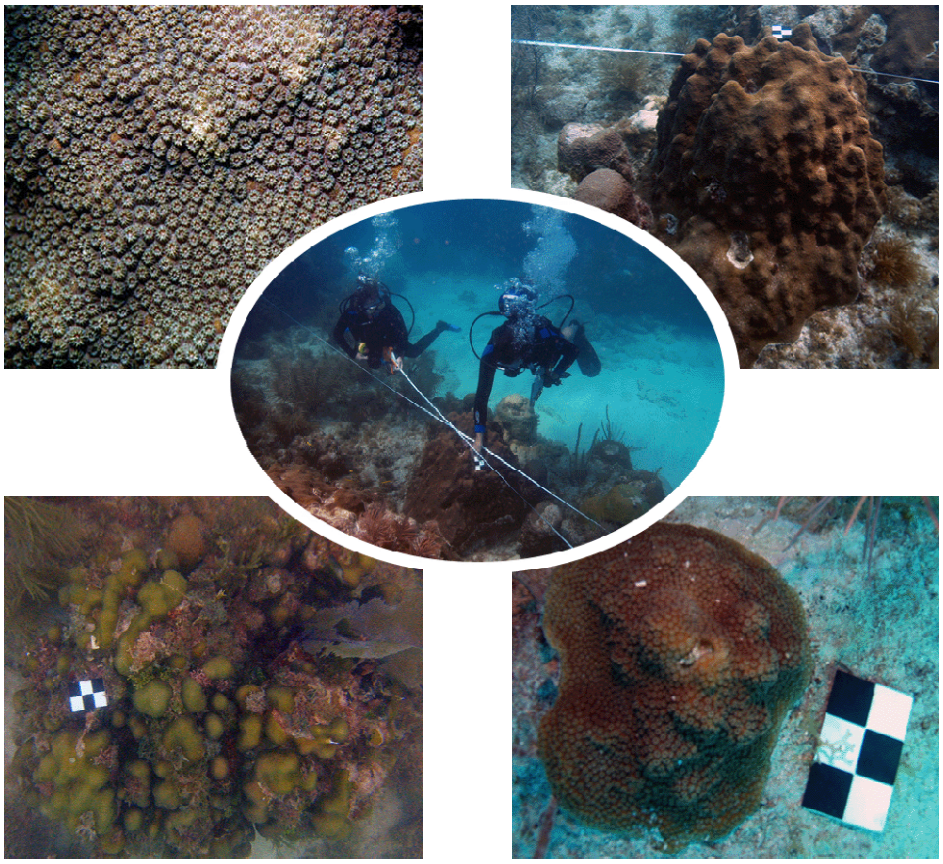
Florida Fish And Wildlife Conservation Commission
Fish And Wildlife Research Institute

Coral Reef Evaluation & Monitoring Project

2006 Executive Summary
EPA Steering Committee Meeting
July 2007



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INTRODUCTION

The Florida Keys Coral Reef Evaluation and Monitoring Project (CREMP) was initiated in 1994 to provide data on the status of coral reef resources of the Florida Keys National Marine Sanctuary (FKNMS) and document changes in status over time. In 1995, forty sites were identified throughout the FKNMS and permanent sampling stations were installed. Data collection began in 1996 and has been conducted annually. Stations were installed at three additional sites in the Dry Tortugas in 1999 and incorporated into the annual sampling protocol (Figure 1).

CREMP inventories the number of different stony coral species at each station (species richness). Stony coral percent cover is obtained from video transects and presented for all stony coral combined and for the five most common species. CREMP also monitors other selected major benthic functional groups at the taxa level (macroalgae, sponges and octocorals). The incidence of disease and bleaching in stony corals and the abundance of the long-spined sea urchin, *Diadema antillarum*, has been recorded at all stations since the inception of the project.

In 2001, surveys of abundance and benthic cover of bioeroding clionid sponges, which aggressively encrust and invade stony coral colonies, were initiated in the FKNMS and the Dry Tortugas. This annual monitoring was initiated at all CREMP stations in response to concerns that clionids were implicated in coral decline. Between 2002 and 2005, added surveys of stony coral abundance and an expanded stony coral disease survey were conducted at a subset of stations at selected sites. However, these data are not summarized herein and will be summarized in a separate report. In 2006, these surveys of stony coral abundance were replaced with a pilot study targeting *Montastraea annularis* (boulder star coral) due to the continued decline in percent cover of this important reef framework builder.

This report presents results for the FKNMS CREMP stations summarized Sanctuary-wide and by region. The regions are defined as Upper Keys, Middle Keys, and Lower Keys (Figure 1). The data for the Dry Tortugas sites are presented separately from those for the FKNMS.

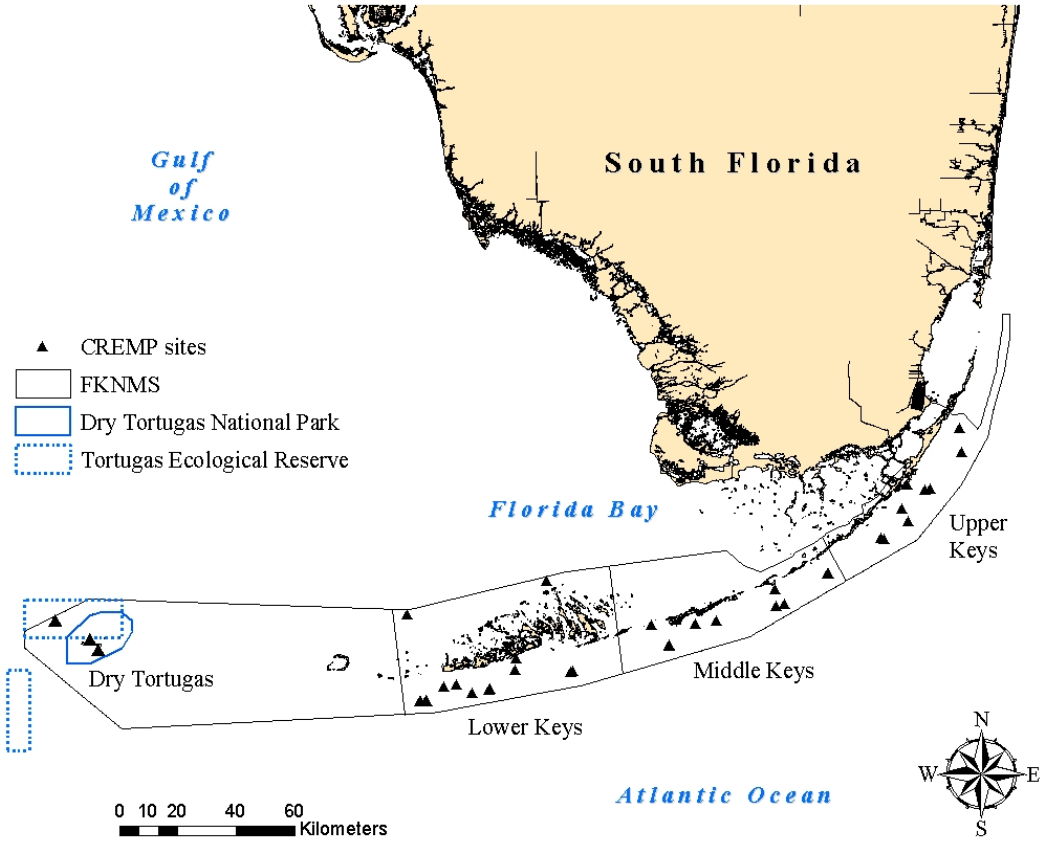

Figure 1. Coral Reef Evaluation and Monitoring Project site locations and region boundaries.

METHODS

The same methods are employed for all CREMP sites. Each sampling station within a site is permanently marked with two stainless steel reference stakes. Two steel poles, three plastic chains, and three measuring tapes are used to define a station's area and sample transects (Figure 2).

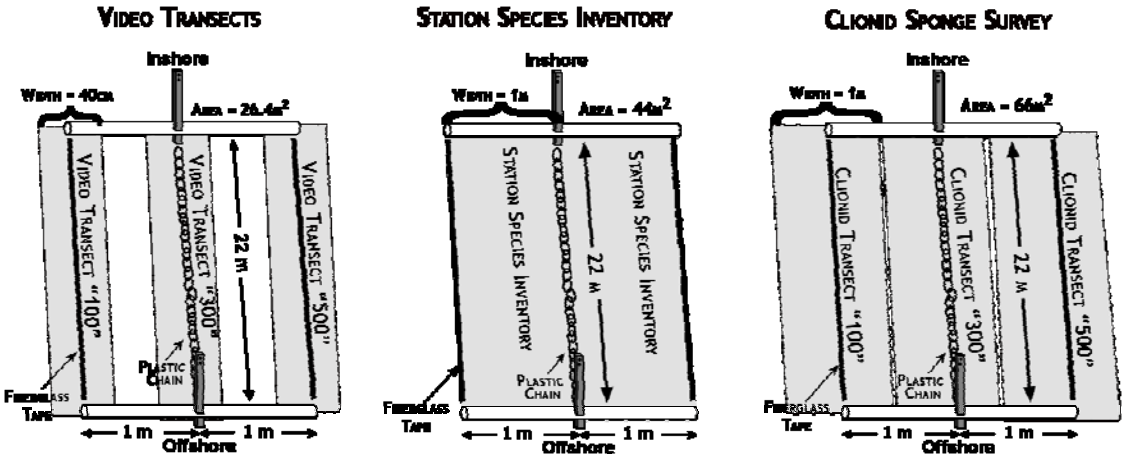

Figure 2. CREMP video transects, station species inventory, and clionid sponge survey station layout.

Station Species Inventory

A pair of observers records the presence of every stony coral species in each station (2x22m) (Figure 2) during a 15-minute search period (Figure 3). The divers initially conduct independent surveys, then check and verify each other's data as a quality control assurance. Incidence of condition (disease and bleaching) and presence of long-spined sea urchins (*Diadema antillarum*) are also recorded. Stony coral species richness is calculated for each station and averaged Sanctuary-wide.

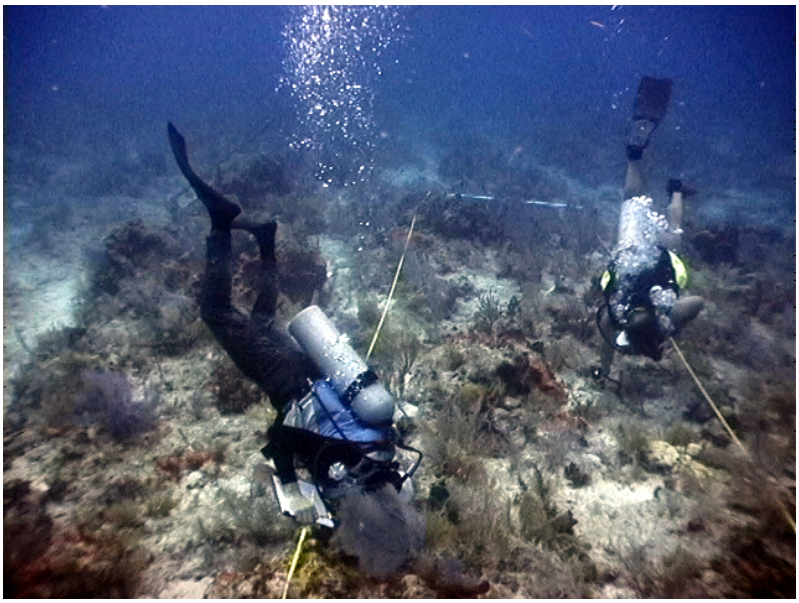

Figure 3. Divers conducting Station Species Inventory.

Video Transects

Video is filmed along each of the three 22m transects (Figures 2 and 4) at each station. Consecutive frames are extracted from the video transects and custom software is used to estimate percent benthic cover of stony corals and other selected taxa.

Figure 4. Diver filming video transects.

Clionid Sponge Survey

The sponge survey area is defined by three 1m wide belt transects within existing CREMP stations (Figure 2). The location, species, and size of bioeroding sponge species (*Cliona delitrix*, *C. lampa* and *C.caribbaea*) as well as the coral species affected are recorded (Figure 5). The total area of clionid sponges measured as square centimeters per square meter of substrate is calculated for each station.

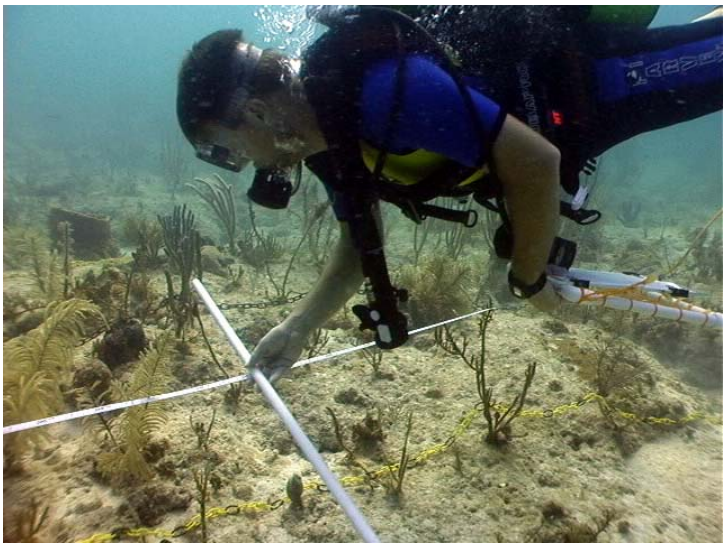
Figure 5. Diver conducting a clionid sponge survey.

Montastraea annularis tracking pilot study

In 2006, a pilot study to track specific colonies of *Montastraea annularis* (boulder star coral) was initiated. A continued decline in percent cover of this important reef framework builder has been documented by CREMP. Designing a method to track changes in the condition of this species is a challenge due to its pattern of growth. Although very old colonies can be massive (several meters in height and circumference), these colonies regularly have portions that have no living tissue. Without adequate photographic documentation it is difficult to determine if changes in percent cover of *M. annularis* are due to mortality and re-growth or recruitment. Multiple colonies at multiple stations were photographed in all three Sanctuary regions during 2006. Compass bearings and distance from permanent station markers was recorded for each photographed colony to assist in relocation (Figure 6).

Figure 6. *Montastraea annularis* tracking pilot study and varied growth forms of the species.

FKNMS RESULTS

Stony Coral Species Richness

The maximum number of species recorded in a single year for all CREMP FKNMS stations was 43 species in 1996. This number has not changed significantly through the study period. By region, the Middle Keys species richness has only declined slightly whereas species richness in both the Upper and Lower Keys has undergone greater decline. However, between 2005 and 2006, the mean number of stony coral species per station declined in all three regions (Figure 7). Statistical analyses of these data are incomplete and the statistical significance has not been determined.

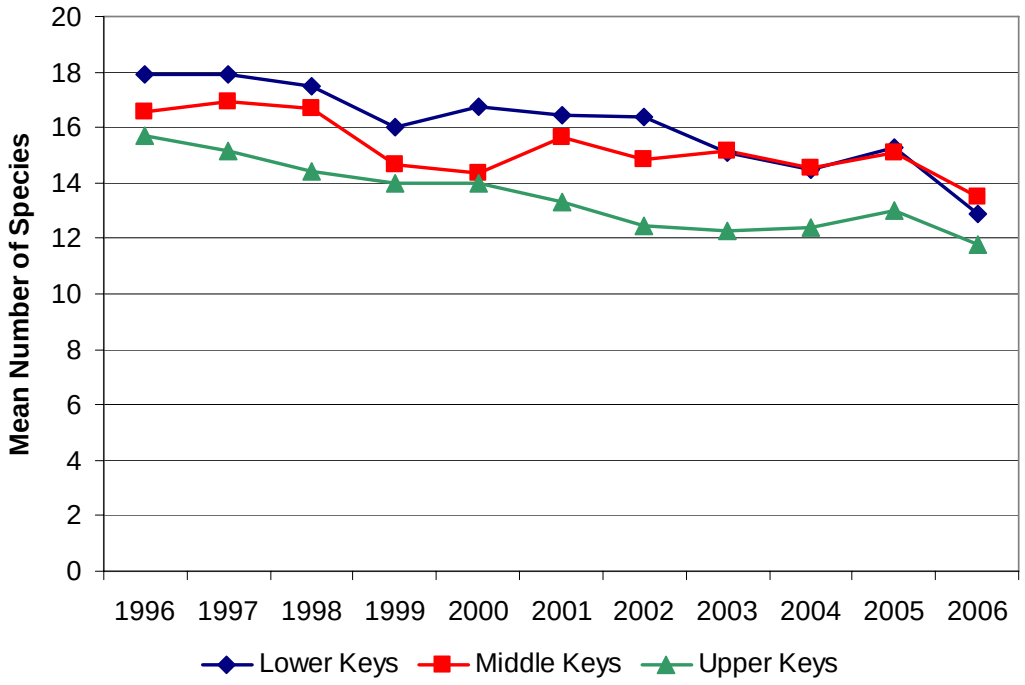

Figure 7. Temporal change in mean number of stony coral species per station by region.

Stony Coral Condition

Diseases were recorded as present or absent for each species during the Station Species Inventory and the type of disease/condition was noted. Data were recorded for three categories; black band, white diseases (i.e. white plague, white band and white pox), and "other" diseases (including dark spot, yellow band and idiopathic diseases) (Figure 8).

Although the incidence of black band disease peaked in 1998, it has never been recorded at more than 10 stations since then. Besides peaks in 1998-1999 and 2001-2002, white disease and the "other" disease conditions have been generally declining. Although the incidence of "other disease" continued to decline between 2005 and 2006, the incidence of white disease increased to more than 50 of the stations sampled in 2006.

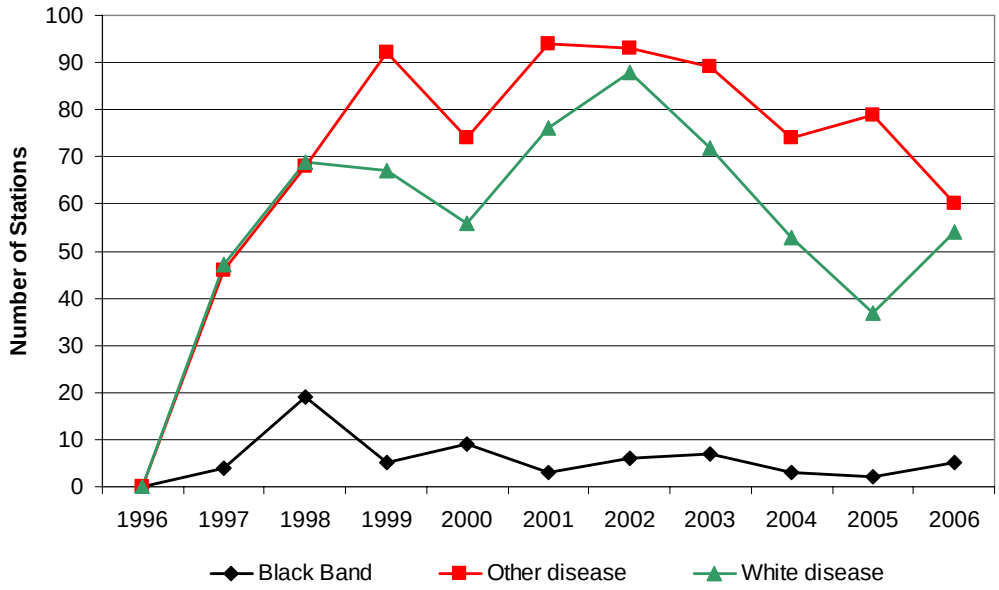

Figure 8. Number of stations with stony coral disease recorded.

Long-Spined Sea Urchin (*Diadema antillarum*) Distribution

D. antillarum has been reported at a maximum of 13 stations for two (2002 and 2005) of the ten years sampled. However, all CREMP data shows an increase in *D. antillarum* distribution mid-way in the project. For the first five years of monitoring, *D. antillarum* were reported at an average of only 5.8 stations. From 2001 to 2005, the average number of stations (11.2) where *D. antillarum* were observed had nearly doubled. Unfortunately, between 2005 and 2006 the observed occurrence of *D. antillarum* decreased to nearly 2003 levels (Figure 9).

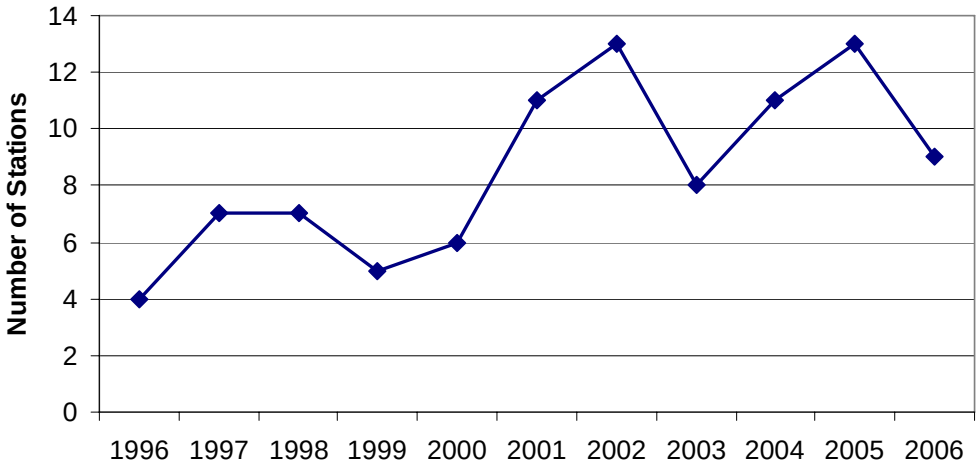

Figure 9. Stations with *D. antillarum* recorded.

Stony Coral Cover

Sanctuary-wide

Although the same broad geographic coverage has been maintained for the duration of the project, minor adjustments have been made in the number of sites/stations sampled. Statistical analyses of the project data in 2001 indicated that sampling a reduced number of stations at sites with low stony coral cover would still produce statistically valid data. During 2006, sampling was omitted for El Radabob (an Upper Keys hardbottom site) which has had less than 0.2% stony coral cover for the duration of the project. Therefore, the total number of stations from which the data for the summaries was compiled, was reduced. These sampling reductions require adjustment and recalculation of the mean percent cover for all years for valid comparisons. Consequently, the values for the mean stony coral percent cover Sanctuary-wide changes slightly from previous reports.

Figure 10 depicts the mean percent cover of stony corals from 1996 through 2006 for the 103 remaining stations. Although the values are slightly different from previous reports, the obvious decline in percent stony coral cover occurred between 1996 and 1999. Percent stony coral cover remained relatively stable between 1999 and 2003. Stony coral cover declined slightly between 2003 and 2005. Although there is a subsequent decline in coral cover from 2005 to 2006, this data has yet to be statistically evaluated.

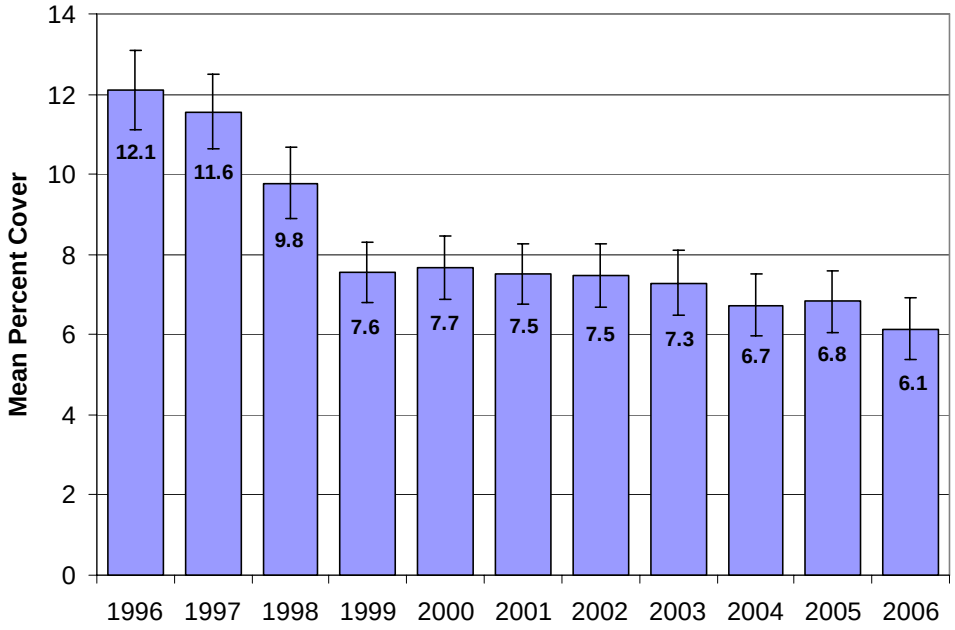

Figure 10. Sanctuary-wide mean percent stony coral cover at CREMP stations.

By Region

The Upper and Lower Keys stations continue to show the greatest loss in mean percent stony coral cover since the beginning of the project (Figure 11). Mean percent coral cover in the Middle Keys stations has not changed significantly since 1999. Between 2005 and 2006, a notable decline in mean percent stony coral cover at CREMP stations Sanctuary-wide occurs in all three regions.

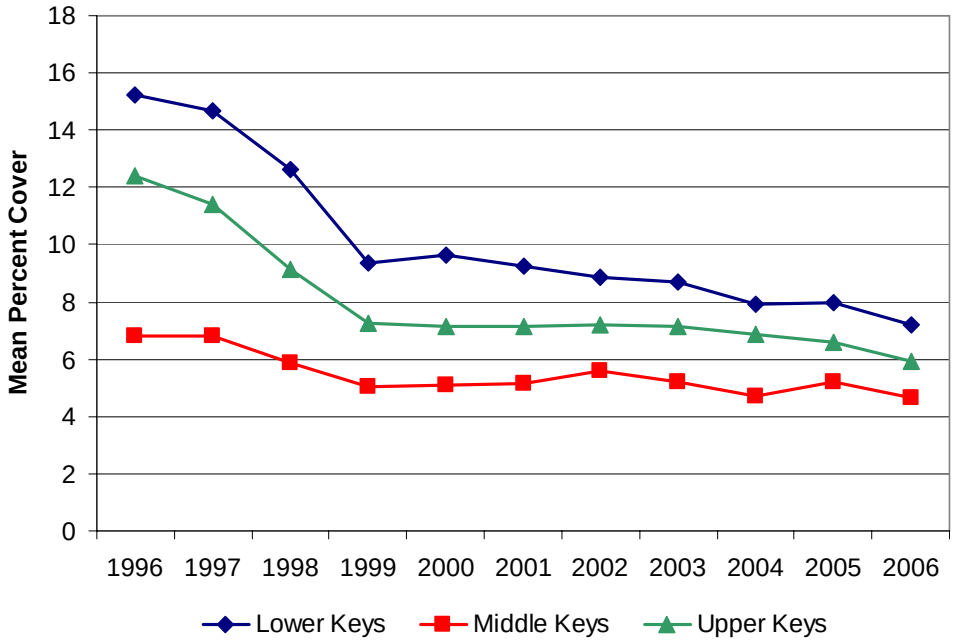

Figure 11. Mean percent stony coral cover for Upper, Middle and Lower Keys stations.

By Species

Underlying trends in stony coral cover can be obtained by analyzing the changes in the most common species. The five most common species in the FKNMS have been *Montastraea annularis* (species complex), *Montastraea cavernosa, Siderastrea siderea, Porites astreoides* and *Colpophyllia natans* since 1999. All except *P. astreoides* commonly attain large size and contribute significantly to the reef framework. Percent cover of *M. cavernosa, S. siderea, P. astreoides* and *C. natans* has been remarkably stable between 1997 and 2006 (Figure 12). However, between 1996 and 1999, drastic declines of *Acropora palmata* and *Millepora complanata*, contributed significantly to the overall decline of mean percent coral cover in the Sanctuary. The continued decline of mean percent cover of *M. annularis* (boulder star coral) has been a major contributor to the general decline of stony coral cover since 1999 documented within CREMP sampling stations in FKNMS.

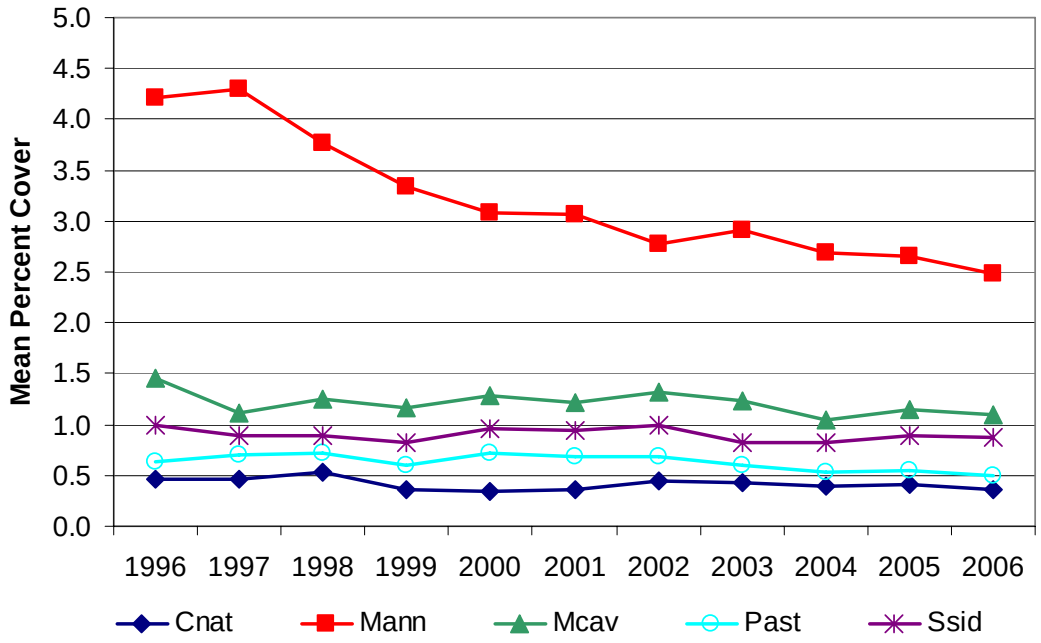

Figure 12. Sanctuary-wide mean percent stony coral cover per station for the five most common species; *Colpophyllia natans* (Cnat)*, Montastraea annularis* (Mann), *Montastraea cavernosa* (Mcav), *Porites astreoides* (Past) and *Siderastrea siderea* (Ssid).

Montastraea annularis tracking

Multiple photographs of a total of 105 *Montastraea annularis* colonies were taken during 2006. Tracking was initiated at one to three stations at twelve sites representing patch reefs as well as shallow and deep offshore reef habitats.

Site Name	Site Code	Region	Station Number	Number of Colonies
Admiral Patch	9P4	Upper Keys	1,4	12
Alligator Shallow	7S1	Upper Keys	2	2
Grecian Rocks	9S2	Upper Keys	4	9
Porter Patch	9P3	Upper Keys	3	11
Sombero Shallow	5S1	Middle Keys	1	10
Dustan Rocks	7P2	Middle Keys	2	7
W. Turtle Shoal	7P1	Middle Keys	4	9
E. Sambo Deep	5D3	Lower Keys	2,3	11
W. Sambo Shallow	5S4	Lower Keys	1,2	9
W. Sambo Deep	5D4	Lower Keys	1,2	11
Sand Key Deep	2D1	Lower Keys	1,2,4	9
Cliff Green	5P3	Lower Keys	3,4	5

Table 1. *Montastraea annularis* tracking data for 2006.

Functional Group Cover

Major biotic functional groups defined in this study are stony corals, octocorals, sponges, and macroalgae. As in the Sanctuary-wide figure (10), mean percent stony coral cover declined at the stations sampled from roughly 12 to 6 percent since the inception of the project (incorporating the station/site reductions that occurred). Although mean percent octocoral cover calculated from the video increased steadily between 2000 and 2004, a decrease was documented between 2005 and 2006. Whereas the mean percent cover for sponges has steadily remained at about two percent, the mean percent cover for macroalgae has varied widely (Figure 13).

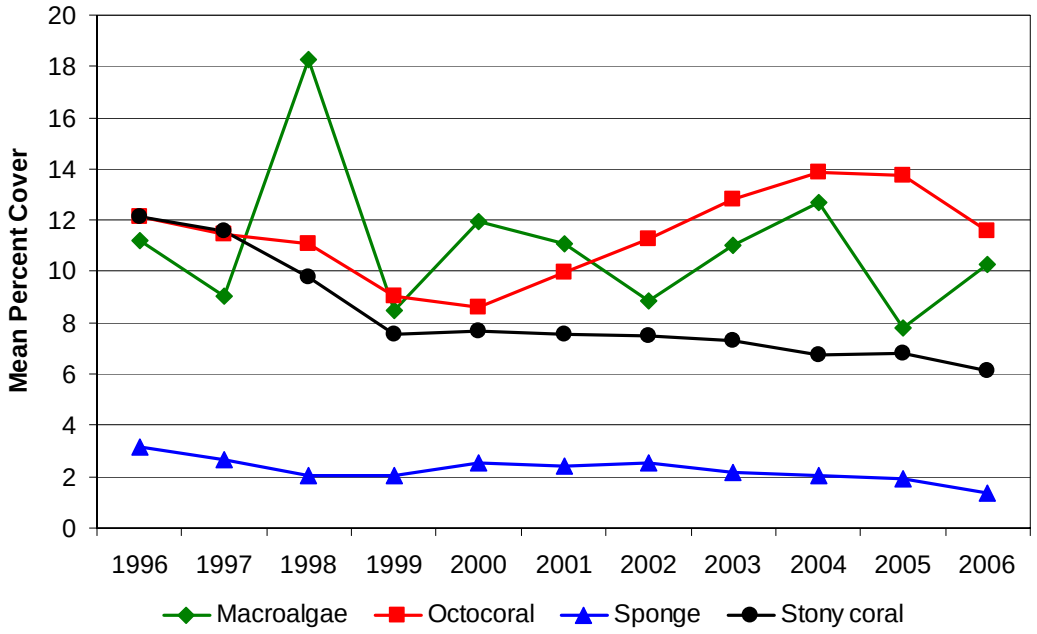

Figure 13. Sanctuary-wide mean percent cover of major biotic functional groups at CREMP stations.

Clionid Area

Three species of clionid sponges (*Cliona delitrix, C. lampa, and C. caribbaea)* are monitored by CREMP. Mean area of the three clionid species combined is presented in figure 14 for all CREMP stations Sanctuary-wide. In 2001, clionid area was 7cm^2/m^2. Sanctuary-wide clionid area decreased sharply in 2002, increased steadily through 2005, and was virtually unchanged between 2005 and 2006. However, when data are grouped by habitat a different picture emerges. Clionid area increased between 2002 and 2006 at hardbottom habitat stations. At both shallow and deep offshore reef sites, the clionid populations have had minor fluctuations in mean clionid area through time. Although patch reef sites had consistently higher clionid area than shallow and deep reef sites, the same minor fluctuations in area occurred (Figure 15).

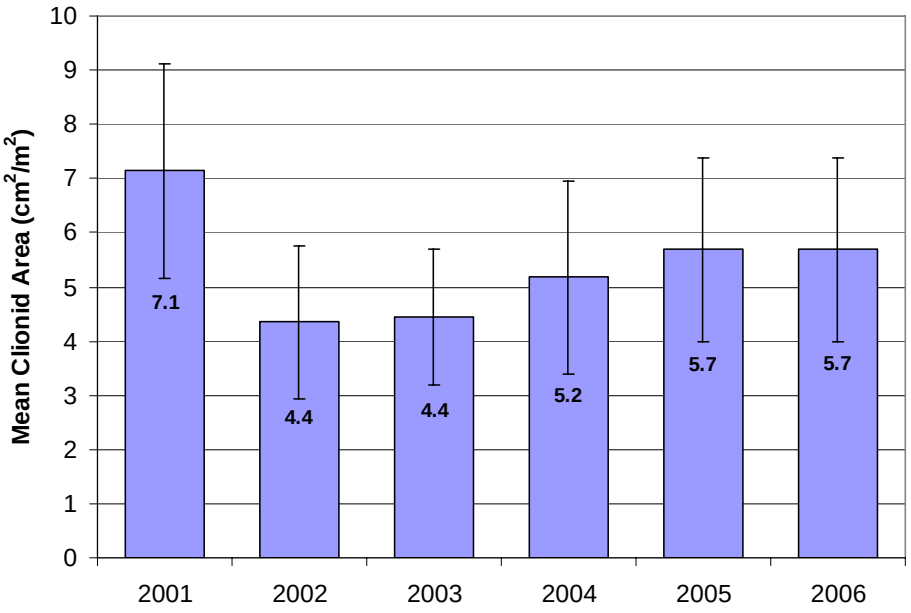

Figure 14. Sanctuary-wide temporal changes in area of clionid sponges at CREMP stations.

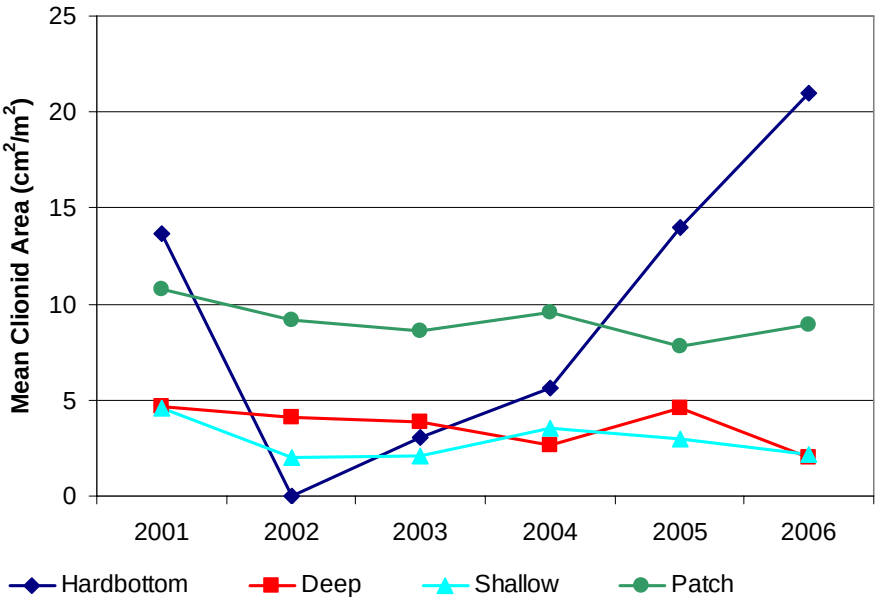

Figure 15. Temporal changes in area of clionid sponges by habitat at CREMP stations.

DRY TORTUGAS RESULTS

Stony Coral Species Richness

A maximum of 33 species has been recorded for the Dry Tortugas in a single year in 1999, compared to a maximum of 43 species in the FKNMS in 1996. This is partly due to the limited number of stations sampled in the Dry Tortugas and the range of habitat types sampled in the Florida Keys. However, mean stony coral species richness by station is often higher in the Dry Tortugas than in the Florida Keys.

Although the mean number of species recorded between 1999 and 2003 was relatively similar, the mean number of species for 2004 through 2006 has declined (Figure 16). Statistical analyses of these data are incomplete.

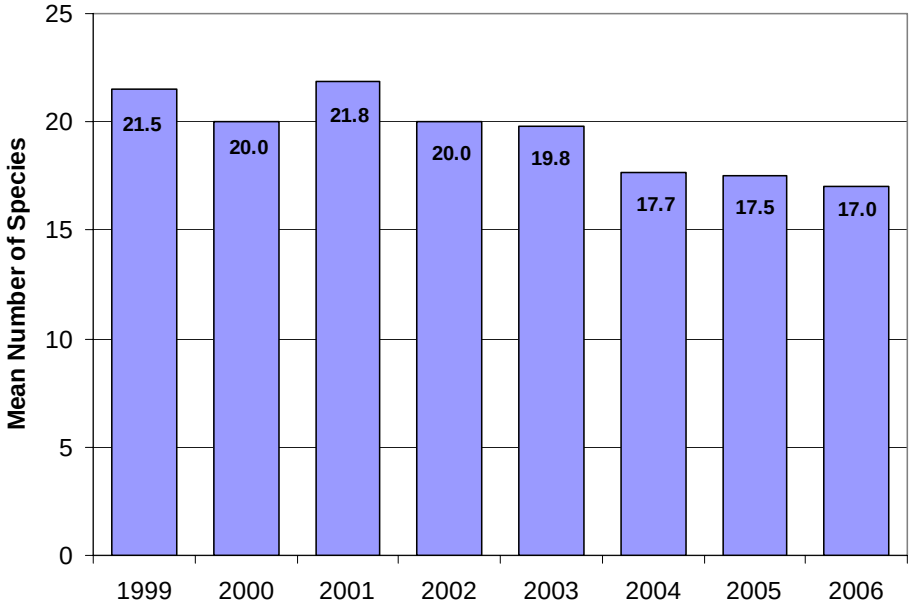

Figure 16. Temporal changes in the mean number of stony coral species by station at the Dry Tortugas.

Stony Coral Condition

Between 1999 and 2004, at least one disease condition recorded during CREMP sampling was present in 80-100% of the 12 stations sampled (Figure 17). Although black band disease was recorded in 2000, it has not been present in any station since then. “Other” disease conditions were recorded consistently in 9-10 stations through 2003, but presence in stations declined consistently from 2003 to 2005 and leveled off between 2005 and 2006. Although white disease was recorded in all 12 stations in 2000 and 2003, the presence of this condition has varied significantly throughout the duration of sampling in the Dry Tortugas. Although no white disease conditions were observed at any stations in 2005, incidence was recorded in 7 stations in 2006.

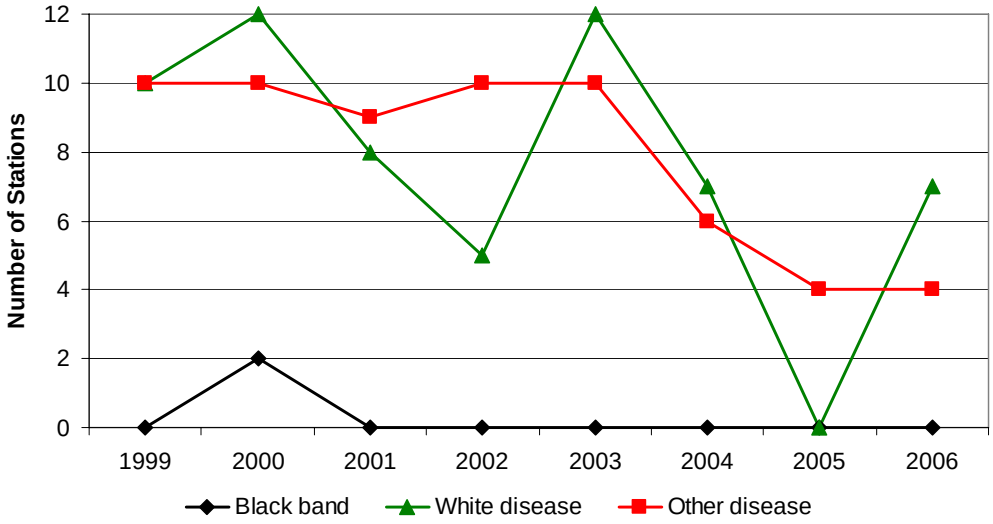

Figure 17. Number of stations with incidence of three disease conditions at the Dry Tortugas.

Long-Spined Sea Urchin (*D. antillarum*) Occurrence

Among the Dry Tortugas CREMP stations, observations of *D. antillarum* declined between 1999 and 2000, rebounded slightly for the next three years and again declined between 2003 and 2005 (Figure 18). Although, it was reported from only 1/3 of the stations in 1999 and none of the stations in 2000, in 2006 the number of stations with *D. antillarum* increased to the same number of stations as in 1999.

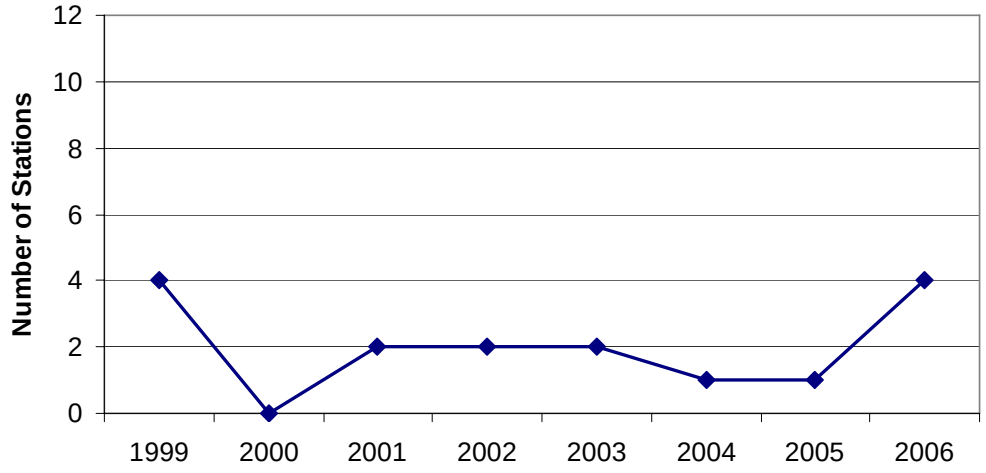

Figure 18. Number of stations with long-spined urchins (*Diadema antillarum)* at the Dry Tortugas.

Stony Coral Cover

Mean percent stony coral cover for the twelve Dry Tortugas stations was nearly 19% in 1999 with a slight decrease to about 17% through 2001. Since 2001, the mean percent stony coral cover decreased fairly steadily to 11% in 2005 then dropped to less than 9% in 2006 (Figure 19). Statistical analyses of these data is incomplete.

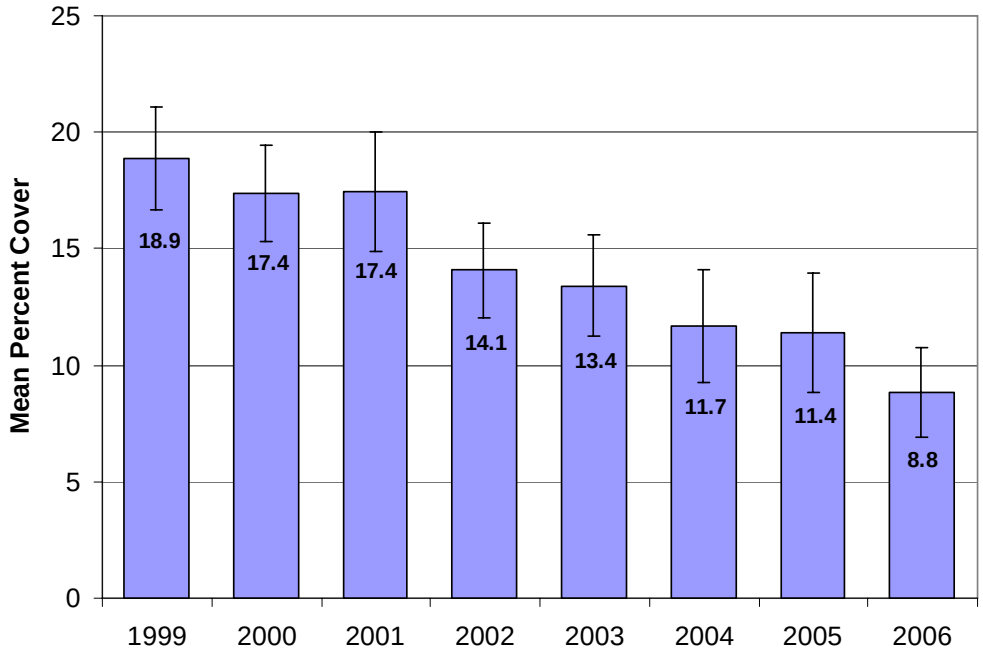

Figure 19. Temporal changes in mean percent stony coral cover by station at the Dry Tortugas.

By Habitat

The highest mean percent coral cover at the Dry Tortugas has been recorded at the two deep reef habitat sites (Figure 20). The patch reef site has consistently had less than half the mean percent coral cover as the deep reef sites since the inception of sampling. Except for a slight increase at the deep reef sites from 2000 to 2001 mean percent coral cover at the Dry Tortugas has declined steadily at all sites over the past eight years.

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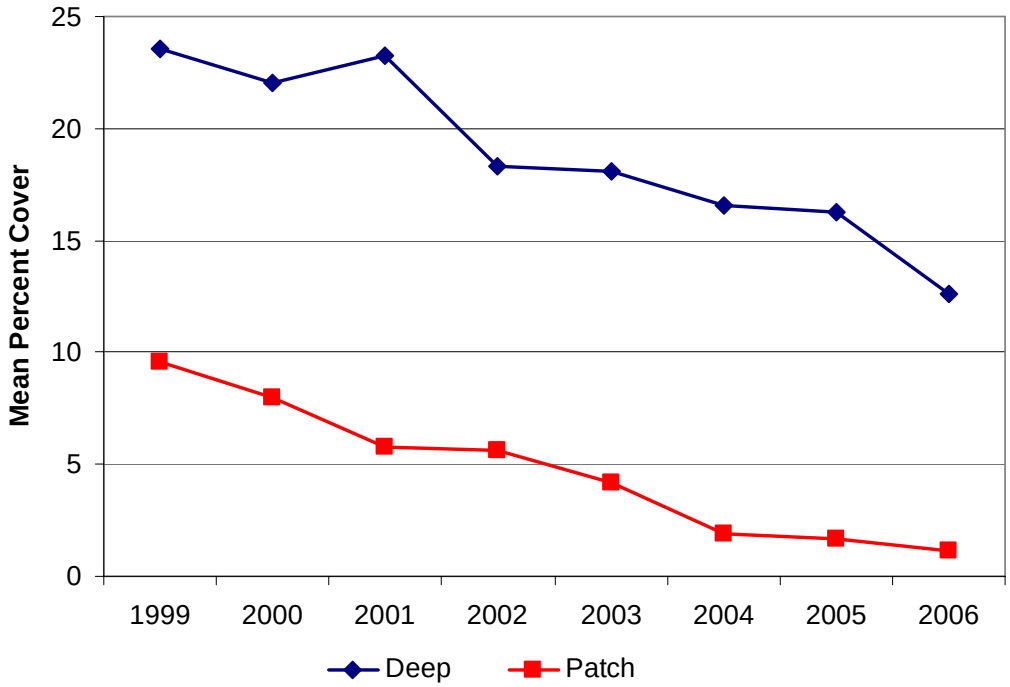

Figure 20. Temporal changes in mean stony coral cover by habitat at Dry Tortugas stations.

By Species

The five most common species in the Dry Tortugas have been *Montastraea annularis* (species complex), *Montastraea cavernosa, Colpophyllia natans, Acropora cervicornis* and *Siderastrea siderea* throughout the duration of the project. Among the five most common in the Florida Keys, *Porites astreoides,* is replaced by *A. cervicornis* in the Dry Tortugas.

Losses in overall mean stony coral cover at the Dry Tortugas stations between 2001 and 2002 were likely driven by the abrupt decline of the boulder star coral *M. annularis*. A decline in mean percent cover of this important framework building coral has been documented from 2001 to 2006 (Figure 21). The boulder type corals, *C. natans (a* brain coral) and *S. siderea,* (a star coral), together represent about 3 percent of the mean percent cover at CREMP stations in 1999 through 2001, but only represented about 1 percent each in 2006. Mean percent cover of the other boulder forming coral, *Montastraea cavernosa,* has also steadily, albeit slowly, declined through 2006. The staghorn coral (*A. cervicornis*) represented about 2 percent of the mean percent cover at sampling stations in 1999, but was virtually absent from these stations in 2006 (Figure 21).

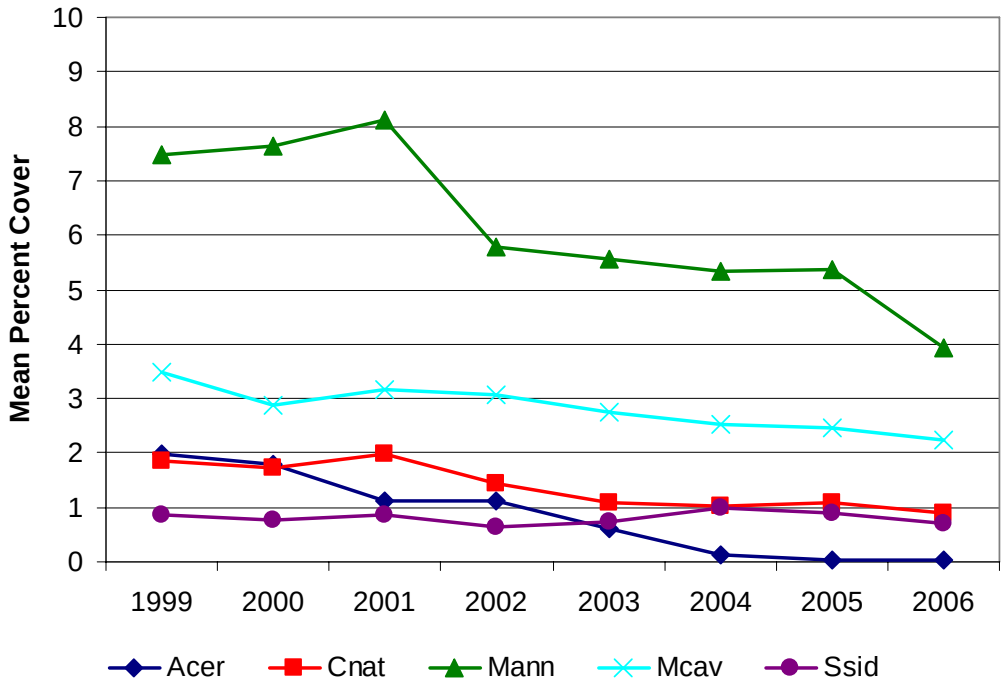

Figure 21. Mean percent stony coral cover of the five most common species; *Acropora cervicornis* (Acer), *Colpophyllia natans* (Cnat), *Montastraea annularis* (Mann), *Montastraea cavernosa* (Mcav) and *Siderastrea siderea* (Ssid) by station at the Dry Tortugas.

Functional Group Cover

Mean percent cover for octocorals fluctuated at slightly more than 12% between 1999 and 2003, but has declined steadily over the past three years. The decline in mean percent sponge cover has been very slow. Since 1999 the mean percent cover has declined from nearly 4% to roughly 1%. Mean percent cover of macroalgae peaked in 2003, declined to its lowest point in 2005, but increased between 2005 and 2006.

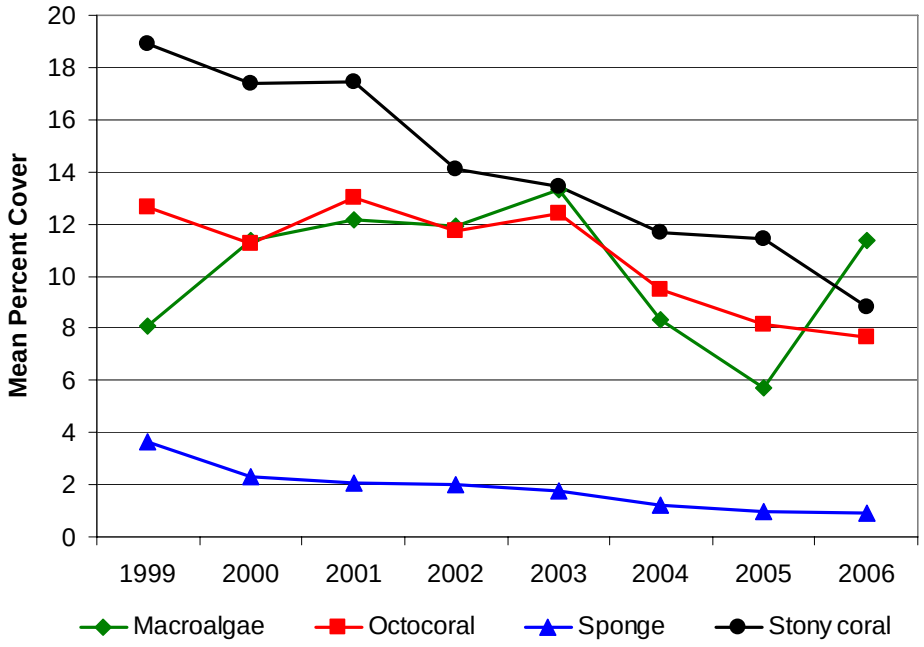

Figure 22. Mean percent cover of major biotic functional groups by station at the Dry Tortugas.

Clionid Area

Mean clionid area decreased between 2001 and 2003, but has steadily increased to the highest cover recorded in 2006 (Figure 23).

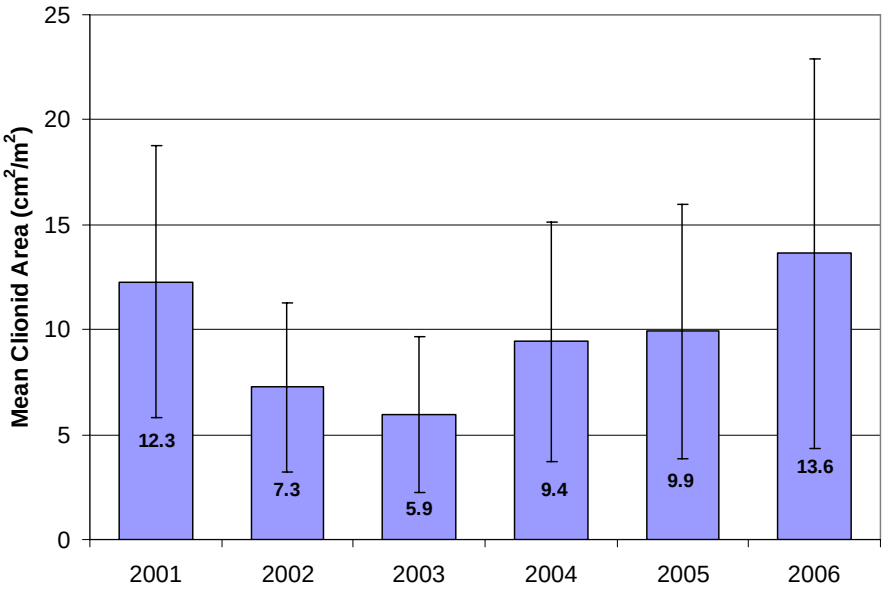

Figure 23. Temporal change in area of clionid sponges by station at the Dry Tortugas.

DISCUSSION

FKNMS

The Station Species Inventory data indicate that the stony coral species richness for all CREMP stations combined Sanctuary-wide has declined from a maximum of 43 species recorded in 1996. The mean number of stony coral species recorded per station has continued to decrease over time. Data on stony coral condition, also collected during the Station Species Inventory shows that incidence of white disease per station has declined between 2002 and 2005; however, it rebounded to more than 50% of the CREMP stations in 2006. This increase in occurrence of white disease was accompanied by a decrease in the number of stations with “other” disease in 2006.

Long spined urchins are herbivores that help keep corals free of algal overgrowth. The ecological importance of the long-spined sea urchins is well documented. Urchin populations suffered a Caribbean-wide mortality event in 1983-84 and their recovery has been slow. CREMP inventory of the long-spined sea urchin, *D. antillarum*, has shown a fluctuation in distribution of this important herbivore. Between 1996 and 2000, these urchins were never observed in more than 7 CREMP stations. Since 2001, urchin observations have been recorded at a range of 8 to 13 stations.

Analysis of the percent cover data from the video transects shows that the mean stony coral cover at CREMP sites within the FKNMS declined sharply between 1996 and 1999. From 1999 through 2003, mean percent stony coral cover was maintained at over 7% for all CREMP sites combined. By 2006, the combined sites had a mean percent stony coral cover barely over 6%. The hurricanes and tropical storms that affected Florida recently have undoubtedly had some impact on the coral habitats. In 2005 hurricanes Dennis, Katrina, Rita and Wilma each passed over some part of the Florida reef tract (Figure 24).

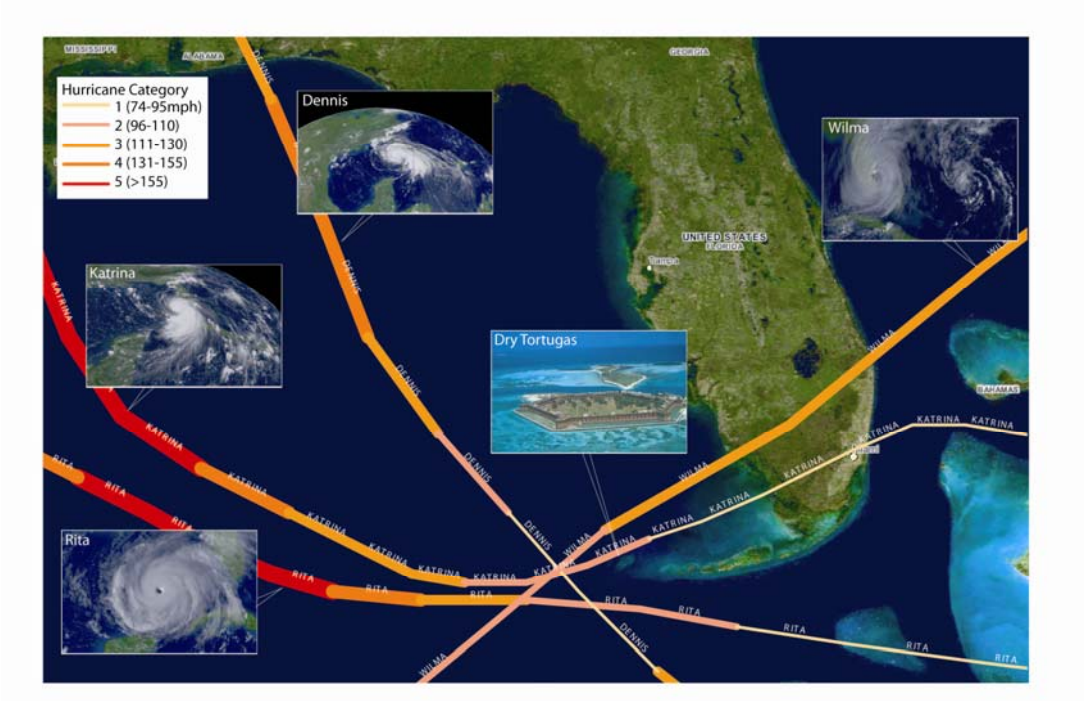

Figure 24. Image of south Florida showing the tracks of four major hurricanes that impacted Florida between 2005 and 2006.

By species, the greatest loss has been observed in mean percent cover of the boulder star coral (*Montastraea annularis* species complex), which forms very large colonies (>2m diameter) throughout the Florida Keys. The complete or partial mortality of a single boulder star coral colony represents a large decrease in coral cover and ultimately habitat structure. The pilot study initiated in 2006 will provide baseline tracking for colonies at selected sites from which to develop a standard monitoring protocol.

Functional group cover shows the prevalence of other important habitat components such as octocorals, sponges, and macroalgae. Changes in the percent cover of major functional groups provides valuable community information, but can also raise a “red flag” for further investigation into the factors driving the changes in coral habitat.

Clionid sponges are common bioeroders of stony corals world-wide, but despite their global distribution very little is known about their biology or ecology. Clionid populations may be influenced by differences in water quality or sponge recruitment dynamics. Inference from CREMP clionid sponge data indicates these sponges have not significantly contributed to the decline in coral cover within CREMP stations in the Sanctuary since the beginning of the clionid survey in 2001.

DRY TORTUGAS

Since the inception of monitoring in the Dry Tortugas in 1999, a combination of disease, hurricanes and potentially some unknown stressors have caused a decline in both coral cover and species richness at CREMP stations. The mean stony coral cover loss appears to have been primarily driven by cover losses in *M. annularis* species complex. However, high levels of mortality from white diseases of the boulder brain coral (*C. natans*) (Figure 25) and the staghorn coral (*A. cervicornis*) have also contributed to the overall decline. A mortality event, documented in 2003, contributed to the further overall decline of acroporids at the Dry Tortugas (Figure 26). Surveys of acroporids, recently listed under ESA, conducted by FWRI for the Department of Interior/National Park Service are documenting distribution of these species at sites within Dry Tortugas National Park. The 2003 acroporid mortality coincides with the peak in white disease recorded at CREMP monitoring sites in 2003.

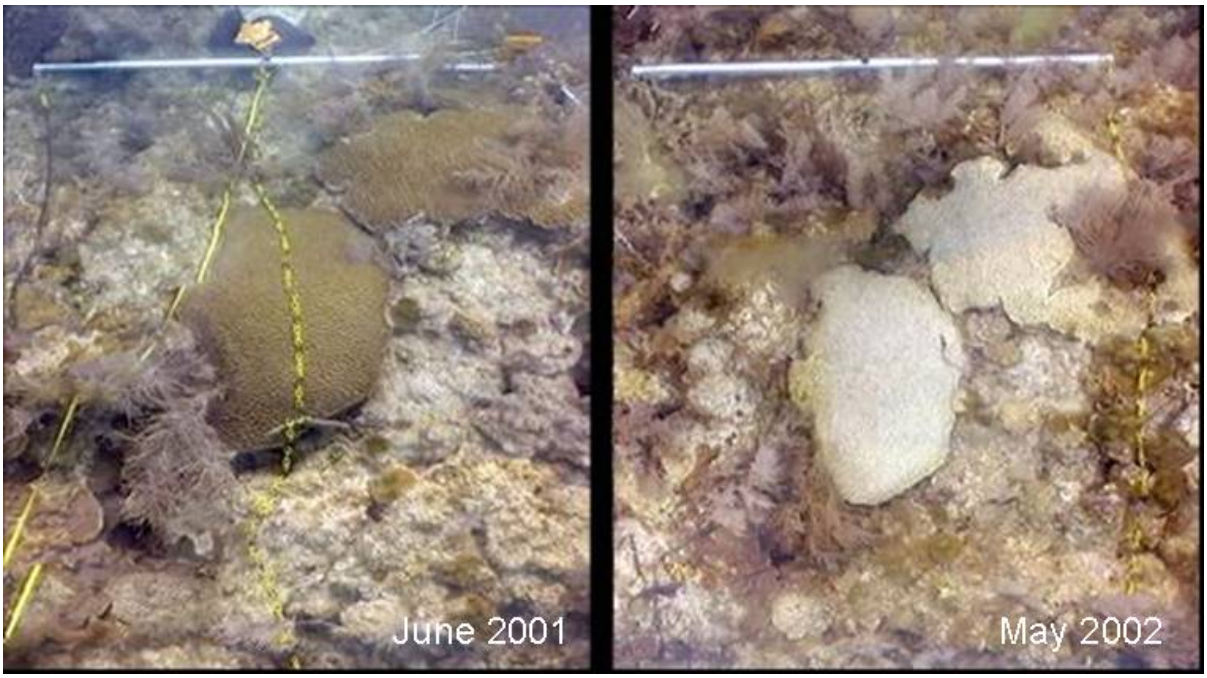

Figure 25. Brain coral colony (*Colpophyilla natans*) at Bird Key Reef, Dry Tortugas.


Figure 26. Acroporid mortality at Dry Tortugas in 2003.

PROPOSED RESEARCH TO BE INCORPORATED IN 2007

In addition to the photographic tracking of multiple *M. annularis* colonies among different habitat types, baseline health sampling (Figure 27) will be conducted on colonies adjacent to the CREMP sampling stations. Site selection for this baseline health sampling is based on the decline in percent cover documented for *M. annularis* since monitoring was initiated in 1996. Sampling will not be conducted in any of the CREMP sites within Sanctuary protection zones.

Montastraea annularis health sampling protocol (representative samples from different diseases :

1 = Samples for histopathology (1 x 1 x 1cm plug) – A,B, C, D along transect**
2 = Samples for bacteriology – (syringe, 1ml) A, B along transect
3 = Samples for microalgae – (scrape with spatula) A, B, C, D along transect
4 = Sample for TEM 3 x 3 x 3mm plug (maximum size)

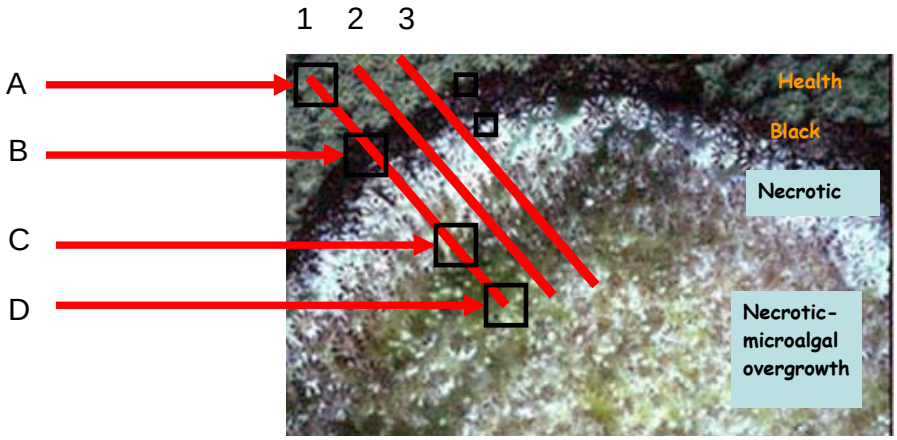

Figure 27. Illustration of proposed *Montastraea annularis* health sampling.

Beginning in 2007, data will be collected on three additional sponge species (*Chondrilla nucula, Xestospongia muta,* and *Spheciospongia vesparium*). These three sponges are well studied and can be identified with little difficulty in the field. *Chondrilla nucula* is a common overgrowing sponge found in many of the Florida Key's reef habitat types. *Xestospongia muta* is commonly found on coral reefs typically at depths greater than 10 m. This sponge contributes greatly to overall sponge biomass and is important in determining reef health, exhibiting bleaching similar to coral. *Spheciospongia vesparium* is also a common reef sponge that is a major contributor to overall sponge biomass on the reef.

Throughout the Florida Keys National Marine Sanctuary, there are numerous unmapped and uncharacterized patch reefs located in and around Hawk Channel. It has been suggested that these patch reefs contribute significantly to the overall stony coral cover of the FKNMS. In an effort to better represent this habitat type, permanent stations will be installed at selected patch reefs in the Upper, Middle, and Lower Keys. Satellite imagery in addition to local knowledge will be used to select potential monitoring sites (Figure 28).

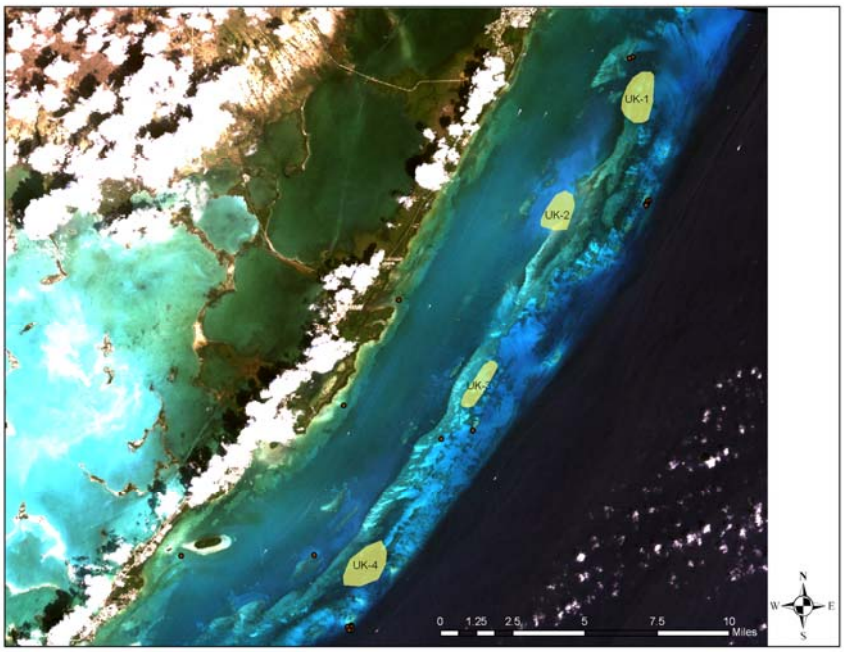

Figure 28. IKONOS imagery (courtesy of NOAA) used to help select potential patch reefs for CREMP monitoring. Highlighted circles represent areas of high interest.