# Population assessment of staghorn (*Acropora cervicornis*) and elkhorn corals (*A. palmata*) in the upper Keys region of the Florida Keys National Marine Sanctuary


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## Cooperating Institutions and Support

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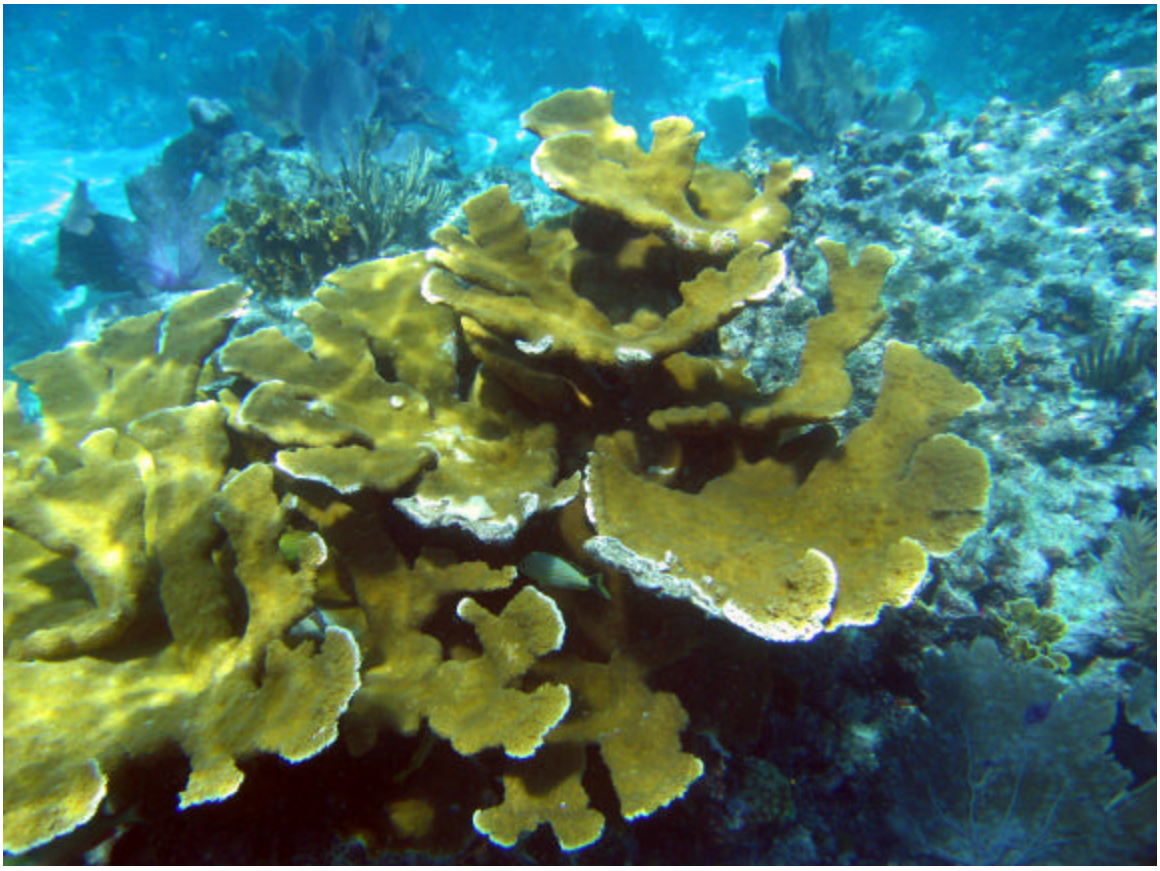

## Sampling Summary

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 over 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 from corallivorous snails and damselfishes. Both corals have been 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.

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 in a portion of the Florida Keys National Marine Sanctuary (FKNMS). During August 1-18, 2006, a total of 107 sites were surveyed in the upper Keys region of the FKNMS from the southern boundary of Biscayne National Park to offshore of Tavernier, a distance of ~46 km along the Florida reef tract. 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 coral species. A two-stage stratified random sampling design was employed for the upper Keys region that incorporated 11 unique habitat types, as well as areas inside and outside of FKNMS no-take zones (Sanctuary Preservation Areas, SPAs) that included Molasses Reef SPA, French Reef SPA, Grecian Rocks SPA, Dry Rocks SPA, and Carysfort/S. Carysfort SPA. The habitat types 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 (< 2 m to 15 m depth). At each site, four transects 15-m in length were surveyed 0.5 m on each transect side to yield data on presence-absence, colony density, size, and condition. Seventeen days of fieldwork were required to sample the 107 sites by a two-person team. At 65 of the 107 sites, the density and test diameter of urchins were also quantified in the four 15-m x 1-m belt transects (60 $m^2$) per site. 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 support provided by a chartered research vessel (R/V *Expedition II*) and diving operations provided by NURC-UNCW.

This quick look report summarizes some of the major findings concerning the habitat distribution, abundance, size, and condition of staghorn and elkhorn corals in the upper Florida Keys. Accompanying tables and figures provide site-level information on these variables. Information is also included on the distribution, abundance, and size distribution of urchins sampled at 65 sites. The information collected during this sampling mission will be used to derive habitat-based population abundance estimates for the two corals, provide a baseline for assessing temporal changes that may occur for these two species, and provide a template for carrying out similar surveys in the middle and lower Keys region planned for 2007. Ultimately, life history models can employ this information to better understand and predict the fate of these two historically abundant coral species.

## Sampling Goals and Objectives

The 2006 sampling of staghorn (*Acropora cervicornis*) and elkhorn (*A. palmata*) corals in the upper Keys region of the Florida Keys National Marine Sanctuary (FKNMS) was undertaken as a spatially focused effort to determine the habitat-based spatial distribution, abundance, size,

and condition of these two important Caribbean reef-building corals. The 2006 surveys conducted during August 1-18 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 include 80 sites sampled in 1999, 45 sites in 2000, 108 sites in 2001, and 195 sites in 2005, not including over 100 sites surveyed in the Tortugas region. 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 August 2006. The objectives of the sampling design in the upper Keys region of the FKNMS were to provide information on:

- Habitat-based presence-absence distribution patterns encompassing diverse hard-bottom and coral reef habitat types from 1 m to 15 m depth, including a photographic archival record of where both species were found;
- Colony density by site, habitat type, and protection level that incorporated all of the existing FKNMS no-take marine reserves in the upper Keys;
- Size distribution of colonies in terms of tissue surface area relative to habitat type;
- Prevalence of colony conditions (normal/healthy, bleaching, disease, predation);
- Population abundance estimates for both species that is habitat and size structured; and
- Density and size of urchins, representing a continuing effort to monitor recovery of the historically abundant *Diadema antillarum*.

The information presented below from the 2006 surveys represents the first system-wide effort to quantify the population status of these corals in the FKNMS.

## Logistics and Field Methods

The August 2006 surveys of *Acropora* corals in the upper Keys region relied upon existing mapping information on the distribution of benthic habitat types in the FKNMS, in addition to 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 (see Table 1). 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. Table 2 lists the presence-absence survey results from 2005 that were used to help guide the sampling plan for the upper Keys region in 2006.

The sampling design for assessing the population status of staghorn and elkhorn corals encompassed 107 sites visited during August 1-18, 2006. Sampling was confined to the upper Keys region between the southern boundary of Biscayne National Park and Pickles Reef offshore of Tavernier (Figure 2). The original sampling design encompassed 108 sites in eleven

habitat types and included all of the no-take marine reserves (Sanctuary Preservation Areas, SPAs) between Pickles Reef and the southern BNP boundary (Table 3). The largest discrepancy between the planned and the actual sampling program concerned areas indicated as low-relief hard-bottom in several of the SPAs, which were instead either patchy hard-bottom or matrix habitats comprised of rubble, sand, and hard-bottom. Figures 3, 4 and 5 show the spatial distribution of sites in the upper Keys region by habitat type, including the boundaries of the SPAs. The habitat strata selected for sampling incorporated all of the hard-bottom, rubble, and coral reef habitat types from the shoreward edge of Hawk Channel to the 15 m depth contour along the reef tract that were known or suspected to potentially support *Acropora* corals. Habitat types included mid-channel and offshore patch reefs, back reef rubble, shallow (< 6 m) and deeper (6-15 m) patchy and continuous low-relief bottom, high-relief spur and groove, and low-relief spur and groove (Figures 6 and 7). The sampling also incorporated a series of inner line spur and groove sites unique to the upper Keys region from south of Grecian Rocks SPA to North-North Dry Rocks and Horseshoe Reef. The list of sites organized by benthic habitat type is provided in Table 5. Site descriptions for each location visited during 2006 are provided in Table 6.

A two-stage stratified random sampling design was used to randomly select sites for assessing staghorn and elkhorn coral populations in the upper Keys region of the FKNMS during August 2006. 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 11 habitat strata in the upper Keys regional sector. The underwater surveys consisted first of locating randomly selected, pre-determined coordinates with a differential global positioning system. Once on-site, a benthic diver team oriented four 15-m transects, marked in 1-m increments, along the bottom. Each diver sampled two of the four transects for *Acropora* corals and urchins. Transect placement was done in a haphazard fashion to cover as much area of the site as possible. 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. In cases where a skeletal unit 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. The condition measurements included an assessment of bleaching, other types of tissue disease, and predation on live tissue. 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). At a subset of sites (65), urchin density and test diameter were quantified on the same transects assessed for *Acropora* corals (total sample area = 60 $m^2$/site).

The 2006 sampling effort (107 sites) required 17 field days from August 1 through August 18 (Table 4). Fortunately, only 1.5 scheduled field days were lost to inclement weather. A private research vessel (R/V *Expedition II*, New World Expeditions, Key Largo) provided vessel support. The survey team consisted of personnel from UNCW (Mark Chiappone and Leanne Rutten) and several reef fish observers from NOAA Fisheries and RSMAS-University of Miami. From two to four reef fish censuses were completed at a subset of the 107 sites surveyed for *Acropora* corals. SCUBA tank fills and lodging were provided by the National Undersea Research Center-UNCW facility on Key Largo. 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 urchins, however, sites with abundant colonies took upwards of 1.5 hours to inventory. Table 7 summarizes the diving statistics for 2006. Benthic surveys for *Acropora* corals and urchins at the 107 sites required 203 dives comprising nearly 100 hours of underwater bottom time.

## Summary of Significant Results

### Status of *Acropora cervicornis*

Staghorn coral (*Acropora cervicornis*) was observed in the general survey area at 19 of the 107 sites (18%) and was recorded within belt transect boundaries at 16 sites (Table 8). The habitat distribution of this coral was limited to five of the eleven habitat types sampled: mid-channel patch reefs (4 of 14 sites, 29%), offshore patch reefs (10 of 23 sites, 43%), shallow (< 6 m) low-relief hard-bottom (1 of 9 sites, 11%), inner line reef tract spur and groove (1 of 8 sites, 13%), and high-relief spur and groove (3 of 17 sites, 18%). Figure 8 illustrates some of the examples of larger colonies that were recorded from these habitat types. Figures 9, 10, and 11 show the spatial distribution of presence-absence in the upper Keys region.

A total of 71 staghorn coral colonies were counted within the belt transect boundaries in five of the habitat types (Table 9). Of these, five colonies (7.0%) were counted from among 14 mid-channel patch reefs (13.1% of sampling effort), 47 colonies (66.2%) from 23 offshore patch reefs (21.5% of sampling effort), 10 colonies (14.1%) from nine shallow (< 6 m) low-relief hard-bottom (8.4% of sampling effort), four colonies (5.6%) from eight inner line reef tract spur and groove sites (7.5%), and five colonies (7.0%) from 17 high-relief spur and groove sites (15.9%). These data indicate that the distribution patterns of staghorn coral were not proportional to the sampling effort and there thus appears to be a preferential distribution of this coral. A greater number of colonies than expected (if the habitat distribution is random) were recorded from the two patch reef habitat types, while fewer colonies than expected were recorded from high-relief spur and groove and six of the other habitat types where no colonies were recorded. Figures 9, 10, and 11 illustrate the spatial variability in site-level colony density for staghorn coral. The greatest mean (± 1 SD) site level densities of 0.333 ± 0.667 colonies/$m^2$ and 0.183 ± 0.240 colonies/$m^2$ were recorded from two offshore patch reefs, one in the western area of Carysfort/S. Carysfort SPA (site #83) (Figure 9), the other on Mosquito Bank (site #26) (Figure 11). Overall habitat-level densities were greatest on offshore patch reefs (0.034 ± 0.079 colonies/$m^2$).

No staghorn coral thickets larger than ~0.5 m in diameter were observed at any location, and most sites with staghorn coral colonies present consisted of mostly small branches (Figure 12). Table 9 provides site-level information on the total surface area of live staghorn coral tissue measured and the mean area per colony. Colony sizes (live tissue surface area) ranged from 7.4 $cm^2$ to 127.5 $cm^2$ and were greatest on mid-channel patch reefs and inner line reef tract spur and groove. Nearly 90% of the sampled colonies were less than 100 cm2 in surface area (Figure 12). Of the staghorn colonies measured, only one colony from the 77 assessed (1.4%) at all sites had obvious signs of damselfish predation (Table 10). No incidences of white band, white pox, or lesions were recorded for staghorn coral during the surveys.

### Status of *Acropora palmata*

Elkhorn coral (*Acropora palmata*) was observed at 18 of the 107 sites (17%) and was recorded within belt transect boundaries at 15 sites (Table 8). The habitat distribution of this coral was limited to four of the eleven habitat types sampled: offshore patch reefs (2 of 23 sites, 9%), shallow (< 6 m) low-relief hard-bottom (1 of 9 sites, 11%), inner line reef tract spur and groove (6 of 8 sites, 75%), and high-relief spur and groove (9 of 17 sites, 53%). Figure 13 illustrates some of the larger colonies, but also smaller juveniles, that were recorded during the August 2006 surveys. Figures 14, 15, and 16 illustrate the spatial pattern of elkhorn coral presence-absence in the upper Keys region.

A total of 388 elkhorn coral colonies were counted within the belt transect boundaries in four of the eleven habitat types sampled (Table 11). Of these, 51 colonies (13.0%) were counted

from among 23 offshore patch reefs (21.5% of sampling effort), 15 colonies (3.9%) from nine shallow (< 6 m) low-relief hard-bottom (8.4% of sampling effort), 100 colonies (25.8%) from eight inner line reef tract spur and groove sites (7.5%), and 222 colonies (57.2%) from 17 high-relief spur and groove sites (15.9%). Clearly the distribution pattern of elkhorn coral with respect to habitat type was not proportional to the sampling effort, indicating a preferential habitat distribution. Figures 14, 15, and 16 further clarify this pattern by illustrating the spatial variation in site-level density in the upper Keys region. A greater number of colonies than expected (if the habitat distribution is random) were recorded from inner line reef tract and high-relief spur and groove habitat types. The greatest mean (± 1 SD) site level densities were recorded from high-relief spur and groove reefs at South Carysfort (site #79, 1.967 ± 2.593 colonies/$m^2$) (Figure 14) and Sand Island (site #66, 1.100 ± 1.343 colonies/$m^2$) and an inner line reef tract site at Horseshoe Reef (site #241, 0.933 ± 1.652 colonies/$m^2$) (Figure 15). Overall habitat-level densities were greatest on high-relief spur and groove and inner line reef tract habitat types (Table 11).

Elkhorn coral colony sizes showed a significantly greater range compared to its congener, and we were encouraged to find several sites with large (> 0.5 cm diameter) colonies (Figure 13). Table 11 provides site-level information on the total surface area of live elkhorn coral tissue measured and the mean area per colony. Colony sizes (live tissue surface area) ranged from 46.3 $cm^2$ to over 2,000 $cm^2$ and were greatest on high-relief spur and groove and inner line reef tract habitats. The size distribution of elkhorn coral colonies measured from all habitat types is illustrated in Figure 12. Of the 387 colonies measured, 46% were smaller than 100 $cm^2$ in surface area, while ~16% were greater than 500 $cm^2$ in surface area. Figure 17 illustrates the size distribution patterns for three of the four habitat types where elkhorn coral was distributed and indicated that the size distribution pattern was relatively similar among these three habitats. While most colonies were less than 100 $cm^2$ in tissue surface area, larger colonies were also relatively common.

Of the elkhorn colonies measured, the most obvious impacts to live tissue were predation by snails (*Coralliophila abbreviata*) and damselfishes (Pomacentridae) (Figure 18). 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 388 colonies assessed for disease and predation, none were found with any visible symptoms of white band, white pox, or tissue necrosis (Table 12). For all sites and habitats combined, 13 colonies (3.4%) were impacted by snail predation and 11 colonies (2.8%) had visible lesions from damselfish predation.

**Density and size distribution of urchins**

Sixty-five sites were surveyed for the species, densities, and test sizes of urchins encountered within four 15-m x 1-m belt transects sampled per site during August 2006. Five species were encountered within transects that encompassed 3,900 $m^2$ of hard-bottom, rubble and coral reef habitat: *Diadema antillarum*, *Echinometra lucunter*, *E. viridis*, *Eucidaris tribuloides*, and *Tripneustes ventricosus* (Figure 19). Table 13 summarizes site-level densities and Table 14 summarizes the test size information. Of the five species and 285 individual urchins encountered, the most abundant species were *E. viridis* (120 individuals, 42.1% of all individuals) and *E. tribuloides* (106 individuals, 37.2%), followed by *D. antillarum* (48 individuals, 16.8%), *E. lucunter* (8 individuals, 2.8%), and *T. ventricosus* (3 individuals, 1.1%). Forty-eight individuals of *Diadema antillarum* were recorded from the 65 upper Keys sites and were distributed among 10 of the 11 habitat types sampled (Table 13). The maximum site-level density of 0.1 individuals/$m^2$ was recorded at two sites: one at a high-relief spur and groove site at Sand Island (Site #41), the other at a shallow (< 6 m) hard-bottom site northwest of Carysfort/S. Carysfort Reef SPA (Site #52). At both of these locations, six individuals were

recorded among four 15-m x 1-m belt transects. Overall stratum-level densities tended to be greatest on the shallow fore reef, including rubble and high-relief spur and groove habitats. Test sizes ranged from 0.4 to 7.5 cm and averaged 3.3 ± 2.2 cm from all habitats combined (Table 14). The test sizes of the individuals recorded indicated a nearly bimodal distribution, with frequency peaks at 2-2.4 cm TD (Figure 20).

Two species of *Echinometra* were encountered during the 2006 surveys. *E. lucunter* was the less abundant of the two species, with only 11 individuals recorded in three of the 11 habitat types sampled: mid-channel patch reefs, offshore patch reefs, and inner line spur and groove (Table 13). Nearly 64% of the *E. lucunter* individuals were recorded from mid-channel patch reefs and densities were < 0.1 individuals per $m^2$ at all sites (Table 14). *E. viridis* was only recorded from four of the 11 habitat types sampled, and most (114 individuals, 95%) were found in mid-channel patch reef environments, along with small numbers of individuals on offshore patch reefs and low-relief hard-bottom and low-relief spur and groove at 6-15 m. Site-level densities of *E. viridis* were generally low and108 of the 120 individuals (90%) were recorded at two shallow mid-channel patch reefs in the Basin Hill Shoals area (site #9 and #11). Site level densities were as high as 1.35 individuals per $m^2$, but most sites yielded no individuals. The test diameter (TD) of individuals ranged from 0.5 cm to 4.5 cm, averaged 2.7 ± 0.8 cm, and showed a modal size class of 2.5-2.9 cm (Figure 20).

*Eucidaris tribuloides* was recorded from 10 of the 11 habitat types and showed a habitat distribution pattern markedly different from *Echinometra* spp. A total of 106 individuals were found and the highest site-level density estimate of 0.25 ± 0.3 individuals/$m^2$ was recorded from the high-relief spur and groove habitat at Sand Island (site #41), where 15 individuals were measured in a 60 $m^2$ area. In contrast to *E. viridis*, densities of *E. tribuloides* tended to be greatest offshore on the shallow fore reef, especially patchy and low-relief hard-bottom < 6 m in depth and high-relief spur and groove (Table 13). Of the 106 individuals encountered, test diameters ranged from 0.9 to 4.0 cm, averaged 2.2 ± 0.7 cm (Table 14), and showed a modal size class of 2.0-2.4 cm (Figure 20).

Only three individuals of *Tripneustes ventricosus* were recorded from the 65 sites, one from a mid-channel patch reef site, one individual from a shallow (< 6 m) patchy hard-bottom site, and one from a deeper (6-15 m) patchy hard-bottom site. The three individuals ranged in size from 4.0 to 9.5 cm and averaged 6.5 ± 2.8 cm TD.

## Future Efforts

Results from the 2006 sampling effort provide the first-ever baseline assessment of *Acropora palmata* and *A. cervicornis* on a large spatial scale in the upper Florida Keys region. Comparisons will be made with results from previously published benthic work in the Florida Keys that unfortunately include only a few sites and started typically after white band disease had already significantly affected population numbers for both corals. We will also compare results from this year with benthic sampling previously conducted as part of our Keys-wide assessment and monitoring program. While our Keys-wide sampling in previous years was not optimized for these two species, the benthic data still provide important opportunities to compare populations across multiple habitat types, including managed areas in the FKNMS. We plan to extend these surveys in 2007 to include the middle and lower Keys, possibly re-sampling the upper Keys as well to capture a system-wide synoptic view. In addition to the comparative work, results will: 1) be used to derive habitat-based population abundance estimates for the two corals; 2) provide a baseline for assessing temporal changes that may occur for these two species, and; 3) provide a template for optimizing our surveys planned for 2007. We will also explore how life history models can employ this information to better understand and predict the fate of these two corals in the Florida Keys.