Florida Fish And Wildlife Conservation Commission
Fish And Wildlife Research Institute
Coral Reef Evaluation & Monitoring Project

Executive Summary 2010

Introduction

- In 1994, the Florida Keys Coral Reef Evaluation and Monitoring Project (CREMP) was initiated to provide data on status and trends of coral habitat in the Florida Keys.
- The program is a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (USEPA), and the Florida Fish and Wildlife Conservation Commission (FWC). The CREMP was designed to be part of a Water Quality Protection Program (WQPP), which has the goal of monitoring seagrass habitats, coral reefs, hardbottom communities, and water quality in the Florida Keys.
- The major criteria for monitoring the coral reefs included determining the Sanctuary-wide spatial coverage of the coral communities, repeatedly surveying them, and statistically documenting the status and trends of the coral communities.
- Current spatial stratification includes three habitat types; patch reefs and shallow and deep fore reefs, in four regions; Upper, Middle, and Lower Keys and Dry Tortugas. Permanent station markers were installed at 40 sites in 1995. Annual sampling began in 1996, and has continued through 2010. Three sites were installed in the Dry Tortugas and sampling began in 1999.

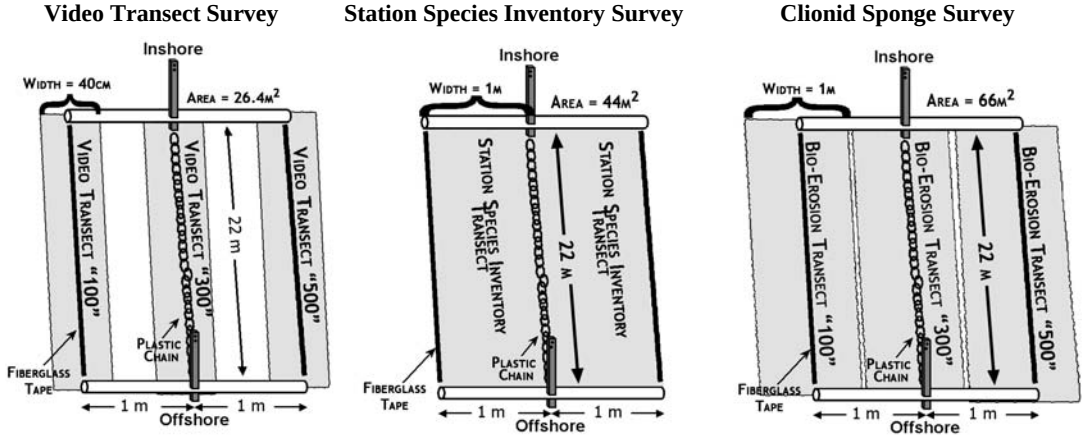

Figure 1: CREMP sites consist of two to four monitoring stations delineated by permanent markers. Stations are approximately 2 x 22 meters and are generally perpendicular to the reef crest. Video transects (three transects per station), a station species inventory (SSI), and a clionid sponge survey are annually conducted.

Results Summary

This summary will highlight results from annual comparisons (2008 vs. 2009), impacts of the 2010 winter mortality, and long-term trends (1999-2009) for macroalgae, octocorals, stony corals, and two sentinel stony corals (*Montastraea annularis*-complex and *Siderastrea siderea*).

Results presented in this summary are reported Sanctuary-wide for the regions defined as Upper Keys (north Key Largo to Conch Reef, "UK"), Middle Keys or "MK" (Alligator Reef to Moser Channel, "MK"), Lower Keys or (Looe Key to Smith Shoal, "LK"), and the Tortugas (Dry Tortugas to Tortugas Banks, "DT"). Surveys are conducted within the habitat types: offshore deep reefs (OD), offshore shallow reefs (OS), and patch reefs (P). The results presented here include data from 109 stations at 37 sites sampled from 1996 and 1999 through 2009 in the Florida Keys and Dry Tortugas, respectively.

2008 vs. 2009

Single year differences (2008 vs. 2009) in stony coral, macroalgae, and octocoral percent cover were compared with a two-way Kenward-Roger mixed model ANOVA with year and habitat*region combinations (e.g. Middle Keys patch reefs) as factors on arcsine square-root transformed data pooled for each station (stations were nested within region*habitat pairings).

- For the first time in CREMP's project history, there was a significant increase stony coral cover (Kenward-Roger 2-Way ANOVA df=1, 97; F=10.09; p<0001). The increase was consistent across the region*habitat pairings except in the Dry Tortugas and Back Country Patch reefs. Overall, mean cover increased from 6.6% to 7.3% (n = 97 stations).
- Macroalgae percent cover was significantly higher in 2009 (Kenward-Roger 2-Way ANOVA df=1, 97; F=11.32 p<0.001), but increases in cover were dependent upon region*habitat combinations because a significant interaction was found (p=0.01). Mean macroalgae cover was 13.7% ± 1.5% SE in 2009. This was 2.7% above the mean for the project (~11%).

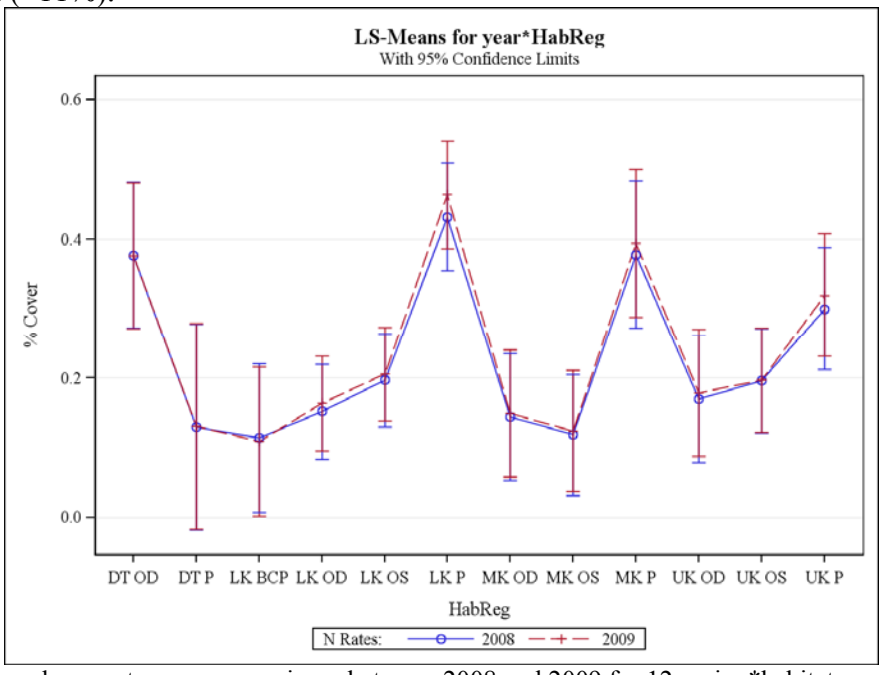

Figure 2. Stony coral percent cover comparisons between 2008 and 2009 for 12 region*habitat combinations in the Florida Keys and Dry Tortugas. Error bars represent 95% confidence intervals around the mean.

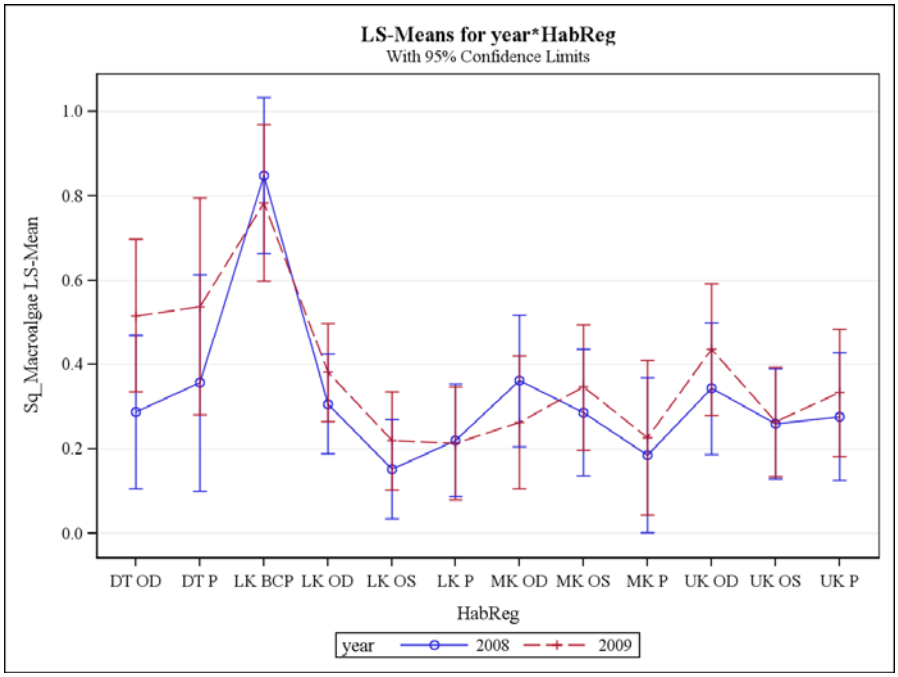

Figure 3. Macroalgae percent cover comparisons between 2008 and 2009 for 12 region*habitat combinations in the Florida Keys and Dry Tortugas. Error bars represent 95% confidence intervals around the mean.

- Mean percent octocoral coral was also significantly higher in 2009 than in 2008 (Kenward-Roger 2-Way ANOVA df=1, 97; F=20.58 p<0.0001). Mean octocoral cover was 14.8% ± 1.1% SE in 2009 - the highest amount ever recorded by CREMP.

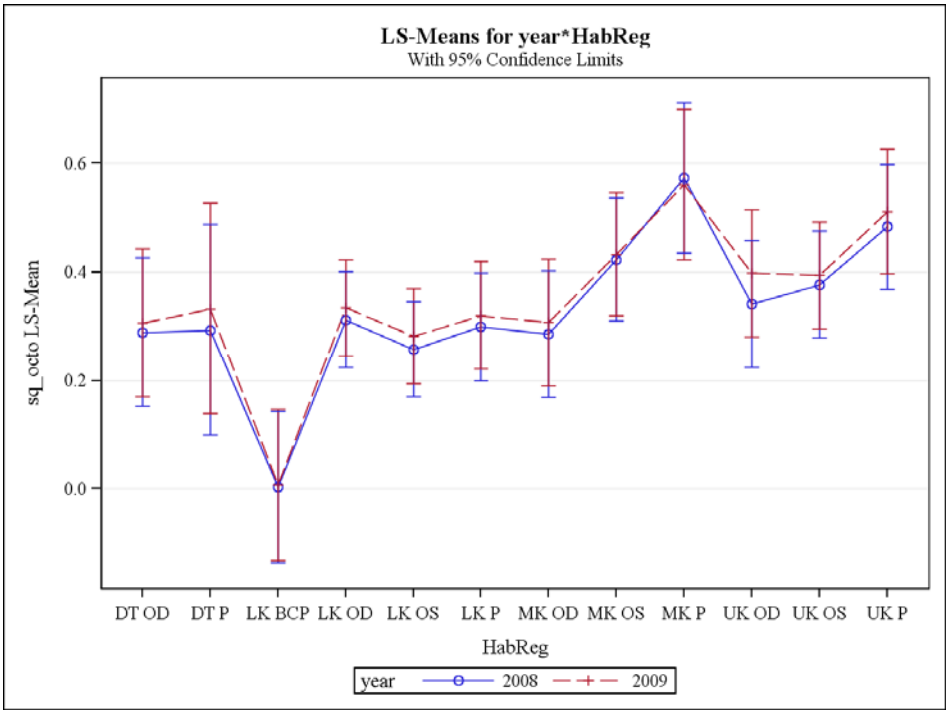

Figure 4. Octocoral percent cover comparisons between 2008 and 2009 for 12 region*habitat combinations in the Florida Keys and Dry Tortugas. Error bars represent 95% confidence intervals around the mean.

2010 Winter Mortality Event

The coldest period observed this winter was between January 2nd and January 13th 2010, when south Florida experienced one of its coldest 12-day periods on record. The cold snap began on January 1st when the first of two arctic cold fronts moved through south Florida. A brief warm-up occurred on January 8th, but a second stronger arctic air mass passed through January 9th and began to depress water temperatures below the lethal limit for corals (~16°C). Water temperatures remained below this threshold and persisted four to five days. The coldest temperatures were observed at exchanges between Florida Bay and the Atlantic (e.g. Moser Channel, Long Key; Figures 5 & 6); however, many patch reefs inshore of Hawk Channel were exposed to lethal temperatures for four consecutive days. In February 2010, the CREMP team conducted video transects at a subset of eight stations within four sites to assess acute changes in benthic cover. Three patch reefs in the Middle Keys and one in the Upper Keys were completed. A Wilcoxon paired sample test on arcsine square root transformed data was used to compare benthic fauna cover between summer 2009 and February of 2010.

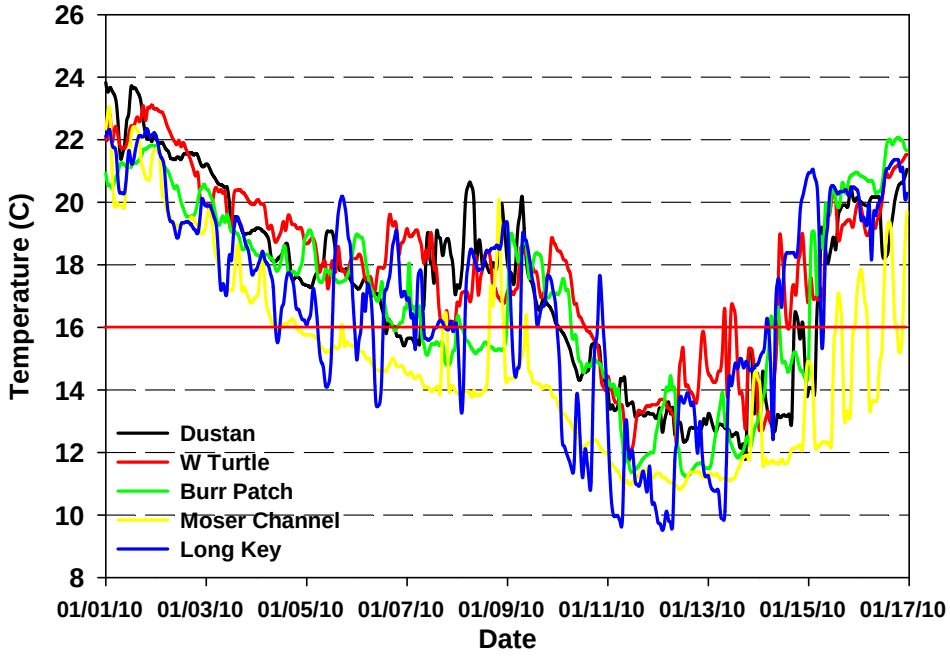

Figure 5. Water temperatures recorded at three CREMP winter survey sites (Dustan, W Turtle, Burr Patch) and two hardbottom sites (Moser Channel and Long Key) near Florida Bay during 1-17 January 2010.

- The most significant coral mortality was observed at sites closest to shore (Figure 7a). The extent of mortality was reduced further offshore. Although shallow and deep forereef were not selected for comparison, temperature data collected from these sites indicated they were not subjected to lethal water temperatures.
- There was a significant decline in mean coral cover across all eight stations (Wilcoxon paired sample test df=7; $p<0.001$). Coral cover declined ~41% across these eight stations, which may result in the largest, single year decline CREMP has observed. The absolute change in coral cover was ~7%, dropping from 17% in summer of 2009 to 10% in February 2010.
- Mortality varied by station due to species composition. Some stations, which were primarily composed by species like *Montastraea annularis* complex and *M. cavernosa*

experienced a greater than 50% reduction in coral cover. These two species, in addition to other less cold tolerant species (e.g. *Porites astreoides*) were severely impacted (Figure 8).

- In many instances, declines in octocoral cover exceeded those of stony corals (Figure 7b). At four stations, a ≥50% loss in cover was recorded. Mean octocoral cover declined ~48% across all eight stations (Wilcoxon paired sample test df=7; p <0.001) and there was a 12% absolute decline in octocoral cover (from 25% in 2009 to 13% in February 2010).
- All phenotypes were affected, including encrusting, lobate, and branching spp.

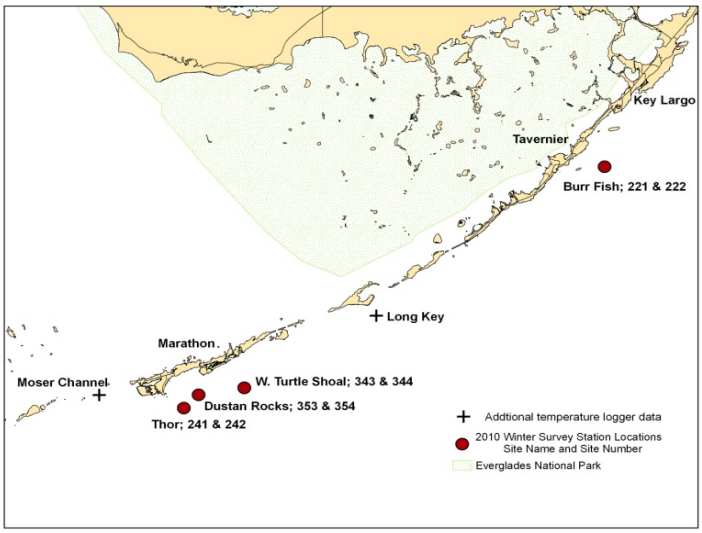

Figure 6. Locations of CREMP 2010 Winter Survey sites and corresponding stations surveyed. Moser Channel and Long Key mark sites to monitor water temperature passing from Florida Bay into the Atlantic.

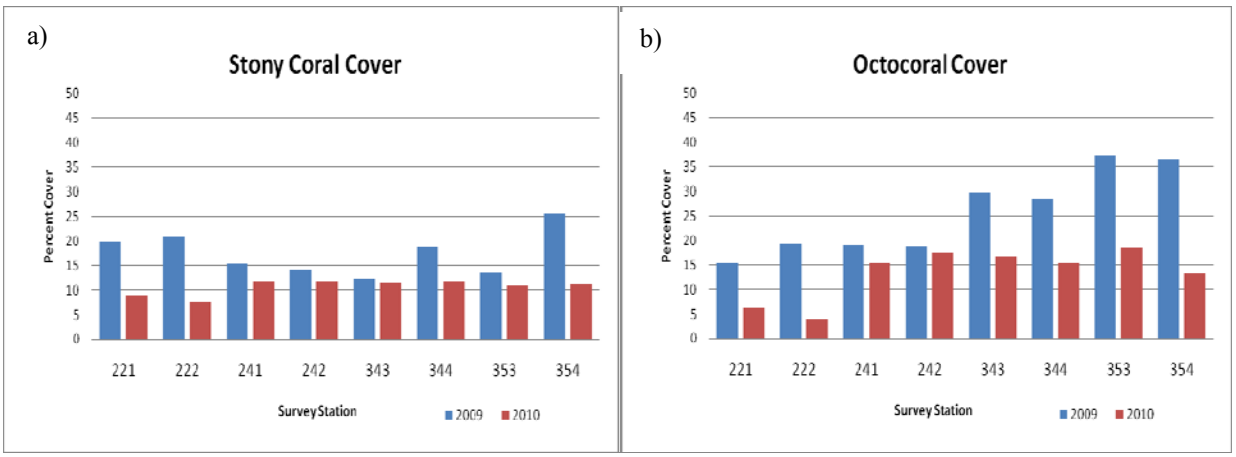

Figure 7. Percent cover comparisons between summer 2009 and February 2010 for a) stony corals and b) octocorals at eight stations sampled at four CREMP Winter Survey sites (see map in Figure 6).

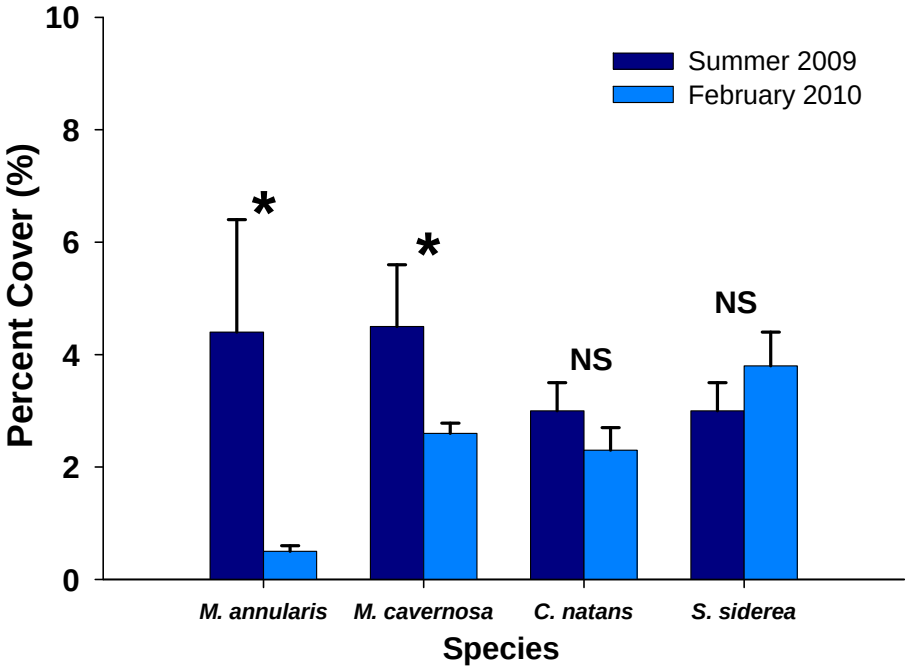

Figure 8. Comparison of percent cover between summer 2009 and February 2010 for four species of major reef-building corals (*Montastraea annularis, M. cavernosa, Colpophyllia natans,* and *Siderastrea siderea*) at eight stations (four CREMP sites; see map in Figure 6). Significant differences in mean cover between periods were identified with a Wilcoxon paired sample test (df=7; * = p <0.05; NS = no difference) on arcsine square root transformed data.

Figure 9. Before and after images from video transects collected in summer of 2009 and February 2010. Top images show complete mortality of *Montastraea annularis*-complex and encrusting gorgonian, *Erythropodium caribaeorum,* while lower images depict partial mortality of *Colpophyllia natans,* and complete mortality of *Montastraea annularis*-complex.

Long-term Trends from 1999-2008

Long-term trends in benthic cover (stony corals, macroalgae, octocorals, and sponges) from 1999-2008 were identified using generalized mixed model regressions (to account for repeated sampling and numeric variability of stations across sites) on square root transformed percent cover data pooled for each station. Stations were nested within sites and results from all sites were pooled together to infer long-term trends in the Keys. Regression lines were calculated starting after the 1997-98 El Nino to determine how benthic variables and individual coral species have responded since then and to remove the strong negative influence of long-term trajectories due events of the first three years of the project. The analysis calculates a slope from the annual percent cover of each station, and the slope was identified as increasing or decreasing (at $p<0.05$, or $p<0.001$) from t-tests that indicated the slope was significantly different from zero.

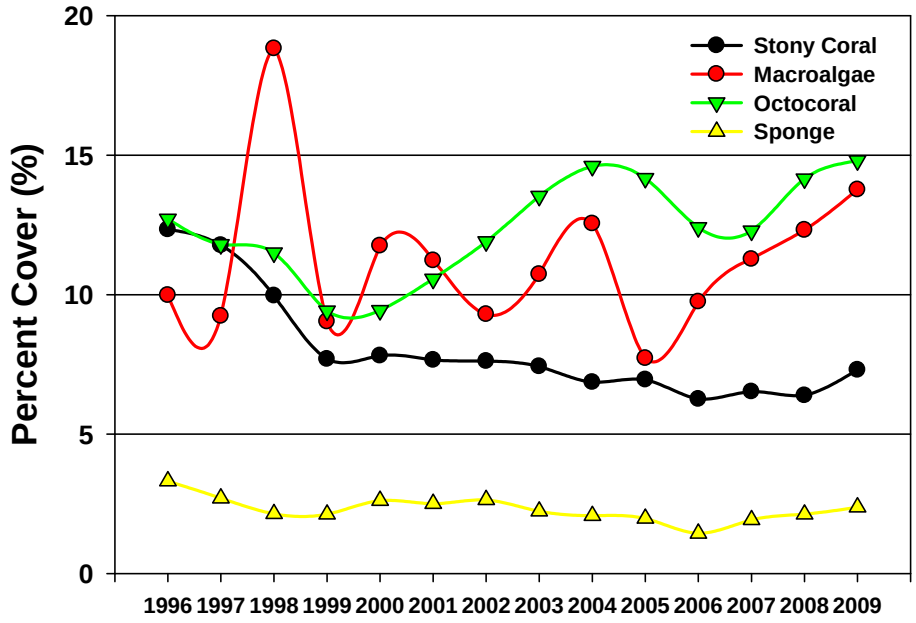

Figure 10. Line graph of mean annual percent cover for the four major benthic taxa recorded in CREMP image analysis. Mean percent cover is pooled from 97 stations in the Florida Keys. Overall trends from 1999 through 2008 were determined from a Kenward-Roger mixed model regression. Trends are as follows: Stony Coral: decreasing ($p<0.001$); Macroalgae: no change ($p>0.05$); Octocoral: increasing ($p<0.001$); Sponge: decreasing ($p<0.001$).

- Coral cover has continued to decline during the last 10 years. However, there was a ~40% decrease in cover during the initial four years of the project. Overall coral cover declined ~48% from 12.7% in 1996 to 6.6% in 2008 (Figure 10), reaching its lowest level after 2006 (6.4). The absolute change in coral cover between 1999 and 2009 is 0.5% (7.8 vs. 7.3%)
- Coral cover has shown a negative trajectory at 21 of 37 sites since 1999 (Figure 11). The declining trend is most apparent at sites in the Lower Keys and Dry Tortugas, where 84% of all sites showed a decreasing trend in coral cover. On the positive side, eight of the nine Atlantic patch reefs showed no difference in coral cover over the last 10 years.

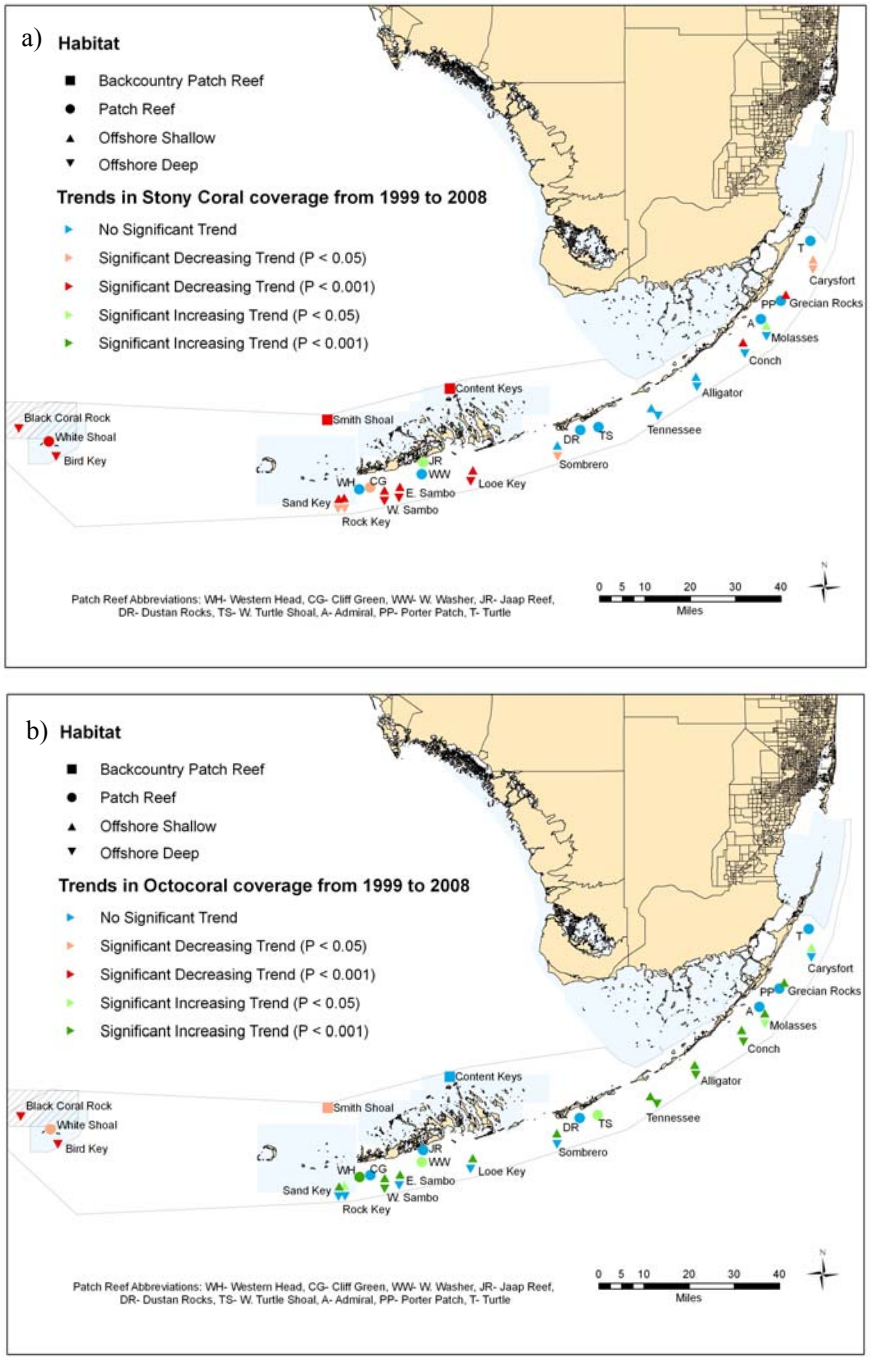

Figure 11. Long term trends of percent cover from 1999-2008 at CREMP sites for a) stony corals and b) octocorals. Shape and color of symbol indicate habitat type and direction and significance of trend (e.g. increasing, decreasing).

- Macroalgae cover has been highly variable, but mean cover throughout the project is ~11% (Figure 10). There has been no trend in macroalgae cover from 1999 through 2008. CREMP findings are consistent with those reported from other Caribbean localities. Although short term spikes have been observed, it appears either periodic scouring by hurricanes or other top-down controls (e.g. herbivorous fishes) successfully regulate macroalgae cover in the Keys.

- Octocoral cover has significantly increased during the last 10 years. Soft coral cover been steadily increasing after reaching a low point in 1999 (9.4%). Cover of soft corals declined during the initial four years of the project, but increased every year from 1999 through 2004. Although cover dipped again due to hurricane damage between 2005 and 2007, it was 14.8% in 2009 - the highest value ever recorded by CREMP.
- Octocoral cover has increased at 54% (20 of 37) of sites since 1999 (Figure 11). This pattern is most evident at the shallow forereef sites. Ten of 12 shallow spur and groove sites demonstrate a strong positive trend ($p<0.001$) in octocoral cover. The increase in cover may be due to both recruitment and horizontal extension of the canopy over story, but in either case, coincides well with the loss of *Acropora palmata* and *Millepora complanata* from these habitats during the mass bleaching and disease outbreaks that occurred from 1997 through 2000.
- Sponges have always provided the smallest contributions to biotic cover. Like stony corals, sponges have shown a negative trend since 1999, and the lowest value for sponges was recorded in 2006 (1.4%). Although the overall slope since 1999 is negative, sponge cover has consecutively increased during the last three years.

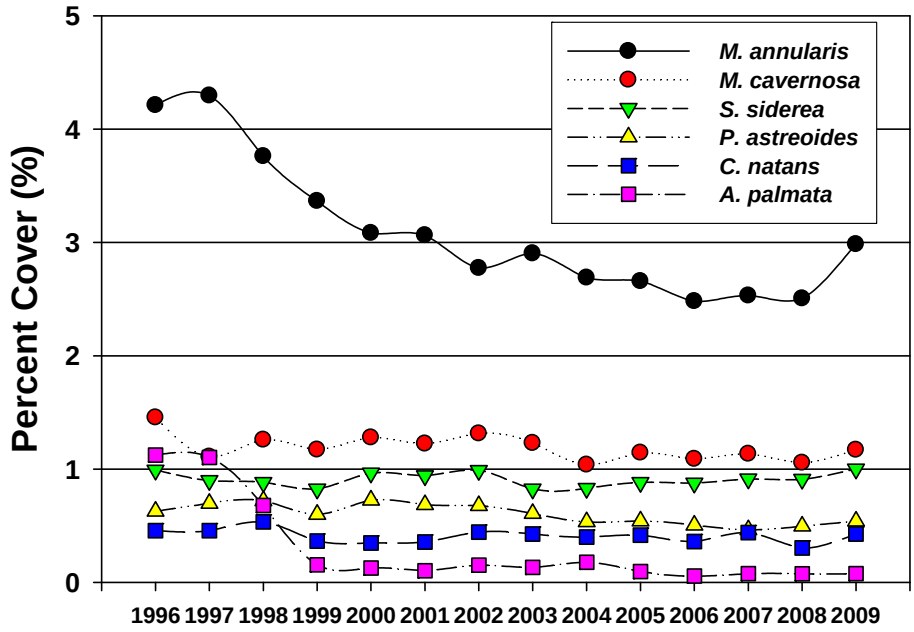

Figure 12. Line graph of mean annual percent cover for six species of corals recorded in CREMP image analysis. Mean percent cover is pooled from 97 stations in the Florida Keys. Overall trends from 1999 through 2008 were determined from a Kenward-Roger mixed model regression. Trends are as follows: *Montastraea annularis*: decreasing ($p<0.001$); *Montastraea cavernosa*: decreasing ($p<0.001$); *Siderastrea siderea*: no change ($p>0.05$)); *Porites astreoides*: decreasing ($p<0.001$); *Colpophyllia natans*: decreasing ($p<0.001$).

- Five of the six most spatially dominant species show a significantly decreasing trend in percent cover (Figure 12). The only exception is *Siderastrea siderea,* which indicates neither a positive nor negative trend.
- Following suit with overall trends in coral cover, the negative trends for *Montastraea annularis*-complex are most recognizable in the Lower Keys and Dry Tortugas. Overall,

43% (16 of 37) of all CREMP sites showed a negative trend. Eleven of these sites are located in the Lower Keys and Dry Tortugas regions (Figure 13).

- In contrast to *M. annularis*-complex, no trend was identified for *Siderastrea siderea* at 95% of all CREMP sites. Unlike *Porites astreoides* in other Caribbean localities, *S. siderea* may be responsible for mediating coral cover in the Keys in the future (Figure 13).

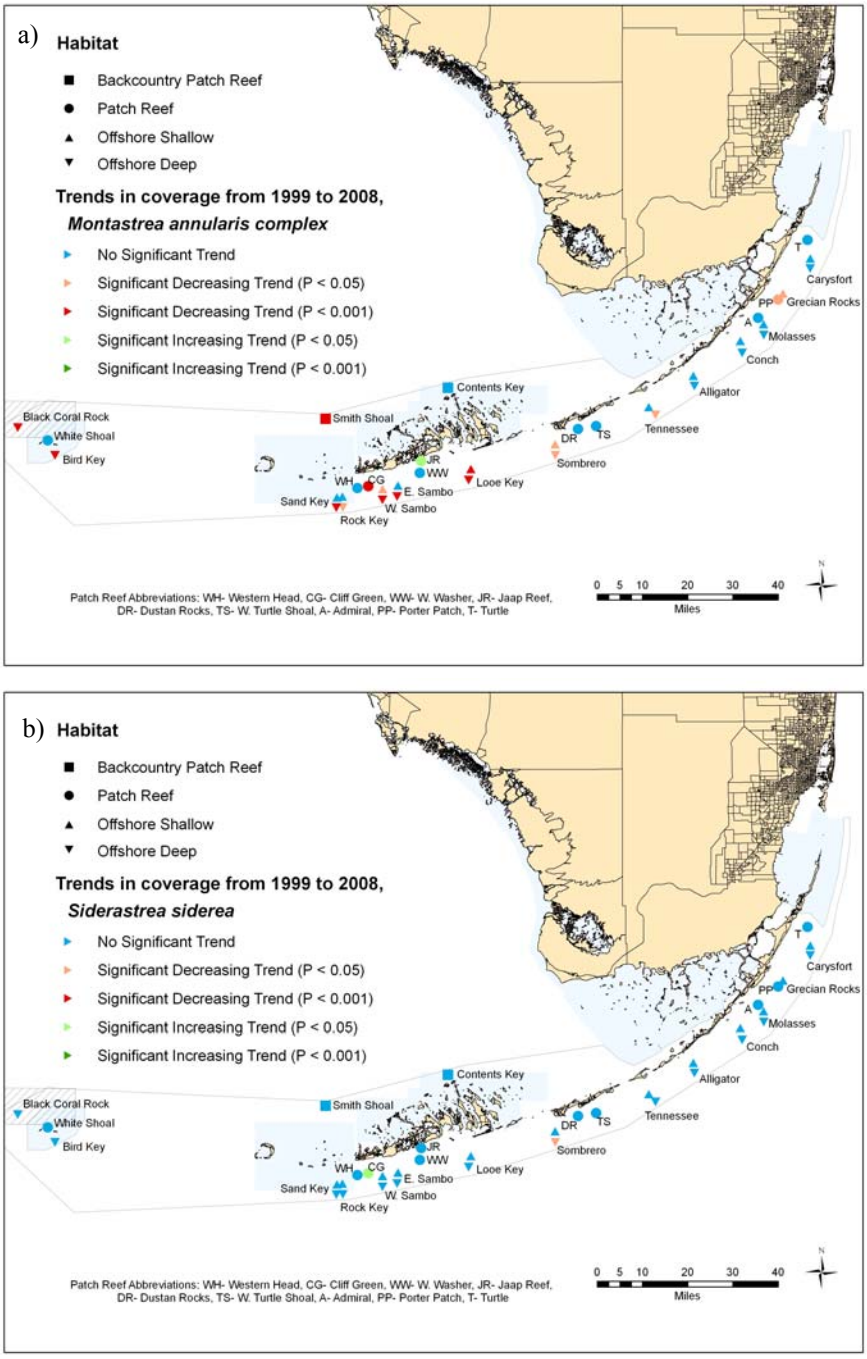

Figure 13. Long term trends of percent cover from 1999-2008 at CREMP sites for a) *Montastrea annularis*-complex and b) *Siderastrea siderea*. Shape and color of symbol indicate habitat type and direction and significance of trend (e.g. increasing, decreasing).