Surveys of benthic coral reef organisms in Dry Tortugas Park and the Tortugas Bank, western Florida Keys National Marine Sanctuary

Quick Look Report: Tortugas Region Cruise, June 5-26, 2006

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Summary of Benthic Sampling

Benthic surveys and accompanying fish surveys of hard-bottom and coral reef habitats from 5 m to 27 m depth were conducted during a three-week research cruise (June 5-26, 2006) aboard the M/V *Spree* (Gulf Diving, Houston, TX) in the Tortugas region encompassing Dry Tortugas National Park (DTNP) and the western extent of the Florida Keys National Marine Sanctuary. This quick-look report summarizes the major findings and provides site-level data for the variables measured at 46 sites surveyed during the research cruise. The 2006 sampling complements previous surveys in the region during similarly organized research cruises in 1999 (24 sites surveyed), 2000 (35 sites), and 2002 (24 sites) in this area, for a total of 129 sites surveyed between 1999 and 2006.

Benthic surveys of hard-bottom and coral reef habitats in the Tortugas region were accomplished by a three to four person team from CMS-UNCW and RSMAS-UM using enriched air Nitrox to allow for multiple daily dives within the 2 m to 26 m depth range surveyed. Surveys of the 46 sites required 153 dives and ~187 hours of underwater bottom time and included sites located in a variety of habitat types within Dry Tortugas National Park, within the Tortugas North no-fishing reserve, within the FKNMS, but outside the Tortugas North reserve, and sites outside the FKNMS boundaries. Habitat types surveyed included patch reefs, low-relief hard-bottom, patchy hard-bottom, high-relief spur and groove, medium-profile reefs, and medium- and high-relief reef terraces. Benthic surveys by the project team were complemented by reef fish

surveys conducted by scientists from RSMAS-University of Miami and NOAA Fisheries at the 46 sampling locations.

A stratified random sampling design using pre-existing benthic habitat mapping data were used to allocate sampling effort (no. of sites per habitat type) and randomly select sites. Benthic variables measured in the Tortugas region during 2006 included percent cover, species richness of sponges and benthic cnidarians, gorgonian densities by species, stony coral densities, sizes, and condition by species, urchin densities and sizes by species, topography, and still photography for archival purposes. All of the variables were recorded underwater on pre-formatted plastic PVC slates and data entered into a database entry program onboard to facilitate relatively rapid data processing for data analyses. Transects 15 m in length were used to obtain percent coverage using the linear point-intercept technique, while data on species richness and invertebrate densities using a 0.5 m scale bar were collected along the transects.

General impressions of the Tortugas region from a benthic perspective are summarized as follows. Many of the surveyed areas suffered obvious physical damage (e.g. overturned corals) and scouring from several tropical cyclones that impacted the region in 2005. Many areas that were gorgonian-dominated hard-bottom habitats in 1999-2000 and 2002, especially in the southern region of DTNP, are now devoid of most gorgonians and sponges. Interestingly, concurrent reef fish surveys documented relatively few juveniles of some species (e.g. black grouper) that were previously relatively abundant in these habitats. Reef terraces on Little Tortugas Bank and the northwestern Tortugas Bank (Sherwood Forest) are still in relatively good condition in terms of coral abundance, but coral cover has apparently declined from ~50% to ~35% in some areas. In these same sites, we noticed a high prevalence of the brown alga *Lobophora variegata* that is now occupying space once covered by live coral. A few sites also exhibited relatively high prevalence of coral disease, especially by what we believe to be white plague. One site in particular had ~25% of the corals afflicted with this condition. The factors responsible for the increased disease prevalence observed compared to previous years are not known. The hypothesis that coral bleaching and other stressors increase susceptibility to disease needs to be tested. However, the extent, severity, and degree of recovery from coral bleaching that occurred in 2005 are unknown.

Relative to 1999-2000, sea urchins, especially *Diadema antillarum*, were more abundant and were found in relatively dense aggregations (> 0.3 individuals/m^2) in some of the shallow-water patch reef, hard-bottom, and medium-profile reef areas in DTNP. While *Diadema* densities are still below the presumed historical (pre-1983) density level of ~1 individual/m^2 for certain habitat types, urchin densities in the Tortugas region, especially within DTNP, remain about an order of magnitude higher than what we have documented for the rest of the Florida Keys. We were encouraged to see the number of juvenile *Diadema* that recently recruited to benthic habitats in the region, as peak recruitment in south Florida normally occurs during August and September. Of the 98 *Diadema* surveyed from the 46 sites, ~75% were less than 1 cm in test diameter and represent individuals that have settled within the past one to two months.

Below is a brief narrative on the overall goals of the UNCW hard-bottom and coral reef habitat assessment and monitoring effort in the Florida Keys and a variable-by-variable summary of significant findings from the 2006 Tortugas region surveys. The report also includes a list of published and planned papers and other products developed from this effort. A suite of 14 appending tables summarize site-level coverage, species richness, coral densities, coral disease prevalence and frequency, gorgonian densities, urchin densities, and anemone/corallimorpharian densities. Time-series analyses comparing the 1999-2000, 2002, and 2006 are in progress.

Study Area Description

The Tortugas region has a long history of scientific study, summarized in Davis (1982) and Jaap et al. (1989), and includes several historical assessments of reef geomorphology and community structure dating back over a century (e.g. Shinn et al. 1977; Dustan 1985). The Dry Tortugas, near the western extent of the Florida Keys National Marine Sanctuary (FKNMS) (Figure 1), are an island group 117 km west of Key West. The islands consist of an elevated atoll-like rim of Holocene coral measuring about 27 km from southeast to northeast and 12 km wide that rests atop a Pleistocene mound (Shinn et al. 1989). The atoll has a discontinuous elevated rim of Holocene coral and several small sandy islands such as Loggerhead Key (site of the Carnegie Institute marine laboratory), and Garden Key. Deep channels (10-20 m depth) separate three major banks (Pulaski, Loggerhead, and Long Key) within what is now Dry Tortugas National Park (formerly Ft. Jefferson National Monument). The Tortugas region represents the western extent of extensive reef growth in the Florida Keys archipelago, with Holocene accumulations up to 17 m (55 feet) in some locations (Shinn et al. 1977). West of the shallow bank encompassing Dry Tortugas National Park is the Tortugas Bank, a deeper (> 12 m) water area extending to the western boundary of the FKNMS. Prior to research cruises in 1999 and 2000 by UNCW, NMFS, and RSMAS-UM, little scientific information existed on the benthic habitats of the Tortugas Bank and few mapping data existed except for the area within Dry Tortugas National Park (Davis 1982). Since 1999, however, fishery independent surveys and habitat mapping have elucidated the spatial pattern of habitats for much of the Tortugas Bank (Franklin et al. 2003).

In response to concerns about declining regional trends in coral reef habitats and multi-species reef fish stocks (see Ault et al. 2002), the FKNMS, National Park Service, State of Florida, and the Gulf of Mexico Fishery Management Council designated 518 km^2 of no-take ecological reserves that includes the Research Natural Area (RNA) within the park, but also two reserves further west: the Tortugas North Ecological Reserve encompassing the northern half of the Tortugas Bank, and the Tortugas South Ecological Reserve encompassing the Riley's Hump area. Because of its up-current position located on the southwestern Florida shelf in the Florida Current, the Tortugas Region is widely considered a principal spawning ground that re-populations waters and provides an essential source of larvae of many invertebrates and commercially important fishers to the Florida Keys and southeastern Florida (Lee et al. 1994).

Sampling Goals and Objectives

The 2006 sampling of coral reef and hard-bottom habitats in Dry Tortugas National Park (DTNP) and the western extent of the Florida Keys National Marine Sanctuary (FKNMS) included both FKNMS no-take marine reserves (NTMR) and corresponding reference habitats that complement earlier efforts in the Tortugas region carried out during 1999-2000 and 2002. The 2006 sampling adds to a growing body of information on the status and condition of coral reef benthic resources throughout the Florida Keys, including NTMRs implemented in 1997 off of islands from Key Largo to Key West, as well the Tortugas North NTMR established in 2001. The goals of the UNCW hard-bottom and coral reef habitat assessment and monitoring effort in the Florida Keys are four-fold:

- To assess the community structure and condition of hard-bottom and coral reef habitats at multiple spatial scales, with particular reference to the no-take marine reserves (NTMR), but also inter-reef, among habitat type, and among regions of the south Florida shelf;
- To assess coral population structure at multiple spatial scales, including among benthic habitat types, regions, and level of protection;

- To assess the condition of habitats related to potential changes due to protecting from fishing within NTMRs, but also changes that may occur at larger spatial scales related to regional or global phenomena; and
- To complement fishery-independent reef fish surveys with "fine-scale" or detailed habitat information, to facilitate experimental and modeling efforts for evaluating essential fishery habitat (in collaboration with Dr. Jerry Ault at RSMAS-UM and Dr. Jim Bohnsack at NOAA Fisheries).

To accomplish these goals, the 2006 Tortugas sampling built upon existing data collected during previous cruises to guide the underwater surveys. Our focus during 2006 was two-fold:

- To survey the complement of hard-bottom and coral reef habitats in the Tortugas region to assess habitat variability in community structure, abundance, and condition of benthic invertebrates and algae.
- To sample enough sites inside and outside of existing (Tortugas North NTMR, DTNP) and proposed management areas (DTNP Research Natural Area) for spatial comparisons and to temporally compare earlier surveys (1999-2000 and 2002) with those in 2006.

Together with the data collected during previous years, this project has amassed an unprecedented data set for the Tortugas region on the abundance and habitat utilization patterns of algae and several invertebrate taxa, including stony corals, gorgonians, sponges, and echinoderms. These data are timely for providing population abundance estimates and trends for reef-building invertebrates, especially stony corals, as well as a temporal comparison of changes in benthic community structure inside and outside of areas protected from fishing. Moreover, these data allow for relevant comparisons with similar habitat types and depths with the rest of the Florida Keys that are subjected to differing levels of impacts such as coastal development and fishing pressure.

Logistics and Methods

A two-stage stratified random sampling design was used to allocate sampling effort and randomly select sites during 2006 following methods presented in Ault et al. (2006). A grid system constructed in a geographic information system (GIS) was used to overlay the existing habitat map of the Tortugas region that was developed from previous research cruises (see Franklin et al. 2003). Cells or blocks 200 m x 200 m in dimension were used to randomly select sites from the following habitat strata in Dry Tortugas National Park, within the Tortugas North no-take marine reserve (NTMR), Tortugas Bank (fished), and outside the FKNMS (Table 1):

- Patchy low- and medium-relief hard-bottom (> 30% sand interspersed with hard-bottom)
- Low-relief hard-bottom (< 30% sand)
- Patch reefs
- High-relief spur and groove
- Medium-profile reefs
- Medium- and high-relief reef terraces

The sampling scheme consisted of 46 sites sampled in the region, with 26 located within Dry Tortugas National Park, four sites outside of DTNP, two sites on the Tortugas Bank, but outside the Tortugas North NTMR, 11 sites within the Tortugas North NTMR, and three sites west of the FKNMS western boundary (Figure 1). Table 2 lists the sampling locations by benthic habitat type and management area, together with the depth ranges of surveyed transects, while Figures

2, 3 and 4 are representative underwater images of the habitat types surveyed. The 2006 Tortugas region sampling of 46 sites was conducted during two 10-day cruises (18 diving days) from June 5 through June 26 (Table 1). Inclement weather resulted in the loss of 2.5 days of fieldwork during the first leg of the cruise. Daily benthic sampling effort was approximately 3-4 hours in the water by a three to four person dive team depending upon site depth. Table 3 summarizes the diving statistics for the benthic habitat sampling. Benthic surveys of the 46 sites required 153 dives comprising more than 187 hours of underwater bottom time. Reef fish surveyors from NOAA Fisheries and RSMAS-UM accompanied the benthic team and completed 87 dives and nearly 87 hours of underwater bottom time.

The 2006 Tortugas region benthic surveys were similar in scope to previous surveys we conducted (Table 4). Briefly, at each pre-determined site a GPS receiver was attached to a buoy to mark the transect positions. Four 15 m transects were deployed at each site in a haphazard fashion. Along each transect, coverage was determined every 15 cm to yield 100 points per transect. The numbers of species of stony corals, gorgonians, and sponges were determined in a 0.5 swath on each side of the four transects, yielding a total sample area of 60 m^2 per site. Gorgonian densities by species were determined along two transects in 1 m x 8 m areas. Stony corals more than 4 cm in maximum diameter were counted, measured, and assessed for condition, including evidence of bleaching and disease, along two of the transects in 1 m x 10 m swaths. Juvenile corals (< 4 cm maximum diameter) were assessed along two transects by sampling ten randomly placed quadrats 0.68 m x 0.45 m in dimension along each of two transects. Urchin density and test diameter, as well as the density of incidental marine invertebrates (see Table 4), were assessed on all four transects (total sample area = 60 m^2/site). *In situ* measurement of topographic complexity on each of the four transects were undertaken to provide an assessment of substratum angle, maximum vertical relief, and the coverage of different relief categories along 15 m x 1 m areas.

Summary of Significant Results

Tropical storms

The summer of 2005 witnessed the passage of four category one or stronger hurricanes, including Dennis, Katrina, Rita, and Wilma, that affected benthic communities on the south Florida shelf to varying degrees. Damage to benthic habitats in the Tortugas region was apparently patchy, with some areas experiencing relatively little evidence of damage, such as reef terraces west of Loggerhead, the northern area of the park, and the northern and western areas of the Tortugas Bank. However, the southern area of DTNP and areas to the south of the park boundary suffered obvious physical damage from these storms (see Figure 3, lower left photo). Areas that were gorgonian-dominated hard-bottom communities in 1999, 2000, and 2002 were nearly completely scoured and devoid of living gorgonians. In those areas believed to experience storm damage in 2005, it appears that branching gorgonians were the most dramatically affected.

Coral bleaching

The summer of 2005 started with doldrums-like conditions during mid-May, with light and variable winds from the west-southwest. By June, predominant winds returned to their seasonal east-southeasterly orientation, but conditions relative to previous summers were unusually calm. By early August there were clear signs of a severe bleaching event in the Florida Keys, with surface and bottom temperatures reaching 31.1° to 32.2°C (88° to 90°F). In the Tortugas region, however, we are not aware of any surveys that were conducted to assess the scope and severity of bleaching in 2005. Surveys during 2006 did not indicate any bleaching in the sites

and habitat types surveyed. Surface and bottom water temperatures were relatively cooler during June 2006. In fact, there was a persistent and rather dramatic thermocline at about 21 m on the Tortugas Bank throughout the research cruise.

Benthic cover

Tables 5 and 6 summarize mean percent coverage data for fire corals, scleractinian corals, the colonial zoanthid *Palythoa*, sponges, and different algal functional groups (turfs, crustose corallines, and macroalgae) for 42 of the 46 Tortugas sites. Benthic cover data are also illustrated in Figures 5 and 6 and are organized by management area and benthic habitat type. Mean stony coral cover ranged from 0.25% to 31% among the 42 sites. Sites with the greatest stony coral cover included medium-profile reefs, medium-relief reef terraces, and high-relief reef terraces in the northeastern and western areas of DTNP, as well as reef terrace sites in the northeastern and western area of Tortugas Bank (Figure 5). Mean sponge cover throughout the region was relatively low, ranging only from 0.5% to 8.25% among sites, as was the coverage by the colonial zoanthid *Palythoa*. Relative to surveys in 1999-2000, there was a clear indication in the Sherwood Forest area of the Tortugas Bank that total coral cover has declined from values of ~50% to ~30%.

Percent cover data for algal functional groups are summarized in Table 6 and Figure 6. Filamentous algal turfs and macroalgae (e.g. *Dictyota*, *Lobophora*, *and Halimeda*) were the predominant algae observed among the sites. Coverage by filamentous algal turfs was particularly high (42-70%) at sites south of the DTNP boundary, perhaps reflecting scouring from storms in 2005.

Species richness

Surveys of the number of species of stony corals, gorgonians, and sponges were conducted at all 46 sites during the 2006 Tortugas surveys. Table 7 summarizes the number of species per site and the average number of species per 15 m x 1 m belt transect for these benthic invertebrate groups. Figure 7 illustrates the spatial patterning in site species richness for the 46 sites by habitat type and management area. Coral site species richness ranged from 5 to 25 species. Not surprisingly, higher relief habitats such as patch reefs within the DTNP, medium-profile reefs within the DTNP and the Tortugas Bank, and medium- and high-relief reef terraces within the DTNP and the Tortugas Bank yielded the greatest numbers of coral species. Lower relief habitats south of the DTNP yielded low numbers of coral species, probably due to scouring effects from the 2005 storms. Site species richness of gorgonians ranged from three to 24 species. Gorgonian richness was greater in DTNP, probably due to shallower depth, than deeper habitats on the Tortugas Bank. Patch reefs and low-relief hard-bottom sites within the DTNP yielded particularly high numbers of gorgonian species, while reef terraces and medium-profile reefs on the Tortugas Bank were devoid of most species. Sponge site species richness ranged from six to 45 species. Species richness of sponges was generally equal to or greater than stony corals and gorgonians combined for many sites.

Coral density, disease and bleaching

Coral density, size, and condition measurements were conducted at all 46 Tortugas region sites by identifying, counting, measuring, and assessing colony condition for corals greater than 4 cm in maximum diameter. A total of 785 *Millepora* spp. colonies (19.8%) and 3,186 scleractinian coral colonies (80.2%) were surveyed, yielding a total coral sampling size of 3,971 colonies (Table 8). Total coral densities among the 46 sites ranged from 0.15 to 17.03 colonies per m^2 and thus exhibited substantial variability among the sites (Figure 8). Relative high coral density

sites were surveyed on reef terrace habitats west of Loggerhead Key, south of the DTNP boundary, on Little Tortugas Bank, and in the Sherwood Forest area, as well as in high-relief spur and groove habitat at Long Key Reef (Figure 1).

The coral condition measurements conducted during 2001 included assessments of competition, predation, bleaching, and disease. As in previous years, the disease prevalence in the habitats and depth range surveyed was relatively low (< 5%), especially black band, "white diseases" such as white plague, and dark spot syndrome (Table 9). However, there were several locations with relatively high disease prevalence, especially white plague. Four disease or disease-like conditions were noted during 2006: 1) dark spot syndrome affecting primarily *Siderastrea siderea* and *Stephanocoenia michelini*, 2) white plague that was affecting a variety of species, 3) dead white skeleton of unknown causes, and 4) tissue necrosis (Figure 9). Of the 3,186 scleractinian corals assessed from all sites, 192 colonies (~6%) exhibited one of these four disease symptoms. White plague was the most prevalent disease condition, affecting 4.5% of all corals sampled and comprising nearly 75% of all disease prevalence, followed by dark spot syndrome (13 colonies, 0.4% prevalence, 6.8% of all disease), dead white skeleton of unknown cause (27 colonies, 0.8% prevalence, 18.9% of all disease), and tissue necrosis (9 colonies, 0.3% prevalence, 4.7% of all disease). The overall prevalence rate is comparatively high relative to surveys throughout the Florida Keys in 2005 and in the Tortugas region during 1999-2000. However, the overall prevalence rate is affected by several locations where disease prevalence was high, especially due to an infestation of white plague affecting multiple species. Interestingly, the high disease prevalence sites (15-37%) were found in medium-profile reefs and patchy hard-bottom habitats in the northern and northeastern areas of DTNP (Table 9, Figure 1), while remaining areas in the DTNP and the Tortugas Bank generally had disease prevalence rates below 5% for the species and numbers of colonies assessed.

Juvenile coral density

Surveys of juvenile coral species composition, density, and maximum diameter were conducted at all 46 Tortugas sites during 2006. Table 10 lists the number of juveniles found per site and mean densities reported as the number of juveniles (< 4 cm max. diameter) per m^2, while Figure 8 illustrates the spatial patterning in juvenile coral densities relative to the established (> 4 cm diameter) coral assemblages among sites. Surveys of the 46 sites resulted in the sampling of 909 quadrats and 283.6 m^2 of benthic habitat. A total of 715 juvenile Scleractinia were counted and identified. Site-level mean ± 1 SD juvenile densities ranged from 0.16 ± 0.23 per m^2 to a high of 5.77 ± 2.77 per m^2. Juvenile coral densities were well within the range surveyed during 1999-2000 in the Tortugas region and similar surveys throughout the Florida Keys since 1999. The greatest juvenile coral densities tended to occur in patch reef, high-relief spur and groove, and high-relief reef terrace habitats within DTNP.

Gorgonian density

Gorgonian species density was surveyed at all 46 sites during 2006 and encompassed 92 belt transects (8 m x 1 m) covering 736 m^2 of benthic habitat. A total of 6,557 gorgonian colonies were identified and counted (Table 10). The most striking result from 2006 relative to previous surveys in 1999-2000 was the dramatically reduced abundances of gorgonians in certain areas, especially the southern area of DTNP and the central region of the Tortugas Bank. Site-level mean ± 1 SD gorgonian densities ranged from 0.06 ± 0.09 colonies per m^2 to 24.88 ± 1.59 colonies per m^2. Generally greater gorgonian densities were found on hard-bottom and patch reef habitats within DTNP (Figure 8). Several of the deeper reef habitats (medium-profile reefs and reef terraces) in both DTNP and the Tortugas Bank had abundant encrusting gorgonians comprised of *Briareum asbestinum* and *Erythropodium caribaeorum*.

Urchin density and size

Sea urchin densities and test sizes were measured at all 46 Dry Tortugas sites (2,760 m^2) during 2006, complementing surveys dating back to 1999-2000 that provide a temporal record of urchin habitat distribution and recovery patterns of the once ubiquitous long-spined sea urchin, *Diadema antillarum* (Chiappone et al. 2001). Four species and 423 urchin individuals were encountered among the 46 sites (Table 11 and Figure 10). *Echinometra lucunter* was the most common urchin (179 individuals, 42% of all urchins), followed by *D. antillarum* (100 individuals, 24%), *E. viridis* (97 individuals, 23%), and *Eucidaris tribuloides* (47 individuals, 11%). While forty-one of the 46 sites surveyed yielded relatively low urchin densities (< 0.1 individuals/m^2), several sites yielded relatively high densities of urchins, including *D. antillarum* (Figure 11). This was especially apparent on shallow-water patch reefs in DTNP. The greatest site density for *D. antillarum*, 0.367 individuals per m^2, was recorded from two patch reef areas within DTNP, one near the central region of the park and the other east of Loggerhead Key. At both sites, 22 *Diadema* were encountered among the four 15 m x 1 m belt transects. Other sea urchins also occurred in relatively high densities on patch reefs or low-relief hard-bottom habitats (Figure 11).

Urchin size distribution data based upon measurements of test diameter for the 46 Tortugas sites are illustrated in Figure 12. For *Diadema antillarum*, the mean (± 1 SD) test size for 98 individuals was 1.76 ± 2.32 cm, ranging from 0.3 cm to 7.8 cm. Size data for this urchin clearly indicate a cohort of recently settled recruits and a second cohort of individuals above 5 cm in test diameter. The other three urchin species encountered during the surveys exhibited a smaller size range and similar mean test sizes relative to *D. antillarum*.

Anemones and corallimorpharians

Surveys of anemone and corallimorpharian density by species were carried out along the four 15 m x 1 m belt transects surveyed at all 46 sites, along with additional invertebrate groups (Table 12). Five anemone species (Cnidaria, Actiniaria) were surveyed from the 46 Tortugas sites representing 2,760 m^2 of benthic habitat: *Bartholomea annulata*, *Condylactis gigantea*, *Epicystis crucifera*, *Heteryactis lucida*, and *Lebrunia danae* (Table 13). Of the 346 anemones counted, *E. crucifera* (150 individuals, 43% of total) and *L. danae* (148 individuals, 43%) were the most common species, followed by *B. annulata* (35 individuals, 10%), *H. lucida* (8 individuals, 2%), and *C. gigantea* (5 individuals, 1%). Anemones tended to be patchily distributed among the sites surveyed and were most abundant on shallow patch reef and hard-bottom habitats in DTNP.

Three species of corallimorpharians were recorded within transect surveys: *Discosoma carlgreni*, *D. sanctithomae*, and *Ricordea florida* (Table 14). Of the three species, *R. florida* was

clearly the most abundant (316 individuals, 93% of total), followed by *D. sanctithomae* (21 individuals, 6%) and *D. carlgreni* (4 individuals, 1%). As we have observed in the rest of the Florida Keys, the two species of *Discosoma* were concentrated in some of the shallow-water patch reef areas within DTNP. Densities of the most common corallimorpharian, *R. florida*, exhibited similar habitat density variations and were most abundant on patch reef, medium-profile reefs, and high-relief spur and groove reefs scattered throughout the park.

Plans for Use of the Data

Below is a list of manuscripts in press or published and those submitted for review that have been developed from surveys in the Florida Keys, including the Tortugas region. While many of these reports are descriptive in nature, many of the variables measured by this program have never been assessed at so many sites representing the complement of shallow-water hard-bottom and coral reef habitats in the Florida Keys. For the Tortugas region data, our plan is to compare results between 1999-2000 with those in 2006 to help characterize the habitats in the region and provide comparisons with spatial and temporal patterns with similar data collected in the rest of the Florida Keys.

In addition to specific analyses for manuscripts, we plan to re-evaluate our existing habitat classification to further optimize our allocation strategy for future surveys. We also intend to continue to work closely with NMFS, RSMAS-UM, and FIU to compare community structure and condition variables with existing water quality, geological, and reef fish survey data.

Manuscripts in press or published

Ault JS, Smith SG, Meester GA, Luo J, Bohnsack JA, Miller SL (2002) Baseline multispecies coral reef fish stock assessment for the Dry Tortugas. NOAA Technical Memorandum NMFS-SEFSC-487, 117 p

Ault JS, Smith SG, Meester GA, Luo J, Franklin EC, Bohnsack JA, Harper DE, McClellan DB, Miller SL, Swanson DW, Chiappone M (2002) Tortugas surveyed: Synoptic habitat and reef fish surveys support establishment of marine reserves in the Dry Tortugas, Florida, USA. *Reef Encounter* 31: 22-23

Chiappone M, Dienes H, Swanson DW, Miller SL (2003) Density and gorgonian host-occupation patterns by flamingo tongue snails (*Cyphoma gibbosum*) in the Florida Keys. *Caribbean Journal of Science* 39(1): 116-127

Chiappone M, Dienes H, Swanson DW, Miller SL (2005) Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. *Biological Conservation* 121: 221-230

Chiappone M, Miller SL, Swanson DW, Ault JS, Smith SG (2001) Comparatively high densities of the long-spined sea urchin in the Dry Tortugas, Florida. *Coral Reefs* 20: 137-138

Chiappone M, Miller SL, Swanson DW (2001) *Condylactis gigantea* – A giant comes under pressure from the aquarium trade in Florida. *Reef Encounter* 30: 29-31

Chiappone M, Swanson DW, Miller SL (2002) Density, spatial distribution and size structure of sea urchins in coral reef and hard-bottom habitats of the Florida Keys. *Marine Ecology Progress Series* 235: 117-126

Chiappone M, Swanson DW, Miller SL, Dienes H (In press) Spatial distribution of lost fishing gear on fished and protected offshore reefs in the Florida Keys National Marine Sanctuary. *Caribbean Journal of Science* 40: 312-326

Chiappone M, Swanson DW, Miller SL, Smith SG (2002) Large-scale surveys on the Florida Reef Tract indicate poor recovery of the long-spined sea urchin *Diadema antillarum*. *Coral Reefs* 21: 155-159

Chiappone M, White A, Swanson DW, Miller SL (2002) Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. *Marine Pollution Bulletin* 44: 597-604

Franklin EC, Ault JS, Smith SG, Luo J, Meester GA, Diaz GA, Chiappone M, Swanson DW, Miller SL, Bohnsack JA (2003) Benthic habitat mapping in the Tortugas region, Florida. *Marine Geodesy* 26: 19-34

Miller SL, Chiappone M, Swanson DW, Ault JS, Smith SG, Meester GA, Luo J, Franklin EC, Bohnsack JA, Harper DE, McClellan DB (2001) An extensive deep reef terrace on the Tortugas Bank, Florida Keys National Marine Sanctuary. *Coral Reefs* 20: 299-300

Miller SL, Precht WF, Chiappone M (2004) Recognizing complexity in biological systems: Making coral reef ecology simple? A Florida case history. *Current (Journal of Marine Education)* 20: 4-11

Miller SL, Swanson DW, Chiappone M (2002) Multiple spatial scale assessment of coral reef and hard-bottom community structure in the Florida Keys National Marine Sanctuary. *Proceedings of the 9th International Coral Reef Symposium* 1: 69-77

Precht WF, Miller SL (2006) Ecological shifts along the Florida reef tract: the past as a key to the future. In Geological approaches to coral reef ecology. Aronson RB (ed), Springer Verlag, NY

Manuscripts in progress or submitted for publication

Chiappone M, Rutten LM, Swanson DW, Miller SL (In progress) Spatial patterns of benthic coral reef organisms in the Florida Keys National Marine Sanctuary. 2. Gorgonian species density, richness, and colony density. *Coral Reefs**

Chiappone M, Rutten LM, Swanson DW, Miller SL (In progress) Spatial patterns of benthic coral reef organisms in the Florida Keys National Marine Sanctuary. 3. Sponge cover and species richness. *Coral Reefs**

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