**South Atlantic MPAs and Deepwater Coral HAPCs:**
**Characterization of Fish Communities, Benthic Habitat, and Benthic Macrobiota**

**Final Report for 2012-2014 NOAA Cruises**

Funding: NOAA Coral Reef Conservation Program (CRCP)
South Atlantic Fishery Management Council (SAFMC)
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# EXECUTIVE SUMMARY

In 2009, the South Atlantic Fishery Management Council (SAFMC) established eight deepwater Marine Protected Areas (MPAs) along the outer continental shelf off the southeastern U.S. Three cruises using ROVs, CTD casts, and multibeam sonar mapping, documented and characterized the benthic habitats, benthic macrobiota, and fish populations within and adjacent to the MPA protected areas which are within the jurisdiction of the SAFMC from north Florida to North Carolina. The six MPA sites included North Florida MPA, Georgia MPA, Edisto MPA, Charleston Deep Artificial MPA, Northern South Carolina MPA, and Snowy Wreck MPA.

This report summarizes the three cruises that were conducted from 2012 to 2014 in support of this NOAA Coral Reef Conservation Program (CRCP) and SAFMC grant. These included: NOAA Ship *Pisces* Cruise 12-03, July 6-19, 2012; NOAA Ship *Pisces* 13-03, July 2-11, 2013; and NOAA Ship *Nancy Foster* Cruise 14-08; June 18-27, 2014. The UNCW *Super Phantom* ROV was used in 2012 and 2013 and the new Flower Garden Banks National Marine Sanctuary (FGBNMS) *Mohawk* ROV (operated by UNCW) with fiber optics umbilical and high-definition video was used in 2014. Collaborators included the Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) at Harbor Branch Oceanographic Institute, Florida Atlantic University (HBOI-FAU), College of Charleston, and University of North Carolina at Wilmington (ROV operations).

Individual cruise reports were submitted previously (Reed et al., 2013, 2014, 2015) which provided detailed quantitative characterization of the benthic habitat, benthic macrobiota, and fish populations for each of the ROV dives conducted during each cruise.

During the three cruises, a total of 98 ROV dives surveyed 37 sites within the MPAs and 61 sites on reefs adjacent to the MPAs. The total dive time was 150.9 hr during which 139.4 km of benthos were surveyed. Video imagery was collected continuously during the dives and 10,299 digital still images documented bottom habitat, macrobiota and fish. A total of 73 CTD casts were made. Thirty-three multibeam sonar surveys provided new maps covering a total area of 543.53 $km^2$ in depths ranging from 43 to 250 m. These sites had never been surveyed previously with multibeam sonar. Georeferenced maps were made for each of the sites and were ground-truthed with the ROV dives. A total of 136 species of macrobiota were documented along with 167 species of fish.

These three cruises provide valuable data for these MPAs which may be referenced and compared to future research cruises as well as previous cruises to identify the long-term health and status of these important ecosystems. These data will be made available to the SAFMC, NOAA Fisheries, NOAA DSCRTP, NOAA CRCP, NOAA Mesophotic Reef Ecosystem Program, and NOAA Marine Sanctuaries to assist management on these habitats and key species.

## ACKNOWLEDGEMENTS

We gratefully acknowledge funding for research support and ROV operations by the NOAA Coral Reef Conservation Program (CRCP) and the South Atlantic Fishery Management Council (CRCP Fishery Management Council Coral Reef Conservation Cooperative Agreements- Grant #: NA11NMF4410061). We also acknowledge the NOAA Office of Ocean Exploration and Research (OER Grant #: NA09OAR4320073), the NOAA Deep Sea Coral Research and Technology Program (DSCRTP), and the NOAA Office of Marine and Aviation Operations (OMAO) which provided support for ship time.

We thank the NOAA Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) at Harbor Branch Oceanographic Institute, Florida Atlantic University (HBOI-FAU), and the Robertson Coral Reef Research and Conservation Program at HBOI. The crews of the NOAA Ship *Nancy Foster*, NOAA Ship *Pisces*, and FGBNMS and UNCW ROVs (Lance Horn, Glynn Taylor, and Jason White) are especially thanked for their support and efforts which made these cruises a success.

## DELIVERABLES AND DATA MANAGEMENT

This Final Report and the previous three Cruise Reports are the deliverables for this NOAA CRCP/SAFMC grant. To date, all data have been archived as required; these data include shipboard data, raw and processed multibeam sonar data, CTD, ROV navigation data, ROV video and digital images, ROV dive annotations, and HBOI Microsoft Access at-Sea Database (Table 1). A complete set of original data are archived by the Principal Investigators at NOAA Fisheries, Panama City (Stacey Harter) and HBOI-FAU (John Reed).

The NOAA Ships *Nancy Foster* and *Pisces* survey departments, under the direction of the Operations Officer, has archived all multibeam data at the National Geophysical Data Center. This archiving will be conducted in consultation with the Principal Investigator to ensure there is not unintentional release of sensitive data to the public.

**Table 1**. Data archives for 2012 and 2013 NOAA Ships *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Principal Investigators- Stacey Harter, Andrew David, NOAA NMFS, Panama Lab; John Reed, HBOI-FAU.

| Source | Description | Format |
|---|---|---|
| Ship | Multibeam (MB) sonar- raw | PDS |
| Ship | MB- processed files (corrected for tides and sound velocity) | CARIS, HDCS,XYZ (ASCII) |
| Ship | MB- GeoTIFF | TIFF |
| Ship | CTD | CSV |
| ROV | ROV video- digital copies of all ROV dives | External hard drives, DVD |
| ROV | ROV digital still images | JPEG; External hard drives, DVD |

| | | |
|---|---|---|
| ROV | Event log | CSV |
| Science | ROV dive track polygons | ArcGIS shapefile |
| Science | Cruise database | Access MDB |

## CIOERT/NOAA COLLABORATION

The primary focus of this research cruise is to advance NOAA OER goals while complementing the management objectives of NOAA CRCP, NOAA DSCRTP, NOAA Mesophotic Reef Ecosystem Program, NOAA CIOERT, and the South Atlantic Fishery Management Council.

For these three cruises, collaborators included NOAA NMFS (Andrew David, Stacey Harter, Heather Moe, Steven Mathews; Panama City), NOAA CIOERT at HBOI-FAU (John Reed, Stephanie Farrington), UNCW (Lance Horn, Jason White, Glenn Taylor), NOAA NOS (Laura Kraker), and College of Charleston (Friedrich Knuth, Kayla Johnson).

## PROJECT OVERVIEW

The South Atlantic Fishery Management Council (SAFMC) and Department of Commerce through the Magnuson-Stevens Fishery Management Act have established eight deepwater Marine Protected Areas (MPAs) and five deepwater Coral Habitat Areas of Particular Concern (CHAPCs) in addition to the *Oculina* Coral HAPC along the outer continental shelf off the southeastern U.S. This project proposed to document and characterize the benthic habitat, benthic sessile biota, and fish populations within some of these protected areas and within the jurisdiction of the SAFMC.

In February 2009, the SAFMC implemented eight Type II MPAs between Cape Hatteras, NC and the Florida Keys to protect seven species of the deepwater snapper-grouper complex. The closures, however, will provide ecosystem-level benefits to the entire complex as well as protect the shelf-edge reef habitat they utilize. These consist of five species of grouper: snowy grouper (*Hyporthodus niveatus*), yellowedge grouper (*H. flavolimbatus*), warsaw grouper (*H. nigritus*), misty grouper (*H. mystacinus*) and speckled hind (*Epinephelus. drummondhayi*), and two species of tilefish: golden tilefish (*Lopholatilus chamaeleonticeps*) and blueline tilefish (*Caulolatilus microps*). The deepwater shelf-edge MPAs are known to contain reef habitat exploited by these five species of grouper as well as deep mud banks used by the two tilefish species. These species are considered to be at risk due to currently low stock densities and to life history characteristics which subject them to substantial fishing mortality.

Bottom-tending fishing gear has been shown to have deleterious effects upon reefs and is now prohibited in the MPAs. These sites were designated by the Council to protect spawning grounds of reef fish. As such, decisions to create future area closures will be based upon the efficacy of these areas and the lessons learned during their implementation. Additionally, the MPAs contain extensive areas infested with the invasive lionfish, whose population continues to rapidly expand. Future monitoring will assist in evaluating the effects of this invasion on the ecosystem. Area closures constitute a politically charged issue that is unlikely to retain support without evidence indicating increases in the target species. This project will benefit coral reef ecosystems directly by improving our understanding of the impact of fishing activities on both fish and invertebrate species.

The monitoring program for the MPAs ensures the Council remain well informed of changes within reef fish populations and coral habitats associated with these MPAs. NOAA NMFS conducted preliminary examinations of five of these potential MPA sites in April-May 2004, June 2006, August 2007 and July 2008. Post-closure data were collected in November 2009, May 2010, July 2012, July 2013, and June 2014. The MPAs afford the opportunity to obviate the criticisms of comparing MPAs with adjacent open-to fishing areas by examining the MPAs for four years prior to the closures. Since monitoring began in 2004, this project has produced population density estimates of targeted reef fish species within the boundaries of five of the eight MPAs and adjacent control areas, before and after closure.

## GOALS

The primary goal of the cruises were to gather additional data on habitat and fish assemblages in the South Atlantic MPAs as part of a long term sampling program to document changes in these areas before and after implementation of fishing restrictions. Efficacy testing of this management tool will aid fishery managers in future use of area restrictions for the protection of valuable habitat and fishery resources.

This project is in direct support of Fishery Management Council activities associated with the characterization of protected shelf-edge and deepwater coral ecosystems and the efficacy testing of existing MPAs. It directly addresses the CRCP National Goals and Objectives of obtaining ecological information for coral reef fishes and spawning aggregations. Activities include: a) studies that identify, map and characterize fisheries habitat (including essential fish habitat, habitat areas of particular concern, and spawning aggregation sites) in U.S. coral reef ecosystems, and assess the condition of the habitat; b) studies associated with coral reef areas that are currently, permanently, or seasonally closed to fishing, or that may merit inclusion in an expanded network of no-take ecological reserves; and c) multibeam or sidescan sonar mapping and ground-truthing, habitat characterization, and monitoring of such areas, including deeper coral reefs, bands and beds.

Ultimately the primary benefits derived from these data are the characterization and documentation of the benthic habitat and fish communities within the shelf-edge MPAs along the southeastern U.S. from south Florida to North Carolina. These data may then be compared to information collected during previous and future research cruises and to areas adjacent to the protected areas to better understand the long-term health and status of these important deepwater coral/sponge ecosystems. These data will be of value to the SAFMC, NOAA Fisheries, NOAA DSCRTP, NOAA CRCP, NOAA Mesophotic Reef Ecosystem Program, and NOAA Sanctuaries by providing for better informed management decisions on these habitats and managed key species.

## OBJECTIVES

The primary objective of the three research cruises (2012, 2013, and 2014) was to gather additional data on habitat and fish assemblages in six of the newly designated shelf-edge, South Atlantic Grouper/Tilefish Marine Protected Areas (MPAs). The data from these cruises are part of a long-term sampling/monitoring program to document changes in these areas before and after fishing restrictions were implemented. Efficacy evaluations of this management tool will aid fishery managers in future use of area restrictions for the conservation of valuable habitat and fishery resources. Specific objectives include:

- Conduct remotely operated vehicle (ROV) transect surveys of benthic habitat and fish populations
- Collect bathymetric acoustic data with the multibeam mapping systems on the ships to locate hard-bottom features and potential ROV dive sites
- Conduct total water column Conductivity-Temperature-Depth (CTD) profiles.

## OUTREACH AND EDUCATION

The goal of the expedition's education and outreach was to promote ocean literacy, knowledge of deep coral ecosystems, and the challenges of exploring deep ocean frontiers for public and classroom audiences. Related outreach/education activities included: hosting a NOAA Teacher-at-Sea each year, web materials for http://teacheratsea.noaa.gov/2014/bilotta.html and CIOERT at HBOI, Skype live-link with classrooms, and shipboard photographic/video documentation of the 2013 cruise.

## METHODS

### ROV Operations

During the 2012 and 2013 cruises the UNCW *Super Phantom* ROV was used (pilots- Lance Horne, Glynn Taylor). In 2014, the new Flower Garden Banks National Marine Sanctuary (FGBNMS) *Mohawk* ROV (operated by UNCW, pilots - Lance Horn, Jason White) was used for the first time on these cruises. ROV transect locations were selected by four methods:

- analysis of the existing multibeam bathymetric and acoustic backscatter maps produced within the preceding decade
- reef locations provided by colleagues
- sites found during previous years of this survey
- analysis of areas mapped on the current cruise.

ROV dives ranged from 1 to 4 hours in length, covering an average length of 1.5 km. The *Mohawk* ROV was equipped with a high-definition digital video camera (using fiber optic cable) mounted on a tilt bar, a fixed digital still camera, and a temperature/depth recorder. The ROV was not outfitted with a manipulator and no samples were collected.

ROV Video Camera (*Mohawk*)

Video was recorded continuously throughout each dive from surface to surface with a high-definition video camera (Insite Pacific Mini Zeus CMOS color zoom camera with 2,000,000 effective pixels). The camera was typically angled down ~30$^{o}$ to view both near field and to the horizon for fish aggregations and habitat, and had 10-cm parallel lasers for scale. High-definition video was recorded to external hard drives and used as the primary data source for viewing by the science team and quantitative analysis of the fish populations. A second standard definition copy was also recorded to a hard drive as well as to DVD for backup and easy viewing on standard DVD drives. The standard definition format had an On-Screen Display (OSD) video overlay which recorded time, date, ROV heading, and ROV depth, and was used as the "pilot" view. A microphone was used for continuous real-time audio annotations by the PIs describing events, habitat, and biota and were later transcribed into a Microsoft Access 2010 database.

ROV Digital Still Camera (*Mohawk*)

Still images were taken for quantitative analysis of habitat and benthic macrobiota. The Kongsberg OE14-408 high-definition digital still camera, with resolution of 3648x2736 pixels, was pointed down 90° from horizontal and had 10-cm parallel lasers for scale. Still images were captured approximately every 2 minutes throughout the dive at a height of 1.3 m to provide a relatively consistent area within each image. Each photo filename was coded with corresponding EDST time and date code (using Stamp 2.8 by Tempest Solutions©). These were then imported into MS Access and linked to the ROV navigation data for site specific data of coordinates and depth before final importation into ArcGIS™ 10.0.

ROV Navigation

The *Mohawk* ROV uses an integrated navigation system consisting of Hypack Max 2014 software on a 64-bit, 3.4 GHz, rack-mounted computer running Windows 7. Additionally, data from an ORE Offshore 4410C Trackpoint II USBL Acoustic Tracking System, Northstar 951XD differential GPS, and Azimuth 1000 digital compass, along with the *Mohawk* ROV data feed to this computer. The Trackpoint II system communicates acoustically to an ORE Offshore 4377A transponder with depth telemetry on the ROV to provide slant range, bearing, and depth from the support vessel. This system allows the ROV to assign latitude and longitude while in operation. The integrated navigation system provides real-time tracking and orientation of the ROV and the ship to the ROV pilot and the ship's bridge for navigation. Georeferenced TIFF files obtained with multibeam sonar can be entered into Hypack as background files to display target sites and features of interest to aid in ROV and ship navigation. Hypack can also export ROV position data in real-time as a NMEA data string. Ship and ROV positions in addition to the ROV depth, heading and altimeter data, are logged and processed after each dive day and provided to the chief scientist in an Excel spreadsheet file. All data documentation (digital images, HD video, dive annotations, and specimen collections) are georeferenced to ROV position by matching the time and date to the ROV navigation files.

ROV Survey Protocol

The primary objectives of each dive were to document benthic habitat, benthic macrobiota, and fish populations, and to conduct photo/video transects which were used for quantitative analyses of the habitat and biota. The general protocol included:

1. Video transects were used for analysis of fish population densities. Video transects kept the ROV as close to the bottom as possible (<0.5 m) with a speed over ground of ~¼ knot. The camera was typically angled down ~30$^o$ to allow viewing in both the near field and far to the horizon for fish counts.
2. Digital still images were used to quantify the percent cover of benthic macrobiota and benthic substrate. Images were captured approximately every 2 minutes throughout the dive during which the ROV hovered at a depth of ~1.3 m to provide similar field of view area for each image (~1.5 $m^2$). The camera was pointed down 90° from horizontal and had 10-cm parallel lasers for scale.
3. Still images captured from the photo transects were analyzed using Coral Point Count with Excel extensions (CPCe 4.1©, Kohler and Gill, 2006) software to determine relative percent cover of benthic macrobiota and habitat types. Non-transect photos, such as to record a specific species, were not included in the quantitative analyses. Poor and unusable photos (out of focus, poorly lit, or off bottom) or overlapping photos were removed from the quantitative analyses.
4. Underwater video was viewed in real-time on the support vessel by investigators familiar with the local deep-water fauna; audio annotations describing habitat, benthic biota, and fish were recorded onto the video and transcribed into a Microsoft Access database.
5. Field notes and video images were reviewed and summarized to identify habitats and biota. These summaries were compiled in ArcGIS format and used to produce habitat maps.
6. All data documentation (digital images, video, and dive annotations) were georeferenced to ROV position after the cruise by matching the date and time to the ROV navigation files in our CIOERT at-Sea Access Database.

**Fish Populations Analyses**

Each dive was divided into transects based on benthic habitat characterization (see Protocol for Benthic Habitat Characterization below) so that each transect consisted of a single habitat type. All fish were identified down to the lowest taxonomic level and counted. Transect area ($m^2$) was calculated by multiplying the transect length (m) by the estimated field of view of the transect width (m). Transect length was determined by using the ROV's tracking system and transect width was estimated for each dive using the paired lasers on the video camera. This varied with the visibility of each dive. Transect area was then used to calculate the density (# of individuals 1000 $m^{-2}$) of each fish species.

**Benthic Analyses**

Percent cover of substrate type and benthic macrobiota was determined by analyzing the quantitative transect images with CPCe and following protocols established in part by Vinick et al. (2012) for offshore, deepwater surveys in this region. Random points overlaid on each image were identified by substrate type and benthic taxa. Substrate categories included: soft bottom (unconsolidated sand, mud) and hard bottom which was subdivided into rock (pavement, boulder, ledge), rock rubble/cobble (generally 5-20 cm), and framework coral (standing coral colonies). All benthic macrobiota (usually >3 cm) were identified to the lowest taxa level possible.

For this report we used the following terminology: hard bottom is sometimes referred to as live bottom due to the amount of living organisms attached to these substrates (SAFMC, 1998). Hard bottom provides anchorage for sessile or semi-sessile organisms (e.g., corals, octocorals, anemones, hydroids, sponges, algae). Coral is defined as hard corals (stony corals- Scleractinia) and other taxa with solid calcareous skeletons (e.g., Stylasteridae), as well as non-accreting taxa such as Octocorallia (Alcyonacea- "gorgonacea") and black corals (Antipatharia) (Lumsden et al., 2007).

Prior to point count analysis, all images were reviewed and a species list was made in a Taxonomic Photo Album using Microsoft Access (Reed and Farrington, 2014). We included benthic algae and sessile macroinvertebrates including Porifera, Scleractinia, Octocorallia (Gorgonacea), Antipatharia, Corallimorpharia, Alcyoniina soft corals, other non-coral Cnidaria (hydroids), and Ascidiacea; and all mobile benthic macroinvertebrates including: echinoderms, mollusks, arthropods, and annelids. The following taxonomists assisted with the species verifications:

Sponges- S. Pomponi, C. Diaz, P. Cardenas, J. Reed
Cnidaria- S. Cairns, P. Etnoyer, C. Messing, J. Voss, M. Nuttall, D. Opresko, C. Moura, J. Reed
Algae- D. Hanisak, S. Reed, M. and D. Littler
Echinoderms- D. Pawson, C. Messing
Fish- A. David, S. Harter, K. Rademacher

Some common taxa could be identified to genus or species level but many could only be identified to a higher level such as family, class, order or even phylum. Sponges, octocorals (gorgonians), and black coral are especially difficult to identify without a specimen in hand. In these cases, a general descriptive taxa was used, e.g., "brown lobate sponge" or "unidentified Demospongiae", which could consist of numerous species. These designations should not be considered equivalent to species level and should not be used for diversity (H') indices calculations. Many deepwater species in this region have nearly identical appearances, such as fan sponges which are polyphyletic and actually may include different orders or classes.

## Protocol for Benthic Habitat Characterization

This protocol defines the habitat categories that were used to define and characterize the benthic habitats for the shelf-edge reefs and MPAs off southeastern U.S. within the jurisdiction of the South Atlantic Fishery Management Council. The habitat categories were entered into the HBOI Microsoft Access at-Sea Database for each ROV dive site and used for PRIMER 6 (Clarke and Warwick, 2001 and Clarke and Gorley, 2006) statistical analyses of the fish populations and benthic communities.

1. *[On/Off Reef]*: "On Reef" or "Off Reef"- Simple designation of when the dive is on Hard Bottom (=On Reef) vs Soft Bottom (=Off Reef). This designation is not for any individual photo, but for a zonation within the dive.

2. *[Habitat Zone= Geomorphology]*: This describes the geological feature; e.g., Ridge-West Slope, Ridge- East Slope, Ridge-Top, Soft Bottom. This category is used to plot the distribution of biota for each habitat zone at each dive site and to plot the dive track overlay on multibeam sonar maps in ArcGIS.

3. [*MPA Status*]: Dive site or transect is within a marine protected area (MPA) or is not within any MPA.

4. [*Depth*]: Depth range (m) of the dive.

5. [*Relief*]: LR= Low Relief (0- <1.0 m), MR= Moderate Relief (1-3 m), HR= High Relief (>3 m). This is modified from the SEAMAP designations of outer continental shelf benthic habitat. This category is dependent on the distance over which the depth change occurs. Relief is defined as the relative height of rock ledges, boulders, or rock outcrops. It can also indicate a region where a drop-off or slope of a mound or ridge occurs over a relatively short distance. This distance is generally in the range of 10-20 m, which is typically within a single field of view of the ROV.

6. [*Rugosity*]: LRu= Low Rugosity, HRu= High Rugosity. Rugosity is defined as a degree of ruggedness of the rock bottom. This is relative to the size of rock ledges, holes, crevices, which tend to provide the greatest fish habitat. High Rugosity on these shelf-edge reefs occurs primarily along the edges of the rock ridges where there are zones of fractured rock slabs, or zones of boulders or rock outcrops. Low Rugosity is the flat rock pavement typically found on top of the ridges or at the base of the mounds and ridges. Low Rugosity also defines the rounded rock mounds and knolls found at some sites that are devoid of ledges and loose boulders. Rugosity, as it is used here, is a non-quantified relative term. Most of the multibeam sonar maps collected are of relatively low resolution (5-10 m) and cannot be used to quantify rugosity at this scale; high resolution (<0.5 m) contour multibeam maps would be needed to quantify this characteristic in the future.

7. [*Substrate*]: Table 2 is a modified subset of SEADESC Habitat Categories which was developed by the NOAA Deep-Sea Coral Program for use in analysis of deep-sea coral surveys (Partyka et al., 2007). The categories which are useful for characterizing deep coral habitat were modified to make them useful for the shelf-edge habitats. The presence of fauna was not included as it is quantified in the Point Count analyses. In the region of this survey, the habitat types included: rock pavement, pavement with ledges, pavement with sediment veneer, rock ledges and boulders, rubble/cobble, and soft bottom. This category is also used to plot the dive track overlay on the multibeam sonar maps in ArcGIS.

Table 2. Benthic habitat category codes (modified SEADESC).

| ID | Code | Habitat Name | Habitat Description |
|---|---|---|---|
| 1 | S | Soft Substrate | Unconsolidated sand/mud, unlithified |
| 2 | SR | Soft Substrate/Rubble/Rock | Soft substrate (>50% cover) with rubble and/or rock |

| | | | |
|---|---|---|---|
| 3 | R | Rubble | Rubble/cobble (~5-20 cm sized rock or coral) |
| 4 | RL | Rock/Ledges | Rocks, boulders, and/or ledges |
| 5 | P | Pavement | Rock pavement |
| 6 | C | Hard Corals | Live and/or dead colonial scleractinian coral; standing individual colonies, bushes, or thickets. |
| 7 | TH | Tilefish (blueline or golden; not sand tile) | Soft bottom with visually identifiable burrows |
| 8 | A | Artificial Substrate | Any artificial structure that provides habitat for fishes and/or invertebrates |

**Statistical Analyses**

Multivariate analyses were used to determine differences in benthic macrobiota and fish assemblages among dives. All analyses were conducted in PRIMER 6 and based on guidelines of Clarke and Warwick (2001) and Clarke and Gorley (2006). The dive sites were compared by their Management Status (Inside MPA vs Outside MPA). For the benthic analysis, CPCe percent cover data of the macrobiota were averaged by location inside and outside the MPAs (e.g., Inside Snowy Wreck MPA and Outside Snowy Wreck MPA). Then these data were square-root transformed to reduce the influences of numerically dominant species in the similarity matrix. For the fish analysis, densities (# individuals 1000 $m^{-2}$) of all species for each transect were analyzed. Density data were then averaged by location inside and outside each MPA and fourth-root transformed to reduce the effect of common species.

Similarities between sites for both fish and benthic biota were then calculated using the S17 Bray-Curtis similarity index. A non-metric multidimensional scaling ordination (MDS) plot and a dendrogram with group-average linking were created showing the results of a concurrently run Similarities Profile (SIMPROF). Similarity Percentages (SIMPER) was utilized where possible to determine which species contributed to the dissimilarities among group pairs.

**Multibeam Sonar Mapping**

NOAA acoustic surveys using multibeam sonar (Simrad ME-70 for 2012 and 2013 *Pisces* cruises and Reson 7125 SV2 for 2014 *Nancy Foster* cruise) for bathymetric data collection were conducted at ROV dive sites where multibeam maps were not available. The main objective of the sonar surveys was to provide background maps to guide ROV exploration at dive sites. Data was processed using CARIS and converted to GeoTIFF images.

# RESULTS AND DISCUSSION

## Study Areas

The three cruises in 2012, 2013, and 2014 took place within the jurisdiction of the South Atlantic Fishery Management Council (SAFMC) on the continental shelf-edge between Jacksonville, Florida and Cape Fear, North Carolina. Six newly designated shelf-edge MPAs were surveyed along with reef habitat of adjacent areas to provide comparative baseline data, inside and outside of the MPAs (Figs. 1-6, Table 3).

## Cruise Summary

During the three cruises, a total of 98 ROV dives were conducted; 37 dives surveyed sites within the shelf-edge MPAs and 61 were conducted at adjacent non-protected sites. Total dive time was 150.9 hr, covering 139.4 km, with continuous video recording and the collection of 10,299 digital still images documenting bottom habitat, macrobiota and fish. A total of 73 CTD casts were made. Thirty-three multibeam sonar surveys provided new maps covering a total area of 543.53 $km^2$ at depths ranging from 43 to 250 m. These sites had never been surveyed previously with multibeam sonar. Georeferenced maps were made for each of the sites and were ground-truthed with the ROV dives. Complete species list with percent cover of benthic marcrobiota and densities of fish for each dive site are listed in Appendices 1 and 2.

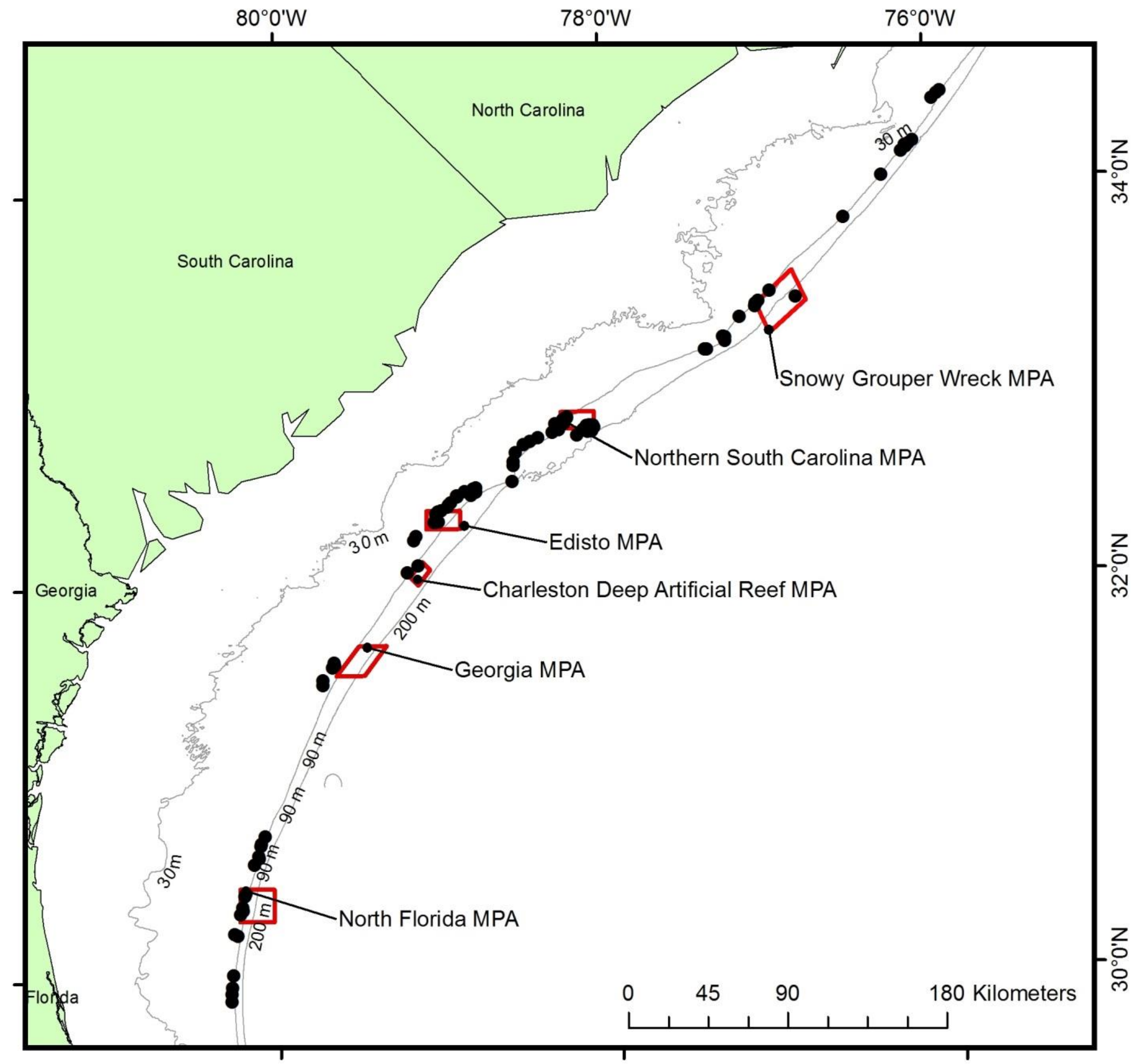



Figure 1. Locations of shelf-edge MPA sites and ROV dive sites off southeastern U.S. during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives.

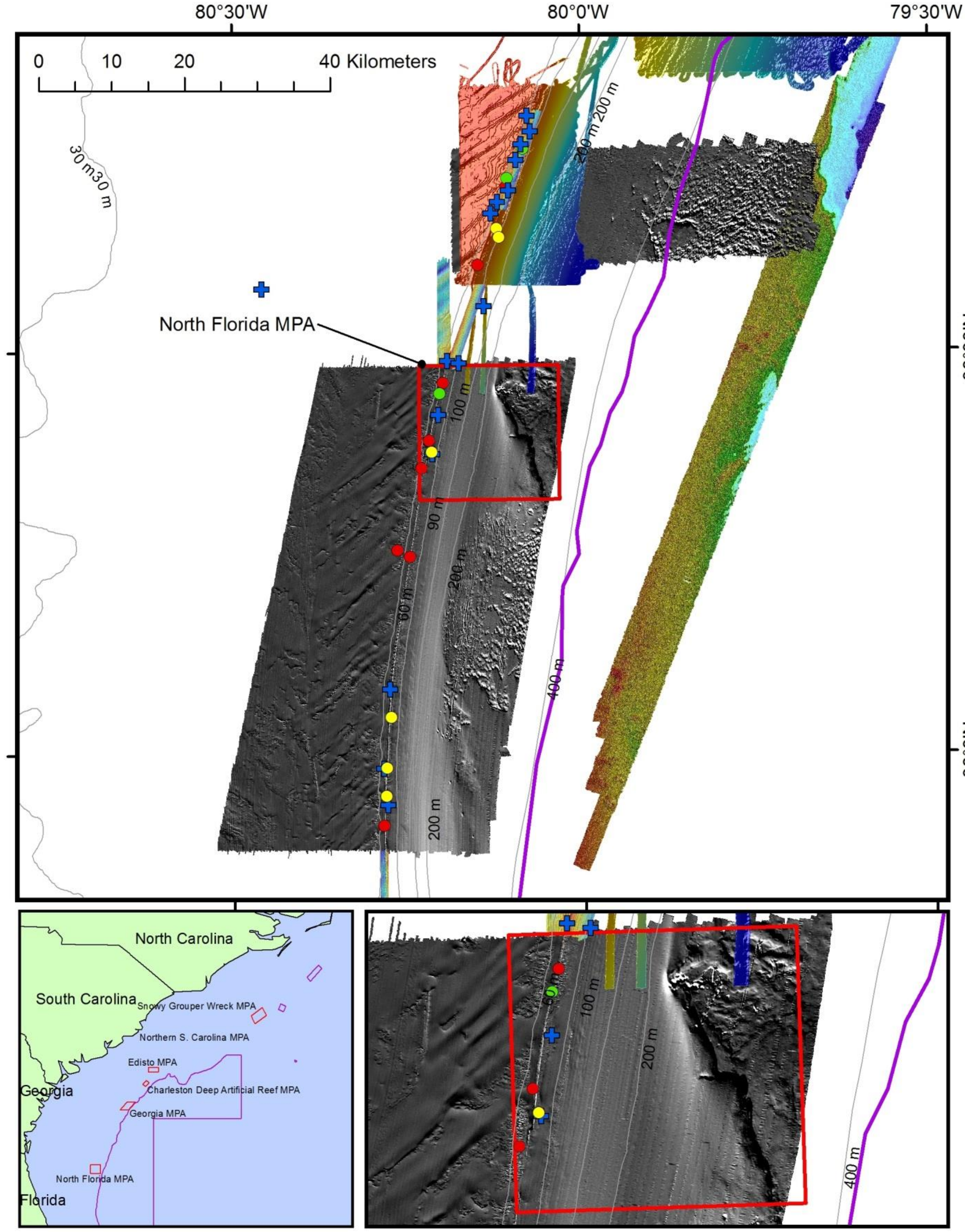



Figure 2. Locations of shelf-edge MPA sites and ROV dive sites off north Florida during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives (red- 2012, yellow- 2013, green- 2014); crosses (+) = CTD casts.

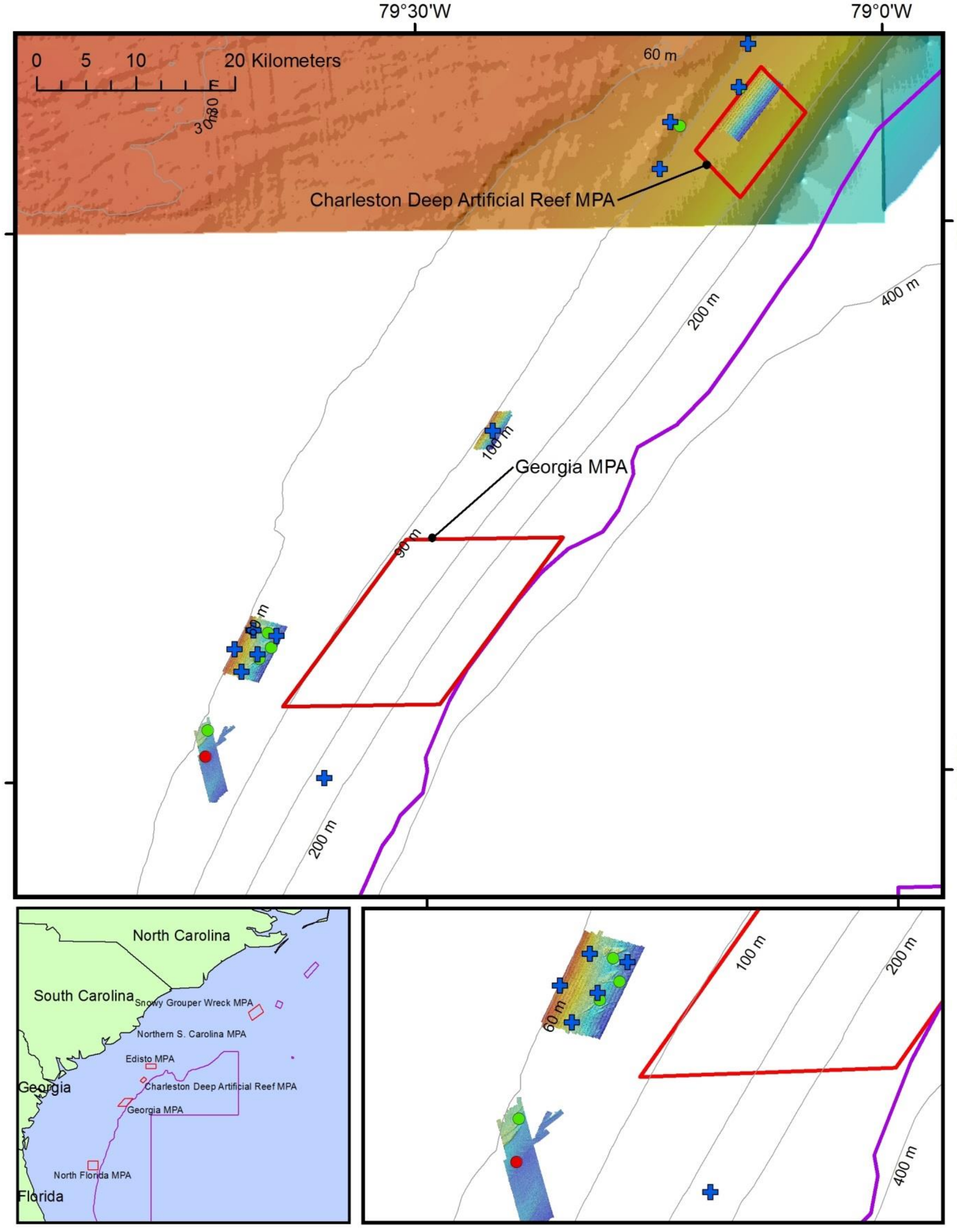



Figure 3. Locations of shelf-edge MPA sites and ROV dive sites off Georgia during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives (red- 2012, yellow- 2013, green- 2014); crosses (+) = CTD casts.

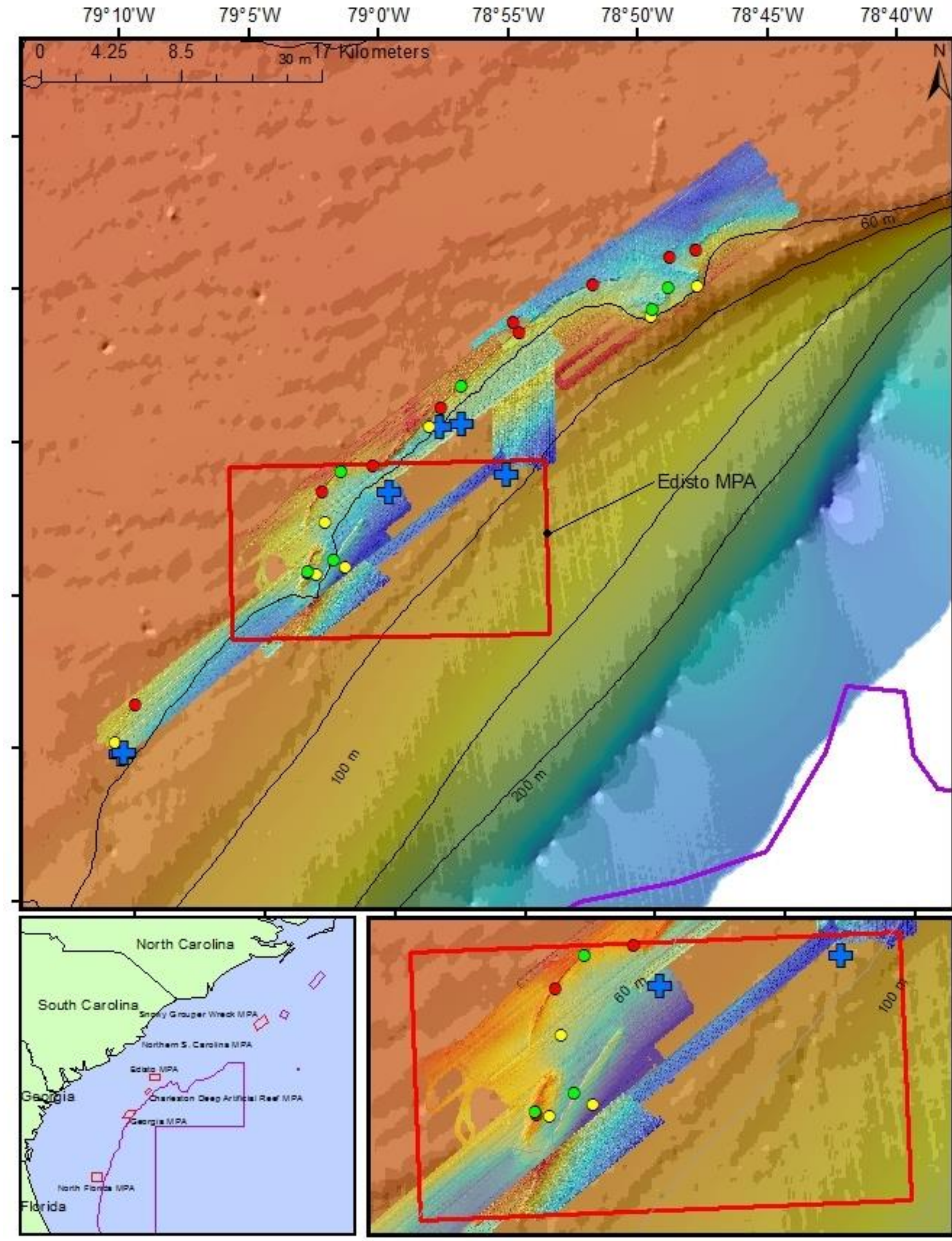



Figure 4. Locations of shelf-edge MPA sites and ROV dive sites off South Carolina during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives (red- 2012, yellow- 2013, green- 2014); crosses (+) = CTD casts.

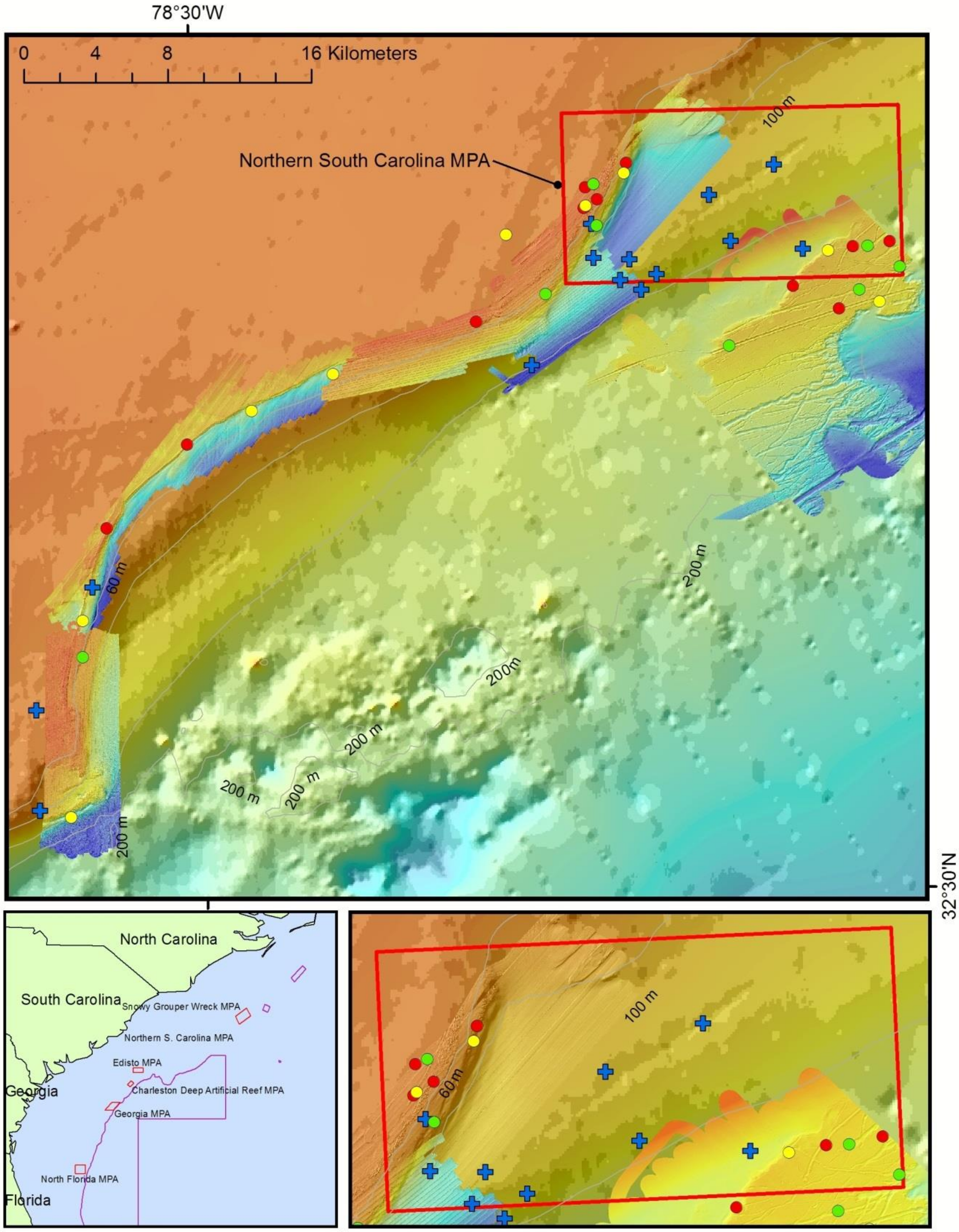



Figure 5. Locations of shelf-edge MPA sites and ROV dive sites off northern South Carolina during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives (red- 2012, yellow- 2013, green- 2014); crosses (+) = CTD casts.

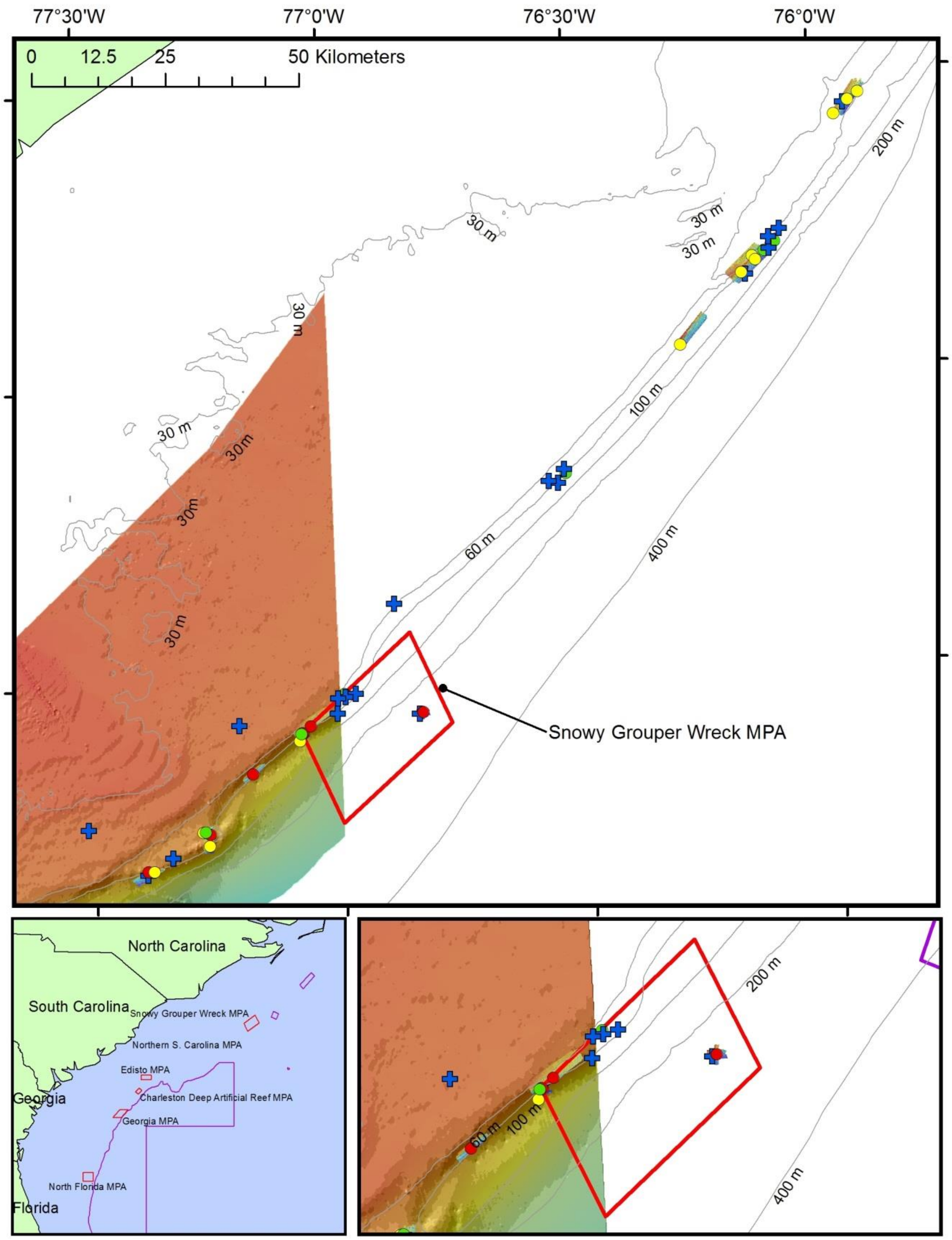



Figure 6. Locations of shelf-edge MPA sites and ROV dive sites off North Carolina during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Red polygons = SAFMC MPA sites; solid dots = ROV dives (red- 2012, yellow- 2013, green- 2014); crosses (+) = CTD casts.

Table 3. List of ROV dive sites by state and MPA status (Inside MPA or Outside MPA) conducted during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08).

| Site | # of Dives | Depth Range (m) |
|---|---|---|
| **FLORIDA** | | |
| North Florida MPA | 5 | 57-63 |
| Outside North Florida MPA | 12 | 49-63 |
| **GEORGIA** | | |
| Outside Georgia MPA | 5 | 62-73 |
| **SOUTH CARLOLINA** | | |
| Edisto MPA | 9 | 47-62 |
| Outside Edisto MPA | 14 | 46-55 |
| Northern S. Carolina MPA | 8 | 48-69 |
| Outside Northern S. Carolina MPA | 9 | 45-119 |
| Northern S. Carolina MPA (iceberg scar site) | 6 | 160-165 |
| Outside Northern S. Carolina MPA (iceberg scar site) | 5 | 161-168 |
| Charleston Deep Artificial Reef MPA | 2 | 85-100 |
| **NORTH CAROLINA** | | |
| Snowy Wreck MPA | 6 | 63-93 |
| Snowy Wreck MPA (wreck site) | 1 | 250-253 |
| Outside Snowy Wreck MPA | 16 | 69-109 |

**Multibeam Sonar**

Thirty-three multibeam sonar surveys provided new maps covering a total area of 543.53 $km^2$ at depths ranging from 43 to 250 m (Table 4). These sites had never been surveyed previously with multibeam sonar. Georeferenced maps were made for each of the sites and were ground-truthed with the ROV dives.

Table 4. Multibeam sonar surveys conducted during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08).

| Name | Area ($mi^2$) | Area ($km^2$) | Min Depth (m) | Max Depth (m) |
|---|---|---|---|---|
| Charleston Deep Artificial Reef MPA | 0.10 | 0.27 | 62 | 101 |
| Edisto MPA | 4.70 | 12.18 | 60 | 81 |
| Northern South Carolina MPA | 18.28 | 47.34 | 100 | 179 |
| Outside Edisto MPA | 36.30 | 92.50 | 50 | 142 |

| | | | | |
|---|---|---|---|---|
| Outside Georgia MPA | 18.04 | 45.19 | 60 | 108 |
| Outside North Florida MPA | 36.51 | 94.17 | 43 | 75 |
| Outside Northern S. Carolina MPA | 44.77 | 118.42 | 45 | 250 |
| Outside Snowy Wreck MPA | 37.05 | 96.88 | 53 | 147 |
| Snowy Wreck MPA | 12.60 | 32.58 | 56 | 122 |
| Snowy Wreck MPA (wreck site) | 1.50 | 4.00 | 250 | 250 |
| **Total** | 209.85 | 543.53 | | |

**CTD Operations**

A total of 73 shipboard CTD casts were conducted at the multibeam sites during the three cruises (Figures 2-6). A smaller instrument was attached to the ROV on almost all dives between 2012 and 2014 that measured temperature and depth throughout the dives. CTD data are presented in the individual cruise reports (Reed et al., 2013a, 2014b, 2015).

**MPA Site Descriptions**

These are the first *in situ* observations of some of the newly designated shelf-edge MPA sites. The following are descriptions of the geomorphology of each MPA site based on the ROV dives from excerpts of the individual Cruise Reports (Reed et al., 2013, 2014, 2015).

North Florida MPA

The multibeam for the MPA (Navy_2011_CONFIDENTIALUSWTR_Tif) shows a N-S linear ledge along the west side of the MPA; five dives were made along this ledge (Figures 7-9). Another moderate to high-relief hard bottom feature is apparent in the multibeam along the northeastern corner but no dives were made there.

Dive 12-01: North end of N-S oriented ridge. This transect is primarily low relief pavement on top and low relief, eroded rock slabs on the east and west slopes. Depth range: 52-60 m.

Dive 12-02: Low relief, hard bottom about 500 m west of main ridge, with rubble and cobble on soft bottom. Depth range: 54-59 m.

Dive 12-03: Central part of main ridge. Top is low relief ledges and pavement; the east and west slopes are moderate relief ledges, fractured rock slabs, and rugged fissures of high rugosity. Depth range: 52-60 m.

Dive 13-04: Transect on east slope and top of main ridge; ridge top- 56-59 m; east base- 62-65 m. East slope is mostly low slope 10-20°, low to moderate relief, 1-3 m rock slabs and boulders with 0.5 to 1 m relief; and mostly high rugosity. Ridge top is flat, rock pavement with low 0.5 m ledges, sand with rubble, and 50% cover hard bottom. East of ridge is off reef, soft bottom, sand with rubble, small boulders. West of ridge, 55 m depth, is pavement with low ledges, sediment and rubble. Dense fish populations were found on east slope with high rugosity. Depth range: 55-65 m.

Dive 14-29: Northern part of main ridge. Ridge top is low relief hard bottom, with flat rocks 0.5-2 m wide, in fractured, puzzle-piece formation; some boulders to 1-2 m; nearly 100% faunal/algal cover on the rock. Depth range: 53-60 m.

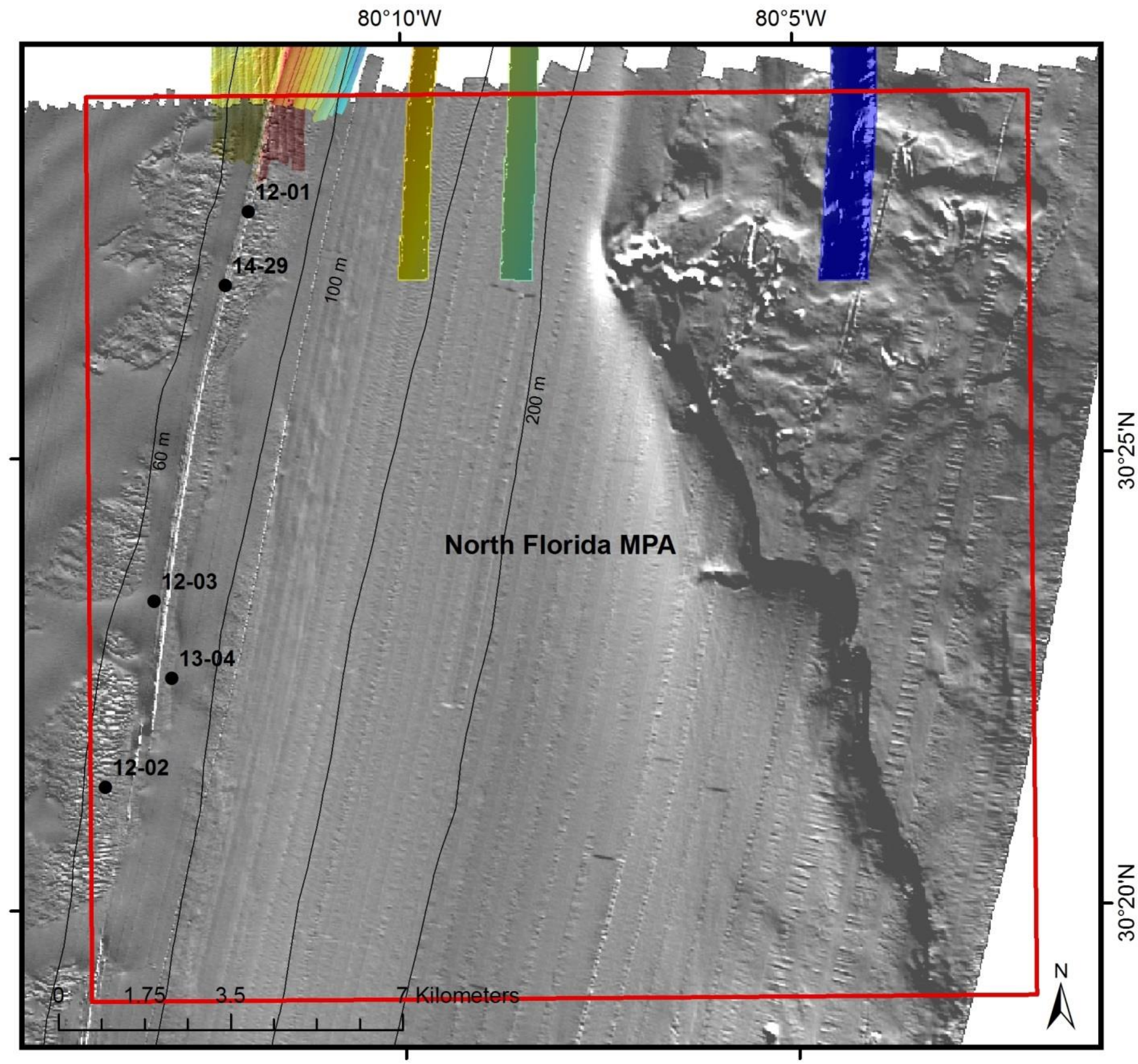



Figure 7. Map of North Florida MPA with 2012-2014 ROV dive sites.

Figure 8. North Florida MPA (ROV 13-04; 59.5 m). Speckled hind (*Epinephelus drummondhayi*) on rugged rock bottom, encrusted with various demosponges and wire coral (*Stichopathes lutkeni*).

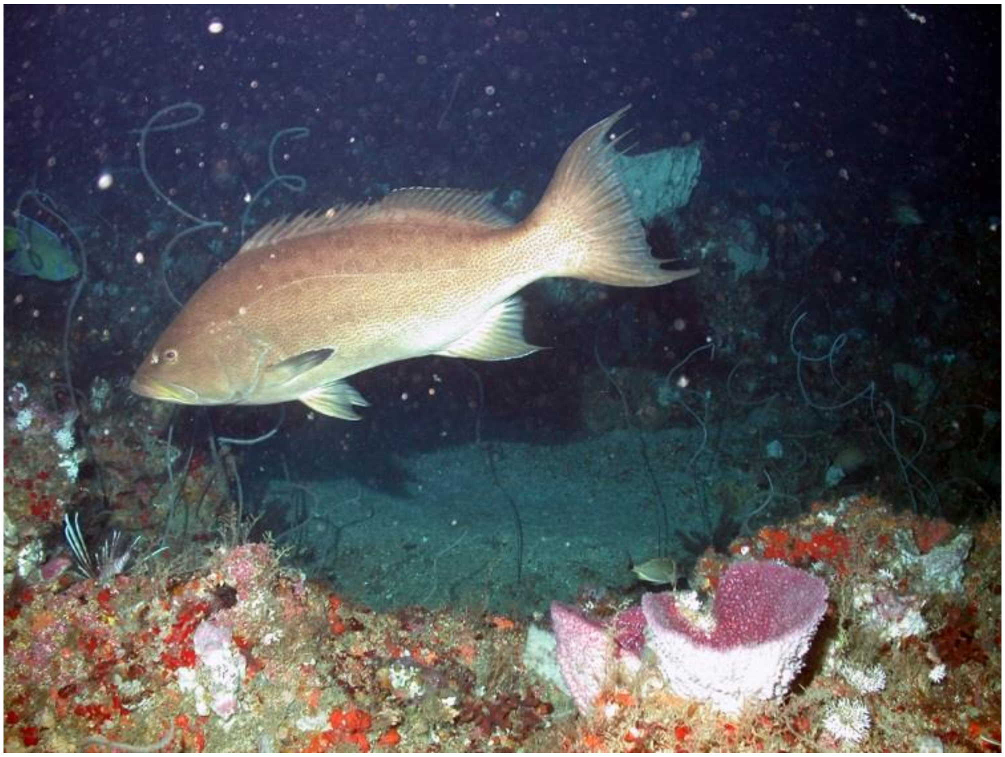


Figure 9. North Florida MPA (ROV 13-04; 57.4 m). Scamp (*Mycteroperca phenax*) on rock ledges with vase sponges (*Ircinia campana*).

Georgia MPA

No multibeam or ROV dives are available for inside this MPA. The following descriptions are of dives adjacent to but outside of the Georgia MPA (Figure 10).

Dive 12-05: 5 nmi SW of MPA. Low relief rock pavement and sediment with sparse rubble and shell hash; hard bottom at 62-64 m. Depth range: 60-72 m.

Dive 14-01: Georgia Reconfig site; west of MPA. Ground-truth multibeam sonar of site (NancyFoster_10_15_GeorgiaEast_bag). Transect NE to SW along 65 m ridge; large boulders, high rugosity; large patches of *Muricea* octocorals in areas. Depth range: 58-74 m.

Dive 14-03: Georgia EXT site. Ground-truth multibeam sonar of site (NancyFoster_14_08_MPA_GA_Grid). Transect west along southern part of V-shaped ridge. Mostly soft bottom with few areas of exposed rock pavement and few outcrops with apparent solution holes. Habitat stayed fairly constant ranging from soft bottom with scattered areas of hardbottom to a few spots of 60-80% cover of exposed pavement and rocks. Depth range: 56-79 m.

Dive 14-04: Georgia Ext site. Southeastern ledge of 66 m plateau. Bottom is exposed hard pavement and rock ledges with a few low relief outcrops and flat pavement with ledges 1 m maximum relief. Rock outcrops are rounded and up to 5 m wide. Depth range: 60-72 m.

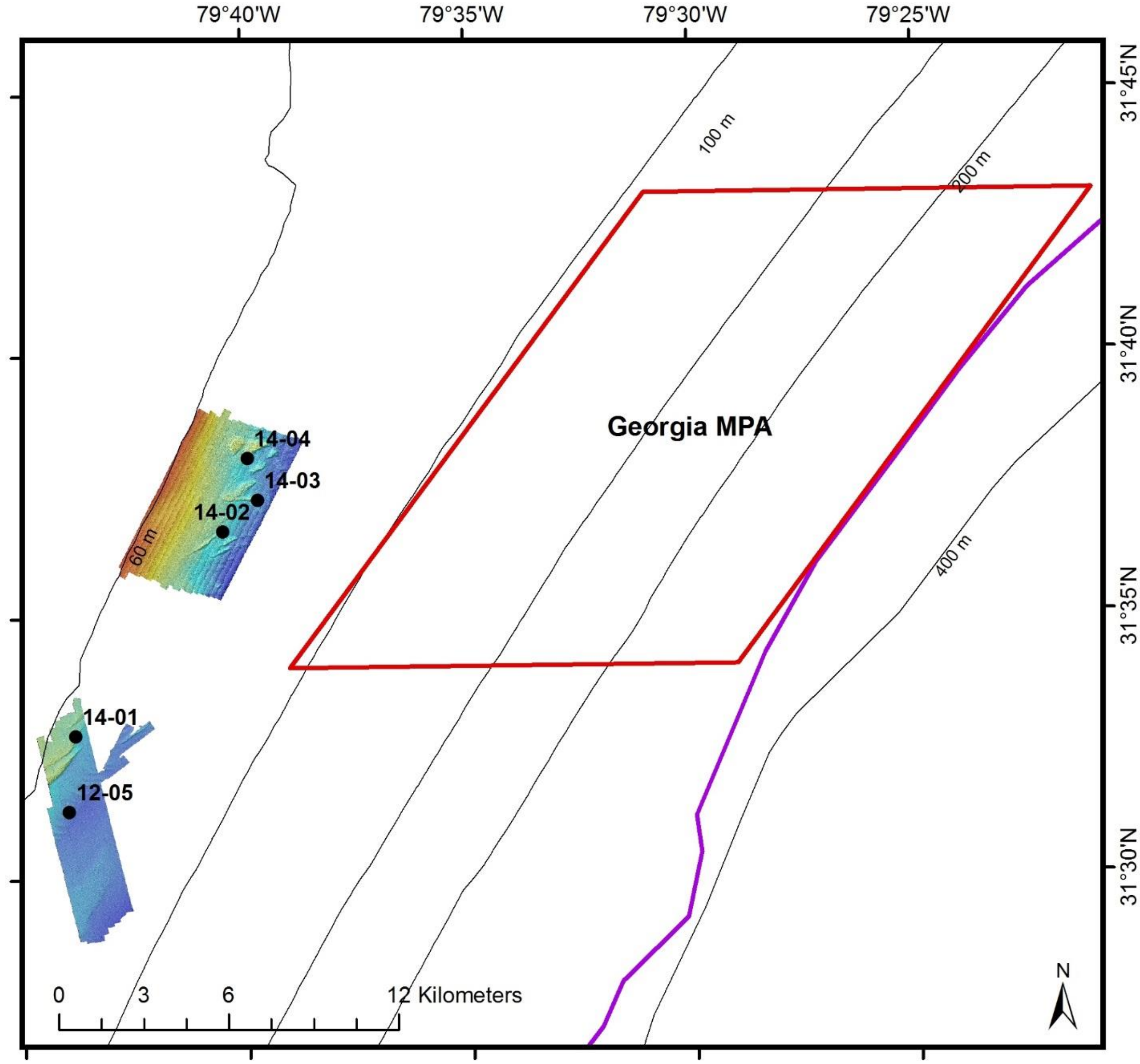



Figure 10.  Map of Georgia MPA with 2012-2014 ROV dive sites.

<u>Charleston Deep Artificial Reef MPA</u>

Two barges were sunk between April and June in 2014 just prior to our ROV dives of that year (Figures 11-13).  The barges ended up west of the planned MPA; the MPA boundaries will be relocated to include the barges (per SAFMC).  Multibeam sonar for Barge 1 (NancyFoster_14_08_Barge1_Grid) shows an intact barge oriented NE-SW with a debris field just off the SW corner, and laying on a relatively featureless, flat bottom.  Multibeam sonar for Barge 2 (NancyFoster_14_08_Barge2_Grid) also shows an intact barge laying NE-SW on a flat bottom.  A divit or hole is apparent at the NE corner (possibly where the barge hit bottom), and two mound features are off the SW corner. Both barges are approximately 80 m long and 20 m wide.

Dive 14-25: The ROV transect was along the eastern side of the barge; it did not cover the debris field. There is a shipping container box about 20 m SW of the barge with a ladder-like structure laying across it. The transect traveled along the starboard side of the barge from aft to forward. The barge is intact but a debris field of items that fell off the deck as it sank lay to the NW of the barge. There was a school of amberjacks swimming above the barge but no other fish or macroinvertebrates were observed. No analysis of benthic biota was conducted on this site as the barge surface was still barren of macrobiota. Depth range: 83-101 m.

Dive 14-26: Landed on the bow of the barge and transected along port side toward the aft (SW). Much of the original structure is still on board the barge but has fallen over or been displaced. The bow is fractured and bent toward the surface. The bottom surrounding the ship is soft sediment. No analysis of benthic biota was conducted on this site as the barge surface was still barren of macrobiota. Depth range: 65-87 m.

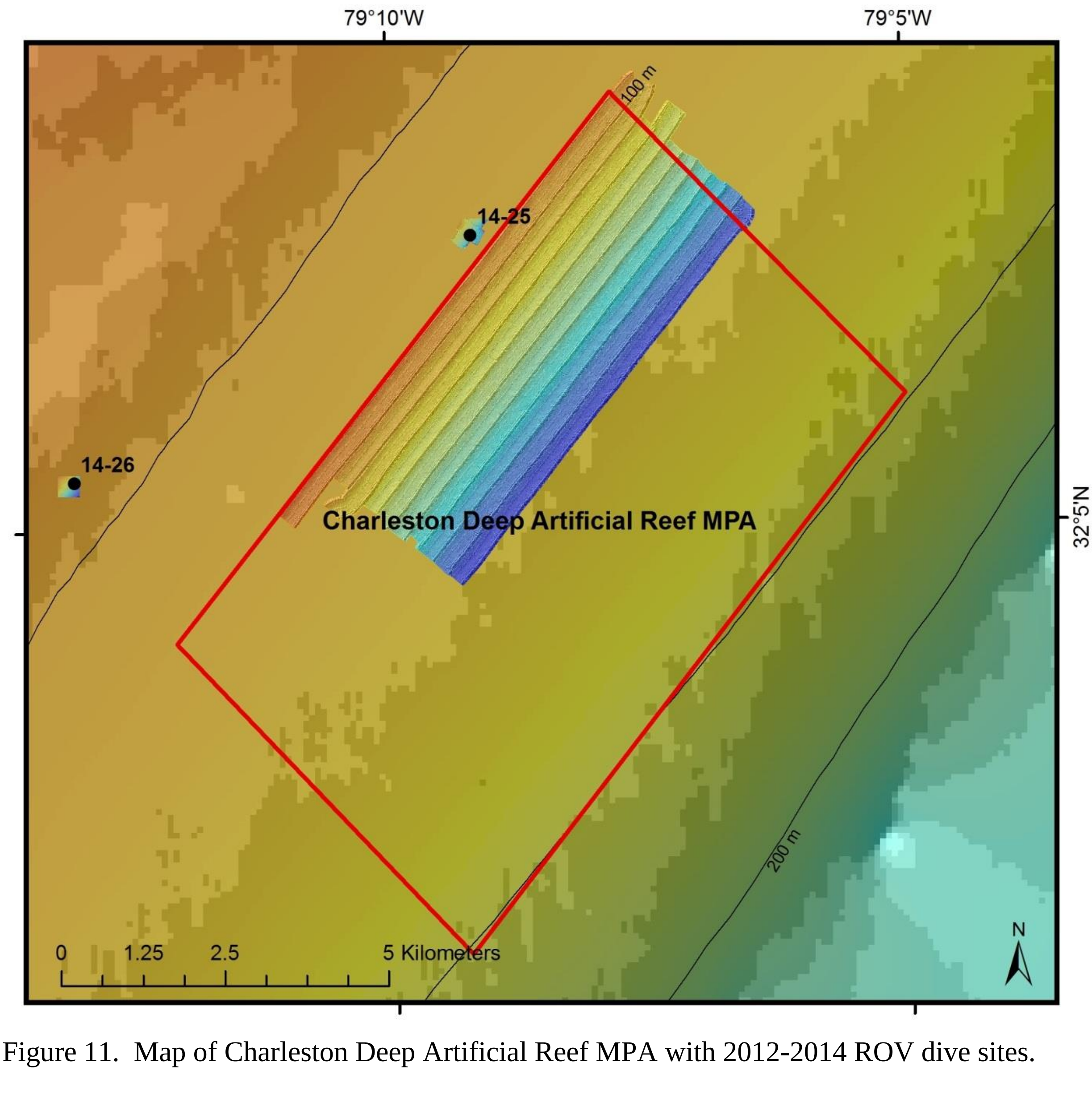



Figure 11. Map of Charleston Deep Artificial Reef MPA with 2012-2014 ROV dive sites.

Figure 12.  Charleston Deep Artificial Reef MPA (ROV 14-25; 92.5 m).  Sunken barge.

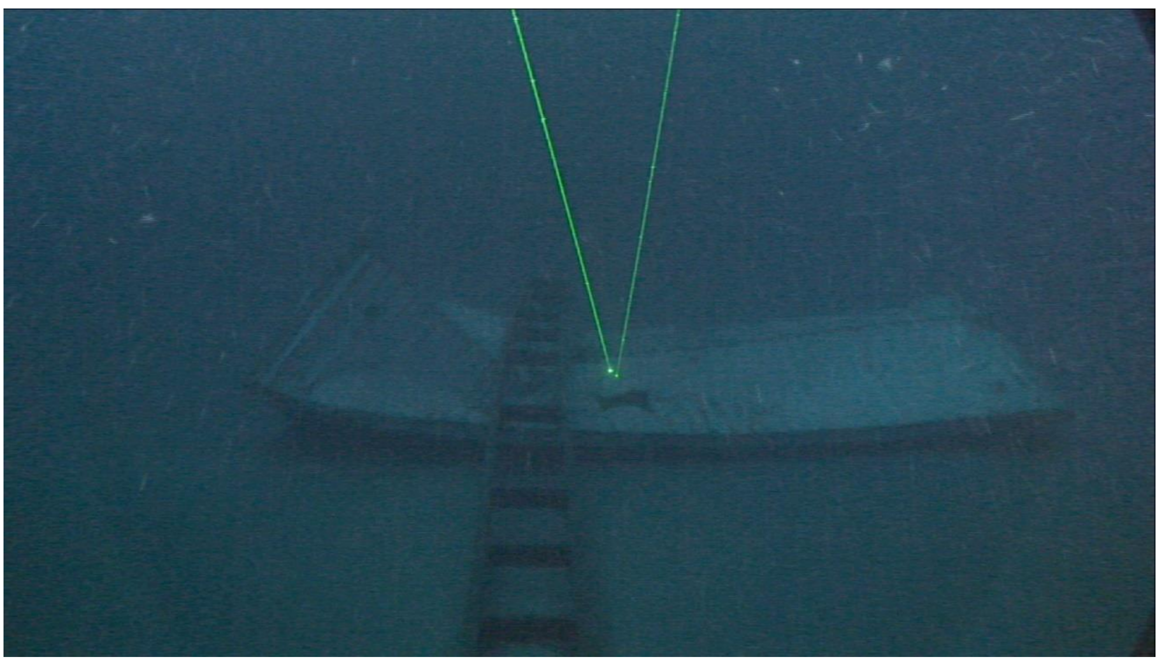


Figure 13.  Charleston Deep Artificial Reef MPA (ROV 14-25; 95.3 m).  Sunken barge.

<u>Edisto MPA</u>

The multibeam sonar (ed1_wgs84; Pisces_2012_EdistoMPA_MB_Grid) shows a distinct NE-SW oriented shelf-edge ridge at 50 m depth cutting through the middle of Edisto MPA (Figure 14).  Nine ROV dives were conducted within the MPA during the three years.  Some of these are described below (Figures 15-18).

Dive 12-06: The dive was at the northern border of the MPA along the 50-m ridge. Transect 1 headed east along border of MPA. The bottom is flat sediment, sand with dense Cyanophyta cover; areas of hardbottom included low relief rock pavement and exposed rock outcrops with 10-50 cm relief. The rock ledge is 47 m at the top and 49.5 m at the base. Transect 2 headed NE parallel to the ridge on the multibeam map. It is all hardbottom with rock pavement, rock outcrops of 10-50 cm relief, and some ledges with 1 m relief. The top of ridge is 80-100% rock cover; the base of the ridge is rock rubble and sediment. The west edge of the ridge is 50% cover of rock boulders, 1 m relief, some 2 m relief, and very rugose. Depth range: 47-51 m.

Dive 12-07: This dive paralleled the 50-m ledge just south of Dive 12-06. The top of the main ridge is ~150 m wide and oriented NE-SW. The middle of ridge is rock pavement with rock outcrops and 80-100% cover of dense biota. The west slope is a steep drop-off with rugged topography and rock slabs undercut and broken off forming 1-2 m ledges, with total relief of 4 m. The top of the slope is 46.5 m; the base of west slope are rock slabs and boulders on sediment, grading into sediment at 52 m. The west slope is ~10-20 m in width. The east edge of the ridge is less rugose than the west slope and consists of rock slabs of 50-100 cm relief. It is 47 m at the top and 50 m at the east slope base. Depth range: 46-52 m.

Dive 12-09: This dive was along the 50-m ridge at the southwestern portion of the MPA. Transect 1- low relief hard bottom within the light orange zone of multibeam; 51.0- 51.5 m. Mostly low relief pavement, smooth exposed rock with no ledges, and pavement with sediment veneer; sediment with Cyanophyta cover; 30-80% hard bottom cover. Sparse epifauna dominated by gorgonians, very few demosponges, and very few fish. Transect 2- in shallowest zone of multibeam; transect in middle region of shallowest zone mostly low relief rock pavement, and pavement with sediment veneer, with few or no small ledges; and sparse sessile fauna and fish. Continued transect along west edge of high relief ridge. Top of ledge is 47.5 m; base of slope is 52-53 m. Slope is very rugged; upper slope has 1 m ledges, undercut slabs, and <$30^o$ slope to base. Lower slope and base consists of rock slabs, boulders, and ledges of 50-100 cm, then grading to sediment with Cyanophyta veneer at 52 m. Depth range: 46-53 m.

Dive 13-08: This dive ground-truthed the multibeam showing a N-S oriented, 2700x778 m flat-topped mound, near the southwestern part of the MPA. Total relief is 6 m; 48 m at top, and 54 m at the base. The east side and top of mound is flat pavement with a few interspersed areas of high rugosity. Areas on top are ~50% hardbottom, sediment with flat pavement, and no ledges. These areas had no fish. The drop-off has low relief ledges with 0.5 to 1 m relief, and low slope ~$5\text{-}10^o$. The west side of the mound is low to moderate relief (1-3 m) and high rugosity. The mound tapers off to the east and north into unconsolidated flat featureless sediment. Fish schools were dense on in small patchy areas of high rugosity.

Dive 13-09: This is an isolated linear ridge (4730 x 365 m) not far from the mound of Dive 13-08. Maximum relief is 2.5 m; 63.5 at base, 61 m on top. The ROV landed 360 m to the east of the targeted linear ridge. Bottom is pavement with sediment veneer and few scatted rubble. Headed west towards the mound; flat bottom, more exposed hardbottom with low relief, <0.5 m, and low rugosity knolls. The knolls are densely covered with *Stichopathes* black coral. The west slope of the ridge has 80-90% cover of 1-2 m diameter, 1-2 m relief , jumble of boulders with high rugosity and eroded undercut ledges. The top of the ridge is 61 m. There is an abrupt end of the rock zone to the west of the ledge (63.5 m) and flat sand occurs to the west at 64.5 m. Depth range: 53-64 m.

Dive 13-10: This dive was near the middle of the MPA along a NE-SW oriented linear ridge (5000 x 300 m). 200 m to the east of the feature is bioturbated sediment at 53.5 m depth. The east slope of the ridge is very rugose, with 1-3 m relief and 49 m deep on top ledge. Under cut ledges occur at the edge, with slanted stacked rock slabs. The top of this feature is a double ridge with a sand region in between. There appears to be two parallel rock "walls" on both the east and west sides of the ridge. The west slope is 1-3 m relief, with high rugosity, and undercut rock slabs jumbled on slope, and 20-30$^{o}$ slope (46 m on top). The west base of the ridge is low relief jumbles of rocks 1-2 m wide, <0.5 m tall. The base of wall is 52 m; total relief from top of ridge to bottom is 6 m. The wall starts to taper off to the north; rugosity drops as well as relief (~1 m tall on edge and flat low rugosity on top). Depth range: 42-54 m.

Dive 14-22: This dive was along the east slope of the main ridge near the northern border of the MPA. The east slope is exposed flat slabs with undercuts, 0.25-0.5 m thick and 2-3 m wide, with sediment veneered pavement, and sediment. The ledge became 4-5 m tall with thick slabs and rough surfaced boulders piled up. The slope is of high rugosity with numerous holes and crevices. The ledge ended abruptly in sediment to the east base. The hard bottom is 100 % covered in macrobiota. Depth range: 48-54 m.

Dive 14-23: This dive was mostly along the west slope of the N-S oriented flat-topped mound (same as Dive 13-09). The western drop-off of the plateau is hardbottom outcrops with 1-3 m relief, rounded knolls and overhangs, and tapers out to the west into small boulders 0.25 m tall. All hardbottom had 100% faunal/algal coverage. One very large patch of the coral *Oculina varicosa* was observed under an overhang. Depth range: 40-51 m.

Dive 14-24: This dive was mostly along the west slope of the ridge described in Dive 13-09. The west drop-off of the ridge is 2-3 m relief with undercut overhangs, on a 45$^{o}$ slope over a few meters width. It tapers to rubble/cobble and ending abruptly in sand; 58.6 m top, 60 m bottom. The top rim of the slope is rounded rocks. The top of the ledge is mostly pavement. Upper plateau has rounded rock knolls with moderate rugosity and few undercuts. All exposed hardbottom is covered with 100% fauna/algae. Depth range: 55-62 m.

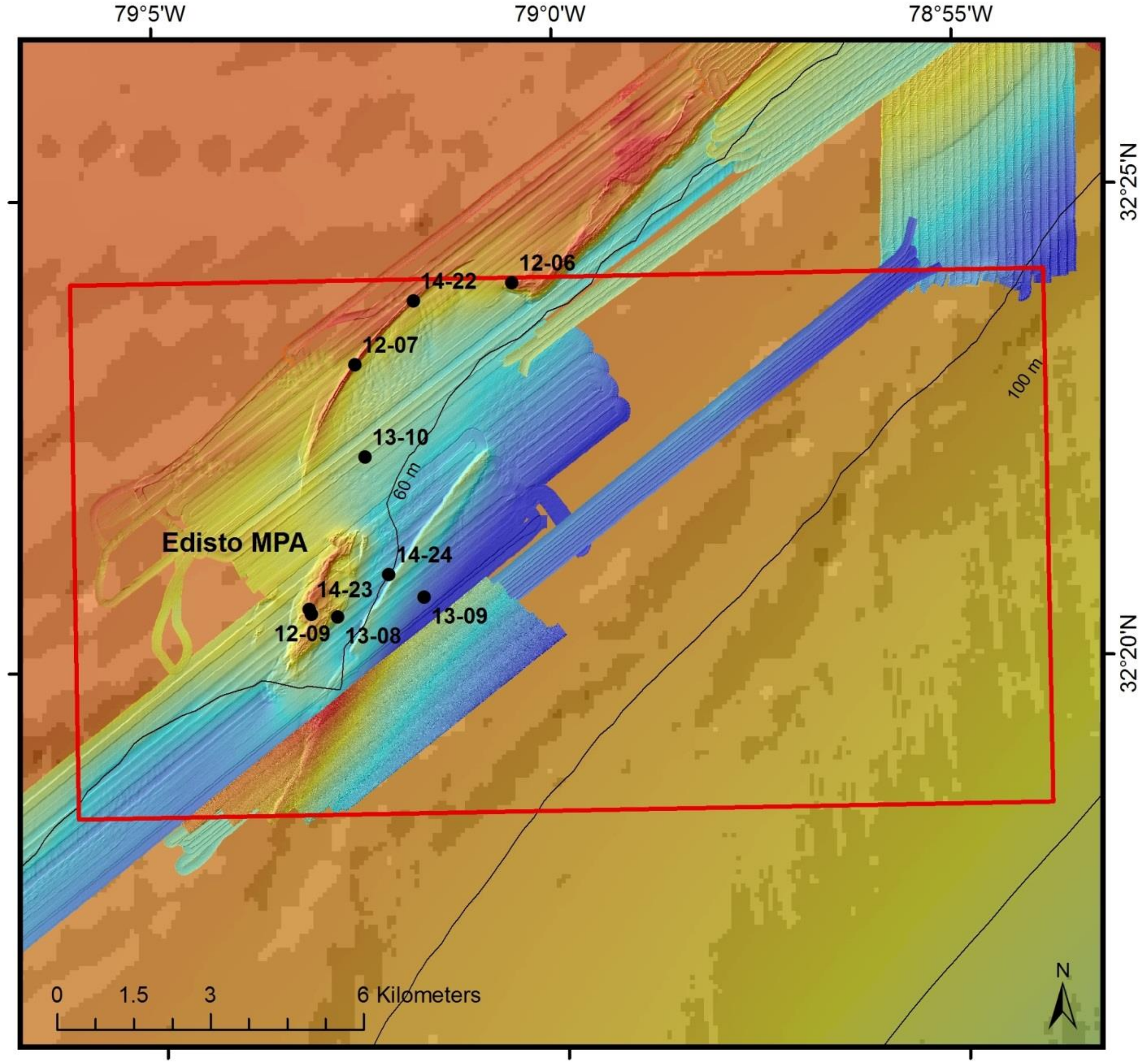



Figure 14. Map of Edisto MPA off South Carolina with 2012-2014 ROV dive sites.

Figure 15. Edisto MPA (ROV 12-09; 48.3 m). Dense *Dictyota* and other brown algae on hardbottom habitat.

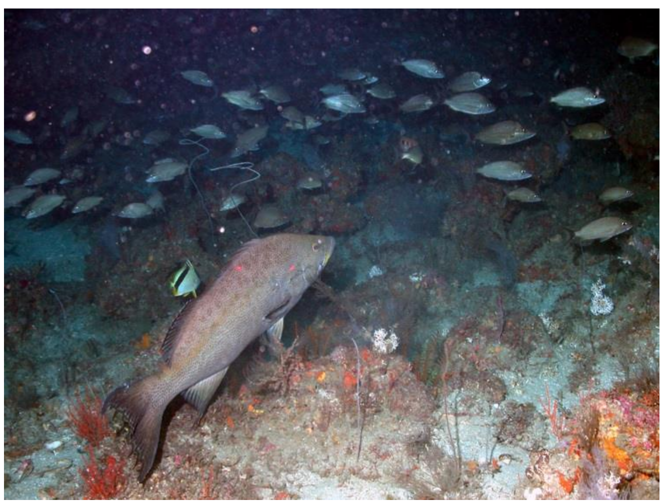


Figure 16. Edisto MPA (ROV 13-09; 60.3 m). Large scamp (*M. phenax*) with school of tomtates (*Haemulon aurolineatum*) and bank butterflyfish (*Prognathodes aya*).

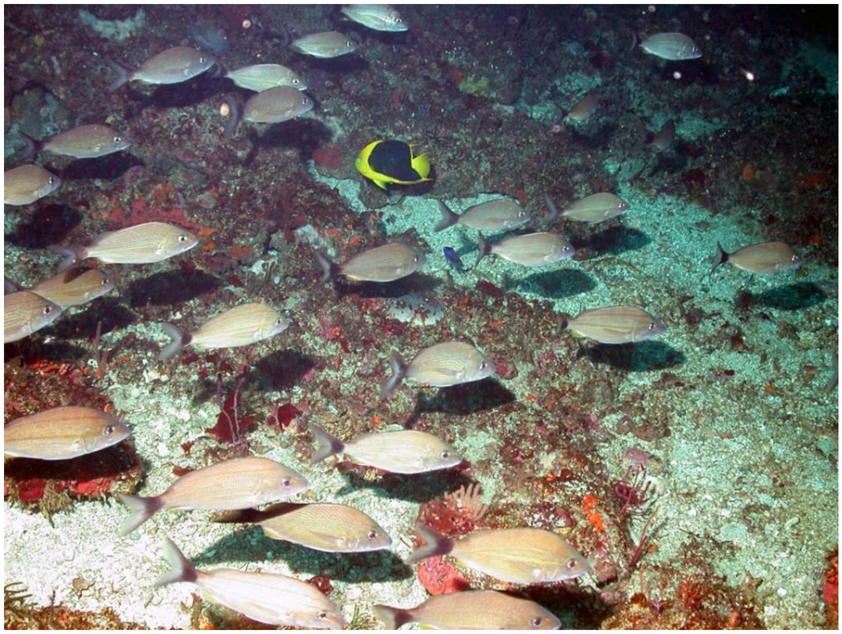


Figure 17. Edisto MPA (ROV 13-08; 47.4 m). School of tomtates (*H. aurolineatum*) with rock beauty (*Holacanthus tricolor*) on low relief rock ledges.

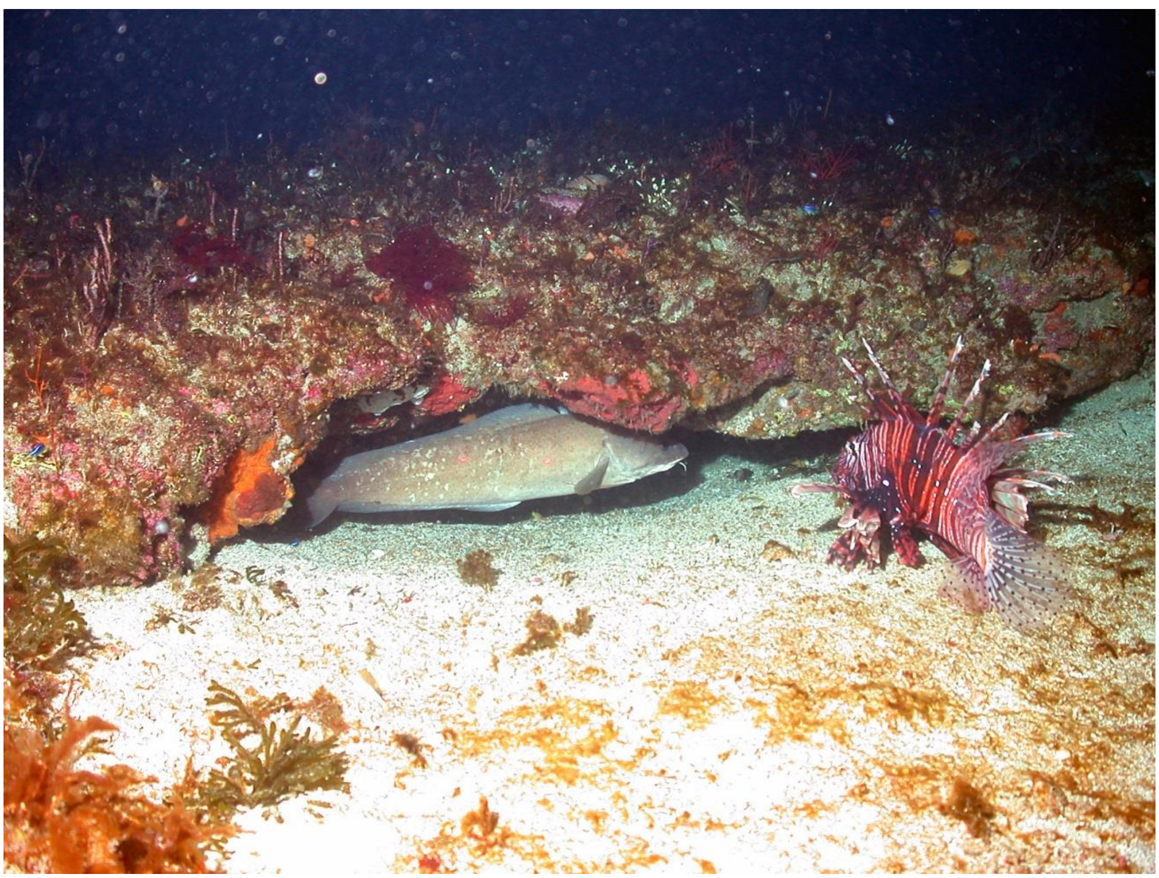


Figure 18. Edisto MPA (ROV 12-06; 48.5 m). Brotulid and lionfish (*Pterois volitans*) on hardbottom low relief outcrops.

Northern South Carolina MPA

The multibeam (OE_Block2; Sedberry_ngdc_UTM17N_MB_Grid) shows the main NE-SW oriented ridge along the western edge of the MPA and another NE-SW oriented drop-off along the middle of the MPA (Figures 19-21). A flat topped plateau (see Iceberg Scar site below) forms the eastern portion of the MPA (described in following section).

Dive 12-23: This dive was along the western ridge. It is mostly low relief rock pavement with sediment veneer, and 30-50% cover of dense algae dominated by Phaeophyta, mostly *Dictyota* and some *Codium* on cobble and exposed rock. Patches of exposed rock, 10 cm relief, probably excavated by bigeye (Priacanthidae). Some areas have sparse 0.5-1 m diameter flat boulders, <1 m relief. Near the end waypoint are low relief rock ledges, 0.5 m relief, and about 10 m wide, oriented NE-SW which appears faintly on multibeam. Depth range: 47.5-48.5 m.

Dive 12-24 was just east of Dive 12-23 and on slightly visible mounds on the multibeam. The transect starts on flat rock pavement with sediment veneer; with patchy 2-3 m diameter exposed rock patches, and excavated pavement with 10 cm relief. Low relief rock knolls occur on flat bottom dominated by Phaeophyta. The second part of the transect crosses numerous high relief rock mounds that are relatively smooth and rounded, 20-30 m diameter, and 3 m relief with 30-45$^{o}$ slope, but few ledges. Most are about 48 m at the top and 51 m at the base on sediment over pavement. Moderate relief mounds are about 10 m diameter and 1 m relief. All the mounds have nearly 100% cover of algae and epifauna. Depth range: 48-52 m.

Dive 12-26: This dive was along the western main ridge, north of dives 23-25. The eastern part of the ridge top is 65 m deep, consisting of flat rock pavement with sediment veneer, rubble, and cobble. Sparse 1 m diameter exposed rocks with 10 cm relief appear excavated by fish, probably bigeyes. There is 10-30% exposed rock cover. The eastern drop-off has 10$^{o}$ slope, some 1 m ledges, and eroded exposed rock. Sediment and rock pavement occur at the base of the slope at 70 m. Depth range: 63-70 m.

Dive 14-07: Southern part of main western ridge. Transected over sediment bottom with few areas of exposed pavement along the slope. Dominated by hydroids, gorgonians, bryozoans and *Ircinia* sponges. Depth range: 66-74 m.

Dive 14-08: Landed on smooth rocky knolls not far from Dive 12-23. Rounded rock knolls, 1 m tall by 5 m wide. Clumped algae and fauna make a thick cover of 100% on the hard ground knolls. So much fauna it is hard to identify it all. Almost no fish, and only 1 scamp. The knolls taper out (get shorter , <1 m tall) to the west. They appear to match the multibeam map. Depth range: 44-52 m.

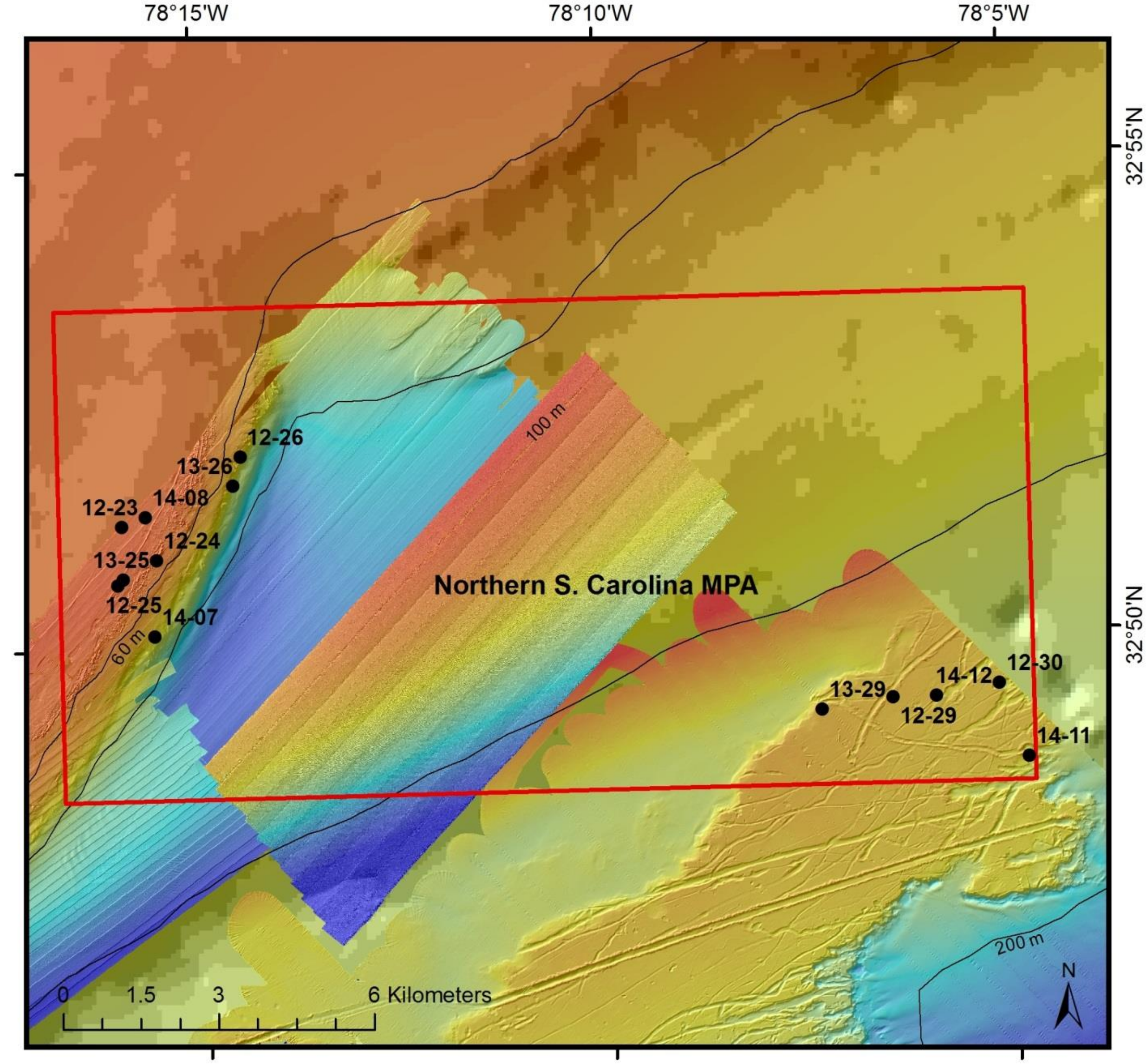



Figure 19. Map of Northern South Carolina MPA with 2012-2014 ROV dive sites.

Figure 20. Northern South Carolina MPA (ROV 12-23; 47.8 m). Red grouper (*Epinephelus morio*) on algal dominated pavement.

Figure 21. Northern South Carolina MPA (ROV 13-26; 70.1 m). Speckled hind (*E. drummondhayi*) with school of cubbyu (*Equetus umbrosus*) on moderate relief rock ledge.

Northern South Carolina MPA (iceberg scar site)

The multibeam sonar (OE_Block2; reprocessed 2013 as oe_block2_5m; Sedberry_OEBlock2_5m_UTM17N_MB_Grid) shows a wide flat plateau intersected with straight deep grooves that are apparent iceberg scars from the last glacial period (Figures 19, 22, 23).

Dive 12-29: Transect starts on flat pavement and sediment with 10-20 cm cobble, 30 cm boulders and ledges. Scattered patches of rock piles with 1 m relief (158 m top- 160 m base). The east rim of a N-S oriented ice berg scar is rugged rock, boulder, cobble, and ledges; top 160 m, valley in scar is 163 m and sediment. Depth range: 158-163 m.

Dive 13-30: Multibeam shows large iceberg scour 3000+ m long, 80 m wide (rim to rim), width of south rim- 60 m; depth of scour valley- 164 m, top of rim- 159 m, terraced hardbottom to south of scour- 162 m. Transect to west along south rim of scour. Landed inside scour valley: 163 m, 5-10 cm rocks on pavement, 0 slope, and low rugosity. Base of scour: 164 m deep, soft bottom, fine sediment, no bioturbation, no sand waves. Iceberg south rim: top of rim, 158 m, rock ledges, low relief rock boulders, 0.5-2 m diameter, 0.5 m relief, 5-10$^{o}$ slope on inside of rim; 12$^{o}$ slope on MB. Dense schools of fish especially in high relief areas on rim edge- red porgies (*Pagrus pagrus*), longspine snipefish (*Macrorhamphosus scolopax*), deepbody boarfish (*Antigonia capros*), and a few snowy grouper (*Hyporthodus niveatus*). Depth range: 156-164 m.

Dive 14-11: Transect along southern side of southern iceberg scar. South of the scar is sediment in 166 m with <10% rock rubble (10 cm). The edge of the scar are large rock boulders 1-4 m tall and wide and covered in *Leiodermatium* sponges. Parts have large >3 m tall rock slabs with undercuts. Snowy grouper were common near larger outcrops. The rugosity, slope and size of the boulders increase in the corners where 2 scars intersect. Observed >50 blueline tilefish (*Caulolatilus microps*) and >20 snowy grouper. Depth range: 156-168 m.

Figure 22. Northern South Carolina MPA (iceberg scar site) (ROV 14-11; 162.1 m). Snowy grouper (*Hyporthodus niveatus*) on high-relief rock habitat.

Figure 23. Northern South Carolina MPA (iceberg scar site) (ROV 13-29; 161.7 m). Yellowedge grouper (*Hyporthodus flavolimbatus*) and snowy grouper (*H. niveatus*).

<u>Snowy Wreck MPA</u>

Only the western corner of the MPA has multibeam and a small area at the Snowy Grouper shipwreck site in the eastern corner of the MPA (SGW_dive32_33_5Mres; Pisces_2012 _SnowyWreckMPA_MB_Grid; NancyFoster_14_08_MPA_NC_SnowyWreck_Grid). This shows a NE-SW oriented ridge with a steep dropoff (Figures 24-26).

Dive 12-20: Transect heads northwest across selected waypoints from new multibeam. The transect starts on the deep drop-off within MPA. The base of reef slope is 118 m, top 75 m. Rock boulders, 1-2 m diameter, occur near base with *Madracis* coral colonies on vertical faces. The rock slope is 10-30$^{o}$, of very eroded rock, rock boulders, outcrops, and 0.5- 1 m relief. At 85 m depth is the top of the steep slope, and is rounded rock. A gradual slope continues up to 71 m depth and flat sand. Here is mostly sand with patchy rock rubble/cobble, and patchy low relief pavement (<30 cm exposed ledges). The dive continues to the NW outside the MPA, 72-62.5 m, which is flat sand, sparse rubble, exposed pavement, and low ledges. Depth range: 85- 118 m.

Dive 12-21: Near Dive 12-20 but along the upper slope at depths of 65-66 m. Mostly soft bottom sediment with scattered 2-3 m diameter patches of exposed rock with 10-20 cm relief which appear to be excavated bedrock and cobble. Depth range: 65-66 m.

Dive 12-22: Along the lower drop-off near Dive 12-20. Transect heads northeast parallel to face of deep drop-off on multibeam map; depth range 123-92 m. Base of reef is 121 m, top 83 m. Waypoint 1 is in cove of multibeam- 83 m; 50% cover with 0.5-1 m diameter rock boulders, 0.5 m relief. Transect continues to the northeast along face of deep drop-off of multibeam. At 93 m is rock cobble and 0.5 m diameter boulders, 50% rock cover; 97 m- 45$^{o}$ slope; 101 m- flattens out, 10-30% rock cobble, 2 m diameter boulders, 0.5 m relief. The coral *Madracis myriaster* is common from 97-112 m. A series of 30-45$^{o}$ drop-offs and terraces occur on the slope down to

110 m where it flattens out. Most of the slope is rugged, eroded rock with 0.5-1 m relief. At 123 m is flat sand and shell-hash. Lots of fishing line is on the bottom. Depth range: 83-123 m.

Dive 14-15: Transected top ridge of slope. Bottom has large boulders and cobble, with rough surface, covered in green or brown algae, and smooth barren sediment between. The top of the plateau is flatter hardbottom pavement. The rim of the slope has more relief, 1-2 up to 3 m in parts. 80% of the hardbottom is exposed. The slope is 10-30 degrees dropping off to the south. After the dog-leg, the top of the ridge is 3 m tall rock outcrops with undercut ledges and the slope is rock cobble/rubble and small boulders on a 10-20° slope. The rocks are 100% covered in mostly algae and fauna. Depth range: 48-66 m.

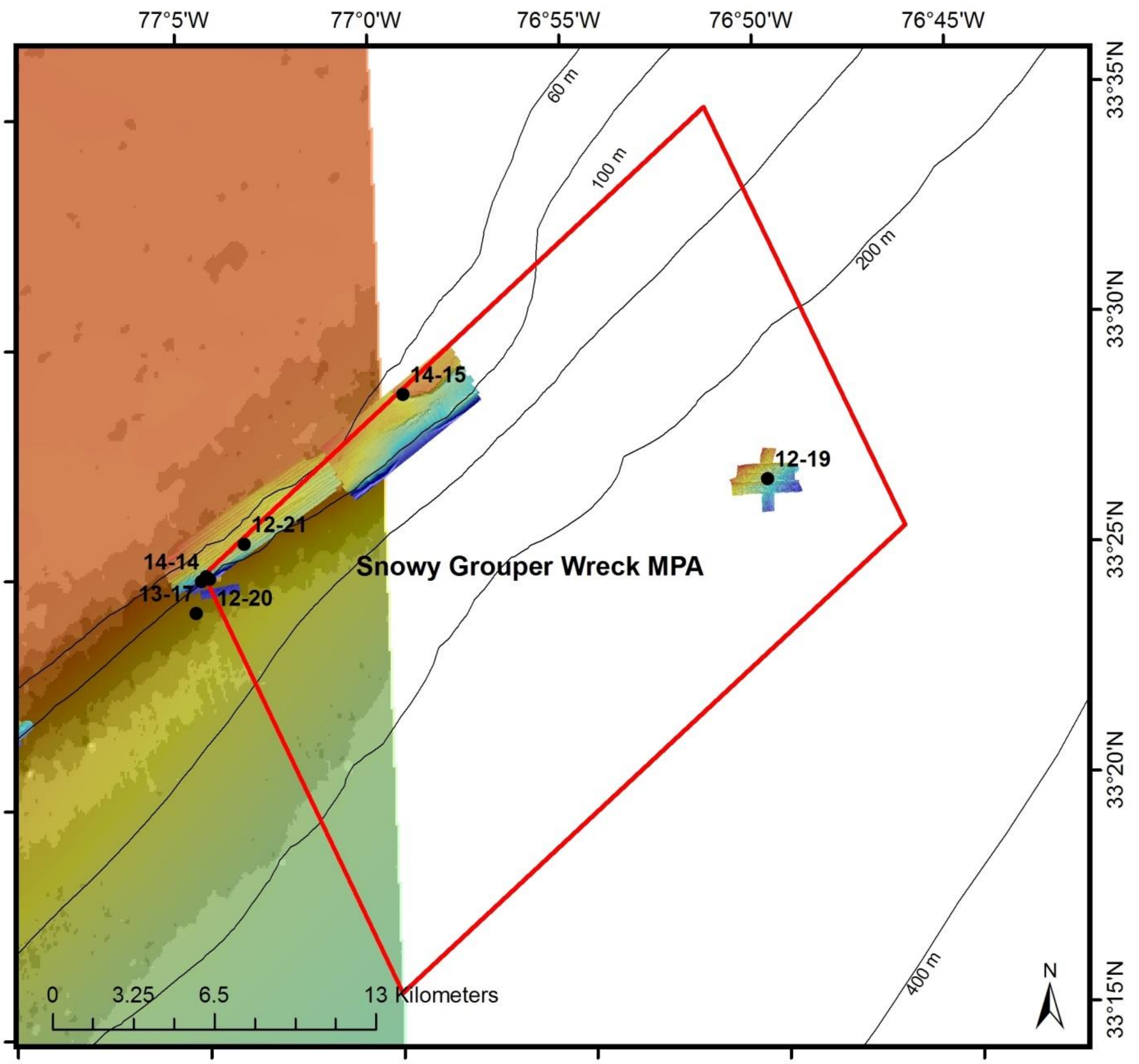



Figure 24. Map of Snowy Wreck MPA off North Carolina with 2012-2014 ROV dive sites. Snowy Grouper shipwreck site is at Dive 12-19.

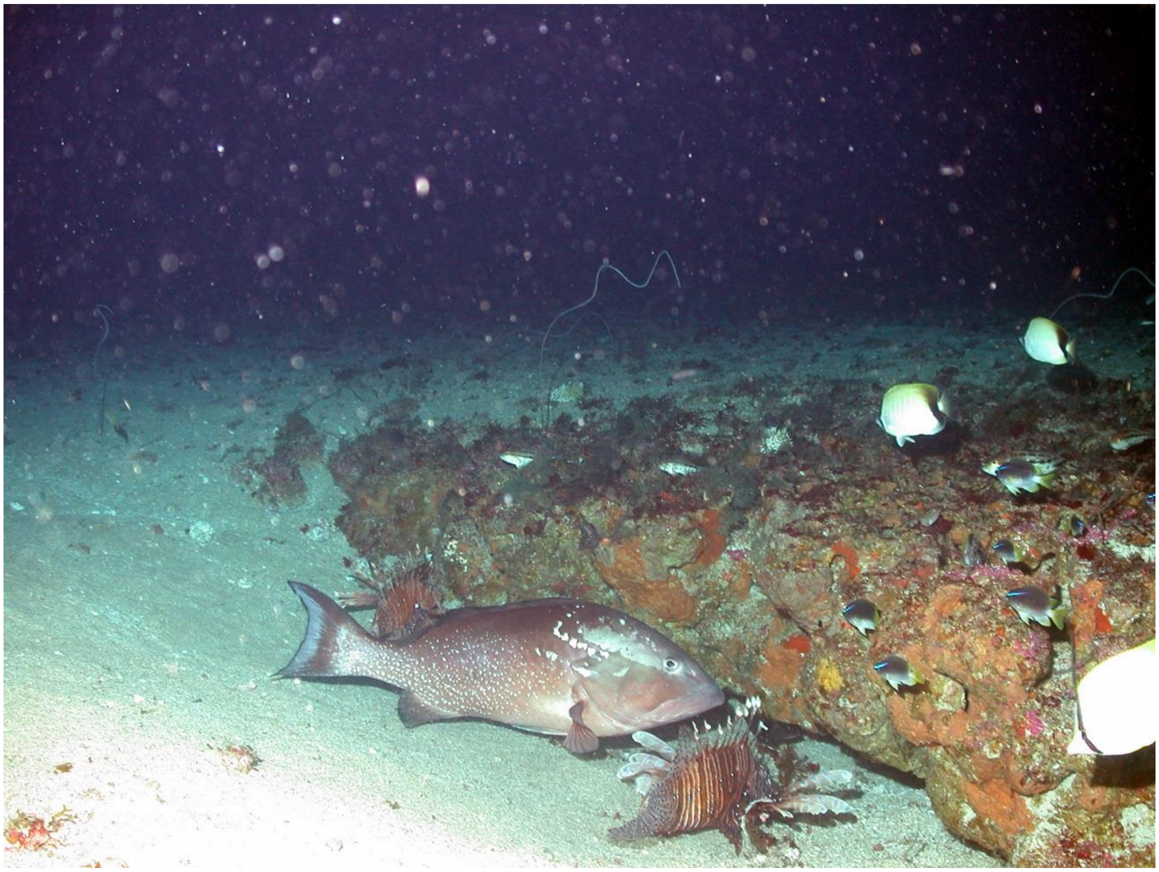


Figure 25. Snowy Wreck MPA (ROV 12-21; 64.7 m). Red grouper (*E. morio*), lionfish (*P. volitans*), and reef butterflyfish (*Chaetodon sedentarius*) on patch of exposed rock.

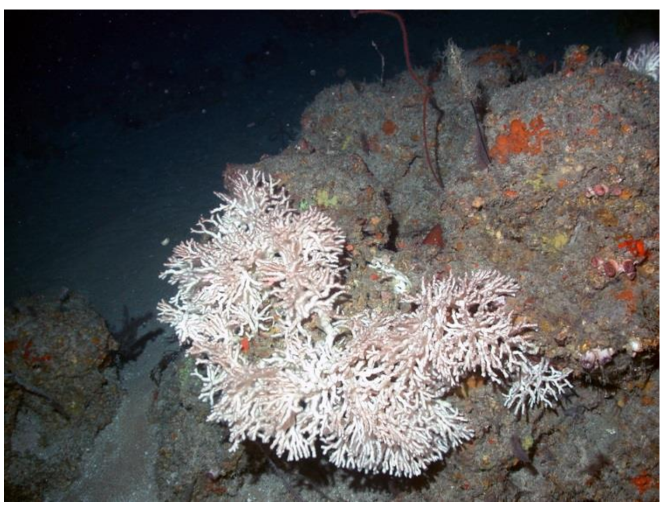


Figure 26. Snowy Wreck MPA (ROV 13-17; 106 m). Large live *Oculina varicosa* coral colony (~50 cm diameter) on rock boulder. The deepwater morphology of *O. varicosa* is white, lacking zooxanthellae.

Snowy Wreck MPA (Wreck Site)

The Snowy Grouper shipwreck lies near the eastern corner of the MPA at depths of 250 m (Figures 24, 27, 28). It is a steel ship of unknown age that is approximately 120 m long and 20 m wide. Known to have once held spawning aggregations of snowy grouper, it was quickly fished down after the wreck was discovered in the 1990's.

Dive 12-19: Transect is along the port hull from bow to stern and on deck. The ship is oriented E-W, bow to west. Maximum depth is 256 m on port side at sediment; bow at deck level is 247 m. Deck level on port side is 245 m; crane on main deck is 242 m. No debris is visible on port side on sediment. The port anchor is in place. The port hull toward the stern is cracked vertically; does not appear to be bent inward or out. Rounded stern is intact; deck plates open; port davits in deployed position over side; with two pairs of davits. The hull is heavily rusted and densely encrusted with anemones, hydroids, gorgonians and sponges. Corals [*Lophelia pertusa* (10-30 cm diameter common; 40-50 cm few)] are common but not abundant. Large schools of snowy grouper were present. Depth range: 242-256 m.

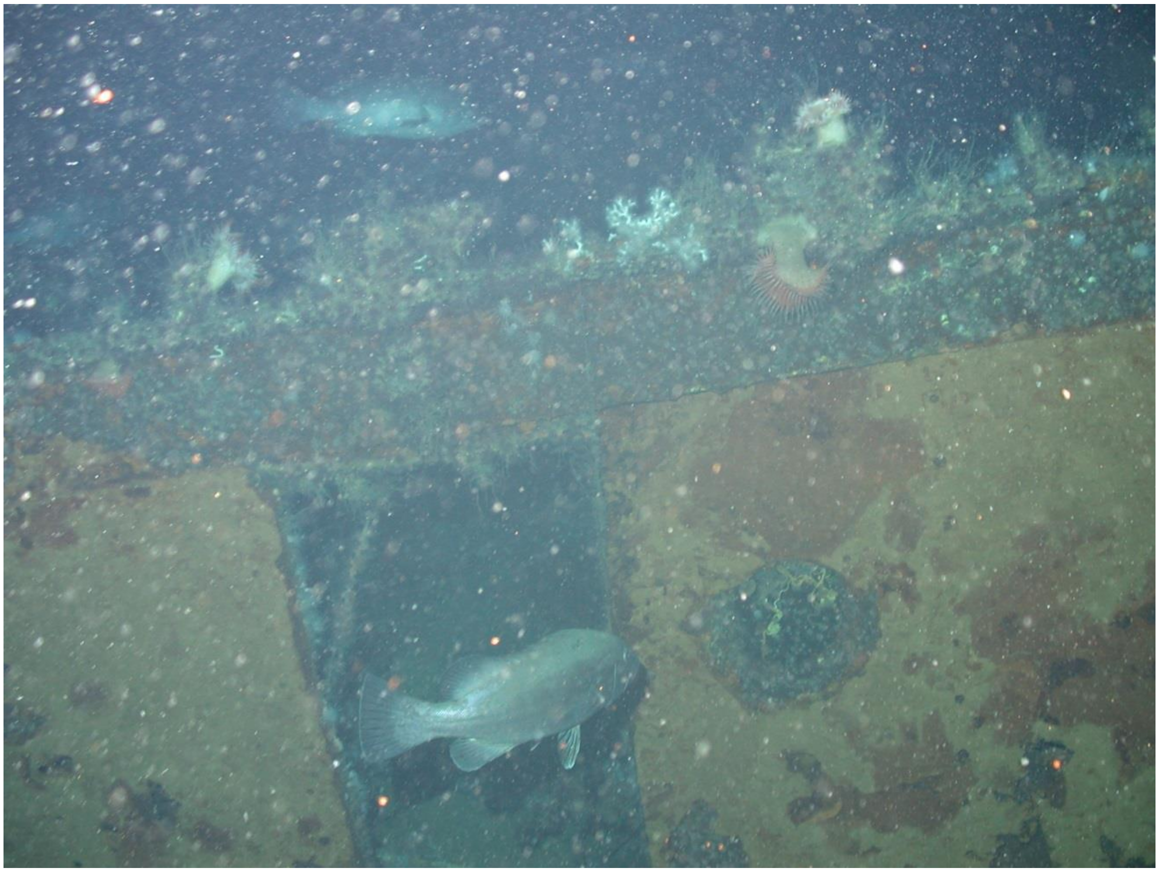


Figure 27. Snowy Wreck MPA (shipwreck site) (ROV 12-19; 240.9 m). Snowy Grouper shipwreck with school of snowy grouper (*H. niveatus*).

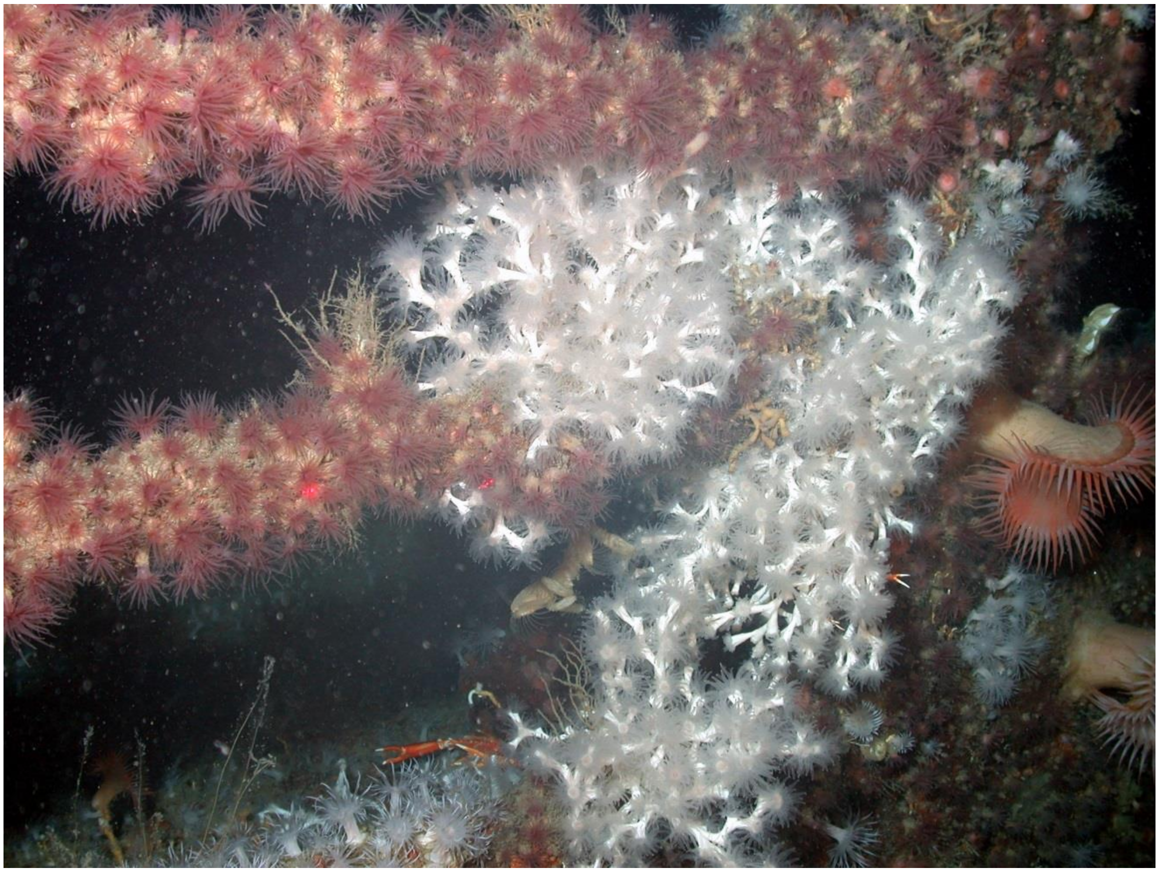


Figure 28. Snowy Wreck MPA (shipwreck site) (ROV 12-19; 250.2 m). *Lophelia pertusa* coral thicket, galatheid crab, *Actinoscyphia* fly-trap anemone, and red anemones on 'Snowy Grouper Shipwreck' railing.

<u>Other Shelf-edge MPA/HAPC Sites off Southeastern U.S.</u>

Other MPA sites off southeastern U.S. include the following but were not part of this study.

Humps MPA: This site is located off the Florida Keys and was described in Reed et al. (2014a) from multibeam surveys and ROV dives in 2011 and from submersible dives in Reed et al. (2005).

St Lucie Humps MPA: No ROV dives or multibeam has been completed of this site off St. Lucie Inlet, Florida. Our team attempted ROV dives in 2010 and 2011 but were unable to get to the bottom due to the strong Florida Current.

*Oculina* HAPC: The deepwater *Oculina* coral reefs have been described in detail from *Johnson-Sea-Link* submersible dives, ROV dives and multibeam (Reed 1980, Reed et al. 2005b, George et al., 2007; Reed et al. 2007, Harter et al., 2009). During our NOAA Ship *Pisces* cruise in 2011, the *Oculina* banks were discovered to extend north of the current HAPC boundaries up to St. Augustine. This has now been added to the extent of the *Oculina* HAPC, nearly doubling its size.

Deep Coral HAPC: The deepwater Coral HAPC was enacted in 2010 and extends from North Carolina to South Florida at depths of 200 m to ~900 m. This habitat is described in Reed et al. (2006) and Reed et al. (2013b).

**Characterization of Fish Populations, Benthic Habitat, and Benthic Macrobiota**

A SEADESC (Southeastern United States Deep-Sea Corals) Level II analysis was presented for each dive in the individual cruise reports (Reed et al., 2013a, 2014b, 2015). These provided the following data for each dive site: cruise and ROV dive metadata, figure showing each ROV dive track overlaid on multibeam sonar maps, plot of ROV temperature profile, dive track data (start and end latitude, longitude, depth), objectives, general description of the habitat and biota, and images of the biota and habitat that characterize the dive site. In addition, these SEADESC Level II reports provided quantitative analyses of each dive site including: 1) CPCe analysis of percent cover of benthic macrobiota and substrate types, and 2) densities of fish populations.

**Analysis of Fish Video Surveys**

One dive was conducted at the wreck site within the Snowy Wreck MPA in 2012 but these data are not included in any of the analyses. Since this dive was not a transecting dive, densities could not be calculated, however a fish species list was assembled and an estimate of abundances made. Fish species observed on the Snowy Wreck included: yellowfin bass (*Anthias nicholsi* - about a dozen of them), snowy grouper (*H. niveatus* - at least 80-100 individuals at the bow area, 40 mid ship, and 80-100 at the stern), one lizardfish (*Synodus* sp.) out in the sand surrounding the wreck, two conger eels running along the base of the wreck, and about a dozen mora cod (*Laemonema* sp.). One ROV dive was also conducted at each of the sunken barges that make up the Charleston Artificial Reef MPA in 2014 and these data are also not included in the analyses. Since they had been sunk only two months prior to diving on them, the only fish species present thus far were schools of amberjack (*Seriola* sp.) circling above the barges. ROV dives will be made in subsequent years on these barges so that a comparison of fish assemblages over time can be made.

Appendix 2 lists all fish species identified from the quantitative video transects at each dive site and their densities (# individual 1000 $m^{-2}$). A total of 167 species were observed. The areas with the highest overall densities of fish were Northern S. Carolina MPA, Outside Northern S. Carolina MPA, and Outside Snowy Wreck MPA and this was primarily due to large numbers of schooling tomtate (*H. aurolineatum*) at all locations and anthiids outside Snowy Wreck. The lowest overall densities of fish were observed outside the Georiga MPA and both inside and outside the Northern S. Carolina iceberg scar sites. The lower densities of fish outside the Georgia MPA is most likely due to the lower habitat relief there compared to the other MPAs and the iceberg scar sites are much deeper than all other sites which probably explains the low densities of fish in those areas. Five of the target species were observed including: speckled hind (*E. drummondhayi*), warsaw grouper (*Hyporthodus nigritus*), snowy grouper (*H. niveatus*), yellowedge grouper (*H. flavolimbatus*), and blueline tilefish (*Caulolatilus microps*). The most abundant grouper species was scamp (*M. phenax*) and the most abundant snapper species was gray snapper (*Lutjanus griseus*).

Fish assemblages inside and outside each MPA were compared using a multi-dimensional scaling (MDS) plot of Bray-Curtis similarities using fourth-root transformed data of fish species. Fish assemblages for the iceberg scar sites were such outliers compared to all other locations, so a subset MDS plot was constructed of all locations minus the iceberg scar sites (Figure 29; PRIMER 6.0). Five statistically different groups resulted from the SIMPROF test ($p<0.05$). Letters in the figure indicate statistically significant groups. Fish assemblages were more similar by geographic region than they were by level of protection (inside vs. outside). Fish assemblages inside and outside each area grouped together at the 75% similarity level with the exception of Snowy Wreck and Georgia.

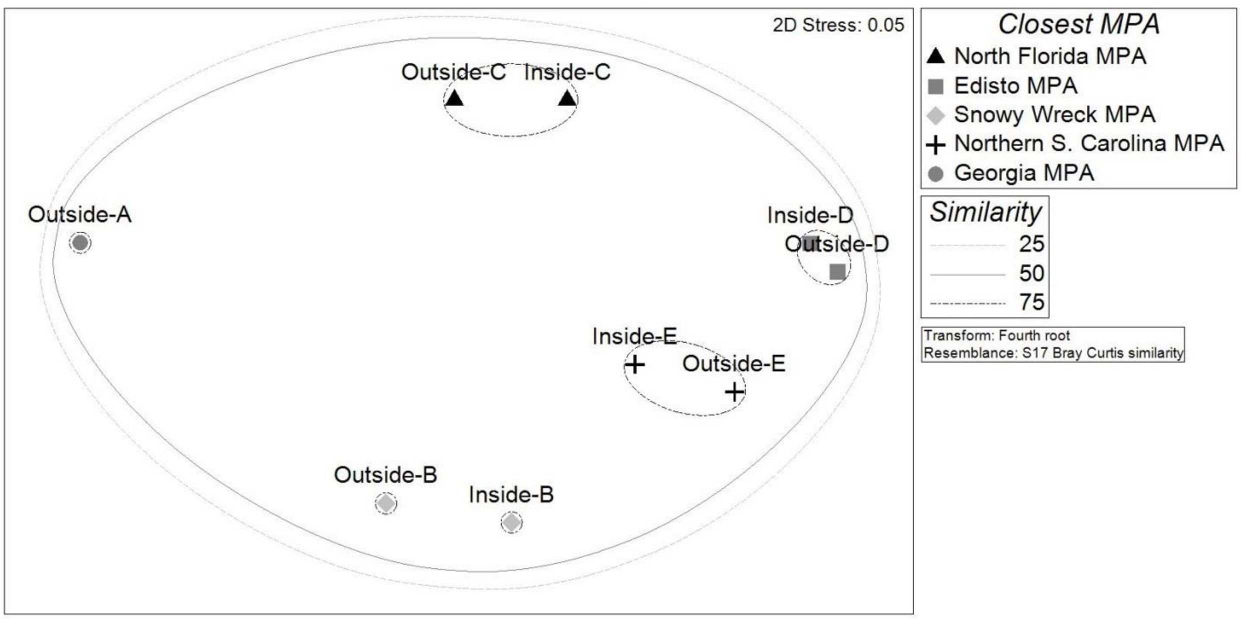



Figure 29. Multi-dimensional scaling (MDS) plot of ROV dive sites within and outside of the protected management areas (MPAs) based on Bray-Curtis similarity matrix calculated using fourth-root transformed data of fish species during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Assemblage similarity at 25, 50, and 75% are indicated. Statistically different groups (SIMPROF, $p<0.05$) are indicated by letters A-D.

Densities of fish species in the snapper-grouper complex were compared inside and outside for each of the MPAs (Table 5). No dives were made inside the Georgia MPA, so comparisons could not be made. Thirty-three species in the snapper-grouper complex were observed on the ROV dives between 2012 and 2014. Average densities of red porgy (*Pagrus pagrus*), blackfin snapper (*Lutjanus buccanella*), and almaco jack (*Seriola rivoliana*) were higher inside the Snowy Wreck MPA compared to outside. Species such as blueline tilefish (*C. microps*), scamp (*M. phenax*), red porgy (*P. pagrus*), and yellowedge grouper (*H. flavolimbatus*) had higher densities inside the Northern S. Carolina MPA (iceberg scar sites). Tomtate (*H. aurolineatum*), white grunt (*Haemulon plumieri*), and gag (*Mycteroperca microlepis*) were among the species more abundant inside Northern S. Carolina MPA compared to outside. Triggerfish (grey – *Balistes capriscus* and queen – *Balistes vetula*) as well as rock hind (*Epinephelus adscensionis*) were more abundant inside the Edisto MPA. Several species had higher average densities inside the North Florida MPA compared to outside. A few of these include: tomtate (*H. aurolineatum*), vermilion snapper (*Rhomboplites aurorubens*), gag (*M. microlepis*), gray snapper (*L. griseus*), and red porgy (*P. pagrus*). There were also fish species that had higher average densities outside each of the MPAs. For this particular table, statistical analyses were not used when determining if average densities were higher inside or outside the MPA. They are based strictly on raw densities. Figure 30 shows where target species were observed as well as any large aggregations of snapper and grouper species. The target species includes the seven deepwater grouper and tilefish the MPAs were originally designed to protect. Aggregations in Figure 30 are not necessarily spawning aggregations (even though spawning coloration and behaviors were observed on a few occasions) but were high densisites of a species together in a small area, which is fairly uncommon for the larger snapper and grouper species.

Table 5. Densities (# individual 1000 $m^{-2}$) for species of the snapper-grouper complex inside and outside each MPA during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). A “Y” indicates a species had a higher density inside compared to outside the MPA while a “N” indicates a species did not have a higher density inside compared to outside the MPA.

| Scientific_Name | Snowy Wreck MPA | Outside Snowy Wreck MPA | Higher Inside MPA | Northern S. Carolina MPA (iceberg scar site) | Outside Northern S. Carolina MPA (iceberg scar site) | Higher Inside MPA | Northern S. Carolina MPA | Outside Northern S. Carolina MPA | Higher Inside MPA | Edisto MPA | Outside Edisto MPA | Higher Inside MPA | Outside Georgia MPA | North Florida MPA | Outside North Florida MPA | Higher Inside MPA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Balistes capriscus* | 0.00 | 32.92 | N | | | | 0.89 | 4.86 | N | 3.47 | 2.61 | Y | 1.22 | 1.67 | 1.56 | Y |
| *Balistes* sp. | | | | | | | | | | 0.50 | 0.88 | N | | 1.00 | | Y |
| *Balistes vetula* | | | | | | | 0.50 | 0.00 | Y | 2.00 | 0.88 | Y | | 1.25 | 0.33 | Y |
| *Calamus* sp. | 1.50 | 3.53 | N | | | | 7.74 | 6.43 | Y | 4.88 | 5.95 | N | 0.60 | 1.11 | 1.15 | N |
| *Caulolatilus microps* | | 0.67 | N | 1.81 | 0.67 | Y | | | | | | | | | | |
| *Centropristis striata* | | | | | | | 0.00 | | Y | | | | 1.00 | | | |
| *Cephalopholis cruentata* | 0.60 | 3.25 | N | | | | 1.88 | 2.12 | N | 2.32 | 2.02 | Y | | 0.00 | | Y |
| *Epinephelus adscensionis* | 0.00 | 5.50 | N | | | | 1.50 | 1.50 | N | 3.00 | 1.36 | Y | | | | |
| *Epinephelus drummondhayi* | 0.00 | 0.50 | N | | | | 1.00 | 1.67 | N | | 1.00 | N | | 1.00 | 2.33 | N |
| *Epinephelus morio* | 2.00 | 2.67 | N | | | | 2.00 | 1.00 | Y | | 0.00 | N | | | 0.00 | N |
| *Haemulon album* | | | | | | | | | | | | | | | 0.00 | N |
| *Haemulon aurolineatum* | 98.33 | 1041.80 | N | | | | 2271.00 | 992.55 | Y | 571.27 | 937.27 | N | 2.00 | 174.26 | 159.31 | Y |
| *Haemulon melanurum* | | | | | | | | | | | 1.00 | N | | | | |
| *Haemulon plumieri* | | | | | | | 23.25 | 2.21 | Y | 1.11 | 1.80 | N | | | | |
| *Haemulon* sp. | | | | | | | | 181.00 | N | | 163.33 | N | | | | |
| *Haemulon striatum* | 8.00 | 423.50 | N | | | | 57.60 | 167.83 | N | 128.83 | 143.80 | N | | 26.64 | 1.00 | Y |
| *Hyporthodus flavolimbatus* | | 1.00 | N | 6.00 | | Y | | | | | | | | | | |
| *Hyporthodus nigritus* | | | | | | | | | | | | | | 1.00 | 1.00 | N |
| *Hyporthodus niveatus* | | 1.60 | N | 4.70 | 6.23 | N | 5.00 | 6.75 | N | 0.00 | 0.00 | | | 0.00 | | Y |
| *Lachnolaimus maximus* | 0.80 | 4.86 | N | | | | 2.50 | 3.59 | N | 1.20 | 0.96 | Y | 0.00 | 0.00 | 0.38 | N |
| Lutjanidae | | | | | | | | | | 2.00 | | Y | | | | |
| *Lutjanus analis* | | | | | | | | | | | | | | 2.00 | | Y |
| *Lutjanus apodus* | | | | | | | | | | | | | | | 0.00 | N |
| *Lutjanus buccanella* | 4.00 | | Y | | | | | | | | 1.00 | N | | | 0.50 | N |
| *Lutjanus campechanus* | | | | | | | | | | | | | 1.00 | 0.00 | | Y |
| *Lutjanus griseus* | | | | | | | | 14.00 | N | 4.00 | 9.29 | N | | 1.50 | 0.00 | Y |
| *Lutjanus jocu* | | | | | | | | | | 0.00 | | Y | | | | |
| *Lutjanus* sp. | | 1.00 | N | | | | 1.00 | 0.00 | Y | 0.25 | | Y | | 1.00 | | Y |
| *Mycteroperca interstitialis* | | 1.00 | N | | | | | 0.00 | N | 0.00 | 1.00 | N | | | | |
| *Mycteroperca microlepis* | 1.00 | 2.50 | N | | | | 8.20 | 1.79 | Y | 1.14 | 1.14 | N | 0.67 | 2.00 | 0.00 | Y |
| *Mycteroperca phenax* | 2.67 | 3.97 | N | 1.00 | | Y | 7.29 | 7.13 | Y | 6.83 | 9.73 | N | 4.33 | 3.43 | 3.25 | Y |
| *Mycteroperca* sp. | 0.00 | 1.00 | N | | | | 1.00 | 0.00 | Y | 0.75 | 1.00 | N | | | | |
| *Ocyrus chrysurus* | | | | | | | | | | | 1.00 | N | | | | |
| *Pagrus pagrus* | 9.80 | 3.20 | Y | 24.07 | 4.69 | Y | 15.29 | 19.22 | N | 12.30 | 13.30 | N | 8.63 | 9.20 | 2.69 | Y |
| *Rhomboplites aurorubens* | 5.50 | 288.50 | N | | | | 16.00 | 106.94 | N | 122.03 | 220.62 | N | 3.33 | 309.30 | 184.70 | Y |
| *Seriola dumerili* | 0.00 | 1.11 | N | | | | 3.40 | 4.29 | N | 0.85 | 3.38 | N | 2.50 | 5.00 | 11.13 | N |
| *Seriola fasciata* | | 0.00 | N | | | | | 16.33 | N | | | | | | | |
| *Seriola rivoliana* | 4.86 | 4.83 | Y | | 0.00 | N | 0.70 | 2.10 | N | 2.00 | 6.25 | N | 0.00 | 1.20 | 2.56 | N |
| *Seriola* sp. | 1.00 | 7.32 | N | | 23.00 | N | 13.42 | 4.52 | Y | 2.97 | 5.37 | N | 2.55 | 2.25 | 2.50 | N |
| Sparidae | | 1.33 | N | | | | 3.17 | 23.40 | N | 2.88 | 6.75 | N | 2.00 | 1.40 | 0.89 | Y |
| **Grand Total** | **14.93** | **43.94** | **N** | **11.86** | **6.67** | **Y** | **140.27** | **120.43** | **Y** | **91.11** | **148.50** | **N** | **3.74** | **82.65** | **71.24** | **Y** |

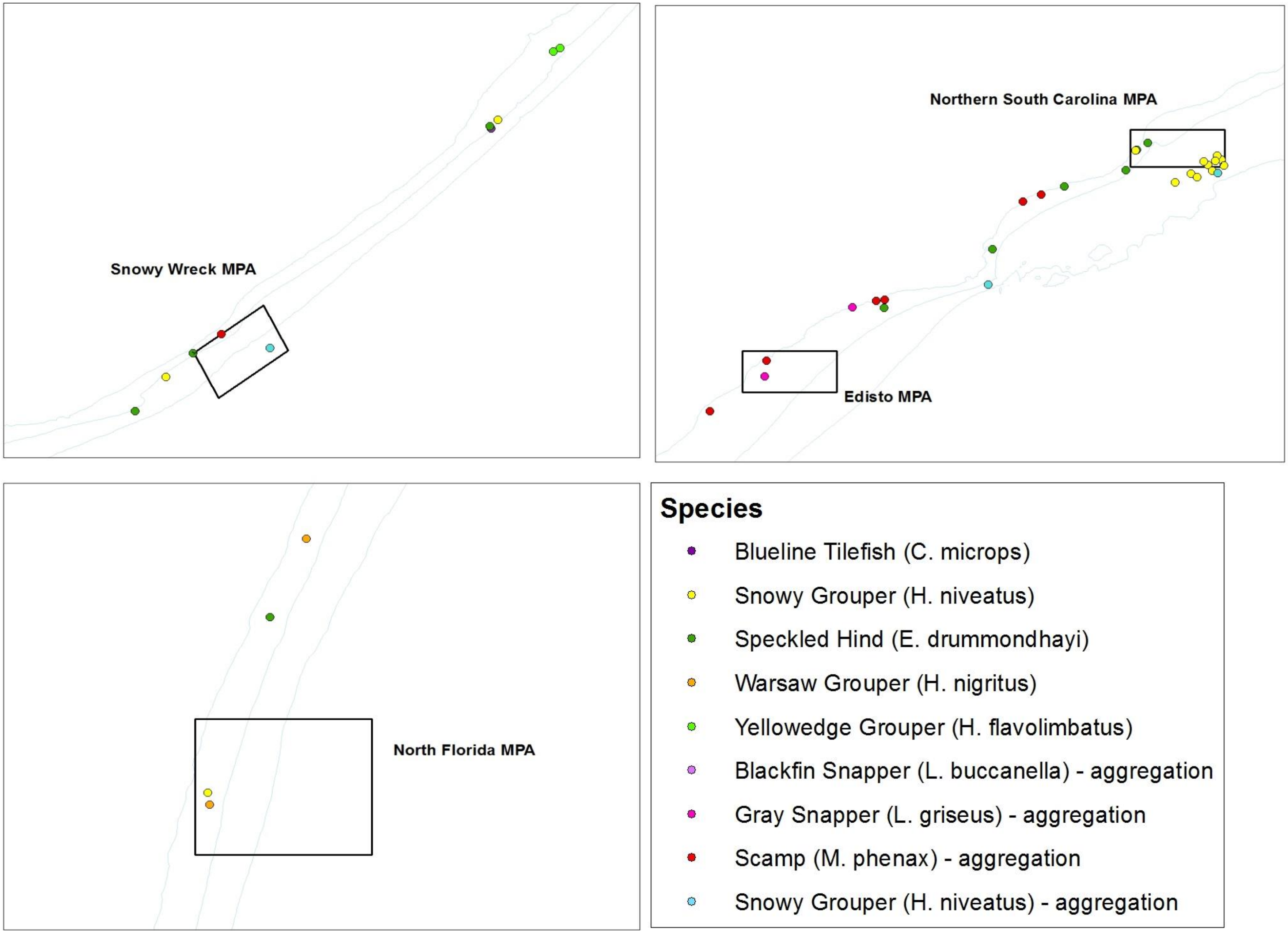
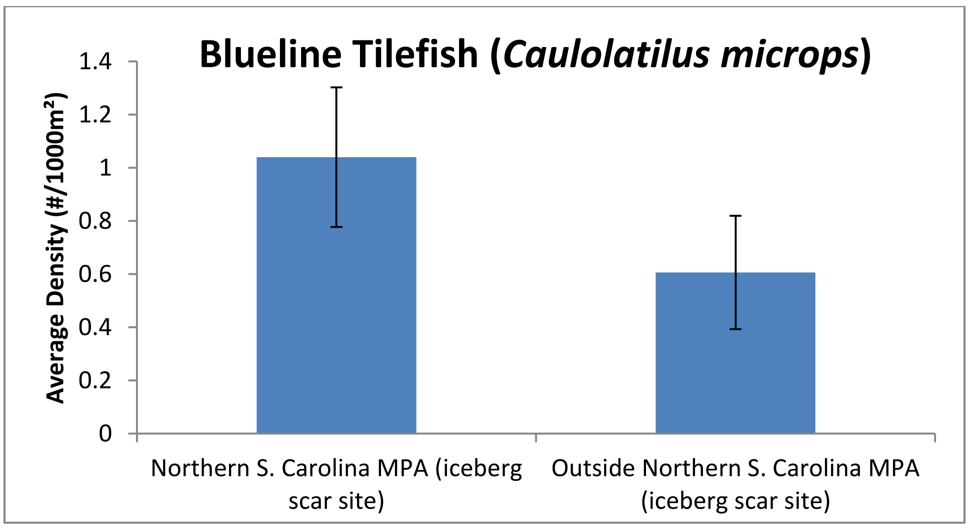
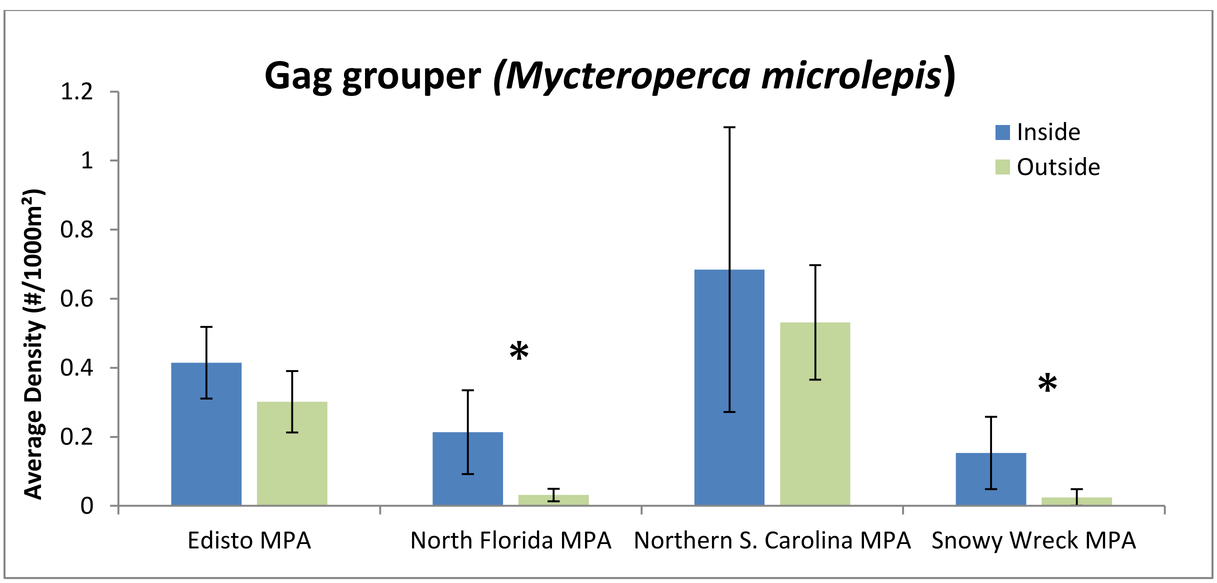
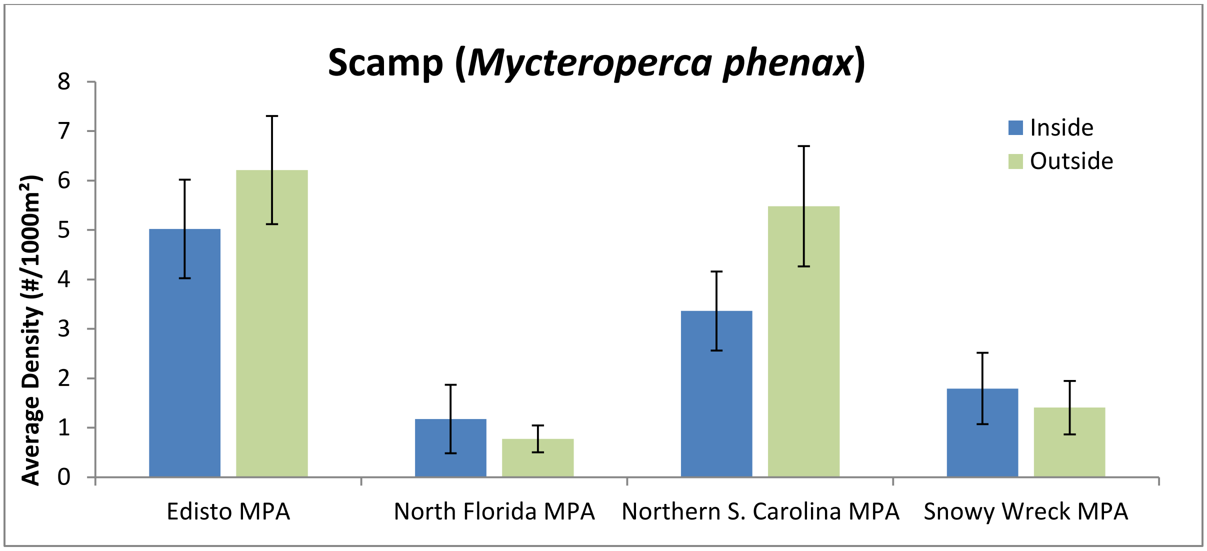


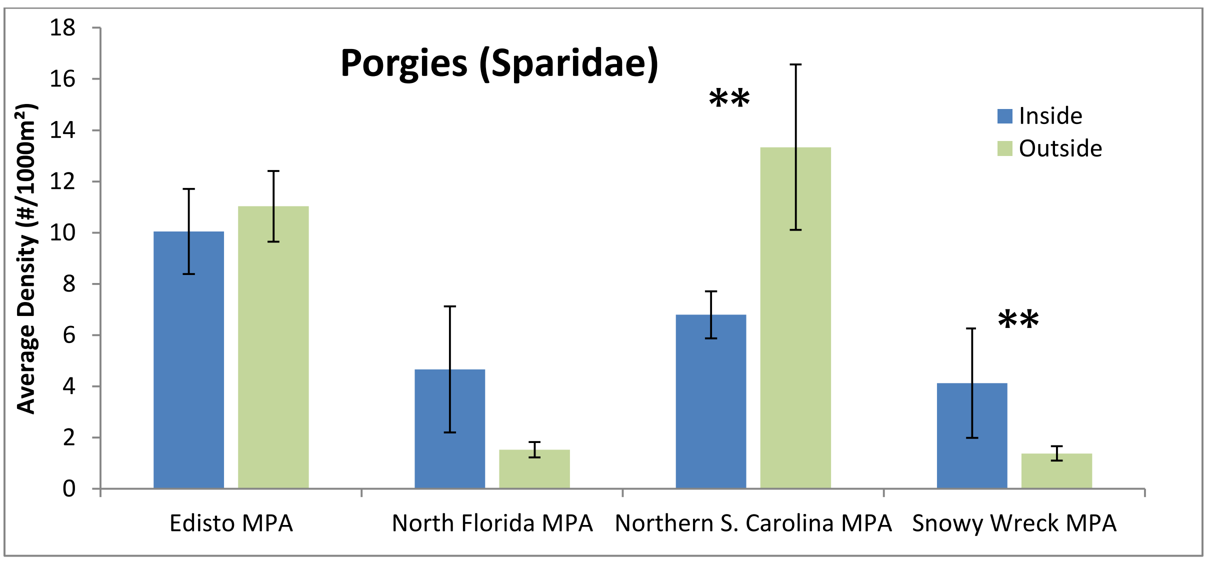

Figure 30. Maps showing where target grouper and tilefish species were observed during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08) as well as any large aggregations of snapper and grouper species.

A one-way ANOVA was conducted on several of the more abundant snapper-grouper complex species to determine if there were significant differences in fish densities inside vs. outside the MPAs (Figure 31). Blueline tilefish (*C. microps*) were only observed on the iceberg scar sites, so only the Northern S. Carolina MPA was tested for this species. There was no significant difference ($p = 0.24$) in mean densities of blueline tilefish among management areas; however, in general, densities were higher inside the MPA. Gag (*M. microlepis*) had higher densities inside all of the MPAs compared to outside, but it was only marginally significant for North Florida MPA ($p = 0.06$) and Snowy Wreck MPA ($p = 0.07$). Scamp (*M. phenax*), the most abundant grouper observed, had higher densities inside North Florida MPA and Snowy Wreck MPA and lower densities inside Edisto MPA and Northern S. Carolina MPA, but none of these trends were statistically significant. Sparidae, a combination of red porgy (*P. pagrus*) and *Calamus* sp. had significantly higher densities outside the Northern S. Carolina MPA ($p = 0.04$) and inside the Snowy Wreck MPA ($p = 0.02$). Tomtate (*H. aurolineatum*), the most abundant schooling fish observed, had higher densities outside the Edisto and this trend was marginally significant ($p = 0.08$).




Scamp (Mycteroperca phenax)
Average Density (#/1000m²)
0
1
2
3
4
5
6
7
8
Inside
Outside
Edisto MPA
North Florida MPA
Northern S. Carolina MPA
Snowy Wreck MPA


Porgies (Sparidae)
Average Density (#/1000m²)
0
2
4
6
8
10
12
14
16
18
**
**
Inside
Outside
Edisto MPA
North Florida MPA
Northern S. Carolina MPA
Snowy Wreck MPA

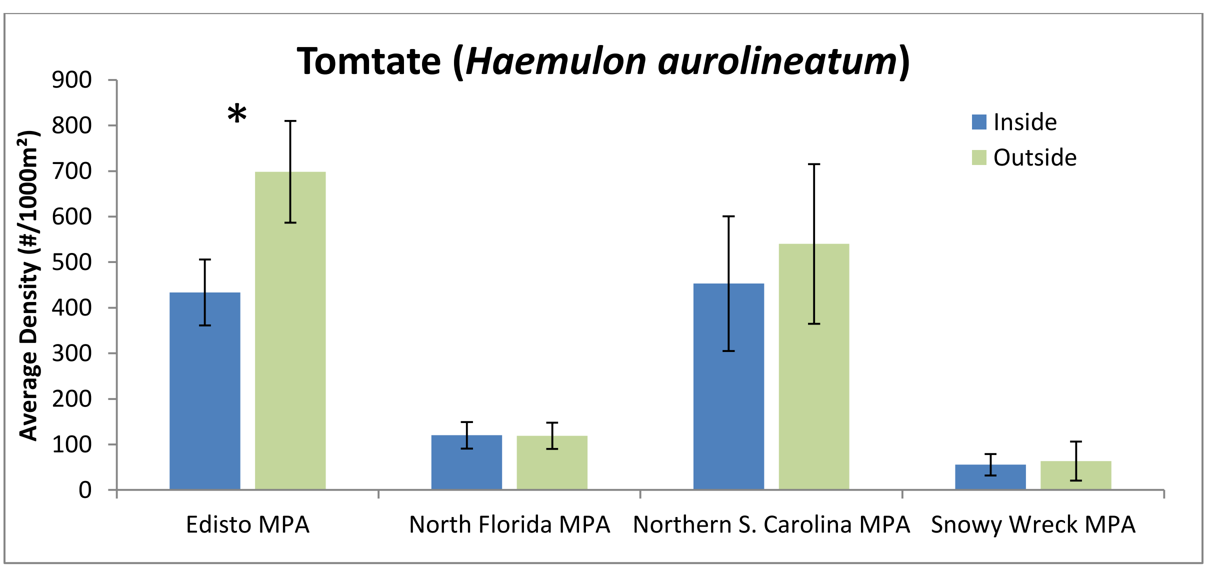

Tomtate (Haemulon aurolineatum)
Average Density (#/1000m²)
0
100
200
300
400
500
600
700
800
900
*
Inside
Outside
Edisto MPA
North Florida MPA
Northern S. Carolina MPA
Snowy Wreck MPA

Figure 31. Average densities of blueline tilefish (*C. microps*), gag grouper (*M. microlepis*), scamp (*M. phenax*), porgies (Sparidae), and tomtate (*H. aurolineatum*) inside and outside each MPA from quantitative ROV video transects during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). An "*" indicates a marginally significant result from one-way ANOVA and a "**" indicates a highly significant result from one-way ANOVA test.

**Lionfish Populations**

Lionfish (*P. volitans*) continue to have a strong presence in and around the south Atlantic MPAs. Densities inside and outside each MPA are presented in Figure 32. A one-way ANOVA was run for each MPA to test for significant differences in lionfish densities inside vs. outside the MPA. The only significant result was higher lionfish densities outside the Northern S. Carolina MPA compared to inside (p=0.002). Overall, lionfish densities were higher in and around the two MPAs off South Carolina and lowest off North Florida. Average lionfish densities for each year are shown in Figure 33. Even though variances were high in 2013, it appears that lionfish densities may be decreasing over time, especially in 2014. The difference thus far, however, is not significant (p=0.1) but it will be interesting to see if this decreasing trend continues in subsequent years.

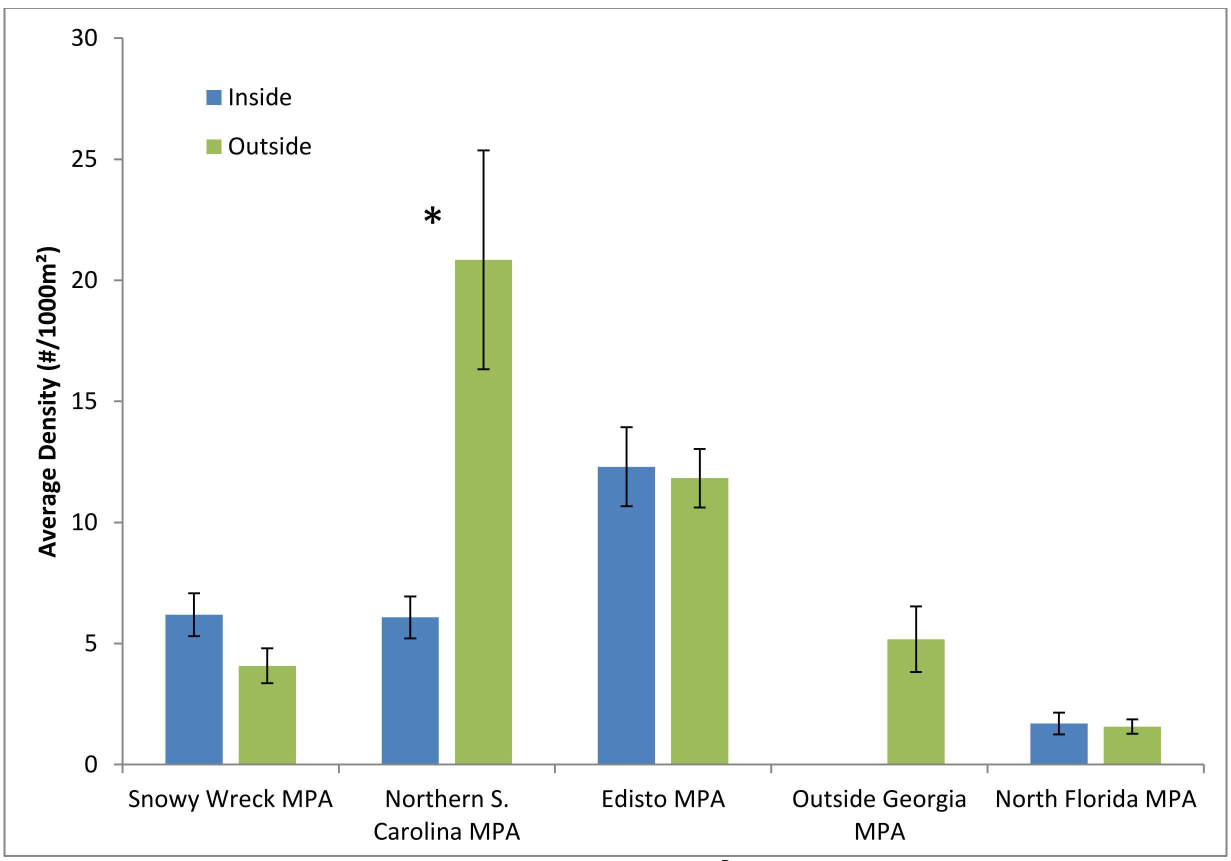



Figure 32. Densities of lionfish (# individuals 1000 $m^{-2}$) from quantitative ROV video transects during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise

(14-08), at sites inside and outside each shelf-edge MPA. An "*" indicates a significant difference in lionfish densities for that MPA (ANOVA, $p<0.05$).

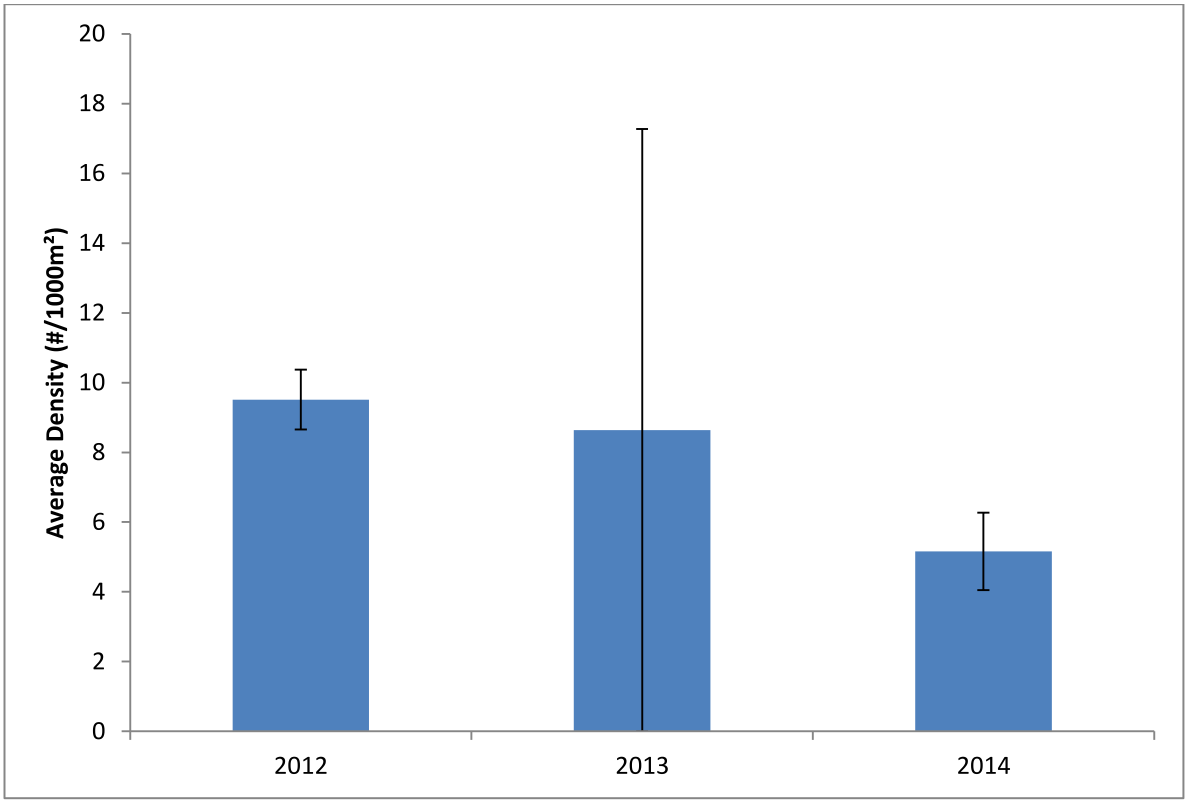



Figure 33. Lionfish densities (# individuals 1000 $m^{-2}$) based on quantitative ROV video transects summarized by year during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08).

**Fish Communities and Habitat Relationships**

Interrelationships of the fish communities with habitat factors were analyzed with MDS plots of similarity (Figure 34). Depth was the most influential factor contributing to fish species composition. Depth of ROV dives was divided into three categories (45-80 m, 81-120 m, and 121-170 m). The MDS plot of depth shows two distinct groupings with all the deepest dives (depths of 121–170 m) clustering together at 40% similarity. These dives consisted of all those conducted at the iceberg scar sites inside and outside of the Northern S. Carolina MPA. Because of the deeper depths here, a distinct community of fish species were observed. The shallower sites (depths of 45–120 m) clustered together at 20%. An Analysis of Similarity (ANOSIM) was conducted on the depth data and confirmed the strong influence of this factor ($R=0.699$) and Similarity Percentages (SIMPER) tests indicated that this difference was due to higher densities of anthiids (Anthiinae), scorpionfish (Scorpaenidae), deepbody boarfish (*Antigonia capros*), and snowy grouper (*H. niveatus*) on the 121-170 m dives.

Habitat type was the second most influential factor in determining fish species composition. Habitat type was divided into four hardbottom categories: pavement (no relief), LRO (low relief outcrops; <1 m relief), MRO (moderate relief outcrops; 1-3 m relief), and HRL (high relief ledge; >3 m relief). Three statistically different groups resulted from the SIMPROF test ($p$< .05). All habitat types except for pavement grouped together at the 75% similarity level. Dives conducted on pavement displayed a distinct fish community and densities. SIMPER analyses indicated that this difference was due primarily to lower densities of tomtate and vermilion snapper and higher densities of short bigeye (*Pristigenys alta*) and tattler (*Serranus phoebe*) on pavement habitat.

Surprisingly, rugosity didn't have much impact on fish species composition and densities (ANOSIM, R=0.156). Year also was not influential on fish assemblages (ANOSIM, R=0.024).

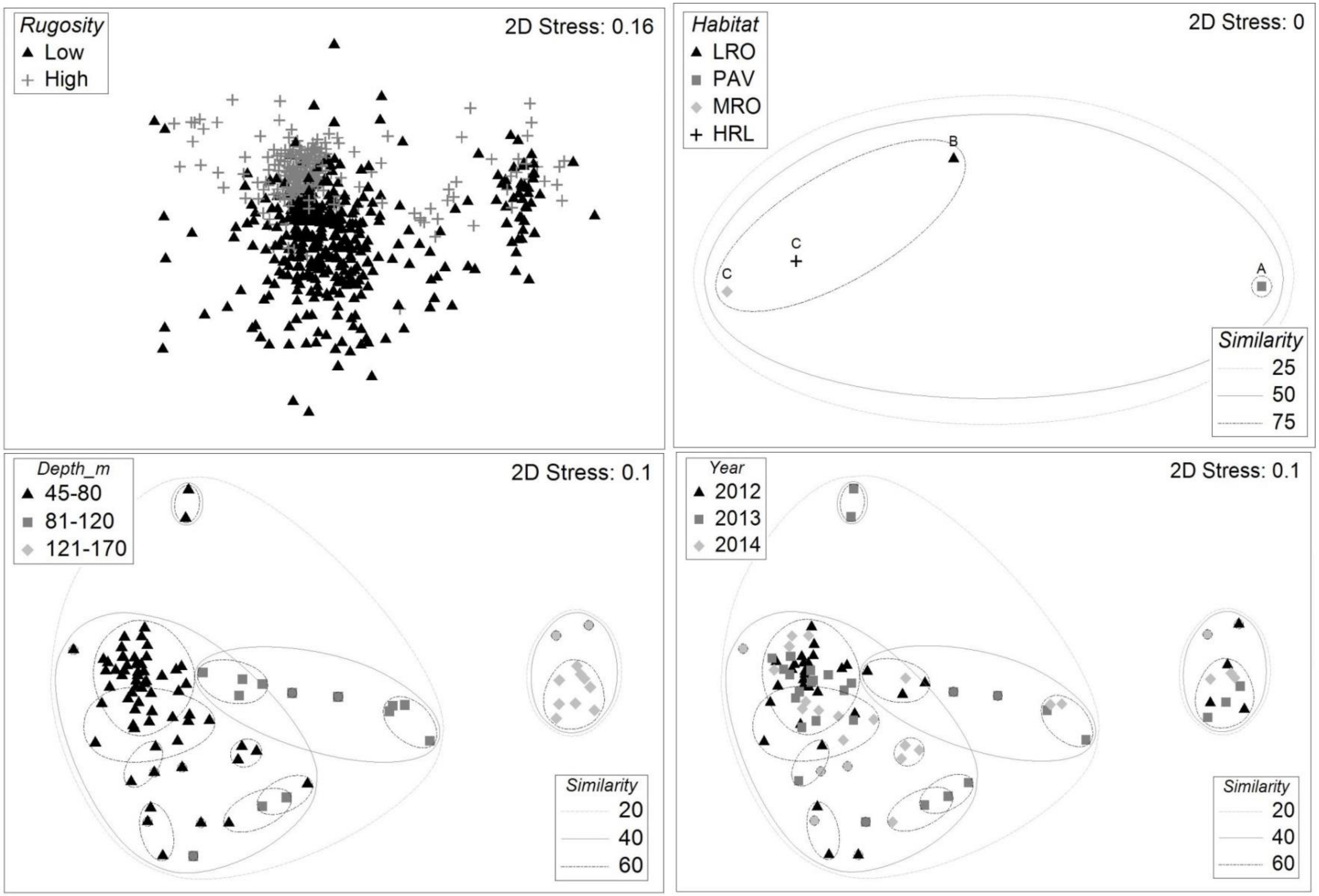



Figure 34. Multi-dimensional scaling (MDS) plot of ROV dive sites based on Bray-Curtis similarity matrix calculated using fourth-root transformed data of fish species during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Fish densities vs. rugosity, habitat type, depth, and year. Habitat types are abbreviated: PAV= pavement (no relief), LRO = low relief outcrops (<1 m relief), MRO= moderate relief outcrops (1-3 m relief), and HRL= high relief ledge (>3 m relief). Assemblage similarity percentages are indicated for habitat, depth, and year. Statistically different groups (SIMPROF, $p<0.05$) are indicated by letters A-C for habitat

**Benthic Habitat and Macrobiota**

Appendix 1 lists the species of benthic macro-invertebrates and algae that were identified from the photo transects over all three years and their percent cover based on CPCe Point Count of the quantitative images. The individual cruise reports (Reed et al., 2013a, 2014b, 2015) present the data for each dive. Appendix 1 and the following results of this report combine the dives by dive site regions which are defined as: the 6 MPA sites, and their respective 'Outside MPA' sites; for example, 'North Florida MPA' and 'Outside North Florida MPA'. The 'Outside' sites are adjacent to the respective MPA but are not protected.

A total of 136 taxa of benthic macrobiota were identified from the quantitative photo transects and were used for CPCe percent cover analyses. These included 39 taxa of Cnidaria which included the following corals: 7- Scleractinia hard corals (*Oculina varicosa*, *Lophelia pertusa*, *Madracis myriaster*, *Madrepora oculata*, *Phyllangia americana*, Scleractinia unidentified colonial, and Scleractinia unidentified solitary); 16- Octocorallia (including, *Bebryce* sp., *Diodogorgia* sp., *Ellisella* spp., Ellisellidae, *Iciligorgia schrammi*, *Leptogorgia* sp., *Muricea sp.*, *Nicella* sp., Primnioidae, *Telesto* sp., and *Titanideum frauenfeldii*); and 5- Antipathidae (*Antipatharia atlantica*, *Antipathes* sp. A, *Tanacetipathes hirta*, and *Stichopathes lutkeni*). Alcyonian soft corals included *Anthomastus* sp., *Chironephthya caribaea*, and *Nidallia occidentalis*. Non-coral Cnidaria included Actiniaria, Corallimorpharia, Zoantharia, *Virgularia presbytes* (sea pen), and Hydroidolina (hydroids).

Porifera were most species rich with 52 taxa; the dominant sponges were demosponges including: *Agelas* sp., *Aiolochroia crassa*, *Aplysina* sp., Astrophorida, *Auletta* sp., *Callyspongia vaginalis*, *Chondrilla* sp., *Chondrosia* sp., *Cinachyra*/*Cinachyrella* sp., *Clathria* sp., *Cliona* sp., Corallistidae, Dictyoceratida, *Desmapsamma anchorata*, *Erylus* sp., *Geodia* sp., *Ircinia campana*, *Ircinia strobilina*, *Leiodermatium* sp., *Neofibularia nolitangere*, *Niphates* sp., *Oceanapia* sp., Poecilosclerida, *Polymastia* sp., *Scopalina* sp., *Siphonodictyon coralliphagum*, Spirastrellidae, *Spongosorites* sp., *Theonella* sp., *Xestospongia muta*, and *Zyzzya* sp. Only one species of Hexactinellida (glass sponge) was identified, *Farrea* sp. Other fauna included Annelida, Mollusca, Arthropoda, Bryozoa, Ascidiacea, and Echinodermata (18 taxa; including, *Arbacia punctulata, Asteroporpa annulata, Centrostephanus meridionalis, Davidaster discoideus, Eucidaris tribuloides, Goniaster tessalatus,* Gorgonocephalidae, *Holothuria lentigenosa, Luidia alternata, Narcissia trigonaria, Ophioderma devaneyi,* and *Paracolochirus mysticus*). Algae were dominant at many of the sites and included Phaeophyta (dominated by *Dictyota* spp.), Chlorophyta, and Rhodophyta (primarily crustose coralline algae); but these were not identified to species level.

CPCe Point Count analysis calculated the percent cover of substrate type and benthic macrobiota and was averaged by region and MPA status (Table 6, Appendix 1). First, the percent cover of hard bottom versus soft bottom was calculated for each region (Figure 35). This did not include points on biota but was based on what type of substrate was under any point on biota. In general, the cover of hard bottom was high in all MPA reef sites (excluding the artificial reefs) ranging from 44.37% at the Snowy Wreck MPA to 67.14% at Edisto MPA. No ROV dives were within the Georgia MPA but the sites outside the Georgia MPA had the lowest cover of hard bottom of all (19.39%). The range of macrobiota cover for the MPA sites ranged from 6.27% at the iceberg scar site of the Northern S. Carolina MPA to 65.7% at the Snowy Wreck MPA shipwreck site (Figure 36, Table 6). In general, the shallower mesophotic reef sites (40-100 m) at South Carolina (Edisto and Northern S. Carolina) had much greater cover of biota (41.05-49.32%) compared to the deeper iceberg scar sites (150-170 m) at Northern S. Carolina (6.27-10.15%). The Outside Georgia MPA sites had the lowest cover of biota (3.62%) of all the reef sites. The Charleston Deep Reef MPA site which consisted of the recently sunken barges had no macrofauna and were not included in the point count analyses.

Overall, algae were the dominant cover averaging 15.76% for all sites (Table 6, Appendix 1). Figure 37 clearly shows the reef sites off South Carolina had much greater algal cover (average 23.93%; maximum of 34.32% at Edisto MPA) than the other regions. Sponges (Porifera) were the next most common taxa averaging 3.42% for all sites. These were relatively of similar density over all the regions (excluding the Outside Georgia sites which were primarily soft sediment) but was greatest at the Florida sites (5.95%).

Table 6. Fish densities from ROV video transects and percent cover of benthic macrobiota and substrate from CPCe Point Count analysis of photographic transects listed by region and MPA status (i.e., inside MPA or outside MPA) during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Coral= Scleractinia hard coral, Octo= Octocorallia (gorgonacea), Antipat.= Antipatharia (black coral), Porifera (sponges), % HB= bare hard bottom.

| Row Labels | Total # of Dives | % HB | Fish- # spp.; Density (#/1000m$^2$) | % Cover Benthic Biota | % Cover Coral | % Cover Octo. | % Cover Antipat. | % Cover Porifera | % Cover Algae |
|---|---|---|---|---|---|---|---|---|---|
| Florida | 17 | 37.06% | 101; 386 | 26.42% | 0.14% | 0.64% | 3.54% | 5.95% | 5.86% |
| North Florida MPA | 5 | 32.09% | 77; 445 | 20.73% | 0.01% | 0.20% | 1.86% | 6.43% | 2.23% |
| Outside North Florida MPA | 12 | 39.59% | 80; 352 | 29.31% | 0.21% | 0.87% | 4.40% | 5.70% | 7.71% |
| Georgia | 5 | 16.96% | 55; 106 | 3.62% | 0.00% | 0.45% | 0.50% | 0.73% | 0.01% |
| Outside Georgia MPA | 5 | 16.96% | 55; 106 | 3.62% | 0.00% | 0.45% | 0.50% | 0.73% | 0.01% |
| South Carolina | 52 | 25.17% | 132; 439 | 39.03% | 0.04% | 1.84% | 0.72% | 3.11% | 23.93% |
| Edisto MPA | 9 | 23.51% | 117; 705 | 49.32% | 0.02% | 2.13% | 1.34% | 3.20% | 34.32% |
| Outside Edisto MPA | 13 | 24.17% | 123; 1004 | 47.91% | 0.08% | 2.48% | 1.10% | 3.92% | 30.23% |
| Charleston Deep Artificial Reef MPA (barges) | 2 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Northern S. Carolina MPA | 8 | 12.99% | 88; 512 | 45.82% | 0.01% | 1.27% | 0.49% | 1.55% | 28.95% |
| Outside Northern S. Carolina MPA | 9 | 23.93% | 103; 847 | 41.05% | 0.02% | 2.05% | 0.31% | 2.70% | 23.41% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Northern S. Carolina MPA (iceberg scar site) | 6 | 33.33% | 38; 136 | 6.27% | 0.00% | 0.92% | 0.02% | 2.54% | 0.01% |
| Outside Northern S. Carolina MPA (iceberg scar site) | 5 | 44.10% | 32; 193 | 10.15% | 0.04% | 0.79% | 0.00% | 4.26% | 0.00% |
| North Carolina | 24 | 32.58% | 110; 289 | 14.14% | 0.41% | 0.82% | 0.63% | 2.85% | 3.17% |
| Snowy Wreck MPA | 6 | 26.18% | 71; 292 | 16.69% | 0.28% | 0.59% | 0.64% | 1.34% | 7.72% |
| Outside Snowy Wreck MPA | 17 | 35.46% | 98; 289 | 11.92% | 0.33% | 0.91% | 0.64% | 3.33% | 1.85% |
| Snowy Wreck MPA (wreck site) | 1 | 0.00% | N/A | 65.70% | 4.68% | 0.00% | 0.00% | 2.20% | 0.00% |
| **Grand Total** | | **28.29%** | **167; 505** | **30.45%** | **0.13%** | **1.38%** | **1.16%** | **3.42%** | **15.76%** |

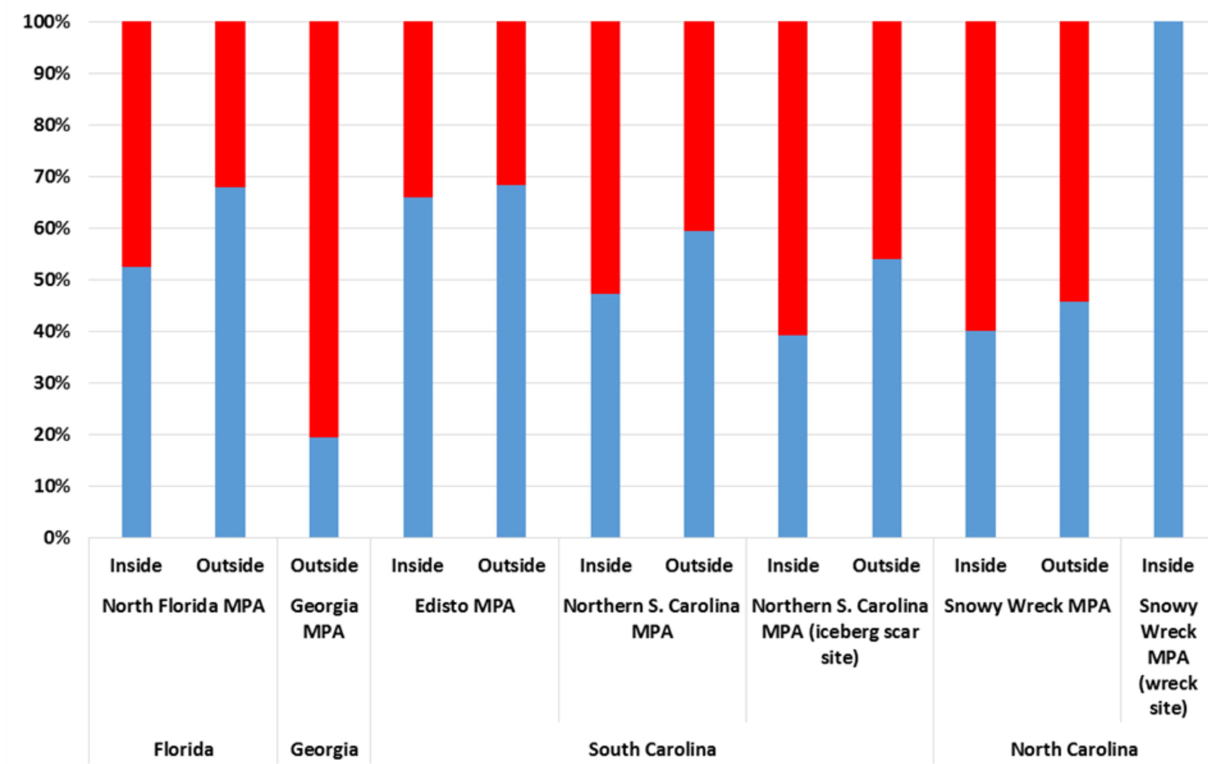



Figure 35. Percent cover of hard bottom (blue) vs soft bottom (red) by region and MPA status during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Points on biota were scored as underlying substrate.

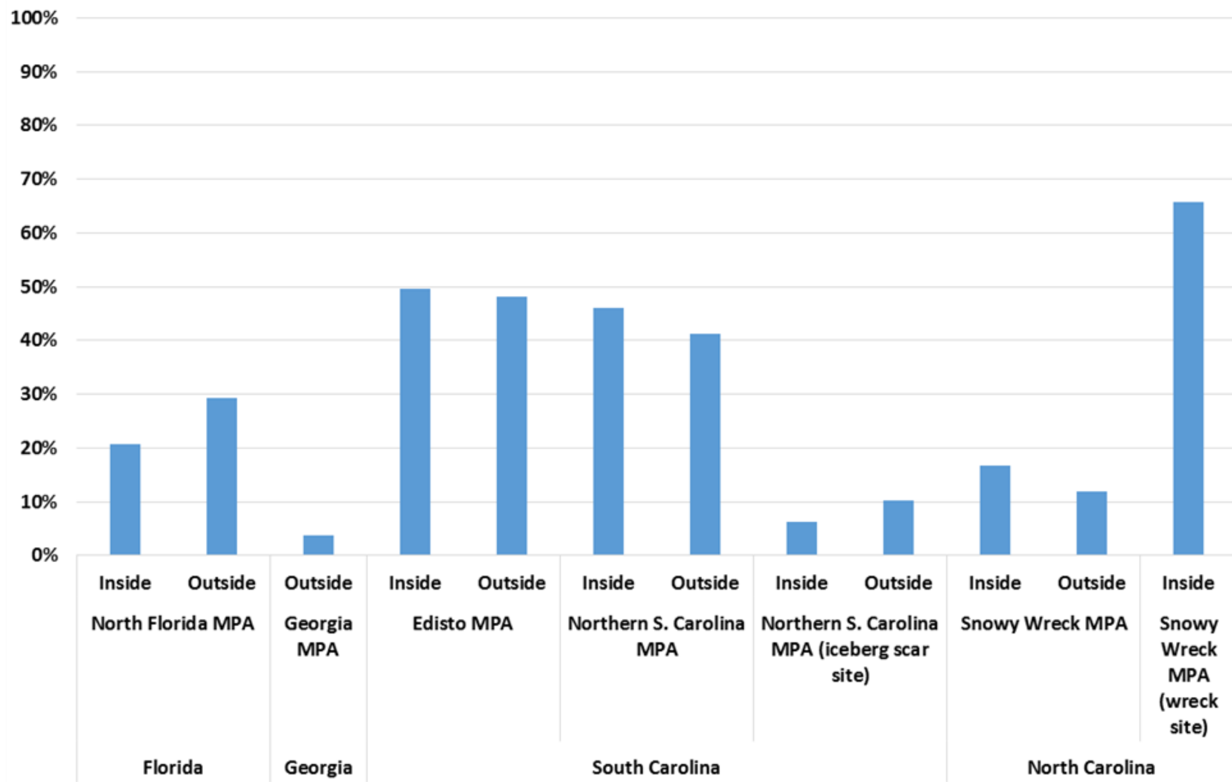



Figure 36. Percent cover of benthic macrobiota by region and MPA status during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08).

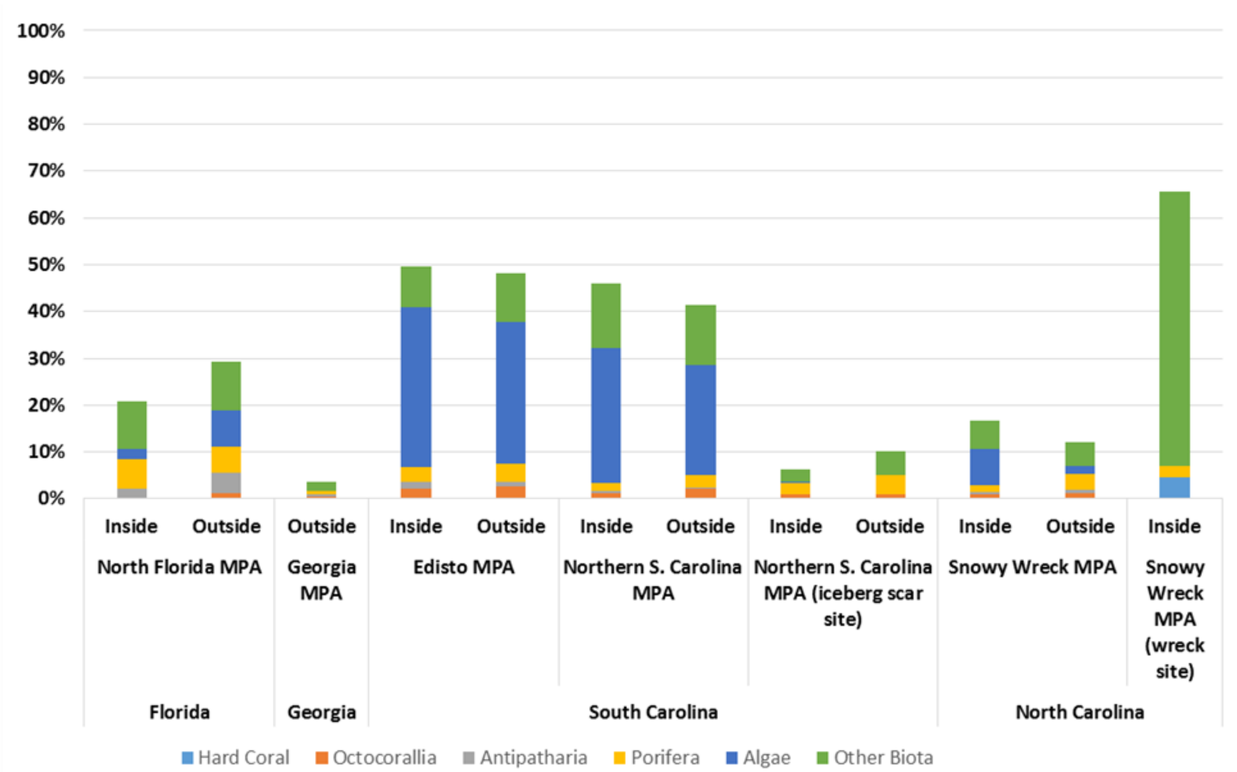


Figure 37. Percent cover of major benthic macrobiota taxa by region and MPA status during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08).

Coral Cover

Based on CPCe Point Count, the percent cover of hard corals averaged 0.13% for all sites but ranged up to 4.68% (*Lophelia pertusa*) at the Snowy Wreck MPA Shipwreck Site (Appendix 1, Table 6, Figure 37). The Outside Georgia MPA site, being mostly sediment, had no hard coral. Within the mesophotic depth MPA reef sites, average coral cover was similar at North Florida MPA (0.01%), Edisto MPA (0.02%), and Northern S. Carolina MPA (0.01%), but was greatest at the Snowy Wreck MPA reef sites (0.28%). The greatest disparity of coral cover inside vs outside an MPA was at the North Florida MPA (0.21% Outside, 0.01% Inside). *Oculina varicosa* was the dominant coral species at many sites and especially at Outside North Florida MPA, Edisto MPA, and Snowy Wreck MPA; percent cover was greatest at Outside Snowy Wreck MPA reef sites (0.21%). However, the deepwater azooxanthellate (white due to low light levels) form of *Oculina varicosa* colonies (>10 cm diameter) were quite abundant at the North Cape Lookout 3 site (Dives 14-16, 14-17) which is a deepwater ledge habitat at 110 m. *O. varicosa* was common (41 counted) on the rock outcrops and ledges, and were quite healthy, but a few were standing dead colonies. At another deeper site, Snowy Wreck MPA site (Dive 14-14), a deep ridge (80-96 m depth) also had large, azooxanthellate (up to 40 cm diameter) *O. varicosa* colonies. Unfortunately, none of the points of the Point Count landed on the coral at these sites, so Appendix 1 indicates 0% coral. The deepest recorded depth for *Oculina varicosa* for all sites was 111.5 m. Other common coral species included *Madracis myriaster* (maximum cover- 0.25% at Snowy Wreck MPA reef sites) and *Madrepora oculata* at Outside Snowy Wreck MPA sites.

Other non-scleractinian corals included Octocorals (gorgonians) which consisted of at least 16 species and probably more. Many could only be identified to genus or family without a specimen in hand. Percent cover of gorgonians averaged 1.38% for all sites and ranged from 0.45% cover in the region of Georgia, 0.64% at Florida, 0.82% at North Carolina, and 1.84% at South Carolina (Table 6, Figure 38). In general, for each region, the Outside MPA sites had greater gorgonian cover than Inside MPA sites. Outside Edisto MPA had the greatest cover of 2.48%. Antipatharia black corals averaged 1.16% cover, and was greatest at North Florida (4.40% Outside MPA, 1.86% Inside MPA).

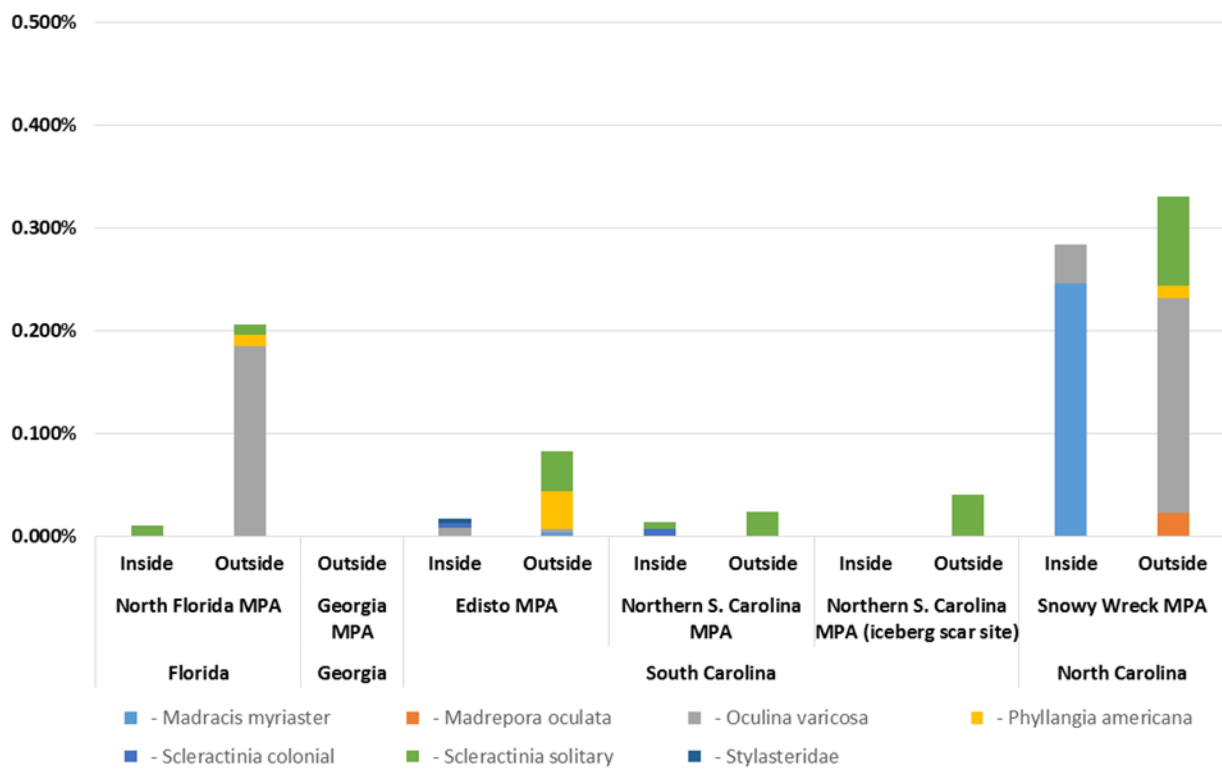



Figure 38. Percent cover of hard corals by region and MPA status during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). The Snowy Grouper MPA Shipwreck site had 4.68% cover of the deepwater coral *Lophelia pertusa* and is not included.

**Benthic Biota and Habitat Relationships**

The benthic communities were compared among sites using multi-dimensional scaling (MDS) plots of the Bray-Curtis Similarity index for benthic macrobiota percent cover (with square-root transformation). First the communities were compared by region (State) to see if there were regional or latitudinal variances. All the dives, both inside and outside of each MPA, were plotted (Figure 39.) In general, there was a fairly strong clustering by region. The Northern South Carolina MPA Iceberg Scar Site clearly stood out as dissimilar from the other benthic communities. This is likely due to depth rather than latitude. The Snowy Wreck MPA Shipwreck Site also was singled out; also due to its disparately greater depth (250 m) compared to all the other sites. The remaining sites are mostly mesophotic depth (40-80 m) reefs and more comparable for any latitudinal differences. North Florida and Georgia sites generally clustered together. The South Carolina Edisto region formed a very tight community but was not much different from the Northern South Carolina region. The North Carolina Snowy Wreck reef sites (excluding the shipwreck) also tended to cluster together but the diversity of sites over the wide geographical range resulted in a wider scattering of these sites. Two individual dives of North Florida and Georgia which clustered in the upper right of the plot were similar in that they were primarily soft bottom habitat (80-83% cover sediment).

Figure 40 shows the MDS plot of similarity of Inside vs Outside of each MPA site. First this was plotted with all data, but the two deep sites (Northern S. Carolina MPA Iceberg Scar Site and the Snowy Wreck MPA Shipwreck Site) were such outliers, these were removed from the plot. Also there were no sites within the Georgia MPA so it was excluded also. In general, there was little difference between the Outside MPA sites compared to the adjacent Inside MPA sites. North Florida MPA Inside and Outside sites were very similar (60% similarity). Edisto MPA was also tightly clustered as was the Northern S. Carolina sites. Only the Snowy Wreck MPA reef sites were considerably different inside versus outside the MPA. A SIMPROF dendrogram of these same data show the statistically different groups ($p<0.05$ are indicated by red bars) (Figure 41). These similarities between the Inside versus Outside MPA sites are a good sign that the outside sites are comparable to the MPAs for future surveys. These surveys appear to provide good baseline data for the MPA sites which only have been of protected status for less than a decade.

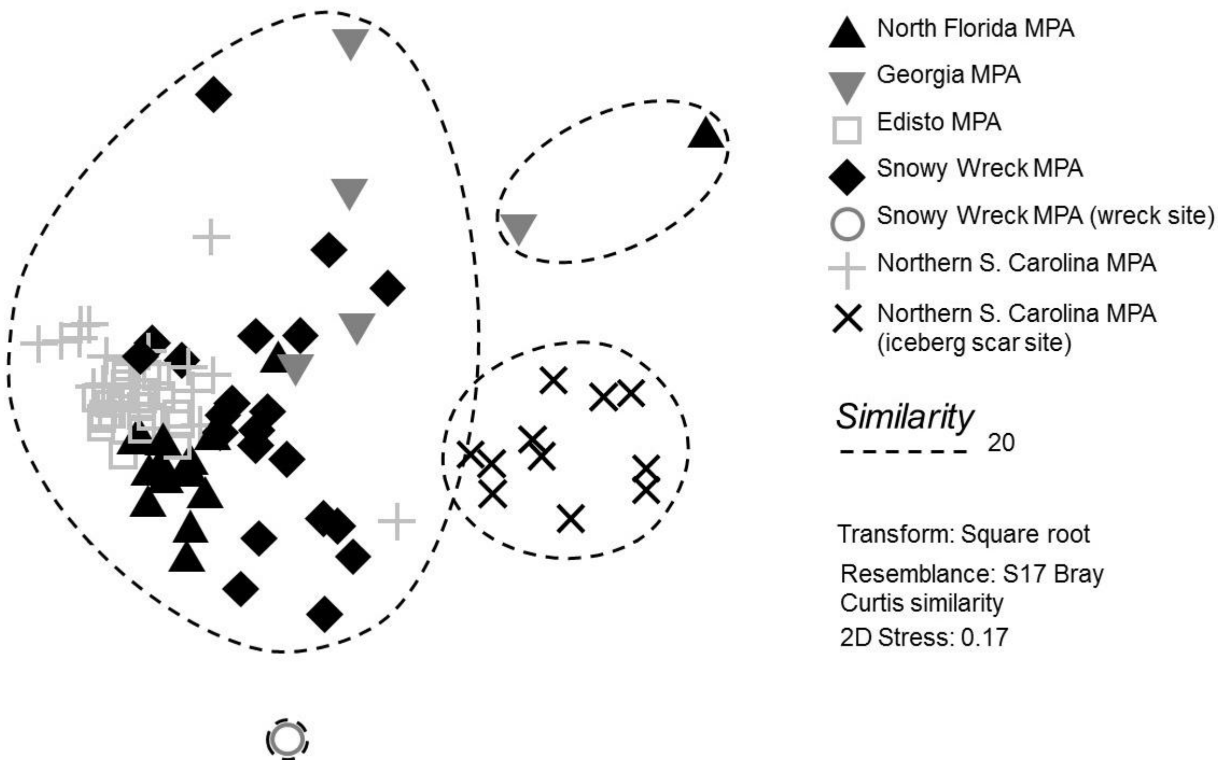



Figure 39. Multi-dimensional scaling (MDS) plot of shelf-edge MPA sites by region (data for all dives inside and outside of each MPA site) based on Bray-Curtis similarity matrix calculated from square-root transformation of benthic macrobiota percent cover during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Assemblage similarity at 20% is indicated.

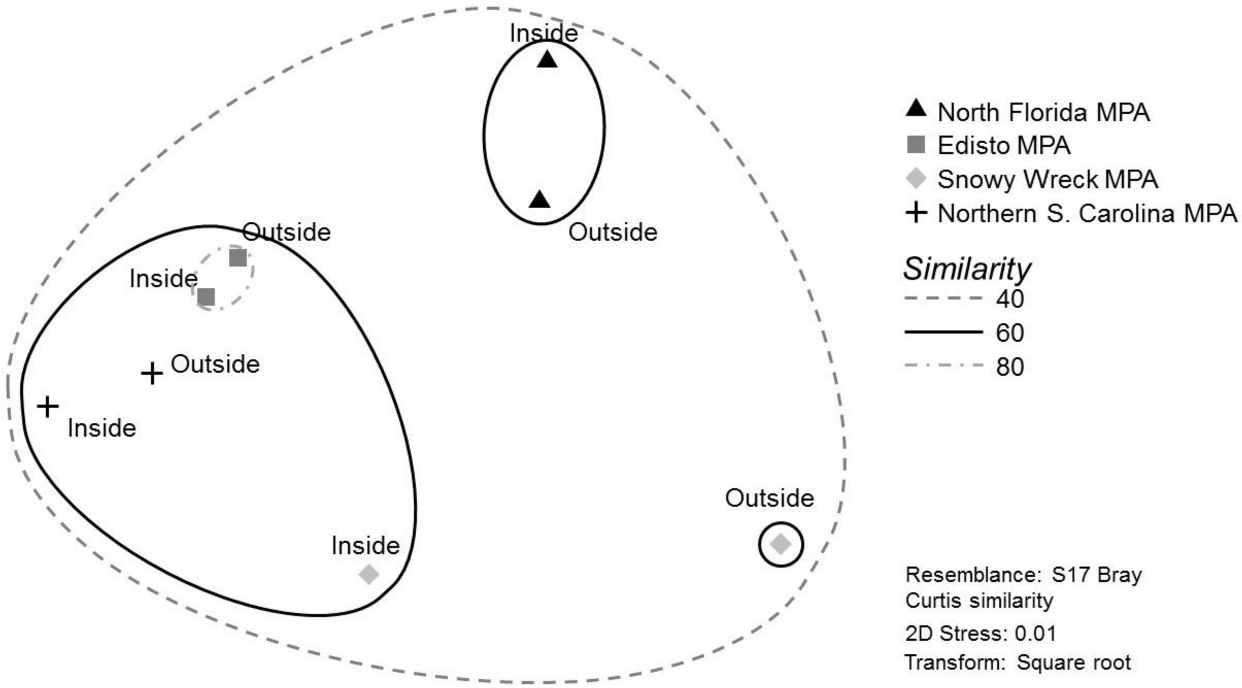



Figure 40. Multi-dimensional scaling (MDS) plot comparing dive sites averaged by Inside vs Outside of each MPA based on Bray-Curtis similarity matrix calculated from square-root transformation of benthic macrobiota percent cover during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Assemblage similarity at 40-80% are indicated.

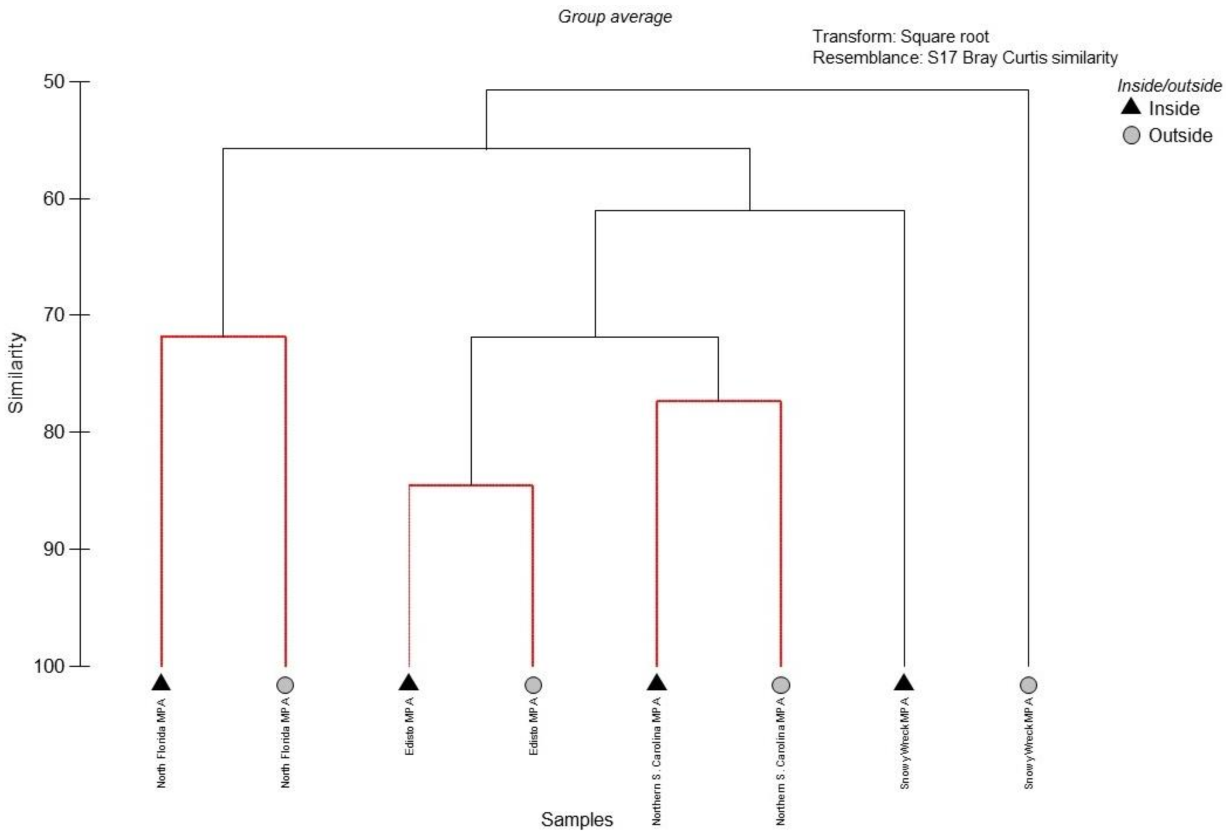



Figure 41. SIMPROF dendrogram showing Bray-Curtis similarity of percent cover of benthic biota for inside and outside of MPAs of each region. Statistically different groups ($p<0.05$) are indicated by red bars.

Finally the MPAs were compared using MDS similarity plots of the benthic communities from just the Inside MPA sites (Figure 42). These again show the very distinct benthic community found at the deepest site (Snowy Wreck Shipwreck Site) and the second deepest site, the Northern South Carolina Iceberg Scar Site. The Iceberg Scar Site consisted of the following benthic taxa not found at the other sites: *Leiodermatium* sp. (sponge), *Paracolochirus mysticus* (sea cucumber), Majidae crabs, and *Nicella* sp. gorgonians. The Snowy Shipwreck Site was also unique with the taxa: *Lophelia pertusa* (deepwater coral), unidentified Alcyoniina (soft coral), various Actiniaria (anemones including venus flytrap anemones), and *Eumunida picta* (squat lobster). The remaining MPA reef sites were most similar.

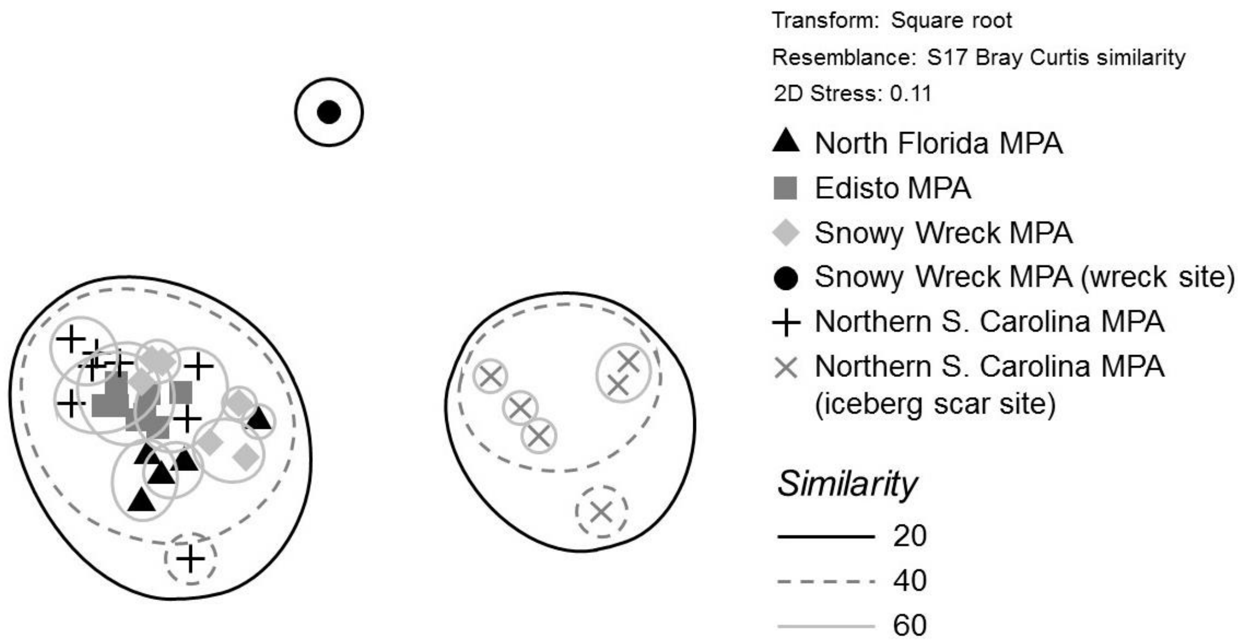


Figure 42. Multi-dimensional scaling (MDS) plot comparing just the MPA sites (excluding all Outside MPA sites) based on Bray-Curtis similarity matrix calculated from square-root transformation of benthic macrobiota percent cover during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Assemblage similarity at 20-60% are indicated.

**Human Debris**

CPCe Point Count of the quantitative ROV photo transects was used to plot the amount of human debris at each dive site (Figure 43). The presence of debris, either fishing lines, longlines, bottles, ansd other litter was relatively small overall (<0.1% cover). The greatest lost fishing gear was at Snowy Wreck MPA reef sites (not the shipwreck), both inside and outside the MPA. The North Florida MPA site (Inside) and the Northern South Carolina MPA site (Inside Iceberg Scar site) also had relatively more fishing gear.

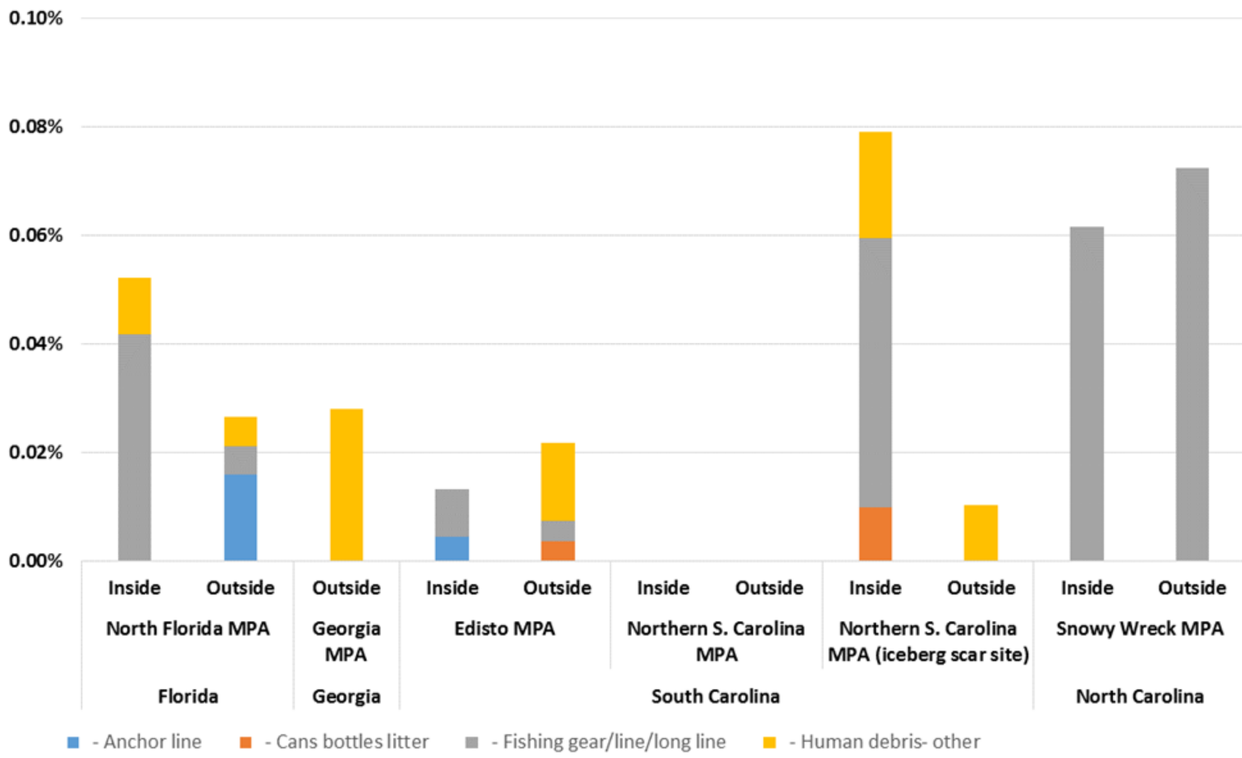



Figure 43. Percent cover of human debris calculated from the quantitative ROV photo transects by state and MPA status during 2012 and 2013 NOAA Ship *Pisces* cruises (12-03, 13-03) and 2014 *Nancy Foster* cruise (14-08). Snowy Shipwreck Site was removed from the plot.

## FUTURE WORK AND CONCLUSIONS

This cruise and research has resulted in a rich set of new data discovering and characterizing deepwater MPA sites and fish populations off the southeastern United States within the jurisdiction of the South Atlantic Fishery Management Council. New sonar maps, ground-truthed by ROV dives, and CTD casts have provided data for characterizing these newly designated shelf-edge MPA sites and adjacent areas. The new multibeam maps provide a wealth of information for future ROV dives both within and outside the current MPA sites. These data will be important for managers and scientists with NOAA Fisheries, the South Atlantic Fishery Management Council, NOAA DSCRTP, NOAA CRCP, and NOAA Mesophotic Reef Ecosystem Program. These data may then be compared to previous and future research cruises and to areas adjacent to the protected areas to better understand the long-term health and status of these important deepwater coral/sponge ecosystems. Another three year CRCP/SAFMC grant has been awarded to this team to continue to collect valuable information on these MPAs and their surrounding areas to better evaluate the efficacy of the closed areas. The new grant will also include work inside the *Oculina* Experimental Closed Area (OECA).

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# APPENDIX 1

## Species List and Percent Cover of Benthic Macro-Biota

Species list of the benthic macro-invertebrates and algae that were identified from quantitative photo transects. Still images captured from the photo transects were analyzed using CPCe© software to determine average relative percent cover of benthic biota and habitat types for each location.

| | Florida | | Georgia | South Carolina | | | | | | North Carolina | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Florida MPA | | Georgia MPA | Edisto MPA | | Northern S. Carolina MPA | | Northern S. Carolina MPA (iceberg scar site) | | Snowy Wreck MPA | | Snowy Wreck MPA (wreck site) | |
| | Inside | Outside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Grand Total |
| Macrobiota (CPCe Point Count % Cover) | 20.73% | 29.31% | 3.62% | 49.32% | 47.91% | 45.82% | 41.05% | 6.27% | 10.15% | 16.69% | 11.92% | 65.70% | 30.45% |
| Cyanophyta | 0.11% | 1.66% | 0.00% | 19.92% | 14.43% | 4.47% | 1.96% | 0.00% | 0.00% | 0.21% | 0.85% | 0.00% | 5.83% |
| Chlorophyta | 0.00% | 0.06% | 0.00% | 0.36% | 0.55% | 0.43% | 0.34% | 0.00% | 0.00% | 0.16% | 0.02% | 0.00% | 0.22% |
| Phaeophyta | 0.03% | 0.25% | 0.00% | 7.71% | 6.68% | 19.52% | 15.64% | 0.01% | 0.00% | 3.33% | 0.10% | 0.00% | 5.51% |
| Rhodophyta | 2.09% | 5.74% | 0.01% | 6.33% | 8.57% | 4.53% | 5.47% | 0.00% | 0.00% | 4.02% | 0.88% | 0.00% | 4.20% |
| Corallinales/crustose coralline | 0.91% | 3.84% | 0.01% | 2.22% | 2.38% | 0.84% | 1.69% | 0.00% | 0.00% | 1.42% | 0.82% | 0.00% | 1.57% |
| Rhodophyta | 1.18% | 1.90% | 0.00% | 4.10% | 6.19% | 3.70% | 3.78% | 0.00% | 0.00% | 2.60% | 0.06% | 0.00% | 2.62% |
| Porifera | 6.43% | 5.70% | 0.73% | 3.20% | 3.92% | 1.55% | 2.70% | 2.54% | 4.26% | 1.34% | 3.33% | 2.20% | 3.42% |
| Agelas sp. | 0.00% | 0.00% | 0.00% | 0.04% | 0.03% | 0.31% | 0.43% | 0.00% | 0.00% | 0.06% | 0.00% | 0.00% | 0.08% |
| Aiolochroia crassa | 0.02% | 0.03% | 0.04% | 0.05% | 0.11% | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.03% |
| Aplysina sp. | 0.05% | 0.01% | 0.00% | 0.06% | 0.05% | 0.00% | 0.04% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% |
| Astrophorida | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.04% | 0.00% | 0.19% | 0.00% | 0.03% | 0.00% | 0.02% |
| Auletta sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Axinellida | 0.01% | 0.02% | 0.00% | 0.00% | 0.01% | 0.04% | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Callyspongia sp. | 0.02% | 0.00% | 0.00% | 0.00% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Callyspongia vaginalis | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.01% | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Chondrilla sp. | 0.00% | 0.01% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.29% | 0.00% | 0.05% |
| Chondrosia sp. | 0.15% | 0.02% | 0.00% | 0.02% | 0.05% | 0.01% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.03% |
| Chondrosia sp.- lobate gray | 0.07% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Cinachyra sp./Cinachyrella sp. | 0.00% | 0.05% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Clathria sp. | 0.05% | 0.02% | 0.00% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Cliona sp. | 0.00% | 0.01% | 0.00% | 0.03% | 0.10% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% |
| Corallistidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.11% | 0.17% | 0.00% | 0.00% | 0.00% | 0.02% |
| Demospongiae- MPA01 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Demospongiae- MPA03 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.06% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% |
| Demospongiae unid. spp. | 1.93% | 1.99% | 0.31% | 1.38% | 1.63% | 0.63% | 1.16% | 0.74% | 0.98% | 0.59% | 1.46% | 0.00% | 1.30% |
| Demospongiae- ze tan starlet | 0.49% | 0.10% | 0.03% | 0.25% | 0.26% | 0.07% | 0.09% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.13% |
| Demospongiea- ye sphere | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Desmapsamma anchorata | 0.00% | 0.01% | 0.00% | 0.04% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Dictyoceratida | 0.01% | 0.03% | 0.00% | 0.02% | 0.01% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Diplastrella sp. | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% |
| Erylus sp. | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Farrea sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.07% | 0.00% | 0.00% | 0.00% | 0.01% |
| Geodia sp. | 0.00% | 0.03% | 0.00% | 0.10% | 0.07% | 0.02% | 0.00% | 0.00% | 0.10% | 0.00% | 0.00% | 0.00% | 0.03% |
| Hadromerida | 0.05% | 0.07% | 0.03% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Haliclona sp. | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Halisarca sp. | 0.04% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.01% |
| Haplosclerida | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Hexactinellida | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.16% | 0.00% | 0.00% | 0.00% | 0.01% |
| Hymedesmia sp.- blue | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.04% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% |
| Ircinia campana | 0.09% | 0.48% | 0.01% | 0.18% | 0.05% | 0.07% | 0.15% | 0.00% | 0.00% | 0.00% | 0.07% | 0.00% | 0.12% |
| Ircinia sp. | 0.78% | 0.86% | 0.00% | 0.20% | 0.29% | 0.01% | 0.06% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.22% |
| Ircinia strobilina | 0.03% | 0.08% | 0.00% | 0.01% | 0.01% | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% |
| Leiodermatium sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 1.56% | 2.26% | 0.00% | 0.00% | 0.00% | 0.22% |
| Lithistida | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.03% | 0.00% | 0.00% | 0.14% | 0.00% |
| Mycale sp. | 0.03% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Neofibularia nolitangere | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Niphates sp. | 0.00% | 0.00% | 0.00% | 0.02% | 0.03% | 0.02% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Oceanapia sp. | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% |
| Poecilosclerida | 0.04% | 0.06% | 0.00% | 0.02% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Polymastia sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Porifera | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.13% | 0.04% | 0.00% | 0.00% | 0.01% |
| Ptilocaulis sp. | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Scopalina sp. | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% |
| Siphonodictyon coralliphagum | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Spirastrellidae | 2.45% | 1.82% | 0.31% | 0.63% | 1.10% | 0.19% | 0.38% | 0.00% | 0.02% | 0.63% | 1.44% | 2.07% | 0.92% |
| Spongia sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% |
| Spongosorites sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Theonella sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Xestospongia muta | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Xestospongia sp. | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Zyzzya sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.04% | 0.00% | 0.00% | 0.00% | 0.00% |
| Coral | 0.01% | 0.21% | 0.00% | 0.02% | 0.08% | 0.01% | 0.02% | 0.00% | 0.04% | 0.28% | 0.33% | 4.68% | 0.13% |
| Lophelia pertusa | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 4.68% | 0.02% |
| Madracis myriaster | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.25% | 0.00% | 0.00% | 0.01% |
| Madrepora oculata | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% |
| Oculina varicosa | 0.00% | 0.19% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.04% | 0.21% | 0.00% | 0.06% |
| Phyllangia americana | 0.00% | 0.01% | 0.00% | 0.00% | 0.04% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% |
| Scleractinia colonial | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Scleractinia solitary | 0.01% | 0.01% | 0.00% | 0.00% | 0.04% | 0.01% | 0.02% | 0.00% | 0.04% | 0.00% | 0.09% | 0.00% | 0.03% |
| Stylasteridae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Octocorallia | 0.20% | 0.87% | 0.45% | 2.13% | 2.48% | 1.27% | 2.05% | 0.92% | 0.79% | 0.59% | 0.91% | 0.00% | 1.38% |
| Bebryce sp. | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.03% | 0.00% | 0.01% |
| Diodogorgia sp. | 0.10% | 0.16% | 0.35% | 0.73% | 0.86% | 0.26% | 0.46% | 0.00% | 0.00% | 0.00% | 0.05% | 0.00% | 0.35% |

| | Florida | | Georgia | South Carolina | | | | | | North Carolina | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Florida MPA | | Georgia MPA | Edisto MPA | | Northern S. Carolina MPA | | Northern S. Carolina MPA (iceberg scar site) | | Snowy Wreck MPA | | Snowy Wreck MPA (wreck site) | |
| | Inside | Outside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Grand Total |
| Ellisella sp. | 0.01% | 0.05% | 0.03% | 0.18% | 0.17% | 0.17% | 0.15% | 0.00% | 0.00% | 0.04% | 0.02% | 0.00% | 0.09% |
| Ellisellidae | 0.02% | 0.03% | 0.01% | 0.34% | 0.17% | 0.21% | 0.11% | 0.07% | 0.00% | 0.06% | 0.02% | 0.00% | 0.11% |
| Gorgonacea | 0.04% | 0.08% | 0.00% | 0.25% | 0.31% | 0.34% | 0.35% | 0.64% | 0.55% | 0.27% | 0.21% | 0.00% | 0.27% |
| Iciligorgia schrammi | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Leptogorgia sp. | 0.00% | 0.01% | 0.03% | 0.00% | 0.02% | 0.03% | 0.04% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% |
| Muricea sp. | 0.00% | 0.23% | 0.00% | 0.10% | 0.06% | 0.04% | 0.16% | 0.07% | 0.00% | 0.01% | 0.00% | 0.00% | 0.07% |
| Nephtheidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.04% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Nicella sp. | 0.02% | 0.01% | 0.00% | 0.04% | 0.07% | 0.15% | 0.05% | 0.13% | 0.13% | 0.04% | 0.07% | 0.00% | 0.06% |
| Plexauridiae | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% | 0.01% | 0.00% | 0.00% | 0.07% | 0.05% | 0.00% | 0.01% |
| Primnoidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Pseudopterogorgia sp. | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Swiftia exerta | 0.00% | 0.00% | 0.01% | 0.01% | 0.05% | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Telesto sp. | 0.00% | 0.27% | 0.00% | 0.37% | 0.75% | 0.00% | 0.67% | 0.01% | 0.11% | 0.10% | 0.45% | 0.00% | 0.34% |
| Titanideum frauenfeldii | 0.00% | 0.00% | 0.01% | 0.06% | 0.01% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% |
| Alcyonacea | 0.00% | 0.00% | 0.01% | 0.02% | 0.05% | 0.02% | 0.05% | 0.02% | 0.02% | 0.00% | 0.03% | 0.41% | 0.03% |
| Alcyoniina | 0.00% | 0.00% | 0.01% | 0.02% | 0.04% | 0.01% | 0.03% | 0.02% | 0.02% | 0.00% | 0.02% | 0.41% | 0.02% |
| Anthomastus sp. | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% |
| Chironephthya caribaea | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Nidallia occidentalis | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Antipatharia | 1.86% | 4.40% | 0.50% | 1.34% | 1.10% | 0.49% | 0.31% | 0.02% | 0.00% | 0.64% | 0.64% | 0.00% | 1.16% |
| Antipatharia atlantica | 0.00% | 0.00% | 0.00% | 0.04% | 0.03% | 0.00% | 0.01% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.01% |
| Antipatharia unid. sp. | 0.24% | 0.17% | 0.14% | 0.77% | 0.62% | 0.17% | 0.14% | 0.00% | 0.00% | 0.10% | 0.19% | 0.00% | 0.30% |
| Antipathes sp. A | 0.16% | 0.26% | 0.00% | 0.11% | 0.12% | 0.04% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.08% |
| Stichopathes lutkeni | 0.87% | 2.66% | 0.36% | 0.32% | 0.27% | 0.23% | 0.09% | 0.00% | 0.00% | 0.35% | 0.37% | 0.00% | 0.54% |
| Tanacetipathes hirta | 0.59% | 1.30% | 0.00% | 0.11% | 0.06% | 0.05% | 0.07% | 0.02% | 0.00% | 0.16% | 0.08% | 0.00% | 0.23% |
| Cnidaria non-coral | 7.05% | 5.97% | 0.49% | 3.20% | 6.20% | 1.52% | 3.02% | 0.14% | 0.39% | 3.35% | 1.54% | 37.60% | 3.48% |
| Actiniaria | 0.01% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 36.09% | 0.15% |
| Corallimorpharia | 0.00% | 0.00% | 0.00% | 0.02% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Hydroidolina | 7.01% | 5.95% | 0.24% | 3.16% | 6.16% | 1.49% | 3.01% | 0.14% | 0.39% | 3.35% | 1.52% | 1.52% | 3.30% |
| Pennatulacea | 0.00% | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Virgularia presbytes | 0.00% | 0.00% | 0.21% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% |
| Zoantharia | 0.03% | 0.02% | 0.00% | 0.01% | 0.03% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% |
| Annelida | 0.97% | 1.89% | 1.04% | 0.34% | 0.50% | 0.93% | 0.25% | 1.83% | 2.60% | 0.05% | 0.19% | 13.64% | 0.88% |
| Annelida | 0.04% | 0.06% | 0.43% | 0.00% | 0.00% | 0.23% | 0.00% | 0.29% | 0.85% | 0.01% | 0.00% | 0.14% | 0.11% |
| Filograna sp. | 0.66% | 1.50% | 0.00% | 0.32% | 0.46% | 0.70% | 0.21% | 0.01% | 0.03% | 0.01% | 0.10% | 0.00% | 0.41% |
| Hermodice carunculata | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% |
| Sabellidae | 0.25% | 0.29% | 0.60% | 0.00% | 0.03% | 0.00% | 0.02% | 0.26% | 0.37% | 0.01% | 0.06% | 0.00% | 0.12% |
| Serpulidae | 0.02% | 0.02% | 0.00% | 0.00% | 0.01% | 0.01% | 0.02% | 1.28% | 1.35% | 0.01% | 0.02% | 13.50% | 0.22% |
| Spirobranchus gigantea | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Mollusca | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.02% | 0.95% | 0.06% | 0.06% | 0.11% | 0.07% | 0.00% | 0.12% |
| Bivalvia | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.01% | 0.95% | 0.00% | 0.02% | 0.11% | 0.07% | 0.00% | 0.11% |
| Gastropoda | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.03% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% |
| Mollusca | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Perotrochus amabilis | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% |
| Arthropoda | 0.03% | 0.02% | 0.00% | 0.02% | 0.01% | 0.01% | 0.02% | 0.15% | 0.20% | 0.05% | 0.04% | 0.41% | 0.04% |
| Cirripedia | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Decapoda | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.02% | 0.04% | 0.00% | 0.00% | 0.00% | 0.01% |
| Eumunida picta | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.14% | 0.00% |
| Majidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.07% | 0.10% | 0.00% | 0.00% | 0.00% | 0.01% |
| Paguridae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.06% | 0.06% | 0.00% | 0.00% | 0.28% | 0.01% |
| Panulirus argus | 0.03% | 0.02% | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% | 0.01% |
| Penaeidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% |
| Scyllaridae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Stenorhynchus seticornis | 0.00% | 0.01% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.03% | 0.00% | 0.01% |
| Bryozoa | 0.29% | 0.37% | 0.13% | 0.78% | 0.53% | 1.37% | 1.51% | 0.00% | 0.03% | 0.00% | 0.03% | 0.00% | 0.52% |
| Bryozoa | 0.08% | 0.06% | 0.11% | 0.63% | 0.28% | 1.01% | 1.35% | 0.00% | 0.03% | 0.00% | 0.03% | 0.00% | 0.37% |
| Schizoporella sp. | 0.21% | 0.31% | 0.01% | 0.15% | 0.25% | 0.36% | 0.16% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.15% |
| Echinodermata | 0.06% | 0.33% | 0.00% | 0.07% | 0.18% | 0.03% | 0.08% | 0.19% | 0.56% | 0.16% | 2.41% | 0.00% | 0.50% |
| Arbacia punctulata | 0.02% | 0.20% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% |
| Asteroidea | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.00% | 0.01% | 0.00% | 0.01% | 0.00% | 0.00% |
| Asteroporpa annulata | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Centrostephanus longispinus | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.01% |
| Cidaroidea | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.00% | 0.00% |
| Comactinia meridionalis | 0.00% | 0.00% | 0.00% | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 1.32% | 0.00% | 0.21% |
| Crinoidea | 0.02% | 0.00% | 0.00% | 0.04% | 0.13% | 0.02% | 0.03% | 0.00% | 0.00% | 0.15% | 0.80% | 0.00% | 0.16% |
| Davidaster discoideus | 0.00% | 0.00% | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.05% | 0.00% | 0.01% |
| Echinoidea | 0.00% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.02% | 0.06% | 0.00% | 0.01% | 0.00% | 0.01% |
| Eucidaris tribuloides | 0.02% | 0.08% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% |
| Goniaster tessellatus | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Gorgonocephalidae | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% |
| Holothuria lentigenosa enodis | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% |
| Luidia alternata | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Narcissia trigonaria | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Ophioderma devaneyi | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.13% | 0.00% | 0.02% |

| | Florida | | Georgia | South Carolina | | | | | | North Carolina | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Florida MPA | | Georgia MPA | Edisto MPA | | Northern S. Carolina MPA | | Northern S. Carolina MPA (iceberg scar site) | | Snowy Wreck MPA | | Snowy Wreck MPA (wreck site) | |
| | Inside | Outside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Grand Total |
| Ophiuroidea | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.01% | 0.00% | 0.00% |
| Paracolochirus mysticus | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% | 0.15% | 0.43% | 0.00% | 0.00% | 0.00% | 0.03% |
| Chordata | 0.59% | 1.54% | 0.20% | 1.00% | 1.17% | 1.28% | 0.92% | 0.19% | 0.41% | 0.38% | 0.26% | 0.41% | 0.82% |
| Ascidiacea | 0.24% | 0.15% | 0.03% | 0.27% | 0.53% | 0.79% | 0.41% | 0.00% | 0.00% | 0.00% | 0.02% | 0.28% | 0.26% |
| Didemnidae | 0.20% | 0.94% | 0.06% | 0.27% | 0.41% | 0.23% | 0.24% | 0.00% | 0.00% | 0.01% | 0.02% | 0.00% | 0.26% |
| Fish | 0.16% | 0.44% | 0.11% | 0.46% | 0.23% | 0.27% | 0.28% | 0.19% | 0.41% | 0.37% | 0.22% | 0.14% | 0.29% |
| Other organism | 1.00% | 0.32% | 0.06% | 2.88% | 1.45% | 8.36% | 5.75% | 0.20% | 0.80% | 2.00% | 0.30% | 6.34% | 2.22% |
| Bare hard bottom | 32.09% | 39.59% | 16.96% | 23.51% | 24.17% | 12.99% | 23.93% | 33.33% | 44.10% | 26.18% | 35.46% | 0.00% | 28.29% |
| Bare hard bottom | 32.09% | 39.59% | 16.96% | 23.51% | 24.17% | 12.99% | 23.93% | 33.33% | 44.10% | 26.18% | 35.46% | 0.00% | 28.29% |
| Bare rock- pavement boulder ledge | 28.17% | 37.71% | 15.96% | 21.67% | 22.40% | 12.03% | 20.21% | 32.17% | 43.19% | 24.05% | 31.91% | 0.00% | 26.10% |
| Bare rubble- coral | 0.00% | 0.00% | 0.00% | 0.03% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.02% | 0.03% | 0.00% | 0.01% |
| Bare rubble- rock | 3.92% | 1.86% | 0.99% | 1.80% | 1.76% | 0.95% | 3.72% | 1.16% | 0.91% | 2.10% | 3.51% | 0.00% | 2.18% |
| Standing dead coral | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.00% | 0.00% |
| Bare soft bottom | 47.07% | 31.06% | 79.29% | 26.92% | 27.64% | 41.05% | 34.76% | 60.28% | 45.69% | 56.99% | 52.49% | 0.00% | 40.95% |
| Detritus | 0.11% | 0.04% | 0.14% | 0.25% | 0.28% | 0.15% | 0.26% | 0.12% | 0.06% | 0.14% | 0.13% | 34.30% | 0.31% |
| Human debris | 0.05% | 0.03% | 0.03% | 0.01% | 0.02% | 0.00% | 0.00% | 0.08% | 0.01% | 0.06% | 0.07% | 34.30% | 0.18% |
| Anchor line | 0.00% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Cans bottles litter | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Fishing gear/line/long line | 0.04% | 0.01% | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.05% | 0.00% | 0.06% | 0.07% | 0.00% | 0.02% |
| Human debris- other | 0.01% | 0.01% | 0.03% | 0.00% | 0.01% | 0.00% | 0.00% | 0.02% | 0.01% | 0.00% | 0.00% | 34.30% | 0.15% |
| Natural detritus | 0.06% | 0.01% | 0.11% | 0.24% | 0.25% | 0.15% | 0.26% | 0.04% | 0.05% | 0.07% | 0.05% | 0.00% | 0.14% |
| Natural detritus | 0.06% | 0.01% | 0.11% | 0.24% | 0.25% | 0.15% | 0.26% | 0.04% | 0.05% | 0.07% | 0.05% | 0.00% | 0.14% |
| **Grand Total** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** | **100.00%** |

## APPENDIX 2

## Species List and Density of Fish Observations

Species list all of fish that were identified and counted from the quantitative video transects. Average densities (# individuals / 1000 $m^2$) are shown for each location.

| | Florida | | Georgia | South Carolina | | | | | | North Carolina | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Florida MPA | | Georgia MPA | Edisto MPA | | Northern S. Carolina MPA | | Northern S. Carolina MPA (iceberg scar site) | | Snowy Wreck MPA | | |
| Scientific_Name | Inside | Outside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Inside | Outside | Totals |
| Acanthostracion polygonius | | | | 0.95 | 1.88 | | | | | | | **2.84** |
| Acanthurus bahianus | | 1.60 | | 1.70 | 1.71 | | 3.84 | | | | | **8.85** |
| Acanthurus sp. | 1.39 | 1.74 | | 3.17 | 3.28 | 9.37 | 5.08 | | | 3.76 | 6.77 | **34.56** |
| Alerterus sp. | | | | | | 0.33 | | | | | | **0.33** |
| Aluterus monoceros | | | | 0.59 | | | | | | | | **0.59** |
| Aluterus scriptus | | | | 1.01 | 12.58 | | | | | | | **13.58** |
| Anthias nicholsi | | | | | | | | 12.33 | 44.26 | | | **56.59** |
| Anthias woodsi | | | | | | | | 0.62 | 0.56 | | | **1.18** |
| Anthiinae | | | | | | 58.09 | 424.26 | 68.58 | 206.59 | 166.34 | 675.58 | **1599.44** |
| Antigonia capros | | | | | | | | 62.62 | 37.49 | | | **100.11** |
| Antigonia sp. | | | | | | | | 20.20 | 14.44 | | | **34.64** |
| Apogon affinis | | | | | | | 16.33 | | | | | **16.33** |
| Apogon pseudomaculatus | 1.90 | | 0.59 | 0.41 | 1.46 | 0.41 | 4.06 | | | | 1.60 | **10.44** |
| Apogon sp. | | 1.20 | 1.03 | 1.14 | 0.41 | | | | | | 2.35 | **6.14** |
| Aulostomus maculatus | | | | 1.35 | 1.47 | 1.92 | 1.56 | | | | | **6.30** |
| Balistes capriscus | 2.17 | 1.78 | 1.83 | 4.38 | 3.39 | 1.73 | 4.49 | | | 0.75 | 32.16 | **52.69** |
| Balistes sp. | 1.30 | | | 1.35 | 1.89 | | | | | | | **4.54** |
| Balistes vetula | 1.34 | 0.96 | | 3.34 | 1.43 | 1.55 | 0.41 | | | | | **9.03** |
| Bodianus pulchellus | 8.95 | 11.40 | 2.25 | 11.00 | 13.05 | 8.41 | 20.46 | | | 6.64 | 9.13 | **91.30** |
| Bodianus rufus | | | | 0.99 | 1.21 | 1.49 | 1.37 | | | 0.89 | | **5.95** |
| Bothidae | | | | | | | 1.25 | 0.57 | | | | **1.82** |
| Brotula barbata | | | | | | | | | | | 1.83 | **1.83** |
| Calamus sp. | 1.54 | 1.68 | 1.15 | 5.53 | 6.54 | 8.66 | 6.76 | | | 1.51 | 4.34 | **37.71** |
| Canthigaster rostrata | 4.62 | 8.37 | 4.24 | 13.54 | 14.33 | 35.94 | 26.41 | | | 5.49 | 9.47 | **122.41** |
| Carangidae | | 8.11 | | 0.41 | | | 6.44 | | | 1.67 | | **16.62** |
| Caranx bartholomaei | | | | | 10.53 | | | | | | | **10.53** |
| Caranx lugubris | | | | 0.93 | | | | | | | | **0.93** |
| Caranx sp. | | | | 0.72 | | | | | | | | **0.72** |
| Carcharhinidae | | | | 0.29 | | | | | | | | **0.29** |
| Caulolatilus microps | | | | | | | | 2.31 | 1.19 | | 1.30 | **4.80** |
| Centropristis ocyurus | 1.79 | 1.21 | 4.20 | 0.93 | 1.58 | 5.47 | 2.84 | | | 5.46 | 4.24 | **27.71** |
| Centropristis philadelphica | | | | | | | | | | | 1.02 | **1.02** |
| Centropristis sp. | | | | | | | | | | | 0.20 | **0.20** |
| Centropristis striata | | | 1.49 | | | 0.33 | | | | | | **1.82** |
| Centropyge argi | | 2.06 | | 4.40 | 1.06 | 4.16 | 4.68 | | | 0.82 | | **17.18** |
| Cephalopholis cruentata | 0.41 | | | 2.78 | 2.43 | 2.39 | 2.51 | | | 0.99 | 5.07 | **16.59** |
| Chaetodipterus faber | | | | | 5.74 | | | | | | | **5.74** |
| Chaetodon aculeatus | | 0.80 | | 1.66 | 0.74 | 0.70 | 1.27 | | | | 4.02 | **9.19** |
| Chaetodon guyanensis | | | | | | | | | 0.88 | | | **0.88** |
| Chaetodon ocellatus | 2.71 | 3.82 | 3.01 | 5.87 | 4.52 | 7.57 | 6.52 | | | 1.98 | 6.89 | **42.88** |
| Chaetodon sedentarius | 10.67 | 10.34 | 5.14 | 14.99 | 14.61 | 12.57 | 23.07 | | | 6.24 | 8.05 | **105.66** |
| Chaetodon sp. | 3.40 | | | 2.50 | 3.50 | 2.22 | 2.95 | | | | 2.13 | **16.69** |
| Chaetodon striatus | | | | 4.71 | 1.48 | | | | | | | **6.19** |
| Chaetodontidae | 0.82 | | | 0.83 | 2.59 | | | | | | | **4.24** |
| Chilomycterus antennatus | | | | | 0.71 | | | | | | | **0.71** |
| Chilomycterus antillarum | | | | | | | | | | | 1.54 | **1.54** |
| Chilomycterus schoepfi | 2.11 | | | 1.02 | | | | | | | 0.67 | **3.79** |
| Chilomycterus sp. | 1.33 | | | 6.58 | 1.04 | | | | | | 0.67 | **9.62** |
| Chromis cyanea | | | | 2.38 | 7.51 | 7.17 | 16.98 | | | 4.61 | | **38.64** |
| Chromis enchrysurus | 28.24 | 41.56 | 8.92 | 13.31 | 11.93 | 11.44 | 17.35 | | | 11.26 | 20.81 | **164.83** |
| Chromis insolata | 1.87 | 1.88 | 1.34 | 9.52 | 9.05 | 9.95 | 8.70 | | | 10.11 | 3.62 | **56.05** |
| Chromis scotti | 7.99 | 5.74 | 1.83 | 22.05 | 28.24 | 8.83 | 18.01 | | | 1.95 | 10.86 | **105.51** |
| Chromis sp. | 6.62 | 1.99 | 4.84 | 25.76 | 12.77 | 8.06 | 18.08 | | | 6.74 | 3.88 | **88.74** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clepticus parrai | | | | 3.56 | | | | | | 11.84 | | **15.39** |
| Cookeolus boops | | | | | | | 1.05 | 5.24 | 1.66 | | | **7.95** |
| Dactylopterus volitans | 1.39 | | | 1.17 | 5.40 | | | | | | | **7.96** |
| Dasyatis americana | | | | | | | 0.41 | | | | | **0.41** |
| Dasyatis sp. | | | | | 0.41 | | | | | | | **0.41** |
| Decapterus punctatus | | | 195.88 | | | | | | | | | **195.88** |
| Decapterus sp. | | | | | | 190.48 | | | | | | **190.48** |
| Decodon puellaris | | | 0.41 | | | | 1.26 | 3.99 | 2.85 | 0.47 | 2.22 | **11.21** |
| Diodon holocanthus | | 1.55 | | | 0.81 | | | | | | | **2.36** |
| Diodon hystrix | | | | 0.41 | | | 1.18 | | | | | **1.59** |
| Diodon sp. | | 0.80 | | 1.18 | 1.12 | 3.06 | 1.68 | | | | | **7.84** |
| Diplodus holbrooki | | | | 3.59 | 5.21 | | | | | | | **8.80** |
| Epinephelus adscensionis | | | | 3.31 | 2.28 | 1.98 | 1.60 | | | 0.52 | 5.58 | **15.27** |
| Epinephelus drummondhayi | 1.07 | 3.01 | | | 1.80 | 1.66 | 2.05 | | | 0.82 | 1.29 | **11.69** |
| Epinephelus morio | | 0.80 | | | 0.67 | 2.45 | 2.11 | | | 2.83 | 2.97 | **11.83** |
| Equetus lanceolatus | 3.00 | 0.69 | 0.51 | 1.50 | 1.56 | 5.07 | 1.64 | | | 0.85 | 3.15 | **17.98** |
| Fistularia commersonii | | | | | 1.18 | | | | | | | **1.18** |
| Fistularia petimba | | | | | 0.91 | | | | | | 1.07 | **1.98** |
| Fistularia sp. | 0.41 | | | 2.08 | 2.16 | 1.33 | 4.10 | | | | | **10.07** |
| Fistularia tabacaria | 0.41 | | | 1.03 | 2.64 | 1.33 | 1.15 | | | | | **6.56** |
| Gephyroberyx darwinii | | | | | | | | 5.23 | 1.92 | | | **7.14** |
| Ginglymostoma cirratum | | | | | 1.78 | | | | | | | **1.78** |
| Gobiidae | | | | | 3.76 | | | | | | | **3.76** |
| Gonioplectrus hispanus | | | | | | | | | | 0.67 | 1.65 | **2.32** |
| Gymnothorax moringa | 1.63 | | | | 0.67 | 0.46 | 3.60 | | | | 0.82 | **7.17** |
| Gymnothorax sp. | | 1.33 | | | | | | | 1.60 | | | **2.93** |
| Gymnothorax vicinus | | 0.41 | | | | | | | | | | **0.41** |
| Haemulon album | | 0.48 | | | | | | | | | | **0.48** |
| Haemulon aurolineatum | 190.14 | 135.96 | 2.90 | 642.61 | 980.41 | 2158.73 | 923.29 | | | 102.52 | 1064.34 | **6200.90** |
| Haemulon melanurum | | | | | 1.55 | | | | | | | **1.55** |
| Haemulon plumieri | | | | 1.68 | 2.37 | 24.61 | 2.50 | | | | | **31.15** |
| Haemulon sp. | | | | | 187.57 | | 181.82 | | | | | **369.39** |
| Haemulon striatum | 29.97 | 1.54 | | 129.86 | 152.88 | 57.93 | 135.26 | | | 8.16 | 423.79 | **939.40** |
| Halichoeres bathyphilus | 4.87 | 2.65 | | | | | 32.68 | | | 5.55 | | **45.75** |
| Halichoeres bivitattus | | | | | | | 0.41 | | | | 0.70 | **1.11** |
| Halichoeres garnoti | 0.98 | 2.24 | | 4.75 | 2.73 | 7.15 | 3.61 | | | 10.41 | | **31.87** |
| Halichoeres sp. | 29.31 | 14.66 | 9.15 | 25.00 | 18.67 | 51.52 | 33.97 | 0.55 | 0.80 | 11.95 | 19.31 | **214.89** |
| Hemanthias vivanus | | | | | | | | 5.57 | 4.04 | | 45.01 | **54.62** |
| Hemicaranx amblyrhynchus | | | | 5.62 | | | | | | | | **5.62** |
| Hemipteronotus sp. | | | | | 1.86 | | | | | 0.61 | | **2.47** |
| Holacanthus bermudensis | 7.11 | 7.57 | 1.99 | 8.40 | 8.42 | 5.38 | 10.51 | | | 0.85 | 3.59 | **53.82** |
| Holacanthus ciliaris | 1.09 | | | | | | | | | | | **1.09** |
| Holacanthus sp. | 1.05 | | | | | | | | | | | **1.05** |
| Holacanthus tricolor | | 1.54 | | 3.00 | 1.29 | 4.15 | 3.45 | | | 1.32 | 3.55 | **18.29** |
| Holocentridae | 2.51 | 3.52 | 1.33 | 4.55 | 4.93 | 3.39 | 2.42 | 2.26 | 1.57 | 3.28 | 2.40 | **32.16** |
| Holocentrus sp. | 4.58 | 4.55 | | 9.58 | 9.53 | 6.02 | 10.98 | | | 3.10 | 4.22 | **52.56** |
| Hypoplectrus aberrans | | | | | 1.88 | | | | | | | **1.88** |
| Hyporthodus flavolimbatus | | | | | | | | 6.13 | | | 1.23 | **7.35** |
| Hyporthodus nigritis | | 1.60 | | | | | | | | | | **1.60** |
| Hyporthodus nigritus | 1.18 | | | | | | | | | | | **1.18** |
| Hyporthodus niveatus | 0.74 | | | 0.65 | 0.67 | 5.47 | 7.09 | 6.24 | 7.20 | | 1.72 | **29.77** |
| Jeboehklia gladifer | | | | | | | | 0.41 | | | | **0.41** |
| Lachnolaimus maximus | 0.77 | 0.96 | 0.42 | 1.97 | 1.51 | 3.25 | 4.28 | | | 1.70 | 5.55 | **20.40** |
| Lactophrys bicaudalis | | | | | | 1.96 | | | | | | **1.96** |
| Lactophrys polygonia | | 2.61 | | 1.56 | 2.31 | | 0.74 | | | | | **7.21** |
| Lactophrys quadricornis | 1.61 | 0.73 | | 0.95 | 1.28 | 0.33 | 0.89 | | | | 0.77 | **6.55** |
| Lactophrys sp. | 1.44 | 1.97 | 0.67 | 2.13 | 2.77 | 1.83 | 1.92 | | | 2.67 | 1.23 | **16.63** |
| Lactophrys trigonus | 0.88 | | | | | | | | | | | **0.88** |
| Laemonema sp. | | | | | | | | 4.20 | 2.72 | | | **6.92** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liopropoma eukrines | 1.04 | 1.62 | 1.26 | 1.39 | 1.42 | 3.20 | 2.37 | 1.67 | 0.63 | 1.55 | 3.11 | **19.24** |
| Lophius americanus | | | | | | | | 1.09 | | | | **1.09** |
| Lutjanidae | | | | 2.35 | | | | | | | | **2.35** |
| Lutjanus analis | 2.87 | | | | | | | | | | | **2.87** |
| Lutjanus apodus | | 0.47 | | | | | | | | | | **0.47** |
| Lutjanus buccanella | | 1.20 | | | 1.09 | | | | | 4.90 | | **7.18** |
| Lutjanus campechanus | 0.74 | | 1.57 | | | | | | | | | **2.31** |
| Lutjanus griseus | 1.71 | 0.80 | | 3.80 | 11.04 | | 11.79 | | | | | **29.14** |
| Lutjanus jocu | | | | 0.29 | | | | | | | | **0.29** |
| Lutjanus sp. | 1.05 | | | 0.72 | | 1.73 | 0.41 | | | | 1.58 | **5.49** |
| Macrorhamphosus scolopax | | | | | | | | 5.11 | 2.14 | | | **7.25** |
| Malacanthidae | | | | | | | | | | | 1.49 | **1.49** |
| Malacanthus plumieri | 2.88 | 0.82 | | 1.42 | 2.52 | 2.49 | 1.00 | | | 2.81 | 1.75 | **15.69** |
| Mola mola | | | | 3.29 | | | | | | | | **3.29** |
| Monacanthidae | | | | 2.01 | | | | | | | | **2.01** |
| Monacanthus hispidus | | | | 0.64 | 1.66 | | | | | | | **2.29** |
| Monacanthus sp. | | | | 1.72 | 1.43 | | 2.53 | | | | | **5.68** |
| Mulloidichthys martinicus | | | | 12.24 | 3.13 | | 2.22 | | | | | **17.59** |
| Muraena retifera | 0.41 | 1.03 | 0.49 | 1.33 | | 0.57 | 0.41 | 1.66 | 0.41 | 0.41 | 1.43 | **8.14** |
| Muraena robusta | | 2.04 | | | | 1.44 | | | | | 0.77 | **4.25** |
| Muraenidae | 0.86 | 0.47 | 0.74 | 0.72 | 0.57 | 0.70 | 1.16 | 0.48 | | 0.67 | 0.75 | **7.12** |
| Mycteroperca interstitialis | | | | 0.65 | 1.29 | | 0.97 | | | | 1.61 | **4.51** |
| Mycteroperca microlepis | 2.39 | 0.80 | 1.24 | 1.75 | 1.97 | 8.60 | 2.27 | | | 1.23 | 3.66 | **23.91** |
| Mycteroperca phenax | 4.27 | 3.01 | 4.85 | 7.78 | 9.17 | 7.63 | 7.81 | 1.07 | | 2.66 | 5.24 | **53.51** |
| Mycteroperca sp. | | | | 1.70 | 1.60 | 1.44 | 0.74 | | | 0.41 | 1.26 | **7.15** |
| Myrichthys acuminatus | | 0.77 | 0.67 | | | 3.07 | | | | | 1.21 | **5.72** |
| Myrichthys ocellatus | | | | | | 1.61 | | | | | | **1.61** |
| Myripristis jacobus | 4.98 | 4.41 | | 3.40 | 3.71 | 5.10 | 3.40 | | | 1.22 | | **26.21** |
| Myripristis ocyurus | | 1.79 | | | | | | | | | | **1.79** |
| Ocyrus chrysurus | | | | | 1.04 | | | | | | | **1.04** |
| Ogcocephalus sp. | | | | | | | 1.25 | | | | | **1.25** |
| Ophichthidae | | | | 0.65 | 0.47 | | | | | | | **1.11** |
| Opsanus pardus | | | | | 6.54 | | | | | | | **6.54** |
| Opsanus sp. | | 0.68 | | 0.72 | | | | | | | 0.97 | **2.38** |
| Opsanus tau | | | | | | | | | | | 1.12 | **1.12** |
| Ostichthys trachypoma | | | | | | | | 5.37 | 1.53 | | 1.06 | **7.96** |
| Pagrus pagrus | 11.11 | 3.23 | 8.70 | 16.42 | 12.18 | 19.34 | 25.14 | 20.49 | 5.41 | 10.14 | 4.45 | **136.60** |
| Paranthias furcifer | 3.03 | 3.92 | | 4.36 | 4.30 | 2.35 | 16.52 | | | 18.38 | 40.46 | **93.33** |
| Pareques iwamotoi | | 0.93 | 25.18 | | | 23.82 | 11.94 | 8.16 | 1.43 | 0.61 | 6.38 | **78.45** |
| Pareques sp. | | | | | | | 4.18 | | | | 2.45 | **6.62** |
| Pareques umbrosus | 3.99 | 4.77 | 23.77 | 17.67 | 25.42 | 51.60 | 24.05 | | | 49.31 | 80.40 | **280.97** |
| Phycidae | | | | 1.90 | | | | | | | | **1.90** |
| Plectranthias garrupellus | | | | | | | 1.12 | 5.32 | 2.70 | | 3.00 | **12.14** |
| Plectrypops retrospinis | | | | | 0.41 | | | | | 0.82 | 1.47 | **2.69** |
| Pomacanthus arcuatus | | | | 1.96 | 2.10 | 1.97 | | | | | | **6.04** |
| Pomacanthus paru | 1.86 | 0.80 | | 1.62 | 1.54 | 2.87 | 4.01 | | | | 4.19 | **16.89** |
| Pomacanthus sp. | | | | 1.02 | 2.28 | | 1.29 | | | | | **4.59** |
| Priacanthidae | 0.41 | | | | | | | 2.28 | | | | **2.69** |
| Priacanthus arenatus | 1.80 | 2.34 | 0.67 | 4.44 | 3.43 | 1.49 | 4.52 | 2.54 | 2.20 | 7.96 | 3.33 | **34.73** |
| Pristigenys alta | 5.54 | 2.89 | 5.39 | 4.54 | 4.10 | 14.13 | 10.88 | 5.74 | 2.05 | 4.84 | 14.23 | **74.32** |
| Prognathodes aculeatus | | | 0.81 | 1.23 | 0.46 | | | | | 0.41 | | **2.91** |
| Prognathodes aya | 5.57 | 1.80 | 3.11 | 9.31 | 8.48 | 4.50 | 4.59 | 2.48 | 0.60 | 3.51 | 3.73 | **47.68** |
| Prognathodes guyanensis | | | | | | | | 3.46 | | 0.41 | 1.73 | **5.60** |
| Pronotogrammus martinicensis | | 1.40 | | | | 7.13 | 28.07 | 1.21 | 1.09 | 108.91 | 124.65 | **272.44** |
| Pseudupeneus maculatus | 0.82 | 0.51 | | 3.22 | 2.72 | 4.26 | 2.09 | | | 5.31 | 5.38 | **24.30** |
| Ptereleotris calliura | | | | | | 4.28 | | | | | | **4.28** |
| Pterois volitans | 3.34 | 2.88 | 5.60 | 12.55 | 10.95 | 8.75 | 31.05 | | | 5.88 | 6.96 | **87.96** |
| Rachycentron canadum | | | | 0.41 | 1.22 | | | | | | | **1.63** |
| Raja sp. | | 0.77 | | | 0.90 | | | | | | 0.67 | **2.33** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rhomboplites aurorubens | 332.83 | 152.22 | 3.30 | 104.28 | 190.32 | 16.54 | 96.09 | | | 6.12 | 382.74 | **1284.44** |
| Rypticus maculatus | | | 0.82 | 2.42 | 0.67 | | | | | | | **3.91** |
| Rypticus saponaceus | 1.34 | 0.80 | | | 1.48 | 1.94 | 2.76 | | | 1.43 | 3.10 | **12.86** |
| Rypticus sp. | 1.46 | | 0.41 | 0.65 | 0.95 | 1.92 | 1.68 | | | | 0.76 | **7.83** |
| Scarus sp. | | | | 7.28 | | | | | | | | **7.28** |
| Scorpaena plumieri | | | | 0.65 | | | | | | | | **0.65** |
| Scorpaena sp. | | | | 0.72 | | | | | | | | **0.72** |
| Scorpaenidae | 1.18 | 0.68 | 0.42 | 2.15 | 2.24 | 4.05 | 1.63 | 7.27 | 3.91 | 1.21 | 6.20 | **30.94** |
| Seriola dumerili | 5.65 | 10.66 | 3.25 | 1.49 | 4.32 | 3.75 | 6.07 | | | 0.71 | 1.70 | **37.60** |
| Seriola fasciata | | | | | | | 16.74 | | | | 0.41 | **17.15** |
| Seriola rivoliana | 1.83 | 2.92 | 0.41 | 2.64 | 10.01 | 1.49 | 2.97 | | 0.41 | 4.81 | 6.74 | **34.23** |
| Seriola sp. | 2.10 | 2.93 | 2.96 | 3.82 | 5.57 | 14.74 | 5.53 | | 24.59 | 1.78 | 8.16 | **72.17** |
| Serranidae | | | | | 0.47 | | 1.55 | | | 0.41 | | **2.42** |
| Serranus annularis | 2.02 | 1.65 | 1.65 | 2.55 | 2.07 | 6.67 | 3.07 | | | 0.65 | 1.74 | **22.08** |
| Serranus baldwini | 1.87 | 1.49 | | 0.98 | | | | | | | | **4.34** |
| Serranus chionaraia | | | | | | | 0.82 | | | 0.41 | 6.52 | **7.74** |
| Serranus notospilus | | | 1.21 | | 0.97 | | | 4.26 | 2.45 | | 14.03 | **22.92** |
| Serranus phoebe | 6.48 | 4.93 | 4.02 | 6.13 | 6.87 | 13.45 | 10.87 | 0.56 | | 7.59 | 8.66 | **69.56** |
| Serranus sp. | | 1.19 | | | 1.49 | | 1.22 | | | | 2.29 | **6.19** |
| Serranus tigrinus | | | | | 0.89 | | | | | | | **0.89** |
| Sparidae | 1.85 | 1.18 | 2.07 | 3.47 | 8.98 | 4.40 | 29.81 | | | | 2.10 | **53.87** |
| Sparisoma atomarium | | | | 1.49 | 2.29 | 10.67 | 7.97 | | | 0.82 | 6.23 | **29.47** |
| Sparisoma aurofrenatum | | | | | 1.94 | | | | | | | **1.94** |
| Sparisoma chrysopterum | | | | | 1.55 | | | | | | | **1.55** |
| Sparisoma sp. | 0.41 | 1.02 | | 2.75 | | | | | | | | **4.18** |
| Sphoeroides spengleri | | 0.71 | 1.34 | 1.85 | 3.13 | 1.28 | 2.91 | | | | 2.13 | **13.36** |
| Sphyraena barracuda | 1.33 | | | 2.37 | 1.95 | | | | | | | **5.65** |
| Stegastes partitus | 2.59 | 1.97 | 0.41 | 3.31 | 2.13 | 5.90 | 3.87 | | | 1.22 | 2.53 | **23.92** |
| Stephanolepis hispidus | | | | 1.85 | 2.23 | | | | | | | **4.08** |
| Synagrops sp. | | | | | | | | | 0.82 | | | **0.82** |
| Syngnathus sp. | | | | 1.09 | | | | | | | | **1.09** |
| Synodus intermedius | | | 0.41 | 0.41 | | 0.73 | 0.41 | 0.86 | | | 1.61 | **4.42** |
| Synodus sp. | | | 0.81 | | | 1.28 | | 0.56 | | | 1.38 | **4.03** |
| Tautoga onitis | | | | | 1.32 | | | | | | | **1.32** |
| Tetraodontidae | | | 0.41 | 4.76 | 1.14 | | | | | | | **6.31** |
| Thalassoma bifasciatum | | | | 0.82 | 2.22 | | | | | | | **3.04** |
| unknown | 4.06 | 6.70 | 1.40 | 9.75 | 6.49 | 14.04 | 7.54 | 5.79 | 3.42 | 3.52 | 7.98 | **70.70** |
| Urophycis earlii | | | | | | 1.09 | 0.92 | | | | | **2.01** |
| Urophycis sp. | | | 0.73 | | | | | | | | | **0.73** |
| Xanthichthys ringens | | | | | | | 1.22 | | | | 6.48 | **7.70** |
| **Total** | **804.96** | **534.61** | **364.47** | **1331.11** | **1992.45** | **3035.21** | **2434.61** | **294.47** | **385.52** | **670.32** | **3211.85** | |