nutrition-rich water. This is the shallowest record for *L. pertusa* reefs in the western Atlantic Ocean and is under review for protection as a CHAPC under the new Amendment 8 of the MSA (Ross *et al*., 2015).

Percent cover analysis of substrate did not give an accurate portrayal of benthic communities but did assess non-living substrate. Percent cover results showed that depth and location bin classes were dominated by hard-bottom substrate. The West 150-300 depth and location bin class is under no management protection and is primarily hard bottom, dominated by non-scleractinian Cnidaria and hard coral. Based on results of this thesis and Reed *et al*. (2012, 2014), the CHAPC boundaries should be increased to cover this area.

<u>C. Conservation and Management</u>

Hypothesis 2 was deemed inconclusive ANOSIM and Cluster analyses results indicated that protection status had a small impact on differences in benthic communities. However, differences in communities outside vs. inside management zones did not show a clear relationship because protection sites were nested within specific location and depths. Reed *et al.* (2014) found that protection status did not affect fish community diversity either. This problem may have confounded their results as well. Deep-water benthic communities are slow-growing; thus immediate benefits from protection may not be apparent. Because CHAPC and MPA protected areas were only established in 2010 it is most likely too recent to determine whether they have been effective. Nonetheless, the results herein can be used for managing the Pourtalès Terrace benthic communities to conserve these fragile deep-water coral environments. Several important geologic hardbottom features that lie outside of CHAPC/MPA borders were discovered and characterized by this project; these may provide essential fish habitat and should be considered for addition to the CHAPCs. These data will also provide managers and scientists with a valuable baseline for assessing the deep-water habitats within the CHAPC and MPA on Pourtalès Terrace, and the effectiveness of the protected areas over time. In addition, the strong relationship between depth and location and community structure indicates that these factors could be used as a proxy for creating habitat maps of benthic communities in unmapped areas.

VI. Conclusions

Based on results of this thesis and those of Reed *et al.* (2012, 2014), benthic community appears to be determined chiefly by depth followed by geomorphology. The strong relationship between depth and location indicates they could be used as a proxy for creating habitat maps of benthic communities. Protection status appears to have no influence on benthic communities as yet, most likely because protection boundaries were implemented too recently to have had any effect. However, the detailed nature of these results offers them as baseline data for future community assessments and comparisons between protected and unprotected habitats to measure the effectiveness of deep-water marine protected areas protections and for developing management strategies and decisions that will ensure conservation of the fragile deep-water coral environments on the Pourtalès Terrace.

Several new geologic features discovered and characterized also include the southernmost *Lophelia pertusa* coral mound in U.S. waters. Some important hardbottom geologic features that lie outside of CHAPC/MPA borders were discovered and characterized which suggests new HAPC borders should be designated.

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Appendix 1. Transect Characterization

Table 1. General transect name, transect by geomorphology, transect by habitat bin class, image range (image number) number of images, area per m^2 of each transect, mean depth, and protection status.

General Transect Name	Transects By Geomorphology	Transects by Depth and Location Bin Classes	Image Range	Number of Images	Area/m^2	Mean Depth (m)	Protection Status
Transect 1	Dive 13 Valley A	West150-300	3225-3253	13	30	284.93	No Protection
Transect 2	Dive 13 Valley B	West150-300	3254-3279	24	31	285.26	No Protection
Transect 3	Dive 16 Mound-Slope	North Central150-250	3951-3961	9	29.9	239.25	MPA/CHAPC
Transect 4	Dive 16 Mound-Top A	North Central150-250	3872-3902	29	30	189.87	MPA/CHAPC
Transect 5	Dive 16 Mound-Top B	North Central150-250	3908-3933	26	30.1	194.2	MPA/CHAPC
Transect 6	Dive 17 Mound-Slope A	Central250-300	4050-4079	29	29.9	258.03	MPA/CHAPC
Transect 7	Dive 17 Mound-Slope B	North Central150-250	4084-4137	27	30.1	241.14	MPA/CHAPC
Transect 8	Dive 17 Mound-Slope C	North Central150-250	4140-4174	29	26.4	215.91	MPA/CHAPC
Transect 9	Dive 18 Mound-Slope 1	North Central150-250	4241-4292	48	30.1	195.69	CHAPC
Transect 10	Dive 18 Mound-Top	North Central150-250	4392-4424	33	30.3	174.86	CHAPC
Transect 11	Dive 18 Mound-Wall A	North Central150-250	4342-4363	20	30.2	181.14	CHAPC
Transect 12	Dive 18 Mound-Wall B	North Central150-250	4366-4374	9	29.9	176.99	CHAPC
Transect 13	Dive 19 Deep-Mound	North Central150-250	4526-4548	18	30.1	235.66	CHAPC
Transect 14	Dive 19 Mound-Slope A	North Central150-250	4454-4488	21	29	223.72	CHAPC
Transect 15	Dive 19 Mound-Slope B	North Central150-250	4489-4512	22	30.1	211.56	CHAPC
Transect 16	Dive 19 Valley 3	North Central150-250	4554-4568	15	30.2	227.99	CHAPC
Transect 17	Dive 22 Mound-Wall 2	North Central150-250	4915-4929	13	30.4	224.38	CHAPC
Transect 18	Dive 23 Mound-Slope A	Central250-300	5139-5158	16	30.1	298.4	CHAPC
Transect 19	Dive 23 Mound-Slope B	Central250-300	5160-5165	6	29.5	294.48	CHAPC
Transect 20	Dive 23 Mound-Slope C	Central250-300	5167-5180	12	30.7	292.51	CHAPC
Transect 21	Dive 23 Mound-Slope D	Central250-300	5181-5193	10	29.7	289.23	CHAPC

General Transect Name	Transects By Geomorphology	Transects by Depth and Location Bin Classes	Image Range	Number of Images	Area/m²	Mean Depth (m)	Protection Status
Transect 22	Dive 23 Mound-Slope E	Central250-300	5198-5212	12	29.9	285.68	CHAPC
Transect 23	Dive 23 Mound-Slope F	Central250-300	5219-5232	13	30	281.74	CHAPC
Transect 24	Dive 23 Mound-Slope G	Central250-300	5233-5261	28	29.9	290.41	CHAPC
Transect 25	Dive 24 Sinkhole A	South450-500	5272-5286 and 5315-5339	30	29.8	490.91	CHAPC
Transect 26	Dive 24 Sinkhole B	South450-500	5341-5346 and 5391-5407	22	30.1	481.59	CHAPC
Transect 27	Dive 24 Sinkhole C	South450-500	5408-5427	19	29.8	479.47	CHAPC
Transect 28	Dive 24 Sinkhole D	South450-500	5293-5310 and 5348-5354	18	30.1	488.99	CHAPC
Transect 29	Dive 24 Sinkhole E	South450-500	5360-5372	13	29.8	477.8	CHAPC
Transect 30	Dive 25 Lophelia Mound 1	South500-550	5433-5440 and 5537-5554	20	29.9	508.93	CHAPC
Transect 31	Dive 25 Lophelia Mound 2	South500-550	5562-5577	16	30.1	504.71	CHAPC
Transect 32	Dive 25 Lophelia Mound 3	South500-550	5579-5598	15	29.8	517.21	CHAPC
Transect 33	Dive 26 Deep-Mound A	West150-300	5670-5687	14	29.7	251.82	No Protection
Transect 34	Dive 26 Deep-Mound B	West150-300	5688-5698	8	29.9	251.08	No Protection
Transect 35	Dive 26 Deep-Mound C	West150-300	5699-5716	17	30.2	252.11	No Protection
Transect 36	Dive 26 Deep-Mound D	West150-300	5717-5733	17	29.9	251.24	No Protection
Transect 37	Dive 26 Deep-Mound E	West150-300	5741-5767	20	30.2	252.44	No Protection
Transect 38	Dive 26 Deep-Mound F	West150-300	5770-5792	18	30.2	251.02	No Protection
Transect 39	Dive 26 Mound-Slope	West150-300	5845-5877	33	30	216.71	No Protection
Transect 40	Dive 26 Mound-Top A	West150-300	5899-5921	15	30.1	194.93	No Protection
Transect 41	Dive 26 Mound-Top B	West150-300	5925-5957	32	30.1	195.43	No Protection
Transect 42	Dive 26 Valley 2	West150-300	5797-5817	20	30.4	252.56	No Protection

Appendix 2 Percent Cover and Density of Benthic Organisms

Table 1. CPCe© percent cover analysis of 42 transects, using 16 substrate and major benthos categories to characterize substrate. Zero values were excluded from the table, values measured in percent.

CPCe Analysis for Percent Cover Major Categories	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7	Transect 8	Transect 9	Transect 10	Transect 11	Transect 12	Transect 13	Transect 14	Transect 15	Transect 16	Transect 17	Transect 18	Transect 19	Transect 20	Transect 21
Annelida																					
Arthropoda				0.21%				0.07%													
Bryzoa									0.04%	0.06%											
Chordata				0.21%	0.69%		0.07%	0.07%			0.10%		0.11%		0.37%						
Cnidaria Non Scleractinia	1.70%	0.58%		7.24%	6.00%	1.04%	1.27%	3.74%	0.79%	1.03%	2.12%	0.22%	6.39%	1.05%	0.09%	2.81%	6.42%	0.50%	2.40%	0.17%	
Coral		0.58%		28.97%	18.92%	3.12%	4.57%	13.18%	0.38%	0.42%	0.71%		1.57%	0.38%		0.13%	9.55%				
Echinodermata	0.31%		0.22%	0.14%	0.15%																0.21%
Echiura																					
Human Debris		0.08%							0.13%												
Mollusca		0.08%																			
Natural Detritus													0.11%		0.09%			0.13%		0.34%	
Porifera			1.34%	11.52%	6.69%	2.71%	4.49%	2.91%	1.13%	2.42%	0.51%	0.22%	3.59%	1.05%	0.28%	0.13%	7.82%		0.68%		
Unidentified Organism						0.07%	0.30%	0.42%	0.13%	0.06%						0.13%					0.21%
Hard Bottom Substrate	93.82%	98.00%	48.88%	51.72%	67.54%	90.28%	87.42%	72.75%	28.21%	30.67%	41.41%	16.74%	80.49%	40.25%	9.73%	9.22%	76.21%	24.28%	21.92%	22.64%	24.53%
Sediment Ven HB	4.17%	0.67%	49.55%			2.78%	1.87%	6.87%	33.29%	45.88%	47.88%	73.44%	7.74%	57.27%	81.45%	87.57%		70.06%	75.00%	57.80%	60.71%
Soft Bottom Substrate									35.92%	19.45%	7.27%	9.38%			7.99%			5.03%		19.04%	14.35%

CPCe Analysis for Percent Cover Major Categories	Transect 22	Transect 23	Transect 24	Transect 25	Transect 26	Transect 27	Transect 28	Transect 29	Transect 30	Transect 31	Transect 32	Transect 33	Transect 34	Transect 35	Transect 36	Transect 37	Transect 38	Transect 39	Transect 40	Transect 41	Transect 42
Annelida						0.11%															
Arthropoda			0.07%		0.46%					0.25%		0.15%									
Bryzoa					0.09%																
Chordata				0.07%	0.09%						0.27%						0.23%	0.38%		0.13%	
Cnidaria Non Scleractinia		0.63%	2.75%	3.27%	2.75%	2.85%	1.56%	3.85%	0.40%	0.50%	0.67%	1.76%	0.89%	1.50%	1.36%	1.90%	1.39%	1.39%	5.67%	5.45%	1.59%
Coral				3.00%	0.92%	0.74%	1.00%	2.16%	93.00%	96.38%	39.20%	0.59%		0.25%	0.37%	0.21%	0.92%	0.69%	1.23%	2.05%	0.21%
Echinodermata	0.17%	0.63%		0.40%	0.37%	0.11%	0.56%	0.31%		0.25%									2.45%	0.19%	
Echiura				0.07%																	
Human Debris		0.47%																0.19%			
Mollusca															0.12%		0.12%				
Natural Detritus			0.07%	0.20%										0.13%				0.13%			
Porifera		0.16%	1.45%	2.13%	1.65%	0.63%	1.11%	3.08%	0.80%	0.13%	0.53%	0.29%		0.38%	0.12%	0.32%	0.12%	0.06%		0.19%	0.21%
Unidentified Organism			0.29%	0.07%							0.13%					0.11%		0.06%	0.15%		
Hard Bottom Substrate	23.65%	15.18%	14.42%	90.73%	93.66%	95.57%	95.78%	90.60%	5.80%	2.50%	59.07%	44.64%	17.21%	27.57%	66.00%	59.28%	51.68%	71.90%	90.51%	86.48%	34.82%
Sediment Ven HB	70.43%	82.32%	80.94%								0.13%	52.57%	76.26%	63.28%	32.01%	33.76%	45.55%	25.20%		5.51%	44.37%
Soft Bottom Substrate	5.74%	0.63%		0.07%									5.64%	6.89%		4.43%					18.79%

Table 2. Benthic organism density analysis of 42 transects. Zero values were excluded from table. *Lophelia* (1-6) refers to images referenced for taxonomic identification.

Density Table By Phylum/Class(order)/Scientific Name	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7	Transect 8	Transect 9	Transect 10	Transect 11	Transect 12	Transect 13	Transect 14	Transect 15	Transect 16	Transect 17	Transect 18	Transect 19	Transect 20	Transect 21
Porifera																					
Demospongiae																					
Astrophorina unid . sp. 4			0.60	0.63	0.86	0.77	1.26	0.61	0.07	0.13		0.03	0.10		0.03		0.43	0.03			
Astrophorina unid. sp.			0.10					0.04		0.03											
Astrophorina unid. Sp. 1					0.03	0.07	0.07	0.04	0.07	0.26							0.07				
Astrophorina unid. Sp. 2			0.07		0.07	0.43	0.20	0.04	0.13	0.26							0.03	0.07			
Astrophorina unid. Sp. 3			0.03				0.03										0.07				
Astrophorina unid. sp. 5 (1-6)																					
Chondrosia sp. (1 and 2)			0.47	5.77	3.06	0.64	0.27	0.34		0.20				0.21	0.03	0.07	1.78	0.03			
Corallistidae (1-3)			0.07		0.20	0.03	0.47	0.38					0.10				1.64				
Demospongiae unid sp. 2																					
Demospongiae unid. sp. 4						0.23			0.07						0.20						
Demospongiae unid. sp. 5				0.03	0.03			0.19	0.03	0.53	0.03		0.03	0.07			1.81				
Demospongiae unid. sp. 1																					
Demospongiae unid. sp. 3																					
Desmacellidae (blue morphology)					0.07	0.03	0.03		0.63	0.46	0.13	0.07				0.07		0.03			
Desmacellidae (yellow morphology)			0.13			0.13	0.03		0.03	0.40			0.03		0.07	0.17					
Geodia pachydermata?						0.03															
Geodia sp. nov. 1			0.03	0.07	0.10	0.10	0.17										0.03				
Geodia unid. sp. 1																					
Leiodermatium sp.						0.17	1.03		0.03				0.07	0.03			0.16				
Petrosiidae unid. sp.				3.93	0.43	0.40	0.03	0.08	0.03							0.03	0.23				
Phakellia ventalabrum					0.03				0.07	0.07											
Raspailliidae sp. 1										0.03											
Raspailliidae sp. 2				0.07					0.13												
Raspailliidae unid. sp. 3				0.20					0.13												
Vazella?						0.03	0.10	0.11		0.03											
Unidentified Demospongiae			0.23	0.20	0.13	0.40	0.70	0.53	0.43	0.26	0.03		0.27	0.17	0.03		0.10	0.07	0.03	0.03	
Hexactinellida																					
Aphrocallistes beatrix		0.03					0.03													0.03	
Euritidae unid. sp										0.20	0.07		0.07								
Farrea							0.07		0.13	0.07								0.03			
Hexactinellida unid sp. 1			0.60			0.70	1.16	1.17	0.30	0.10			0.03								
Hexactinellida unid. sp 3								0.15													
Hexactinellida unid. sp. 2			0.03	0.10		0.17		0.04	0.20	0.53								0.07			
Iphiteon panicea								0.08	0.03	0.50	0.60	0.10	0.33	0.10							
Nodastrella asconemaoida sp. Nov.						0.03															
Nodastrella unid. sp. 1				0.03			0.03						0.03								
Nodastrella unid. sp. 2																					
Unidentified Hexactinellida			0.20		0.03			0.19	0.43	0.07	0.03				0.23	0.07		0.33			0.07
Cnidaria																					
Hydrozoa/Stylasteridea																					
Distichopora foliacea	0.07			0.03		0.10	0.07				0.03		0.13	0.24			0.66				
Pliobothrus echinatus	0.14	0.06		0.03		0.50	0.13	0.15		0.23	0.36	0.10	0.13	0.17		0.20	0.46				
Stylaster erubescens				0.03		0.03	0.07	0.04	0.30							0.03					
Stylaster filogranus				4.73	2.43	0.03		0.30	0.76	0.10	0.13			0.07		0.17	3.06				
Stylaster miniatus	2.13	1.35		6.97	3.42	1.34	1.23	1.10	2.86	3.14	2.75	0.54	3.26	1.59	0.80	1.59	3.59			0.13	
Stylasteridae unid. sp. 1	0.17	0.45				0.23	0.07		0.03		0.10	0.20	0.07	0.14		0.03	0.03			0.03	0.03
Stylasteridae unid. sp. 2				0.03						0.17											
Unidentified Stylasteridae	0.55	1.06	0.03			0.23		0.08	0.17	0.20		0.03		0.07		0.23					
Anthozoa/Scleractinia																					
Lophelia pertusa (1-6)				0.43	0.30				0.07												
Maybe Madrepora sp.				0.10																	
Unidentified Scleractinia																					
Anthozoa/Octocorallia (Gorgs)																					
Callogorgia sp.																					
Eunicella unid. sp. 1	0.03																				
Isididae unid. sp. 1																					
Isididae unid. sp. 2																		0.40	1.63	0.07	
Octocorallia unid sp. 2																					
Octocorallia unid. sp. 1																					
Octocorallia unid. sp. 3																					
Octocorallia unid. sp. 4								0.04													
Octocorallia unid. sp. 5																					
Octocorallia unid. sp. 6																					
Octocorallia unid. sp. 7																					
Paramuricea sp.																		0.03			
Paramuricea sp. 2																					

Density Table By Phylum/Class(order)/Scientific Name	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7	Transect 8	Transect 9	Transect 10	Transect 11	Transect 12	Transect 13	Transect 14	Transect 15	Transect 16	Transect 17	Transect 18	Transect 19	Transect 20	Transect 21
Paramuricea sp. 3																					
Unidentified Octocorallia														0.03		0.23			0.03		
Anthozoa/Actiniaria																					
Actinoscyphia aurelia	0.07																				
Liponema sp.																		0.10			
Sagartiidae	0.03	0.06																			
Unidentified Actiniaria																					
Anthozoa/ Antipatharia																					
Leiopathes glabberrima																					
Antipatharia unid. sp. 1																					
Antipatharia unid. sp. 2													0.03								
Antipatharia unid. sp. 3																					
Unidentified Antipatharia								0.08													
Anthozoa/Alcyonacea																					
Plumarella 1								6.55	0.03		0.46		5.81	1.62		12.38					
Plumarella 2																					
Unidentified Alyconacea																					
Anthozoa/ Zoantharia																					
Zoantharia unid. sp.																					
Unidentified Zoantharia																					
Hydrozoa																					
Hydroida unid. sp.									0.30	0.07			0.13					0.07		0.03	
Unidentified Hydrozoa								0.04													
Echinodermata																					
Asteroidea																					
Goniasteridae	0.03	0.03	0.03		0.03		0.03		0.03										0.03		0.07
Crinodea																					
Comatonia cristata																					
Echinoidea																					
Calocidaris micans		0.06	0.03	0.03	0.07				0.17				0.10			0.46	0.16	0.10		0.10	0.03
Coelopleurus floridanus				0.07																0.03	
Unidentified Echinoidea				0.07																	
Ophiuroidea																					
Gorgonocephalidae	0.03																				
Ophiuroidea																		0.03			
Unidentified Ophiuroidea																					
Bryozoa																					
Gymolaenmata																					
Membranipora sp.									0.63	0.40			0.03		0.03	0.10					
Arthropoda																					
Malacostraca																					
Chaceon fenneri																					
Eumunida picta																					
Majidae																					
Mithrax				0.20				0.04													
Paguridae		0.03		0.07	0.10	0.03	0.10	0.04	0.07	0.03		0.03									
Rochinia crassa	0.03																				
Unidentified Malcostraca																					
Isopoda																					
Bathynomeus giganteus																					
Mollusca																					
Gastropoda																					
Perotrochus		0.06		0.03				0.04	0.03	0.20									0.03		0.03
Scaphella sp.		0.06					0.03														
Unidentified Gastropoda																					
Annelida																					
Echuira																					
Echiurida unid. Sp. 1																					
Fish																					
Fish	0.07	0.03		0.67	0.20	0.03	0.10	0.08	0.13	0.07	0.10	0.03	0.07		0.10	0.07	0.10	0.03			0.03
Total	3.37	3.32	2.68	24.53	11.59	6.92	7.51	12.54	8.41	8.71	4.83	1.14	10.83	4.52	1.53	15.89	14.41	1.43	1.76	0.46	0.27

Density Table By Phylum/Class(order)/Scientific Name	Transect 22	Transect 23	Transect 24	Transect 25	Transect 26	Transect 27	Transect 28	Transect 29	Transect 30	Transect 31	Transect 32	Transect 33	Transect 34	Transect 35	Transect 36	Transect 37	Transect 38	Transect 39	Transect 40	Transect 41	Transect 42
Porifera																					
Demospongiae																					
Astrophorina unid . sp. 4			0.03	0.57	0.40	0.27	0.23	0.03													
Astrophorina unid. sp.																					
Astrophorina unid. Sp. 1			0.03		0.07	0.03	0.07														
Astrophorina unid. Sp. 2		0.03		0.07		0.07															
Astrophorina unid. Sp. 3				0.07			0.07		0.10	0.10	0.03										
Astrophorina unid. sp. 5 (1-6)																					
Chondrosia sp. (1 and 2)																					0.03
Corallistidae (1-3)				0.07	0.03	0.10	0.10				0.03										
Demospongiae unid sp. 2																					
Demospongiae unid. sp. 4																					
Demospongiae unid. sp. 5																					
Demospongiae unid. sp. 1																					
Demospongiae unid. sp. 3																					
Desmacellidae (blue morphology)		0.03	0.03											0.03	0.03			0.13		0.17	0.07
Desmacellidae (yellow morphology)																					0.03
Geodia pachydermata?				0.03																	
Geodia sp. nov. 1																					
Geodia unid. sp. 1																				0.03	
Leiodermatium sp.																					
Petrosiidae unid. sp.									0.20												
Phakellia ventalabrum			0.03		0.03			0.03													
Raspailliidae sp. 1				0.20		0.03	0.07				0.03										
Raspailliidae sp. 2		0.03	0.07	0.10	0.07		0.17	0.30													
Raspailliidae unid. sp. 3																					
Vazella?							0.03														
Unidentified Demospongiae			0.07	0.34	0.10	0.10	0.07				0.07				0.03						0.03
Hexactinellida																					
Aphrocallistes beatrix					0.03	0.07			0.07		0.27										
Euritidae unid. sp		0.03			0.03									0.03							
Farrea			0.03																		
Hexactinellida unid sp. 1			0.13			0.03						0.03									
Hexactinellida unid. sp 3						0.03															
Hexactinellida unid. sp. 2		0.03				0.03					0.03	0.03									
Iphiteon panicea			0.03													0.03					
Nodastrella asconemaoida sp. Nov.											0.03										
Nodastrella unid. sp. 1									0.03	0.03											
Nodastrella unid. sp. 2																					
Unidentified Hexactinellida			0.03	0.13			0.07			0.03	0.07										
Cnidaria																					
Hydrozoa/Stylasteridea																					
Distichopora foliacea														0.03							0.07
Pliobothrus echinatus				0.13	0.03					0.10		0.24	0.07		0.60	0.56	0.63	0.03	0.03	0.33	0.23
Stylaster erubescens				0.44	0.10	0.13	0.10													0.13	
Stylaster filogranus											0.10								0.03	0.10	
Stylaster miniatus		0.13	0.13		0.03							0.13		0.46	0.77	0.79	1.82	0.20	1.79	6.64	2.20
Stylasteridae unid. sp. 1					0.03	0.07	0.07	0.03						0.20	0.20	0.26	0.53	0.07	1.59	0.73	0.79
Stylasteridae unid. sp. 2														0.03			0.20		0.10	0.13	0.07
Unidentified Stylasteridae						0.03					0.03									0.13	0.39
Anthozoa/Scleractinia																					
Lophelia pertusa (1-6)				0.34	0.10	0.10	0.30	0.20	1.00	2.36	0.54										
Maybe Madrepora sp.				0.03							0.07										
Unidentified Scleractinia																					
Anthozoa/Octocorallia (Gorgs)																					
Callogorgia sp.																					
Eunicella unid. sp. 1			0.03						0.03												
Isididae unid. sp. 1				0.84	0.17		0.17														
Isididae unid. sp. 2			0.03	0.20				0.13			0.37				0.07		0.07				0.03
Octocorallia unid sp. 2		0.07	0.13		0.03																
Octocorallia unid. sp. 1		0.13	0.03																		
Octocorallia unid. sp. 3		0.87	0.54	0.10			0.07				0.13										
Octocorallia unid. sp. 4				0.03	0.13	0.03														0.03	

Density Table By Phylum/Class(order)/Scientific Name	Transect 22	Transect 23	Transect 24	Transect 25	Transect 26	Transect 27	Transect 28	Transect 29	Transect 30	Transect 31	Transect 32	Transect 33	Transect 34	Transect 35	Transect 36	Transect 37	Transect 38	Transect 39	Transect 40	Transect 41	Transect 42
Octocorallia unid. sp. 5												0.07							0.03	0.03	
Octocorallia unid. sp. 6																					
Octocorallia unid. sp. 7				2.92	1.10	0.37	0.30	0.27								0.30	0.20		0.03		
Paramuricea sp.		0.03	0.13																		
Paramuricea sp. 2																					
Paramuricea sp. 3				3.29	1.33	1.81	0.53	0.10	0.03	0.03	0.57										
Unidentified Octocorallia			0.03						0.03			0.03		0.03					0.10		0.10
Anthozoa/Actiniaria																					
Actinoscyphia aurelia																					
Liponema sp.		0.03	0.03	0.03							0.07								0.17		
Sagartiidae												1.75	0.90	3.48	4.08	2.91	2.75	2.70	0.20	1.40	4.54
Unidentified Actiniaria																					
Anthozoa/ Antipatharia																					
Leiopathes glabberrima								0.07													
Antipatharia unid. sp. 1							0.10	0.10						0.03							
Antipatharia unid. sp. 2			0.13								0.07							0.03			
Antipatharia unid. sp. 3			0.13																		
Unidentified Antipatharia				0.10											0.03						
Anthozoa/Alcyonacea																					
Plumarella 1				0.81	0.27	0.03	0.13	0.30	0.17	0.03				0.13							
Plumarella 2				0.03				0.07	0.20	0.30	0.34										
Unidentified Alyconacea																					
Anthozoa/ Zoantharia																					
Zoantharia unid. sp.																					0.03
Unidentified Zoantharia																					
Hydrozoa																					
Hydroida unid. sp.	0.03	0.70	4.68	0.13	0.13	0.07								0.03	0.07			0.13	0.07	1.53	0.07
Unidentified Hydrozoa																		0.03			
Echinodermata																					
Asteroidea																					
Goniasteridae	0.03			0.10	0.17	0.07	0.03					0.03			0.03		0.03	0.07	0.20	0.13	
Crinodea																					
Comatonia cristata				0.60	0.23	0.07	0.47	0.27	0.03										0.33		
Echinoidea																					
Calocidaris micans	0.07	0.13	0.10	0.47	0.07	0.03	0.10	0.03		0.17					0.07			0.03		0.03	
Coelopleurus floridanus		0.10										0.10	0.03		0.13	0.03	0.10		0.03	0.03	
Unidentified Echinoidea																					
Ophiuroidea																					
Gorgonocephalidae																			0.03	0.03	
Ophiuroidea		0.03	0.13			0.03			0.17	0.17	0.03				0.03				0.07		
Unidentified Ophiuroidea																					
Bryozoa																					
Gymolaenmata																					
Membranipora sp.			0.03	0.17	0.13	0.03	0.07														
Arthropoda																					
Malacostraca																					
Chaceon fenneri										0.07											
Eumunida picta								0.03													
Majidae											0.03										
Mithrax																					
Paguridae			0.10									0.03				0.17		0.10	0.07		
Rochinia crassa				0.20	0.50	0.20	0.13	0.17	0.03	0.03	0.03					0.03	0.07	0.03	0.10	0.03	
Unidentified Malcostraca				0.03	0.07																
Isopoda																					
Bathynomeus giganteus																					
Mollusca																					
Gastropoda																					
Perotrochus				0.07									0.10			0.03	0.03	0.03	0.07		0.07
Scaphella sp.												0.10		0.03	0.03	0.20	0.03	0.07	0.10	0.17	0.16
Unidentified Gastropoda																					
Annelida																					
Echuira																					
Echiurida unid. Sp. 1												0.03							0.10		
Fish																					
Fish	0.07	0.03	0.07	0.07	0.03	0.03	0.07				0.10	0.17	0.03	0.10	0.20	0.07	0.50	0.07	0.17	0.60	0.26
Total	0.20	2.43	6.99	12.72	5.42	3.89	3.49	2.15	2.11	3.42	3.05	2.76	1.14	4.64	6.39	5.40	6.95	3.73	5.42	12.43	9.18

Appendix 3. GIS Maps of Transects

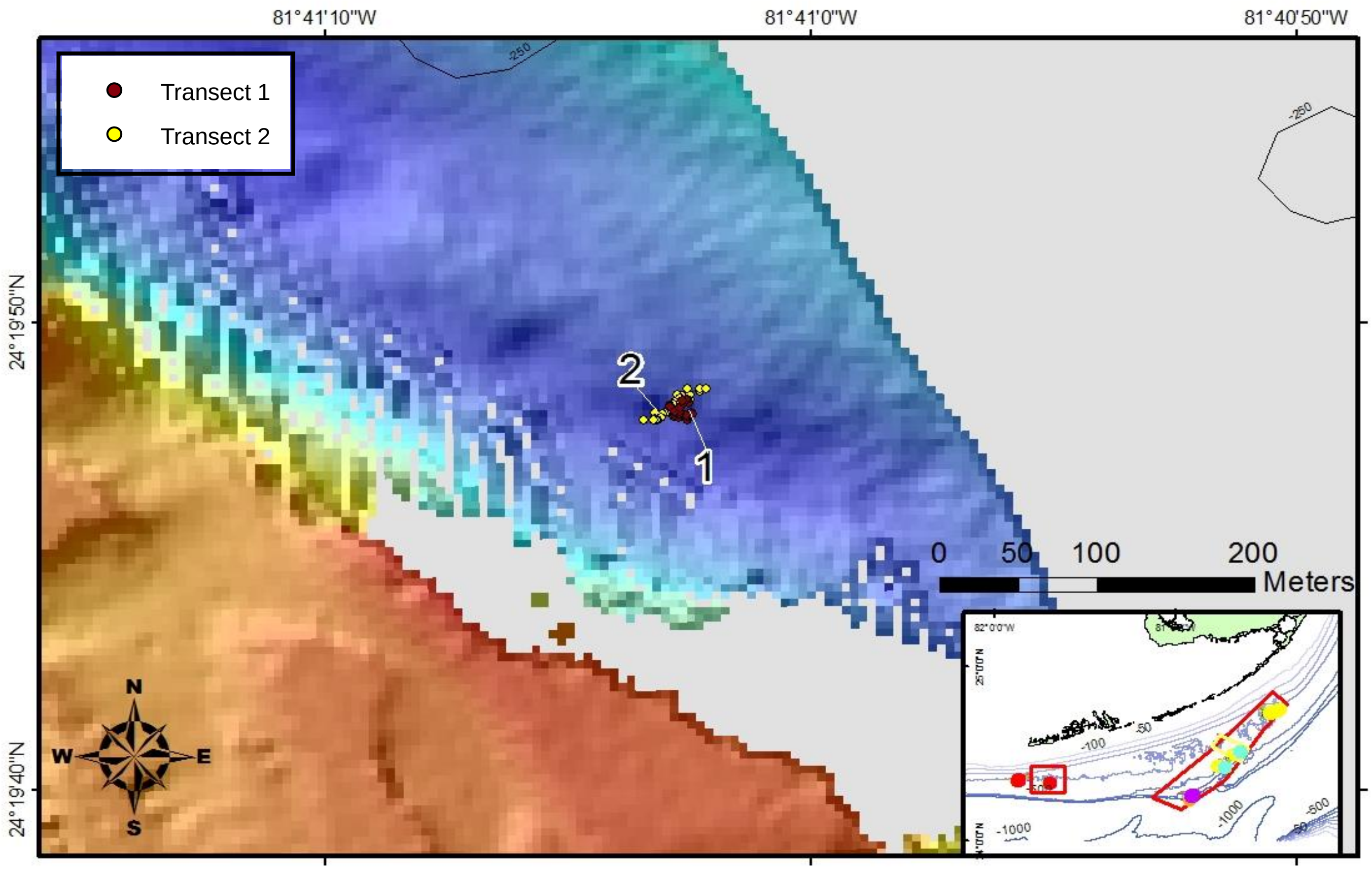

Figure 1. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 1 and 2 (West 150-300), closest isobath at 250 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

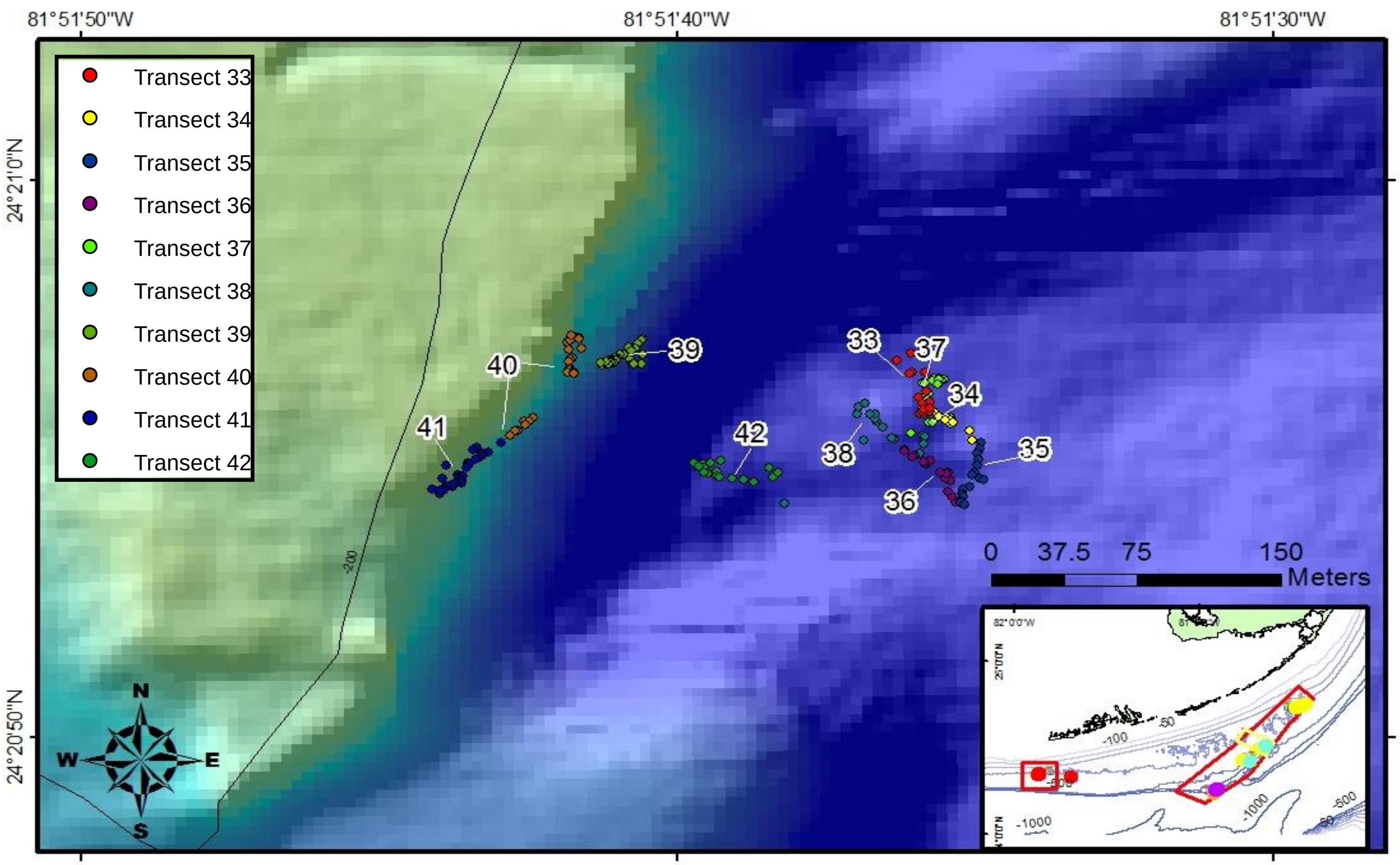

Figure 2. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 33 through 42 (West 150-300), closest isobath at 200 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

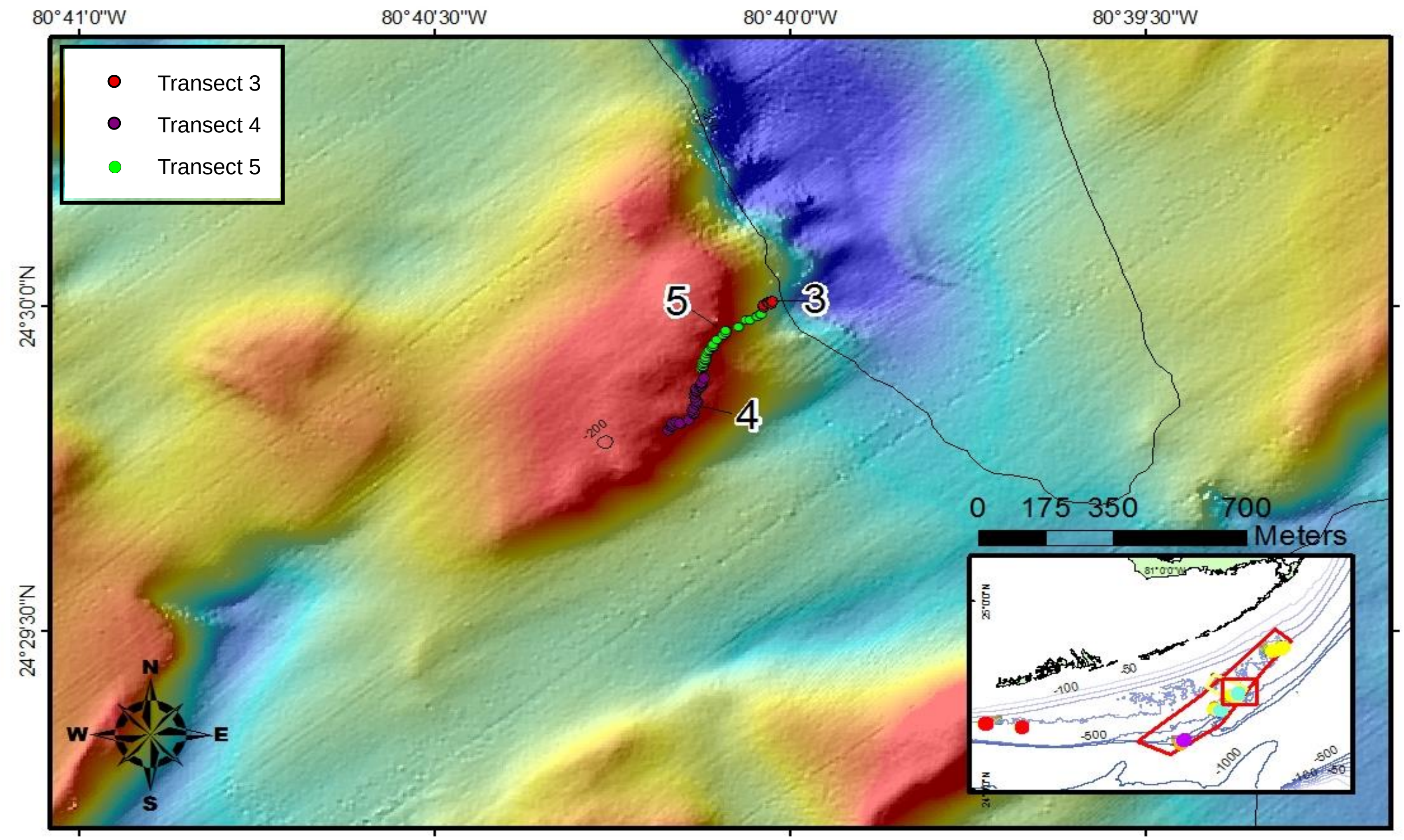

Figure 3. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 3 through 5 (North Central 150-250), closest isobath at 200 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

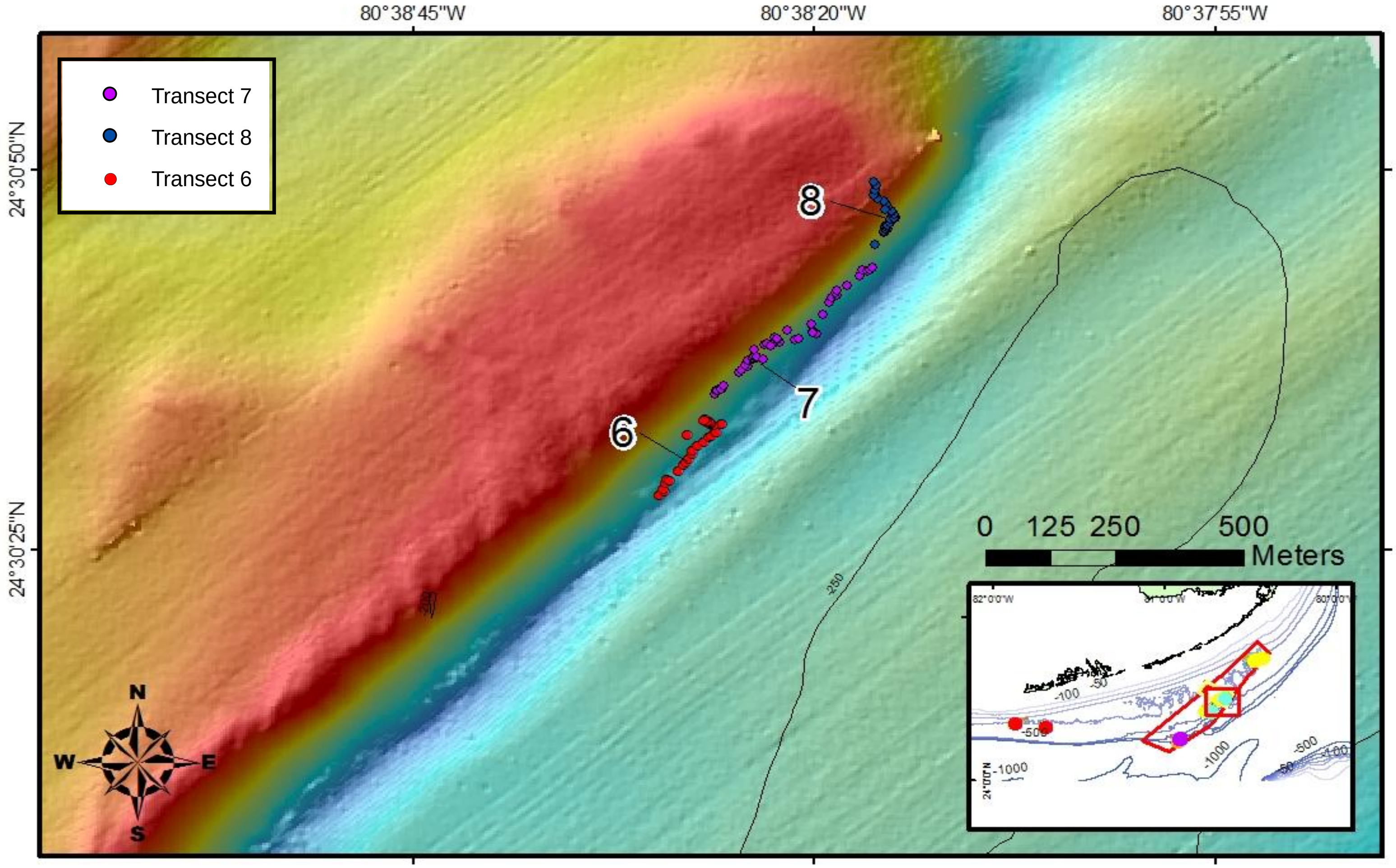

Figure 4. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 6 through 8 (North Central 150-250), closest isobath at 250 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

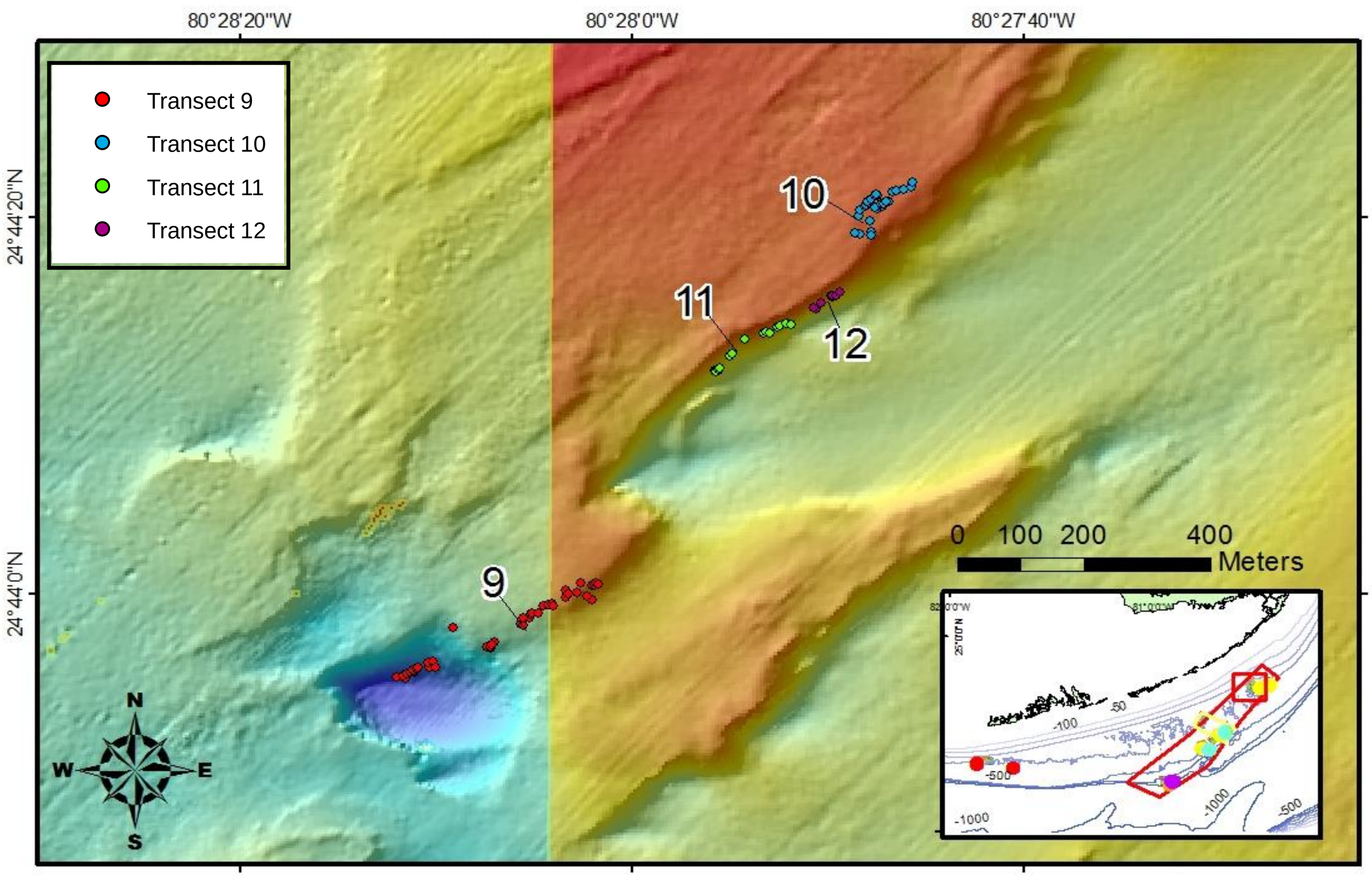

Figure 5. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 9 through 12 (North Central 150-250). Lower right map of Florida with CHAPC border in red, MPA border in yellow.

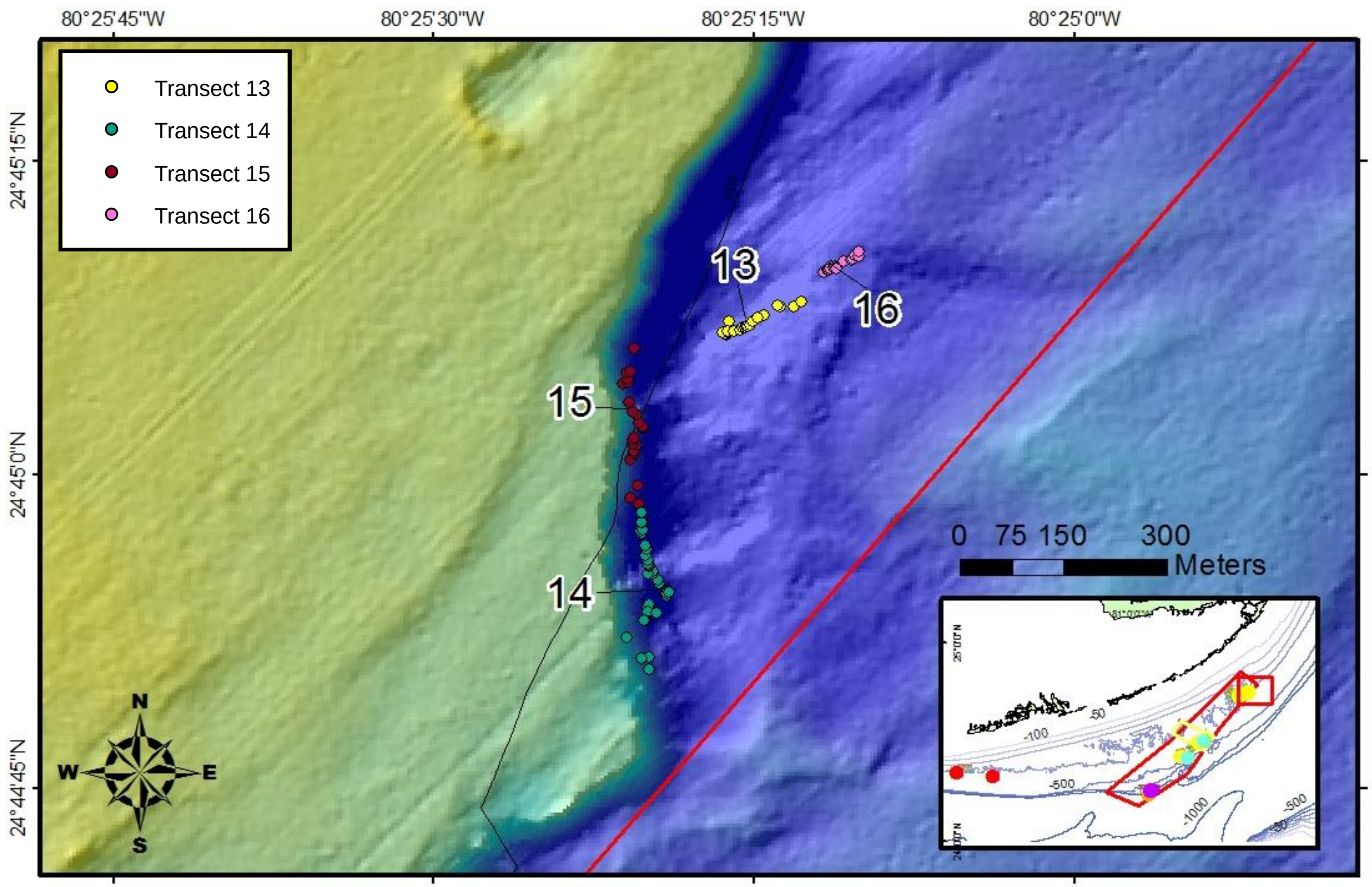

Figure 6. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 14 through 16 (North Central 150-250), closest isobath at 200 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

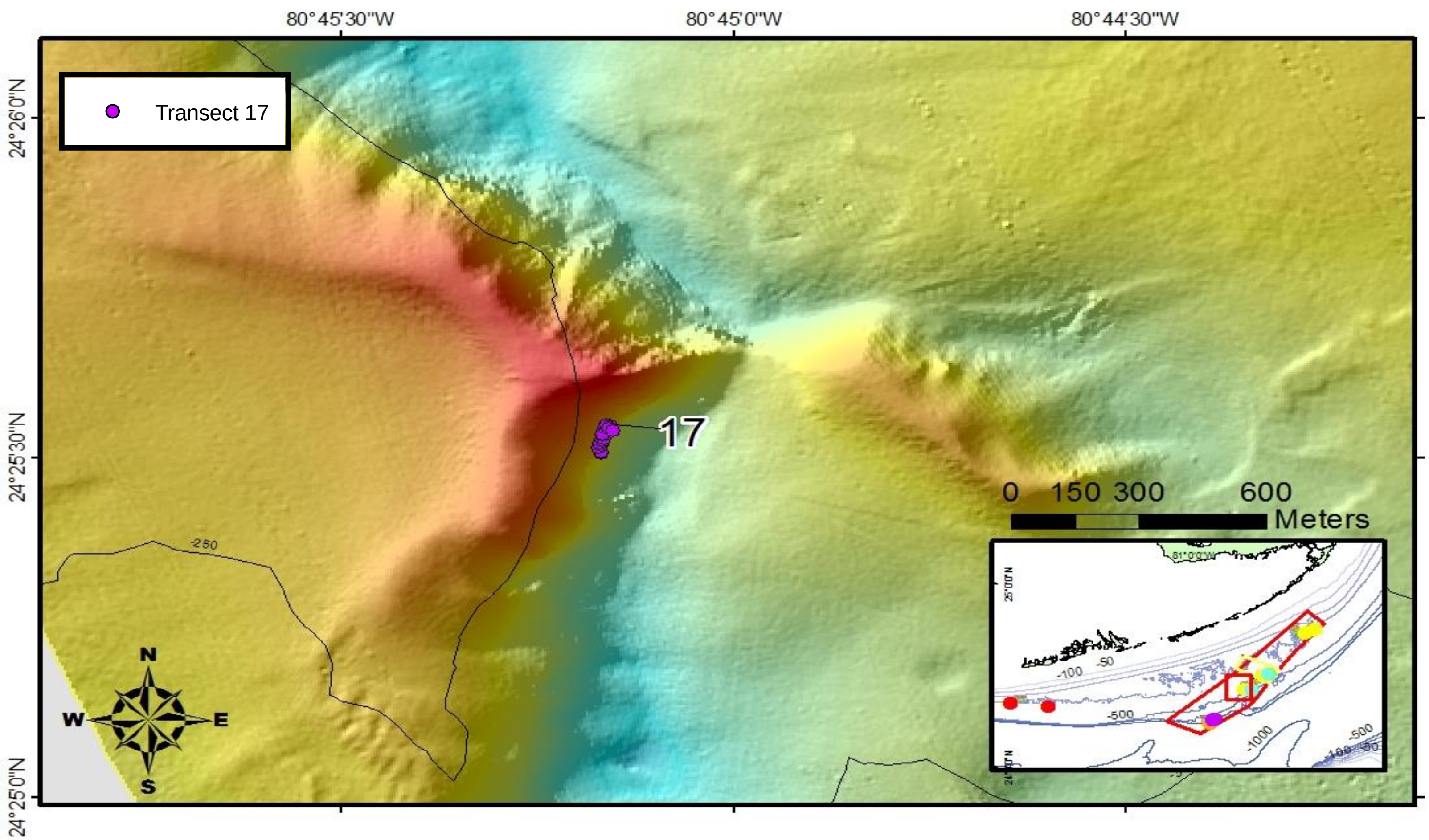

Figure 7. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transect 17(North Central 150-250, closest isobath at 250 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

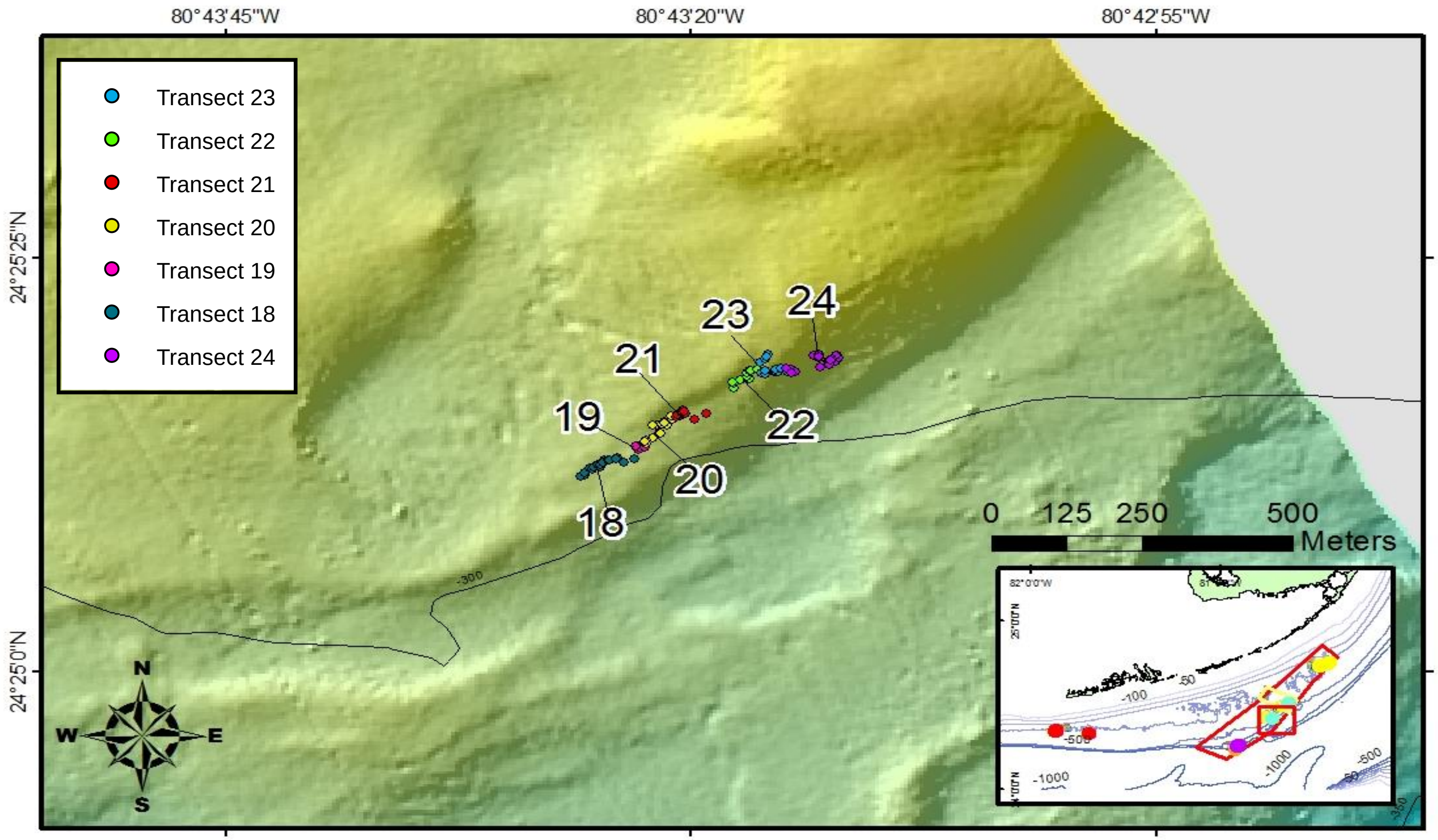

Figure 8. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 18 through 24 (Central 250-300), closest isobath at 300 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

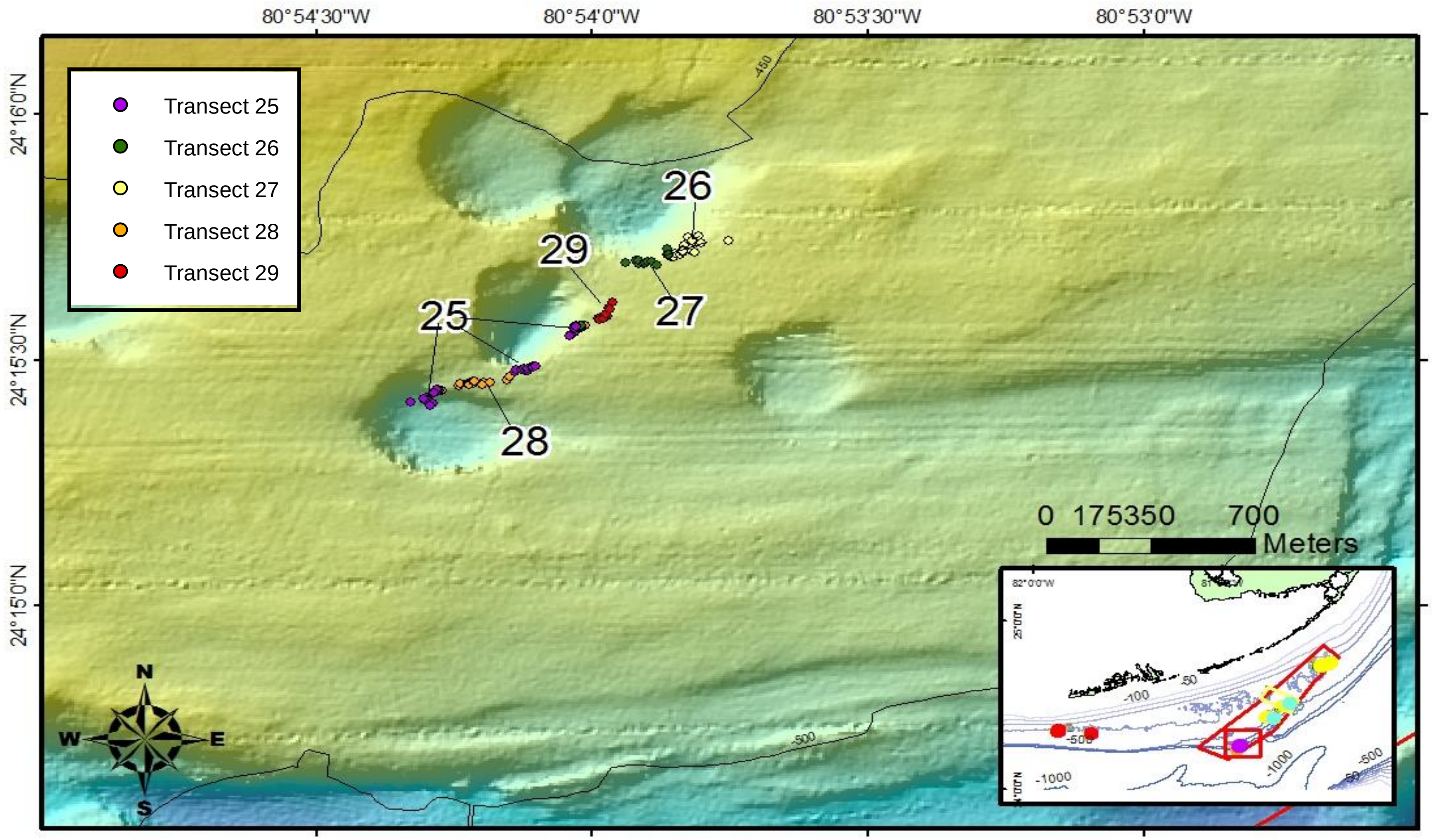

Figure 9. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 25 through 29 (South 450-500), closest isobath at 450 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.

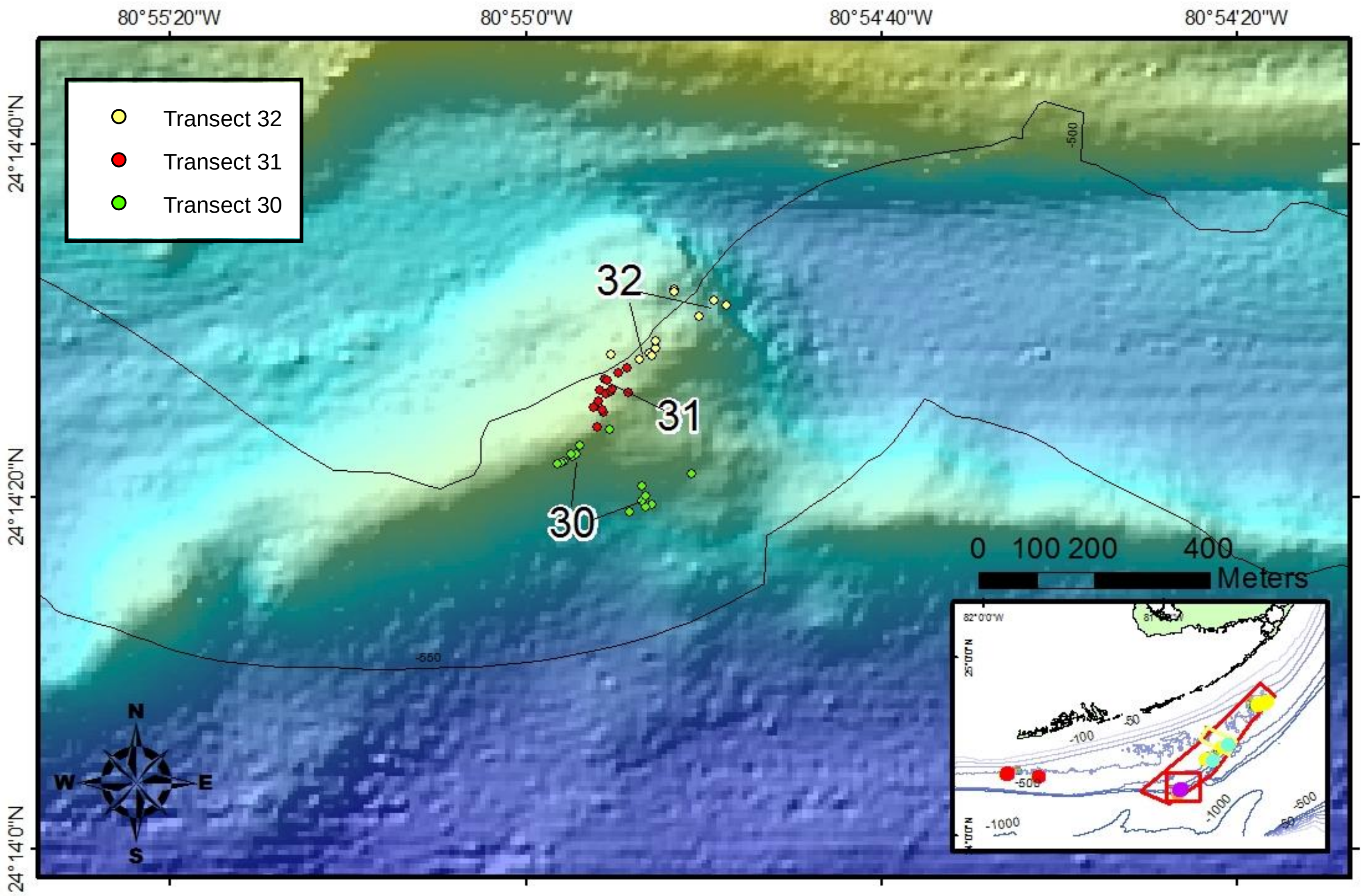

Figure 10. GIS map (background multibeam map provided by NOAA Ship *Nancy Foster*) displaying transects 30 through 32 (South 500-550), closest isobath at 500 m. Lower right map of Florida with CHAPC border in red, MPA border in yellow.