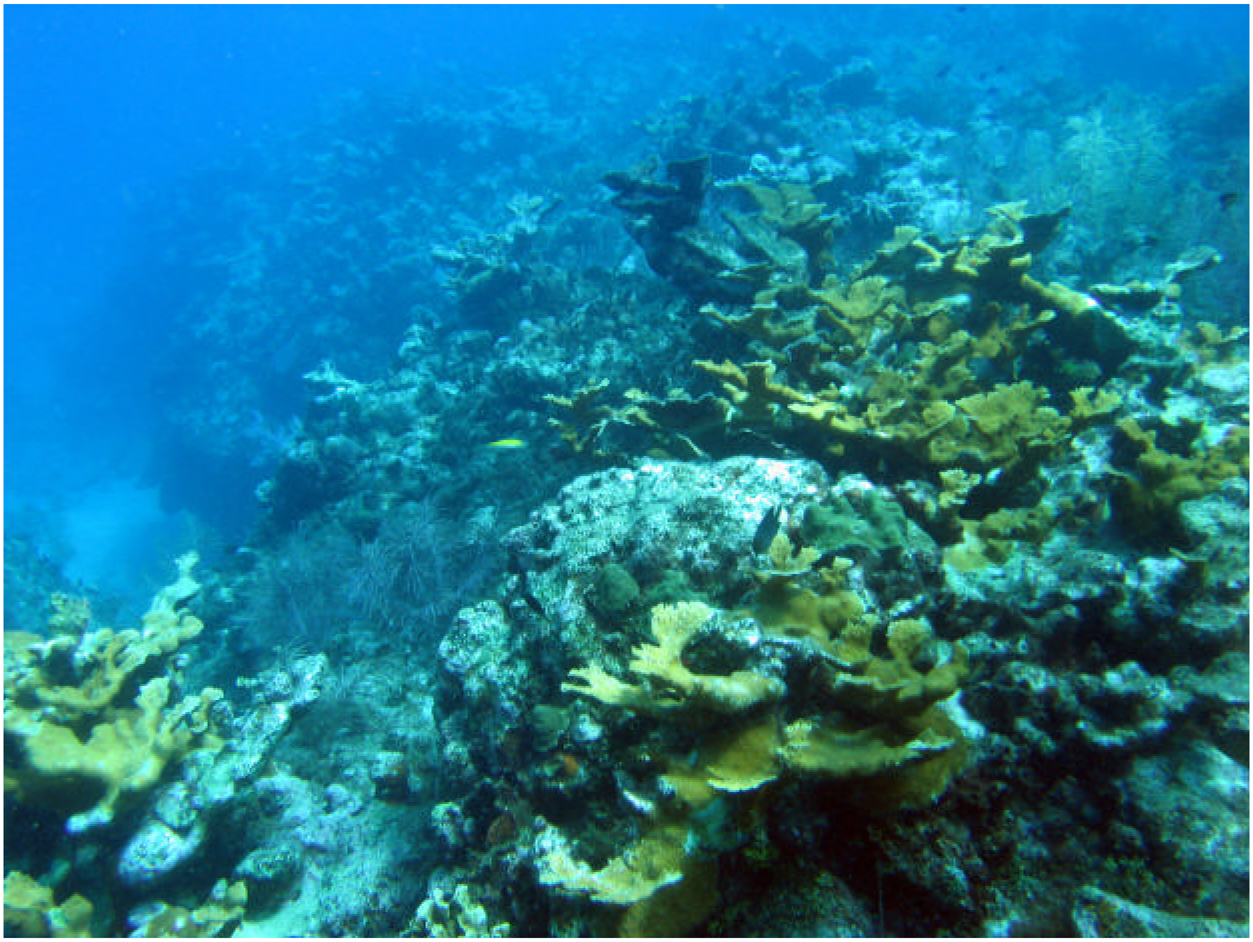
2007 Quick Look Report

Large-scale assessment of *Acropora* corals, coral species richness, urchins and *Coralliophila* snails in the Florida Keys National Marine Sanctuary and Biscayne National Park



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Cover Photo: Elkhorn coral (*Acropora palmata*) within the French Reef Sanctuary Preservation Area, Key Largo

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2007 Sampling Summary

The declines in abundance of two of the principal Caribbean reef-building corals, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*A. palmata*) (Figure 1), are often-cited examples of the changes in western Atlantic reefs that have occurred during the past several decades. The causes of these declines, which began in the late 1970s, include large-scale factors such as coral bleaching and disease, especially white band disease, as well as smaller scale effects from storms and predation by corallivorous snails and damselfishes. Both coral species were under consideration for addition to the U.S. Endangered Species List since the early 1990s and were formally added to the list as threatened in 2005 based upon Caribbean-wide population declines and poor recovery. The reader is referred to the *Acropora* Biological Review Team summary at http://sero.nmfs.noaa.gov/pr/pdf/050303%20status%20review.pdf for further information.

To help support NOAA's efforts to ascertain the current status of both staghorn and elkhorn corals, scientists from the Center for Marine Science, University of North Carolina-Wilmington (UNCW) undertook an intensive assessment of the spatial distribution, colony abundance, size, and condition of both staghorn and elkhorn corals throughout the Florida Keys, including both the Florida Keys National Marine Sanctuary (FKNMS) and Biscayne National Park (BNP). During June-August 2007, a total of 235 sites were surveyed from the northern extent of Biscayne National Park (Fowey Rocks) to southwest of Key West near Satan Shoal, thus covering most of the Florida Reef Tract minus the Marquesas Keys and the Dry Tortugas further west. Previous surveys conducted by this program dating back to 1999 aided in optimizing a sampling plan for obtaining abundance and size distribution estimates for the two *Acropora* coral species. Similar surveys conducted in the upper Keys region during 2006 were especially useful for delineating the habitats to be sampled and the effort needed per site. Quick Look reports from previous years are available at http://people.uncw.edu/millers/CoralReef_QuickLooks.htm. A two-stage stratified random sampling design was employed that incorporated nine unique habitat types, as well as areas inside and outside of FKNMS no-take zones: Sanctuary Preservation Areas (SPA), Ecological Reserves (ER), and Research Only Areas (RO). Twenty-two of the twenty-three no-take marine reserves between Carysfort Reef and the Marquesas Keys were sampled.

Hard-bottom and coral reef habitats were sampled from the inshore edge of Hawk Channel to the fore reef slope, essentially encompassing the spectrum of hard-bottom and coral reef habitat types that could presumably support colonies of either species over the depth range considered (< 1 m to 16 m depth). Habitat types sampled were mid-channel and offshore patch reefs, hard-bottom matrix, shallow (< 6 m) and deeper (> 6 m) low-relief hard-bottom, inner line reef tract spur and groove, high-relief spur and groove, patchy hard-bottom in sand, and low-relief spur and groove. At each site, four transects 15-m in length were surveyed 0.5 m on each transect side to yield data on *Acropora* presence-absence, colony density, size, and condition. Data were also obtained on depth and maximum vertical relief, as well as the presence-absence and frequency of occurrence of all stony coral species encountered within the belt transects. Urchins were identified by species and counted and measured for test diameter. *Coralliophila* snails, important coral predators, as well as commonly encountered gastropod mollusks, namely *Thais deltoidea* and *Leucozonia nassa*, were also sampled for density, shell length, and substratum occupancy patterns. Thirty-one days of fieldwork were required to sample the 235 sites by a two-person team. Accompanying reef fish surveys were carried out by researchers from NOAA Fisheries and RSMAS-University of Miami at a subset of the sites surveyed for *Acropora* corals. All work was conducted using SCUBA, with boat and diving support provided by a chartered research vessel (R/V *Expedition II*), NURC-UNCW, and local area dive shops in Marathon and Key West, Florida.

This quick look report summarizes results concerning the habitat distribution, abundance, size, and condition of staghorn and elkhorn corals in the Florida Keys. Nineteen accompanying tables and 29 figures provide site-level information on coral, snail, and urchin variables. The information collected during 2007 will be used to derive habitat-based population abundance estimates for the two *Acropora* corals covering the northern extent of the Florida Reef Tract to the Marquesas Keys. The coral species richness data adds to a growing data set on the habitat distribution patterns of reef-building corals in the region, and provides useful spatial data relative to the location of current no-take marine reserves. The urchin density and size data add to a growing information base on the spatial and temporal patterns of these organisms, in particular the potential recovery of *Diadema antillarum* 25 years after the Caribbean-wide mass mortality. The spatial extent of the 2007 surveys should also provide helpful information for updating the existing benthic habitat maps for the study area.

2007 Sampling Goals and Objectives

The 2007 sampling of staghorn (*Acropora cervicornis*) and elkhorn (*A. palmata*) corals in the Florida Keys National Marine Sanctuary (FKNMS) and Biscayne National Park (BNP) was undertaken as a spatially intensive effort to determine the habitat-based spatial distribution, abundance, size, and condition of these two important Caribbean reef-building corals. The 2007 surveys conducted during June 23 to August 18 were an outgrowth of previous efforts conducted by UNCW dating back to 1999 to quantify the abundance and condition of coral reef benthos throughout the FKNMS, including the Tortugas region. Previous surveys from southwest of Key West to Biscayne National Park included 80 sites sampled in 1999, 45 sites in 2000, 108 sites in 2001, 195 sites in 2005, and 107 sites in the upper

Keys region in 2006. Data obtained from these earlier efforts, together with existing habitat mapping information for the FKNMS, were used to guide the sampling of *Acropora* corals during 2007. Five publications are in the final stages of preparation based on results from the previous sampling efforts. The objectives of the 2007 sampling design were to provide information on:

- Habitat-based presence-absence distribution patterns encompassing diverse hard-bottom and coral reef habitat types from 1 m to 16 m depth, including a photographic archival record of where both *Acropora* coral species were found;
- *Acropora* coral colony density by site, habitat type, and protection level that incorporated most of the existing FKNMS no-take marine reserves from northern Key Largo to southwest of Key West;
- *Acropora* coral colony size distribution in terms of tissue surface area;
- Prevalence of *Acropora* coral colony conditions (normal/healthy, bleaching, disease, predation);
- Population abundance estimates for both species that is habitat and size structured;
- Density, size, and substratum occupancy patterns of *Coralliophila* snails, potentially important predators of *Acropora* coral tissue;
- Density and size of urchins, representing a continuing effort to monitor recovery of the historically abundant *Diadema antillarum*; and
- Stony coral species richness and frequency of occurrence.

The information presented below represents a nearly system-wide effort to quantify these variables from the northern extent of the Florida Reef Tract southwest to the Marquesas Keys. Because of the timing of the surveys, we were also able to collect information on the extent and severity of scleractinian coral bleaching, the results of which will be presented elsewhere.

Logistics and Field Methodology

The 2007 surveys of *Acropora* corals in the FKNMS and BNP relied upon existing mapping information on the distribution of benthic habitat types in the region, as well as previous presence-absence and abundance surveys for corals conducted since 1999. Previous surveys conducted by UNCW have principally focused on: 1) the Florida Keys from southwest of Key West to Biscayne National Park and 2) the Tortugas Region, including Dry Tortugas National Park and the Tortugas Bank. In 1999, benthic coral reef organisms were sampled at 80 sites from southwest of Key West to north of Carysfort Reef. Coral abundance was determined in two 25-m x 0.4-m belt transects per site (20 m^2), while the presence-absence of coral species was determine in four 25-m x 0.4-m belt transects per site (80 m^2). In 2000, a total of 45 sites were surveyed in the lower Keys region (SW of Key West to Bahia Honda) that encompassed habitats from the inshore edge of Hawk Channel to 15 m depth on the fore reef slope. Similar methods were used as in 1999, except 10-m transects were used on smaller size patch reefs. In 2001, a total of 86 sites were surveyed from southwest of Key West to upper Key Largo. These surveys were complemented by surveying larger belt transects 100 m^2 in area for the density of *Acropora* colonies. In 2005, a total of 195 sites were surveyed from south of the Marquesas Keys to the northern Biscayne National Park boundary. Coral abundance, size, and condition were sampled in two 10-m x 1-m belt transects per site, while the presence-absence of species was determined in four 15-m x 1-m belt transect areas. In 2006, a pilot study of *Acropora* coral density, size, and condition resulted in the sampling of 107 sites in the upper FKNMS.

The sampling design for assessing the population status of staghorn and elkhorn corals encompassed 235 sites visited during June-August 2007. Sites were distributed from northern Biscayne National Park (BNP) at Fowey Rocks to southwest of Key West at Satan Shoal (Figure 2). The original sampling design encompassed 180 sites in eight habitat types and included 17 of the 23 no-take marine reserves designated as Sanctuary Preservation Areas (SPA), Ecological Reserves (ER), and Research Only Areas (RO) in the FKNMS, not including the Tortugas region (Table 1). Due to excellent weather conditions and logistics, we were able to sample an additional 55 sites, 28 of which were in BNP. All of the FKNMS zones except for Newfound Harbor SPA were visited and all eight habitat types were sampled, in addition to several sites that were hard-bottom matrix areas. Table 2 chronologically lists the sampling locations during June-August 2007. The largest discrepancy between the planned and the actual sampling program concerned areas indicated as low-relief hard-bottom in several of the SPAs, especially in the lower Florida Keys region, which instead tended to comprise patchy hard-bottom in sand (Table 1). We also added several high-relief spur and groove sites in both the upper and lower FKNMS regions. Some areas designated as low-relief hard-bottom were in fact matrix habitats consisting of a mosaic of hard-bottom, rubble, sand, and sometimes seagrass. The BNP sampling, due to time constraints, focused on mid-channel and offshore patch reefs, shallow hard-bottom, and high-relief spur and groove. Based upon the paucity of both *Acropora* coral species on deeper (> 10 m) hard-bottom and spur and groove in BNP during 2005, we chose to focus on shallower hard-bottom and reef habitats in that area.

The habitat strata selected for the 2007 sampling incorporated all of the hard-bottom and coral reef habitat types from the shoreward edge of Hawk Channel to 16 m depth along the reef tract that were known or suspected to potentially support *Acropora* corals. Based upon results from the 2006 surveys in the upper Florida Keys, the back reef rubble habitat type was not surveyed, as this habitat did not yielded any *Acropora* corals in that year. In addition, we did not sample nearshore hard-bottom and seagrass areas, although we suspect that *A. cervicornis* could be present in these habitats. Habitats sampled during 2007 were mid-channel and offshore patch reefs, shallow (< 6 m) and deeper (6-15 m) low-relief hard-bottom, patchy low-relief hard-bottom, high-relief spur and groove, and low-relief spur and groove (Figures 3 and 4). The sampling also incorporated a series of inner line spur and groove sites unique to the upper Keys region from Grecian Rocks SPA to Turtle Reef. The list of sites organized by benthic habitat type is provided in Table 3, together with site-level data on depth and maximum vertical relief. Site descriptions for each of the 235 sampling locations visited during 2007 are provided in Table 4 and should be useful for updating existing habitat mapping information for the region.

A two-stage stratified random sampling design was used to randomly select sites for assessing staghorn and elkhorn coral populations in the Florida Keys. A grid system constructed in a geographic information system (GIS) was used to overlay the existing habitat map of the Florida Keys. Cells or blocks 200 m x 200 m in dimension were used to randomly select sites from eight habitat strata. A second level of stratification was accomplished by delineating regional sectors as follows: Biscayne National Park (Fowey Rocks to southern BNP boundary), upper Florida Keys (BNP boundary south to Pickles Reef), middle Florida Keys (Conch Reef southwest to Moser Channel), and lower Florida Keys (Big Pine Shoal west to Satan Shoal). Regional sectors potentially reflect differences in oceanographic influences, geological history, and habitat distribution. A third stratification variable was protection level which included sites inside and outside of FKNMS no-take marine reserves (SPA, ER, and RO). Within each no-take zone, two replicate sites were sampled in a given habitat type. The power of the stratified random sampling approach is essentially two-fold. First, the habitats comprising the most area are allocated more sites than those with less area (i.e., a proportional design). Second, habitats with more variability (e.g. coral density) are allocated more sites than those with less variability. The ultimate power of this approach is derived from the number of sites sampled rather than the effort expended per site.

The underwater surveys consisted first of locating randomly selected, pre-determined coordinates with a differential global positioning system. The original sampling list included 180 sampling locations, with an additional 145 alternate sites for the upper, middle, and lower Florida Keys regions. As we originally did not intend to sample sites within BNP, we randomly selected a subset of sites allocated for NOAA Fisheries sampling in BNP using the same methodology as for the rest of the Florida Keys, but limited to patch reef, shallow hard-bottom, and high-relief spur and groove habitats. If the original waypoint was not the intended habitat type, the closest alternate site was sampled instead. Once on-site, a two-person benthic diver team oriented four transect tapes 15 in length, marked in 1-m increments, along the bottom. A 60 m^2 area, therefore, was surveyed at each site for the variables described below. Each of divers surveyed two of the four transects for depth, maximum vertical relief, *Acropora* corals, stony coral species richness, *Coralliophila* and other selected other gastropod snails, and urchins. Transects were placed in a haphazard fashion, but in a way that adequately represented the habitat at the randomly selected site coordinates. Once transects were deployed, divers determined the minimum and maximum depth along the transect using a digital depth gauge, as well as the maximum vertical relief along each transect using a 50-cm scale bar. Maximum vertical relief took into consideration hard substratum, corals, and sponges, but did not include gorgonian height. Depth was measured using a digital depth gauge and maximum vertical relief with a 50-cm PVC scale bar marked in 5-cm increments. Digital photographs of each site were taken to record general site features and *Acropora* corals, urchins, and *Coralliophila* snails encountered.

Any *Acropora* corals that were observed within the 15-m x 1-m belt transects were counted, measured, and assessed for colony condition. For this study, a colony was considered to be a patch of continuous live tissue (ramet). In cases where a skeletal unit, possibly representing a single genet, was divided into one or more patches of tissue with clearly defined boundaries, each patch was considered to be a separate colony. Dimensions of live tissue patches were measured to estimate the surface area of each colony using applicable surface area formulas. The condition measurements included an assessment of bleaching, other types of tissue disease, predation on live tissue, and overgrowth by algae, sponges, and other biota. NOAA's coral disease web site was consulted to assist with the identification of disease-like conditions in the field (www.coral.noaa.gov/coral_disease).

In addition to the *Acropora* coral variables, several other variables were measured during the 2007 sampling. Stony coral species richness for each transect and each site was determined by recording all of the stony coral species (Milleporina and Scleractinia) within each of the four belt transect boundaries. This yielded information on the number of species per station (transect), total species per site, and the frequency of occurrence (proportion of transects present) for each species. All identifications were made *in situ*; however, underwater photographs were also taken for archival purposes. The species, number, and test diameter of all urchins were also recorded. Based upon the 2006 surveys, we included an assessment of the density, size, and substratum occupancy patterns of *Coralliophila* snails. During the surveys, we also encountered relatively large numbers of other gastropod mollusks, namely the deltoid rock shell (*Thais deltoidea*) and the common lesser tulip shell (*Leucozonia nassa*). *Coralliophila* and the other two snail species were counted and measured for total shell length. In addition, we recorded the substratum that the snail was found upon when surveyed, whether it was live coral, turf algae, coralline algae, etc. A few specimens of each species were collected and identifications were confirmed by scientists at the Fish and Wildlife Conservation Commission in Marathon, Florida. Similar to observations in 2005, we noted the beginning of coral bleaching during July 2007. Information was collected on the stony corals exhibiting a bleaching response and notes were made on whether a given species was observed as normal, pale, partially bleached, or completely bleached along the belt transects at each site. Once we reached

BNP by August 15, detailed information on the severity of bleaching by species was collected, including colony numbers, colony sizes, the amount of live tissue, and the extent of bleaching. Data were also recorded on water temperature during the time of the surveys.

The 2007 sampling effort (235 sites) required 33 field days from June 23 through August 18 (Table 2). Fortunately, no days were lost to inclement weather or other logistical challenges. The June-August sampling was generally marked by outstanding underwater visibility and calm seas. This was particularly noticeable in the lower Florida Keys. A private research vessel (R/V *Expedition II*, New World Expeditions, Key Largo, captained by Bernie Altmeir) provided on-the-water diving support. The survey team consisted of personnel from the Center for Marine Science/UNCW (Mark Chiappone and Leanne Rutten) (Table 5). SCUBA tank fills and lodging were provided by the National Undersea Research Center-UNCW facility on Key Largo and local area dive shops and hotels/marinas in Marathon, Cudjoe Key, and Key West. The sampling effort depended upon 6 to 7 hours in the water daily by a two-person benthic team to complete an average of 6-8 sites per day. Typically 30-45 minutes per site was needed to sample all four transects for *Acropora* corals and the other variables; however, sites with abundant *Acropora* colonies took upwards of 1.5-2 hours to inventory. Table 5 summarizes the diving statistics for 2007. Benthic surveys for *Acropora* corals and the other specified variables at the 235 sites required 470 dives by a two-person comprising nearly 284 hours of underwater bottom time.

Summary of Results

Table 3 provides a list of the 235 sampling locations by habitat type and geographic location. This table also includes the average depth and maximum vertical relief for each site. Below is summary information on *Acropora* corals, *Coralliophila* and other gastropod snails, urchins, and stony coral species richness.

Density, size, and condition of staghorn coral (*Acropora cervicornis*)

Staghorn coral (*Acropora cervicornis*) was observed in the general survey area at 55 of the 235 sites (23%) and was recorded within belt transect boundaries at 45 sites (19%) (Table 6). The habitat distribution staghorn coral was much broader than elkhorn coral, with colonies found in all but one of the nine habitat types sampled: mid-channel patch reefs (30.6% of 36 sites within transects), offshore patch reefs (40.5% of 42 sites), shallow (< 6 m) low-relief hard-bottom (20% of 25 sites), inner line reef tract spur and groove (50% of 8 sites), high-relief spur and groove (7.8% of 51 sites), deeper (6-15 m) hard-bottom (6.7% of 15 sites), patchy hard-bottom (9.5% of 21 sites), and low-relief spur and groove (6.1% of

33 sites). Figure 5 illustrates some of the examples of colonies that were recorded from various habitat types in 2007. Regional variations in staghorn coral presence-absence by habitat type were evident. *A. cervicornis* was more commonly found within transects on mid-channel patch reefs in the lower Keys (67% of 12 sites) compared to all other regions. On offshore patch reefs, *A. cervicornis* was more commonly encountered in BNP and the middle Keys compared to the upper and lower Keys. Relative to other regions, the lower Keys was the only region where *A. cervicornis* was found within transects in high-relief spur and groove, deeper hard-bottom (> 6 m), patchy hard-bottom, and low-relief spur and groove sites. Figures 6-14 show the spatial distribution of presence-absence and site-level colony densities from northern BNP to Satan Shoal.

A total of 508 staghorn coral colonies were counted within the belt transect boundaries in eight of the nine habitat types (Table 7). Of these, 113 colonies (22.2%) were counted from among 36 mid-channel patch reefs (15.3% of the sampling effort), 246 colonies (48.4%) from 42 offshore patch reefs (17.9% of the sampling effort), 15 colonies (3.0%) from 25 shallow (< 6 m) low-relief hard-bottom (10.6% of the sampling effort), 29 colonies (5.7%) from eight inner line reef tract spur and groove sites (3.4% of the total sampling effort), 90 colonies (17.7%) from 51 high-relief spur and groove sites (21.7% of the total sampling effort), one colony (0.2%) from 15 deeper (> 6 m) hard-bottom sites (6.4% of the total sampling effort), six colonies (1.2%) from 21 patchy hard-bottom sites (8.9% of the total sampling effort), and eight colonies (1.6%) from 33 low-relief spur and groove sites (14.0% of the total sampling effort). These data illustrate that the distribution of staghorn coral was not proportional to the sampling effort, indicating preferential habitat distribution. Greater numbers of colonies than expected were recorded from the two patch reef habitat types, while fewer colonies than expected were recorded from the remaining seven habitat types, especially on the deeper fore reef slope below 6 m depth. Figures 6-14 illustrate the spatial variability in site-level colony density for staghorn coral throughout the study area. Three of the highest density sites recorded from mid-channel and offshore patch reefs. The greatest mean (± 1 SE) site level densities (no. colonies per m^2) were 1.217 ± 1.780 on an offshore patch reef north of Looe Key SPA (site #131), 0.783 ± 0.683 colonies/m^2 on a mid-channel patch reef offshore of Broad Creek (site #406), and 0.683 ± 0.252 colonies/m^2 on an offshore patch reef northwest of Triumph Reef (site #471) (Table 7). Despite these relatively high site-level densities, *A. cervicornis* was extremely patchy in its distribution. Overall habitat-level densities were greatest on offshore patch reefs (0.098 ± 0.034 colonies/m^2), inner line reef tract spur and groove (0.060 ± 0.037 colonies/m^2), and mid-channel patch reefs (0.052 ± 0.024 colonies/m^2).

Although most staghorn coral colonies were relatively small (< 0.5 m in max. diameter) and consisted of individual colonies, there were some locations with relatively larger thickets, but these were limited to mid-channel and offshore patch reefs (Figure 5). Table 7 provides site-level information on the total surface area of live staghorn coral tissue measured, the mean percent cover (tissue surface area per m^2) by site, and the mean area per colony. While larger colony sizes were evident on mid-channel patch reefs and offshore patch reefs, nearly 90% of the sampled colonies were less than 100 cm^2 in surface area. The percentage of live tissue surface area per m^2 of substratum was greatest on several mid-channel and offshore patch reefs, with site-level percent cover as high as 2%. Mean ± 1 SE percent cover by habitat type was < 0.2% for all nine habitats, with offshore patch reefs (0.16 ± 0.06%), inner line reef tract (0.11 ± 0.06%), and mid-channel patch reefs (0.10 ± 0.05%) yielding the greatest habitat-level cover, albeit at obviously very low values. Average colony size by site was substantially greater in BNP on both mid-channel (331 ± 103 cm^2/colony) and offshore patch reefs (393 ± 307 cm^2/colony) compared to other regions. The greatest mean colony size (1312 ± 1486 cm^2/colony) for a site was recorded from a mid-channel patch reef (#456) inshore of Pacific Reef, albeit with substantial variability in colony sizes.

Of the 481 staghorn colonies measured for condition, no obvious incidence of white band disease, white plague, tissue necrosis, or *Coralliophila* predation was observed (Table 8). However, nine colonies or 2.2% of the total had obvious signs of damselfish predation, with most cases involving one or more damselfish present per colony. Of these nine cases, six (5.3% of 113 colonies) were on mid-channel patch reefs and three cases (1.3% of 236 colonies) were on offshore patch reefs. Entanglement with lobster trap rope was common, especially on patch reefs where nearly 75% of all staghorn coral colonies were found. Of the 78 patch reefs sampled during 2007, more than 90% of sites, even those within the no-take zones, contained remnant lobster trap debris. There were several instances where staghorn coral colonies were entangled where obvious tissue damage and colony breakage occurred from rope abrasion.

Density, size, and condition of elkhorn coral (*Acropora palmata*)

Elkhorn coral (*Acropora palmata*) was observed in the general survey area at 24 of the 235 sites (10.2%) and was recorded within belt transect boundaries at 19 sites (8.1%) (Table 6). The habitat distribution of this coral was much narrower than its congener and was only found within belt transects in three of the nine habitat types: offshore patch reefs (4.8% of 42 sites), inner line reef tract spur and groove (37.5% of 8 sites), and high-relief spur and groove (27.5% of 51 sites). Figure 15 illustrates some of the examples of colonies that were recorded from the various habitat types. In addition to habitat variations in elkhorn presence-absence, regional variations were also evident (Table 6). *A. palmata* was more commonly found within transects on high-relief spur and groove reefs in the upper Keys (53% of 17 sites) compared to all other regions. Figures 16-24 show the spatial distribution of presence-absence and site-level colony densities from northern BNP to Satan Shoal.

A total of 403 elkhorn coral colonies were counted and measured for colony size within the belt transect boundaries in three of the nine habitat types sampled (Table 9). Of these, 15 colonies (3.7% of the total) were counted from among 42 offshore patch reefs (17.9% of the sampling effort), 10 colonies (2.5%) from eight inner line reef tract spur and groove sites (3.4 % of the sampling effort), and 378 colonies (93.8%) from 51 high-relief spur and groove sites (21.7% of the sampling effort). The distribution pattern of elkhorn coral with respect to habitat type was not proportional to the sampling effort, indicating preferential habitat distribution. Figures 16-24 clarify this pattern by illustrating the spatial variation in site-level density throughout the Florida Keys. Greater numbers of colonies than expected (if the habitat distribution is random) occurred in high-relief spur and groove sites. The greatest mean ± 1 SE site level densities (no. colonies per m^2) were recorded from high-relief spur and groove reefs at Elbow Reef SPA (site #28, 1.250 ± 0.959), Sombrero Key SPA (site #84, 1.133 ± 2.048), French Reef SPA (site #29, 0.900 ± 1.045), and South Carysfort Reef SPA (site #217, 0.833 ± 0.168) (Table 9). We were encouraged to find relatively extensive thickets of elkhorn coral at the following sites from northeast to southwest: South Carysfort Reef, Elbow Reef, Horseshoe Reef, French Reef, Molasses Reef, Sand Island, Sombrero Key, and Looe Key.

Elkhorn coral colony sizes showed a significantly greater range compared to its congener, and we were encouraged to find several sites with relatively large (> 0.5 cm diameter) colonies (Figure 15). Table 9 provides site-level information on the total surface area of live elkhorn coral tissue measured, the mean percent cover by site, and the mean area per colony. High-relief spur and groove reefs yielded the largest colonies and percent cover values. Although the mean percent cover on all 51 high-relief spur groove sites was 1.6 ± 0.6%, mean cover was greater than 8% on several sites: South Carysfort Reef (24.6%), Elbow Reef (11.9%), Sombrero Reef (11.4%), and Sand Island (8.9%). These areas also yielded the largest colony sizes, with several sites yielding mean surface areas of > 1,000 cm^2 per colony.

Of the elkhorn colonies measured, the most obvious impacts to live tissue were predation by snails (*Coralliophila abbreviata*) and damselfishes (F. Pomacentridae) (Figure 25). We were discouraged to find lobster trap rope entangled in thickets of live colonies at South Carysfort Reef, but were encouraged by the absence of visible diseases such as white band and white pox. Of the colonies assessed for disease and predation, none were found with any visible symptoms of white band, white pox, or tissue necrosis (Table 10). For all sites and habitats combined, eight colonies (1.9% of the total measured), seven of which were from high-relief spur and groove, were impacted by *Coralliophila* snail predation. A total of 21 colonies (4.9%), all from high-relief spur and groove sites, were impacted by damselfish territories.

Density, size and substratum occupancy of *Coralliophila* and other gastropod snails

Before the 2007 sampling began, the decision was made to sample *Coralliophila* snails, well-known corallivores of *Acropora* corals and perhaps one of the factors inhibiting coral recovery. At all 235 sites, *Coralliophila* snails were counted and measured for total shell length (Figure 26). The type of substratum occupied by the snail was also recorded. We also encountered two species of gastropod mollusks, *Thais deltoidea* and *Leucozonia nassa*, that were included in the census, not only because they were extremely prevalent, but also because basic information on habitat-related patterns in density and size are poorly known (Figure 26).

A total of 48 *Coralliophila* sp. individuals were encountered in surveys of 235 sites encompassing 14,100 m^2 of hard-bottom and coral reef substratum. Table 11 summarizes site-level densities for *Coralliophila* sp. The 48 individuals were distributed among only three of the nine habitat types: offshore patch reefs (2 individuals, 4.2% of total), high-relief spur and groove (39 individuals, 81.3%), and low-relief spur and groove (7 individuals, 14.6%). The distribution of *Coralliophila* sp. was clearly non-random with respect to habitat type, as 81% of all individuals were recorded from high-relief spur and groove, despite this habitat only representing 22% of the total sampling effort. Mean densities in the upper Florida Keys in high-relief spur and groove were three to six times greater than in the middle and lower Keys (Table 11). The highest site-level mean ± 1 SE densities were 0.250 ± 0.145 and 0.217 ± 0.217 at Molasses Reef SPA (site #31) and Looe Key SPA (site #148), respectively. The 48 *Coralliophila* sp. individuals had a mean ± 1 SE total shell length of 2.1 ± 0.1 cm and ranged from 0.8 to 4.8 cm. Nearly 81% of all individuals were less than 2.9 cm in shell length (Figure 27). Of the 48 snails recorded, 41 individuals or 85% were found on live coral, while the remaining individuals were either found on algal turf, crustose coralline algae, or another *Coralliophila* shell (Table 12).

The most abundant gastropod mollusk included in our 2007 census was the deltoid rock shell (*Thais deltoidea*) (Figure 26). A total of 1,671 *T. deltoidea* individuals were encountered, with individuals distributed among five of the nine habitat types as follows: mid-channel patch reefs (3 individuals, 0.2% of total), offshore patch reefs (12 individuals, 0.7% of total), shallow (< 6 m) hard-bottom (84 individuals, 5% of total), and high-relief spur and groove (1,495 individuals, 89.5% of total). Similar to *Coralliophila* sp., the distribution of *T. deltoidea* was clearly non-random, with greater than expected individuals in the high-relief spur and groove habitat (Table 11). Mean site-level densities were as high 2.5 individuals per m^2, and the average density for the 23 high-relief spur and groove sites in the lower Keys was three to 24 times greater than for BNP, the upper Keys, or the middle Keys. The 1,671 *T. deltoidea* individuals had a mean total shell length of 2.7 cm, ranging from 1.0 to 4.9 cm. Nearly 88% of all individuals were between 2 cm and 4 cm in shell length (Figure 27). Of the 1,671 individuals recorded, 1,557 individuals or ~93% were found on either algal turf or crustose coralline algae (Table 12). This mollusk species appeared to have a clear affinity for this substratum type, which was especially prevalent in the high-relief spur and groove sites, although we could not ascertain *in situ* what the snails were eating.

The third gastropod mollusk sampled during 2007 was the common lesser tulip shell (*Leucozonia nassa*) (Figure 26), a species that exhibited the widest habitat distribution of the three gastropod mollusks sampled. A total of 248 *L. nassa* individuals were encountered, with individuals distributed among seven of the nine habitat types as follows: mid-channel patch reefs (4 individuals, 1.6% of total), offshore patch reefs (1 individual, 0.4% of total), shallow (< 6 m) hard-bottom (5 individuals, 2% of total), inner line reef tract (13 individuals, 5.2% of total), high-relief spur and groove (222 individuals, 89.5% of total), deeper hard-bottom (2 individuals, 0.8% of total), and patchy hard-bottom (1 individual, 0.4% of total). Similar to the other two gastropod mollusks sampled, the distribution of *L. nassa* was clearly non-random, with greater than expected individuals in the high-relief spur and groove habitat. Mean site-level densities were as high 0.33 individuals per m^2 (Table 11), with average densities generally higher in spur and groove reefs, especially those in the lower Keys region. The 248 *L. nassa* individuals had a mean total shell length of 3.0 cm, ranging from 0.8 to 6.0 cm. Nearly 77% of all individuals were between 2 cm and 4 cm in shell length (Figure 27). Of the 248 individuals recorded, 232 individuals or ~94% were found on either algal turf or crustose coralline algae, similar to *T. deltoidea* (Table 12).

Density and size distribution of urchins

Since 1999, surveys of sea urchin density and test size have been carried out throughout the southeast Florida coast and continued in 2007 at all 235 sites. Six species were encountered within transects that encompassed 14,100 m^2 of hard-bottom and coral reef substratum: *Diadema antillarum*, *Echinometra lucunter*, *E. viridis*, *Eucidaris tribuloides*, *Lytechinus variegatus*, and *Tripneustes ventricosus* (Figure 28). Tables 13-15 summarize site-level densities for each species and Table 16 provides the mean and ranges in test diameters (TD) by habitat and for the entire sampling domain. Of the six urchin species and 3,170 individuals encountered, the most abundant species were *E. viridis* (1,901 individuals, 60% of all individuals) and *E. tribuloides* (853 individuals, 26.9%), followed by *D. antillarum* (297 individuals, 9.4%), *E. lucunter* (103 individuals, 3.3%), *T. ventricosus* (15 individuals, 0.5%), and *L. variegatus* (1 individual, 0.03%).

A total of 297 individuals of *Diadema antillarum* were recorded, with individuals distributed among all nine habitats sampled (Table 13). The maximum site-level density of 0.267 individuals/m^2 occurred at an offshore patch reef inshore of Molasses Reef (site #7). Relative to similar surveys dating back to 1999, we noticed an appreciable increase in the number of sites where *D. antillarum* was found and a general trend towards larger test sizes, especially on patch reefs. Habitat-level densities were greatest on offshore patch reefs (Table 13). Test sizes ranged from 0.3 to 10.0 cm and averaged 3.6 ± 0.1 cm from all habitats combined (Table 16). The test sizes of the individuals recorded indicated a mixed distribution, with not only abundant recruits, but also over one-third of individuals greater than 5.0 cm TD (Figure 29).

Two species of *Echinometra* were encountered during the 2007 surveys. *E. lucunter* was the less abundant of the two species, with 103 individuals recorded among six of the nine habitats (Table 13). Nearly 74% of *E. lucunter* were recorded from high-relief spur and groove, with densities as high as 1.1 individuals per m^2 at one of three sites at Maryland Shoal (site #144) (Table 14). Similar to its congener, *E. viridis* was widely distributed among habitat types and was most abundant on mid-channel patch reefs, with 1,810 (95%) of the 1,901 individuals recorded from this habitat. Site-level densities of *E. viridis* were as high as 9.3 individuals per m^2 on mid-channel patch reefs and were relatively higher in BNP, the upper Keys, and the lower Keys (Table 14). The test diameter (TD) of individuals ranged from 0.5 cm to 5.0 cm and averaged 2.4 cm (Figure 29).

Eucidaris tribuloides was recorded from all nine habitats and exhibited a habitat distribution pattern similar to *Diadema antillarum.* A total of 853 individuals were found, with the highest site-level density estimate of 0.70 ± 0.08 individuals/m^2 recorded from a high-relief spur and groove site at Pelican Shoal (site #139) (Table 14). Densities tended to be greatest on offshore patch reefs and high-relief spur and groove habitats. Of the 853 individuals encountered, test diameters ranged from 0.5 cm to 4.6 cm, averaged 2.1 cm (Table 16), and showed a modal size class between 1.5 and 2.4 cm (Figure 29).

Stony coral species richness

The 2007 surveys also included an assessment of all stony coral species present along each of the four transects sampled at each site. A total of 47 taxa were observed among the 235 sites, represented by two milleporid hydrocorals and 45 scleractinian corals (Table 17). Table 18 provides habitat-level proportional transect frequency data for all 47 coral taxa, which further highlights habitat distribution patterns. These data allow for the discrimination of very common (e.g. *Agaricia agaricites*, *Porites astreoides*, *Siderastrea siderea*) to relatively rare corals (e.g. *A. lamarcki* and *Dendrogyra cylindrus*). Table 19 summaries the average number of species per station (transect) by site, region, and habitat type, as well as the total numbers of coral species observed per site by region and by habitat type. The patterns observed by species and for total species richness are similar to previous surveys dating back to 1999. For example, greater site species richness is apparent for mid-channel and offshore patch reefs, followed by relatively lower numbers of species for shallower fore reef habitats, then increasing on the deeper fore reef slope habitats. Subsequent analyses will provide statistical comparisons of species frequency of occurrence and site-level species richness among habitats, among regions, and between no-take marine reserves and corresponding reference areas.

Future Efforts

Results from the 2007 sampling effort provide a nearly system-wide assessment of *Acropora palmata* and *A. cervicornis* in the Florida Keys. Subsequent analyses will yield domain-wide abundance estimates, structured by colony size that will provide for estimates of population size by habitat, region, and for individual no-take marine reserves. While our Keys-wide sampling in previous years was not optimized for *Acropora* corals, the benthic data still provide important opportunities to compare populations across multiple habitat types, including managed areas in the FKNMS. What is apparent from the *Acropora* surveys is that the distribution and abundance patterns of these two species are clearly different, perhaps necessitating different management approaches. Although 34 different spur and groove reefs, including inner line reef tract, were sampled, our results indicate that significant *A. palmata* stands remain at only a handful of sites, namely South Carysfort Reef, Elbow Reef, Horseshoe Reef, French Reef, Molasses Reef, Sand Island, Sombrero Key, and Looe Key. While most of these sites are within existing FKNMS no-take zones, predation by snails and damselfishes, as well as physical impacts from lost fishing gear is still prevalent. In contrast, the distribution pattern of *A. cervicornis* reflects the importance of patch reefs to the possible recovery of this species. While there are over 5,000 patch reef sites on the south Florida shelf, staghorn is currently very patchily distributed, and the factors responsible for this pattern are not well known.

The sheer number of sites visited will allow us to update existing habitat maps for the study area, as well as assist in further optimizing future Keys-wide sampling. We also hope that this information will highlight the importance of the Florida Keys patch reef environment, little of which is located within no-take marine reserves, with most sites visited impacted by derelict fishing gear. Patch reefs include many of the best remaining reefs in the region, particularly in terms of coral cover and diversity. The sheer number of patch reefs inshore of the reef tract, their coral species composition that is dominated by mounding corals, and a highly variable natural physical environment (i.e., temperature, turbidity, sedimentation), are factors that contrast with habitats typically found along the outer reef tract. Why patch reefs appear to be in relatively good condition compared especially to the offshore spur-and-groove habitats is an important research and management question. Finally, as shown by results from these surveys, patch reefs support the most numerous stands of staghorn coral. However, patch reefs are also subjected to physical damage caused by lost fishing gear. This reflects both the higher coral cover remaining on patch reefs, significant habitat heterogeneity compared to surrounding areas (resulting in accumulation or concentration of debris), their large number, proximity to trap placements, and generally favored status as fishing sites. Under current conditions of diminished population numbers, damage from lost fishing gear is one factor that potentially affects extant staghorn corals. While we did not observe disease, both disease and coral bleaching (and acidification) remain major threats to species recovery throughout the Florida Keys and wider Caribbean. Promising management options for the recovery of *Acropora* corals do not currently exist, yet there are obvious actions that can be taken at the local level to enhance survival of existing populations that include removing trap and fishing debris and minimizing potential for trap and fishing debris to affect select patch reefs.