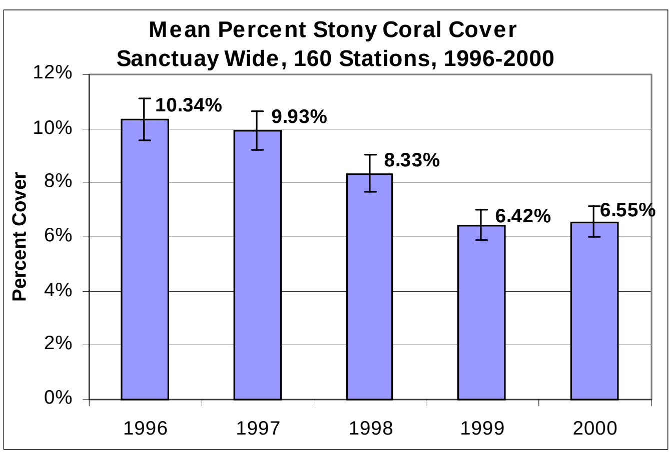
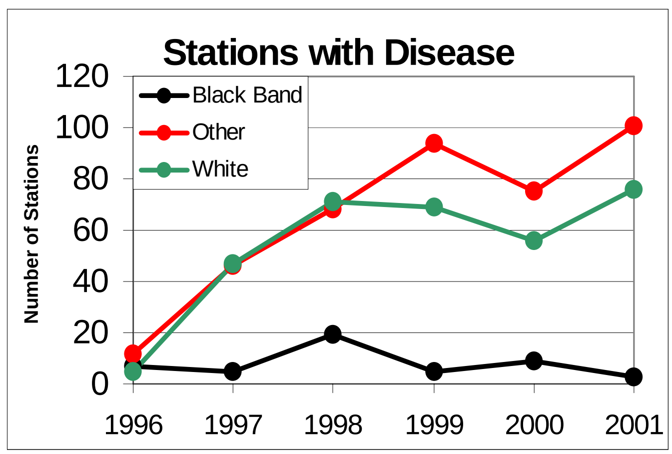
EPA/FKNMS Coral Reef Monitoring Project

Executive Summary 2001

FKNMS Symposium: An Ecosystem Report Card
Washington DC, December 2001





A product of the Florida Fish and Wildlife Conservation Commission
and the University of Georgia, Athens.

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Abstract

The Florida Keys National Marine Sanctuary (FKNMS) and Protection Act (HR5909) designated over 2,800 square nautical miles of coastal waters as the FKNMS. In cooperation with NOAA, the US Environmental Protection Agency and the State of Florida implemented a Water Quality Protection Program to monitor seagrass habitats, coral reefs and hardbottom communities, and water quality. The Coral Reef Monitoring Project (CRMP) sampling strategy and methods were developed in conjunction with EPA, FKNMS, Continental Shelf Associates, and the Principal Investigators in 1994. The major criteria for coral reef monitoring included Sanctuary-wide spatial coverage, repeated sampling, and statistically valid findings to document status and trends of the coral communities. The results were intended to assist managers in understanding, protecting, and restoring the living marine resources of the FKNMS.

The 40 original CRMP sampling sites, including inshore hard bottom habitats, midshelf patch reefs and offshore bank reefs were selected and installed in 1995 using US EPA e-map protocols. Annual, non-consumptive sampling began in 1996 at 160 permanently marked stations (4 stations per site) throughout the FKNMS. In 1999, 3 sites (12 stations) were added in Dry Tortugas. Stony coral species richness and disease presence are documented at each station. Analyses of video transect images yield percent cover for stony coral and other benthic categories.

Between 1996 and 2000, the CRMP reported a 37% reduction in stony coral cover Sanctuary-wide. Hypothesis testing revealed that 63.9% of project stations suffered a significant loss in stony coral cover while only 3.5% showed a significant increase. For all stations, 67% lost one or more stony coral species. The project documented a concurrent increase in disease infection. The number of stations where disease was documented increased from 26 in 1996 to 131 in 2000 and the number of species infected by disease increased from 11 to 36. These trends are alarming, however, they are reasonably consistent with trends documented by researchers elsewhere in the Caribbean basin. There is general consensus that multiple stressors acting at local, regional and global scales are contributing to coral decline in Florida.

The Comprehensive Everglades Restoration Plan (CERP) aims to re-establish the historical flow of water through south Florida and Florida Bay. This project will inevitably alter biological communities and water quality in Florida Bay. Downstream of Florida Bay, the Florida Keys reef tract provides the last opportunity to quantify CERP induced changes. Therefore, continued monitoring is crucial in order to document status and trends of coral reefs in the FKNMS. The CRMP intends to expand its sampling strategy in order to better understand causes of coral decline and effects of multiple stressors.

The enhanced Coral Reef Evalulation and Monitoring Project (CREMP) will consist of the ongoing strategies to document stony coral cover, species richness, bleaching, and disease; expanded sampling will provide data on bioeroders, temperature, individual coral colony status, human enteroviruses, recruitment and sedimentation. This comprehensive data set will assist Coastal Ocean Program (COP) development of landscape-seascape models to characterize physical, chemical and biological stressors. The CREMP will provide a better understanding of coral community dynamics and mortality rates associated with individual stressors by following the fate of individual coral colonies and using multi-variate statistical analyses. These data will assist managers in determining if the fully protected Tortugas Ecological Reserve and other Sanctuary Preservation Areas (SPAs) are protecting sensitive resources; it will also provide definitive feedback on the downstream effects of CERP.

Introduction

The Florida Keys coastal ecosystem exhibits the typical Caribbean pattern: mangroves at the coastal interface and a mosaic of sedimentary, seagrass, hardbottom, and coral reef habitats off the coast. The majority of coral reefs are located on the ocean side of the Keys. Hardbottom habitat exists on the ocean side and in Florida Bay as well. Coral reefs are least abundant of the benthic habitat types, estimated to comprise approximately one percent of the seafloor within the Florida Keys National Marine Sanctuary (FKNMS).

The Florida Keys National Marine Sanctuary and Protection Act (HR5909) designated over 2,800 square nautical miles of coastal waters as the Florida Keys National Marine Sanctuary. In cooperation with the National Oceanographic and Atmospheric Administration (NOAA), the US Environmental Protection Agency (USEPA) and the State of Florida implemented a Water Quality Protection Program to monitor seagrass habitats, coral reefs and hardbottom communities, and water quality.

The Coral Reef Monitoring Project (CRMP) sampling strategy and methods were developed in conjunction with USEPA, FKNMS, Continental Shelf Associates and the Principal Investigators in 1994. The major criteria for coral reef monitoring included Sanctuary-wide spatial coverage, replicate sampling, and statistically valid findings to document status and trends of coral communities. Results assist managers in understanding, protecting, and restoring the living marine resources of the FKNMS. Results are also useful to the general public, educators and the research community.

Methods

Sampling site locations were chosen in 1994 using a stratified random sampling procedure (US EPA E-map). Forty reef sites were selected within the FKNMS and permanent station markers were installed in 1995. Annual sampling began in 1996 and has continued through 2001. Three additional sites were installed and sampled in the Dry Tortugas beginning in 1999 (Figure 1). The project's 43 sampling sites include 7 hardbottom, 11 patch, 12 offshore shallow, and 13 offshore deep reef sites. Field sampling consists of station species inventories and video transects (three video transects per station) conducted at 4 stations at each site as illustrated in Figure 2.

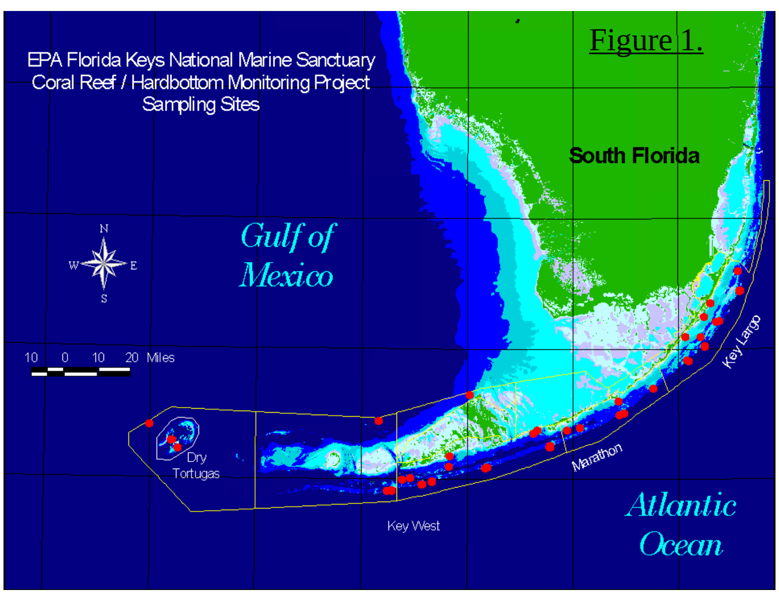


Figure 1.

Station Species Inventory (SSI)

Stony coral species (Milleporina and Scleractinia) presence recorded at each station provides data on stony coral species richness (S). Two observers conduct simultaneous timed (15min) inventories within the roughly 22 x 2 m stations and enter the data on underwater data sheets. Each observer records all stony coral taxa and fire corals and enumerates long-spined urchins (*Diadema antillarum*) within the station boundaries. After recording the data, observers compare (5min) data underwater and confirm species recorded by only one observer. Data sheets are verified aboard the vessel and forwarded to FMRI for data entry and processing. This

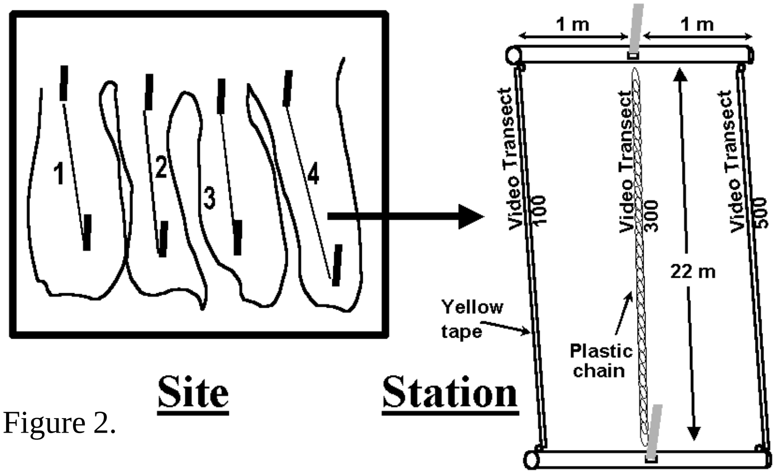


Figure 2.

method facilitates data collection with broad spatial coverage at optimal expenditure of time and labor.

Diseases/Conditions

During the species inventory any species within a station that exhibits specific signs of either bleaching or disease (black band, white complex and other) is documented on the data sheet.

Videography

All sampling through 1999 was filmed with a Sony CCD-VX3 using full automatic settings. Beginning in 2000, the project upgraded to digital video filming all sites with a SONY TRV 900. In order to insure quality images, artificial lights are used when necessary. A convergent laser light system aids the videographer in maintaining the camera at a uniform distance above the reef surface (40 cm). The videographer films a clapperboard prior to beginning each transect. This provides a complete record of date and location of each segment recorded. Filming is conducted at a constant swim speed of about 4 meters per minute yielding approximately 9,000 video frames per transect. Images for all transects are framegrabbed, written to and archived on CD-ROM.

Image Analysis

Benthic cover analysis is predicated on selecting video frames that abut, with minimal overlap between images. At the filming distance of 40cm above the reef surface, the field of view is 40cm wide. Approximately 9000 frames of video are collected for each transect. Through 2000, a subset of still images was frame grabbed based on swim speed. From this subset, the analyst selected images that approximated a non-overlapping mosaic. Starting with 2001 data, a newly developed image processing tool, RavenView™, was used to create a mosaic of the transect using all 9,000 images. From the complete mosaic, a subset of exactly abutting images is selected and distributed to the analysts. Image analysis is conducted using a custom software application PointCount for coral reefs, developed specifically for the CRMP. When the analyst opens each image, the software overlays ten random points on the image. Selected benthic taxa (stony coral species, octocoral, zoanthid, sponge, seagrass and macroalgae) and substrate are identified under each point. The software has a “point and click” feature that feeds the identification data into a backend spreadsheet. After all images are analyzed, the data is converted to an ASCII file for Quality Assurance and entry into the master ACCESS data set.

Statistical Analyses

In addition to the descriptive methods of organizing and summarizing the data, hypothesis testing was conducted by independent statistical consultants to analyze the percent cover, species richness, and disease/condition data. The decision to reject or not to reject the null hypothesis that there is no significant difference in the data for certain years is based on the minimum detectable difference for different significance levels and powers. Six combinations for significance level (α) and power ($1-\beta$) were considered: $\alpha = 0.05$, $1-\beta = 0.75$; $\alpha = 0.10$, $1-\beta = 0.75$; $\alpha = 0.20$, $1-\beta = 0.75$; $\alpha = 0.05$, $1-\beta = 0.80$; $\alpha = 0.10$,

$1-\beta = 0.80$; and $\alpha = 0.20$, $1-\beta = 0.80$. When the one-sided alternative is tested, the above values for α must be divided by two. The output consists of the minimum detectable difference for a certain pair (α, $1-\beta$), which can be used to construct a $(1-\alpha)$ % confidence interval and provides a measure of the test accuracy.

Multi-variate Analyses

Non-metric multi-dimensional scaling (MDS) analyses using the Primer™ software package were used to determine similarity of sampling locations for successive years. The time period in which the greatest change in coral abundance occurred can be identified. Further analyses rank individual species that contribute to the increase or decrease. The analysis of similarities (SIMPER) routine delves deeper into the data and ranks the species with the greatest contribution to the change. The ANOSIM routine is another multivariate method that tests significance of change.

Benthic Cover Analyses

Hypotheses testing looked at differences in proportions at the station level of:

- total stony coral
- within stony coral, i.e., relative percent cover of individual species

The conditions for normality were met and hypothesis testing was completed for all temporal pair-wise comparisons between 1996 and 2000. Tests were run for: $H_0 : p_1 = p_2$ vs. $H_a : p_1 \neq p_2$ If either one of the one-sided alternatives is of interest, $H_a : p_1 > p_2$ or $H_a : p_1 < p_2$, then the above significance level must be divided by two. To perform the above hypothesis testing, an S-PLUS code was written.

Results presented herein are for the significance level of 0.20 (0.10 for a one-sided alternative) and power of 0.75. Three colors signify change as follows: yellow, no significant change; green, significant increase; red, significant decrease.

Species Inventory and Disease / Condition Analyses

To investigate species richness data, the hypothesis of whether there is difference in the proportion of the number of stations where each species is present was tested. Results are sanctuary-wide. Species richness is highly influenced by presence/absence of the relatively rare species.

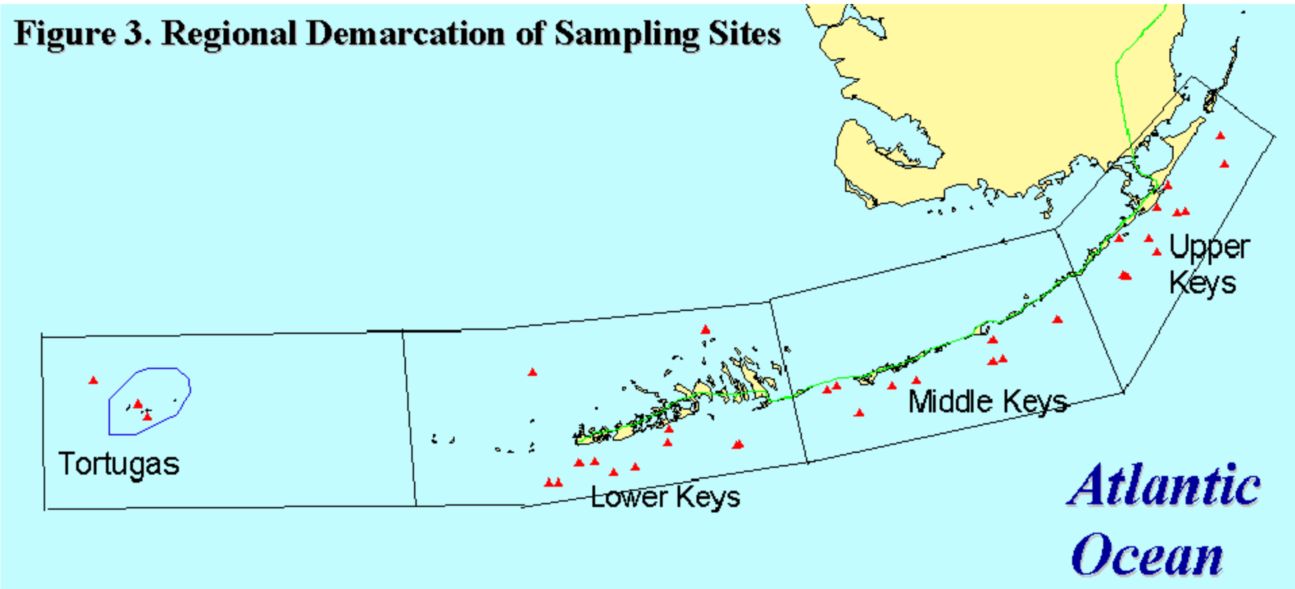
Pair-wise tests were run for total stony coral and for individual species with adequate data in order to determine whether there was significant change in number of stations with presence of a certain disease/ condition from 1996 to 2001.

Station Reduction

Before the 2001 sampling season, the statistical consultants re-evaluated the number of stations and concluded that certain sampling stations could be eliminated while allowing the project to maintain it's spatial coverage and robust data set. The decision to eliminate one or two of the four stations at an individual site was based on statistical analyses of the similarity in stony coral cover. Hypothesis testing was used to identify differences in the proportion of stony coral cover at the four stations within each site (Fleiss, 1981). This exercise reduced the original 160 stations to 111 stations. Permanent station markers remain in place for future reference if needed.

Results and Analyses

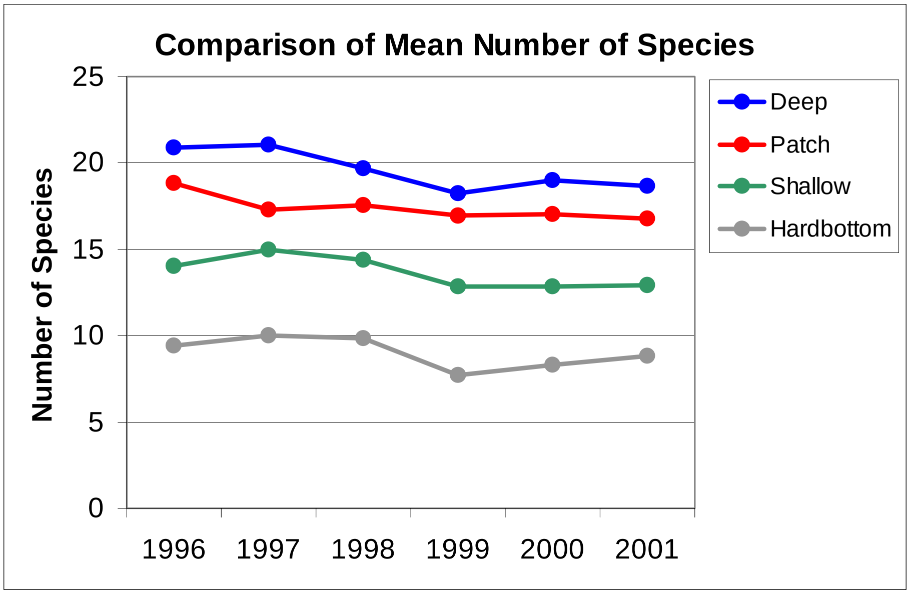
Results are reported by regions defined as follows: Upper Keys (north Key Largo to Conch Reef), Middle Keys (Alligator Reef to Molasses Keys), Lower Keys (Looe Key to Smith Shoal), and Tortugas (Dry Tortugas to Tortugas Banks) (Figure 3). SSI data from 1996-2001 for 111 stations that remained after station reduction are presented. Benthic cover analyses are for 1996-2000. Dry Tortugas data are presented separately as sampling began in 1999.



Stony Coral Species Richness

The project documented a decline in stony coral species richness for all habitat types (Figure 4). The offshore deep and patch reef stations had the greatest numbers of stony coral taxa; hardbottom stations had the least.

Figure 4. Species Richness by Habitat Type, 111 stations, 1996-2001



Between 1996 and 2001, in the Upper Keys, there was a loss of stony coral species at 26 of 34 stations (76.5%); 5 stations gained species, and at 3 stations, presence of stony coral species was unchanged (Figure 5).

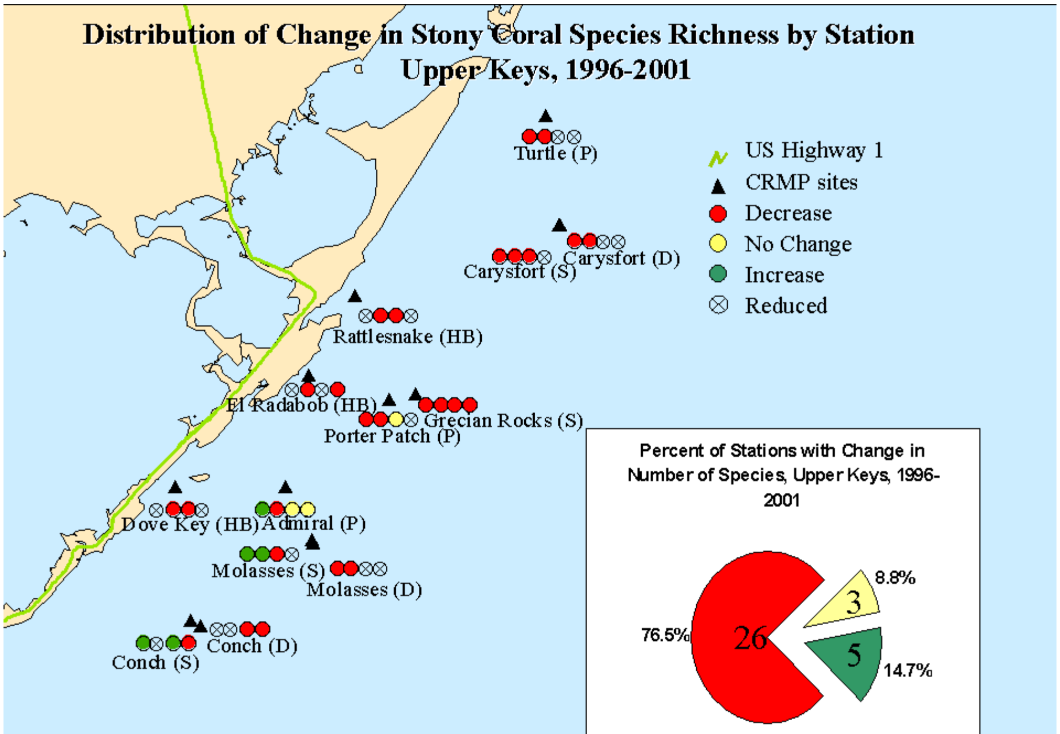


Figure 5

In the Middle Keys, 17 of 31 stations (54.8%) lost stony coral species; 9 stations gained species, and 5 stations were unchanged (Figure 6).

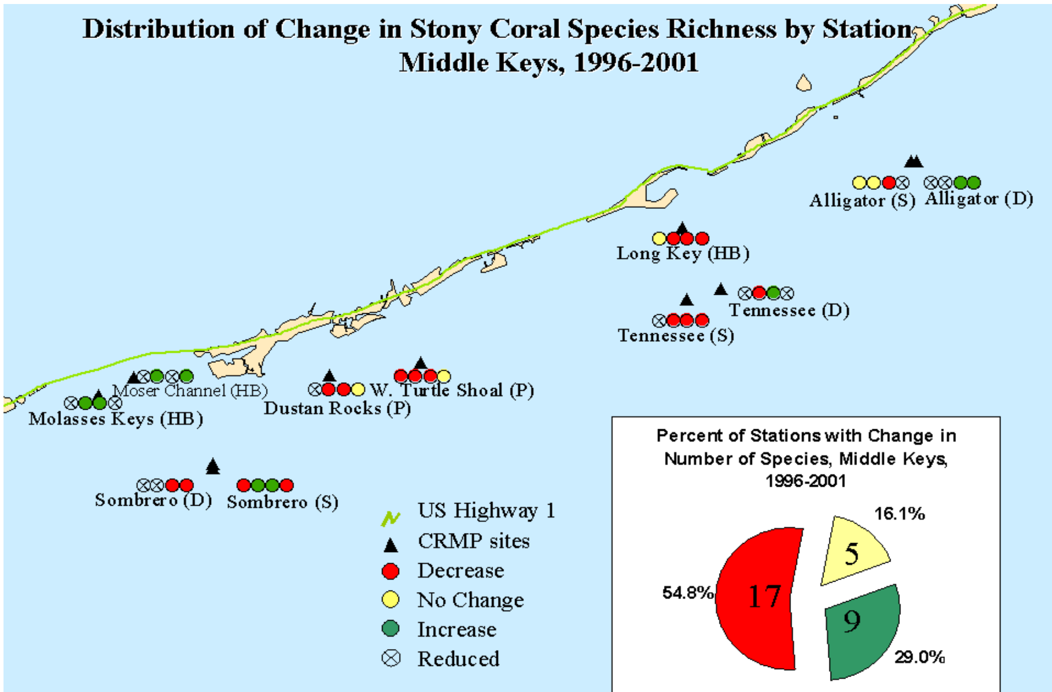


Figure 6

In the Lower Keys, 27 of 46 stations (58.7%) lost stony coral species; 14 stations gained species, and 5 stations were unchanged (Figure 7).

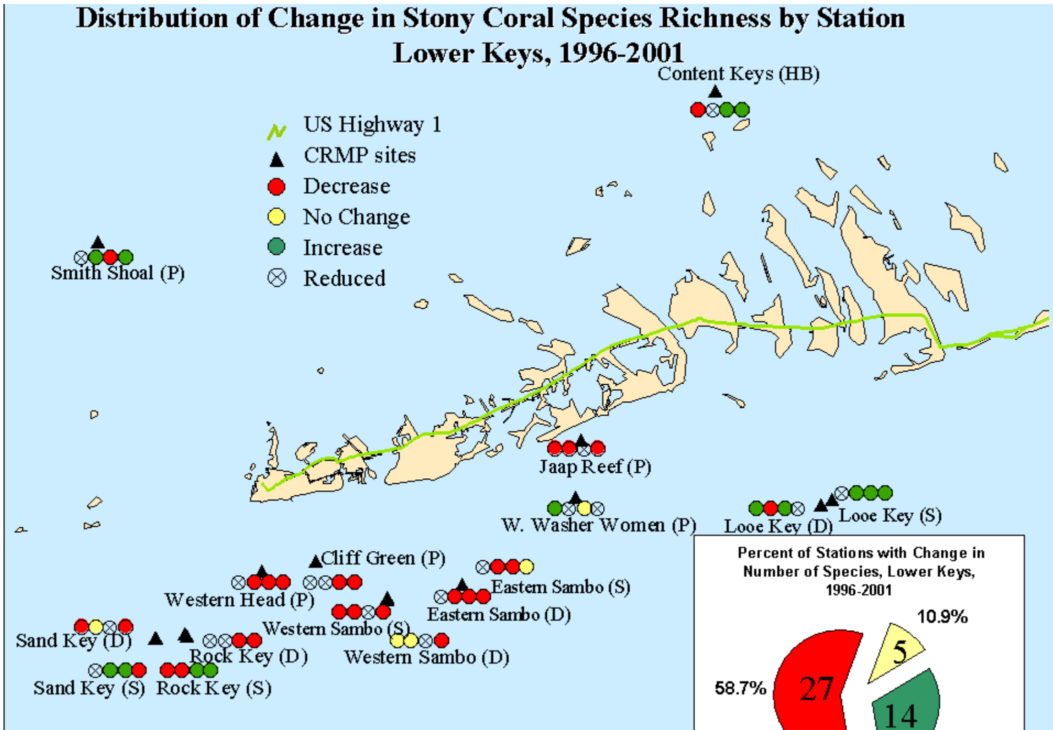


Figure 7

By habitat type (Table 1), 19 (65.5%) of 29 patch reef stations had stony coral species losses; 4 stations gained, and 6 stations were unchanged. For shallow reef stations, 23 of 39 (59.0%) showed stony coral species losses; 13 stations gained, and 3 were unchanged. Eighteen of 26 (69.2%) deep reef stations had stony coral species losses, 5 stations gained, and 3 stations were unchanged. Ten of 17 (58.8%) hardbottom stations had stony coral species losses; 6 hardbottom stations gained, and 1 station was unchanged.

Table 1. Number of Stations with Change in Stony Coral Species Richness, by Habitat Type, 1996-2001

Habitat Type	Patch Number of Stations With:			Shallow Number of Stations With:			Deep Number of Stations With:			Hardbottom Number of Stations With:			Total Number of Stations With:		
Comparison	No Change	Gain	Loss	No Change	Gain	Loss	No Change	Gain	Loss	No Change	Gain	Loss	No Change	Gain	Loss
1996 vs 1997	5	3	21	6	24	9	4	11	11	2	10	5	17	48	46
1997 vs 1998	7	13	9	8	9	22	4	4	18	5	5	7	24	31	56
1998 vs 1999	7	8	14	6	6	27	5	4	17	2	0	15	20	18	73
1999 vs 2000	8	12	9	8	14	17	7	14	5	4	8	5	27	48	36
2000 vs 2001	5	11	13	9	17	13	3	9	14	1	9	7	18	46	47
1996 vs 2001	6	4	19	3	13	23	3	5	18	1	6	10	13	28	70

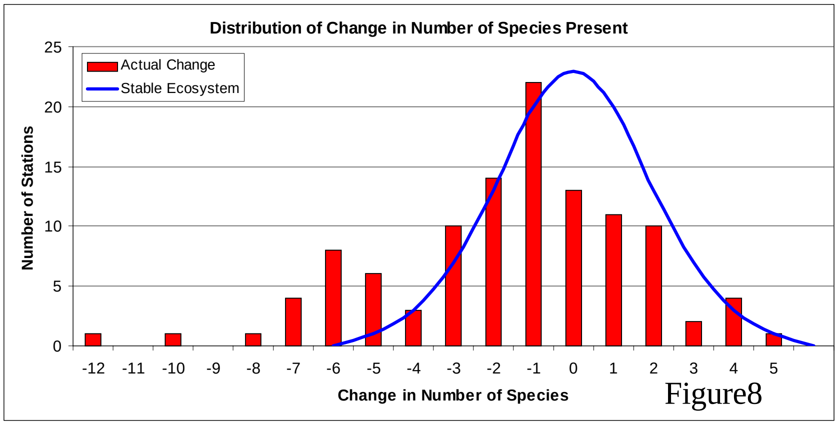


Figure8

Looe Key Shallow Station 2 had a maximum of five stony coral species gained. Grecian Rocks Station 4 had the greatest loss in stony coral species richness at a single station, where 12 species were lost.

Figure 8 represents the distribution of change for CRMP stations along with a normal distribution of change expected in a stable environment. The CRMP data is skewed to the left, indicating a decline in species richness. Sanctuary-wide from 1996 to 2001 stony coral species richness declined at 70 stations (63.1%), 28 stations (25.2%) had a gain and 13 stations (11.7%) were unchanged.

In the Dry Tortugas from 1999 to 2001, 5 stations (41.7%) showed a decrease in the number of stony coral species identified, 6 stations (50.0%) gained and 1 station (8.3%) was unchanged (Figure 9).

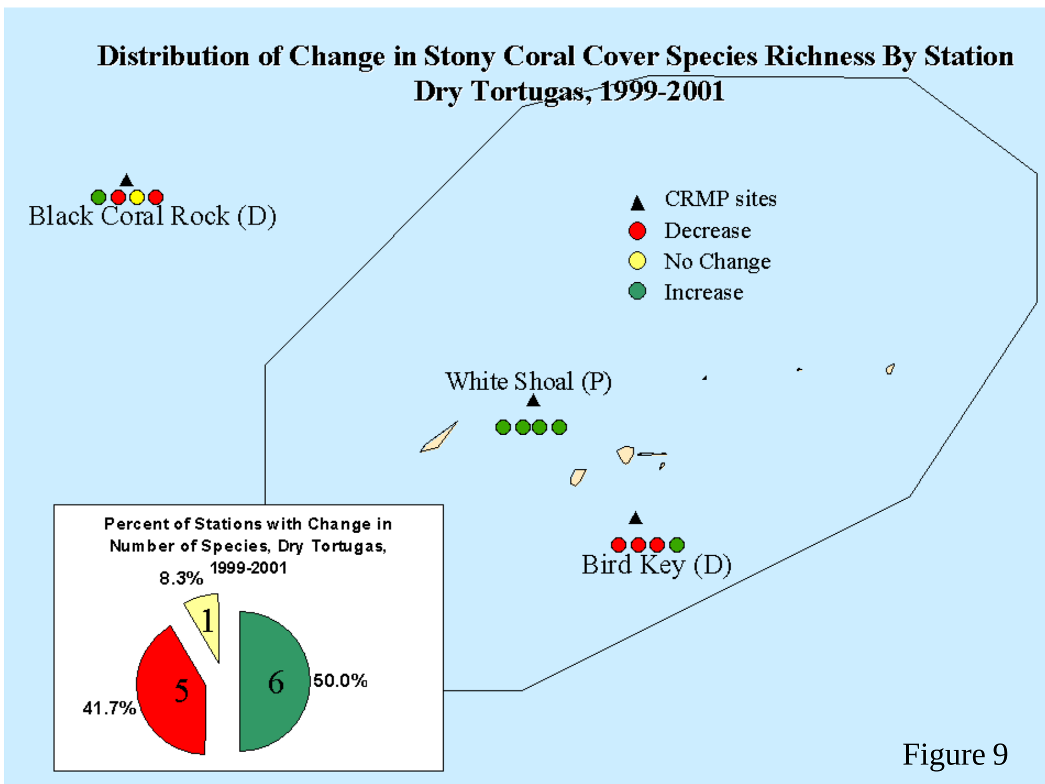


Figure 9

From 1996 to 2001 statistical analyses revelaed significant decreases in the number of stations where *Acropora cervicornis, Millepora alcicornis, Mycetophyllia lamarckiana* were docuemnted (α =0.10 and 1-β= 0.75). *Siderastrea siderea* was the only species with a significant gain.

Stony Coral Condition

In general, stony corals in CRMP stations experienced an increase in disease infections from 1996 to 2001 (Figure 10). A significant increase in the number of stations with corals affected by white and other disease was reported between 1996-2001 (α =0.10 and 1-β= 0.75). The number of stations with corals affected by black band disease was statistically unchanged. Overall, there were increases in the number of stations containing diseased coral, the number species with disease, and the different types of diseases that were observed.

Further analysis of the disease data by species shows the number of stations with all selected species infected by Black Band disease peaked in 1998. Black Band infections declined thereafter (Figure 11).

In 1997 and 1998, four of the selected species experienced peaks in "white" disease, but have since declined (Figure 12). The apparent reduction in "white" disease for *Acropora cervicornis* and *A. palmata* is likely attributable to 97% and 88% reductions in percent cover, respectively. Three species had a maximum occurrence of white disease in 2001. The number of stations where "white" disease infected *Agaricia agaricites* in 2001 nearly tripled the previous high.

In the "other" disease category, the number of stations infected peaked in 2001 for all species depicted (Figure 13). Four species (*M annularis, M. cavernosa, P. asteroides, S. siderea*) provide 80% of all living coral in the survey. The number of stations where "other" disease infected each of these four species more than doubled between 2000 and 2001.

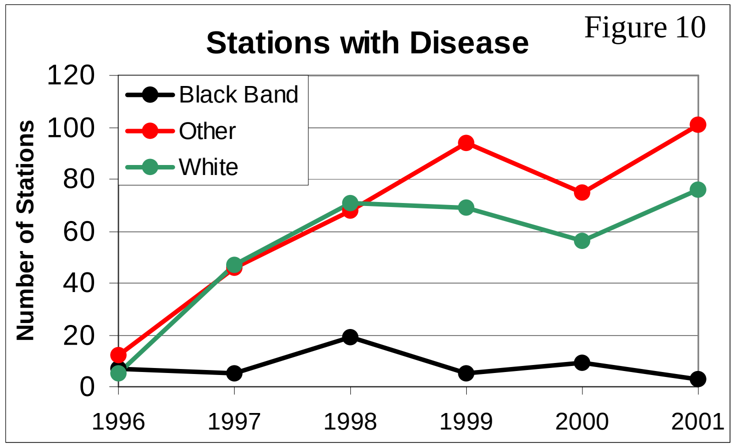


Figure 10

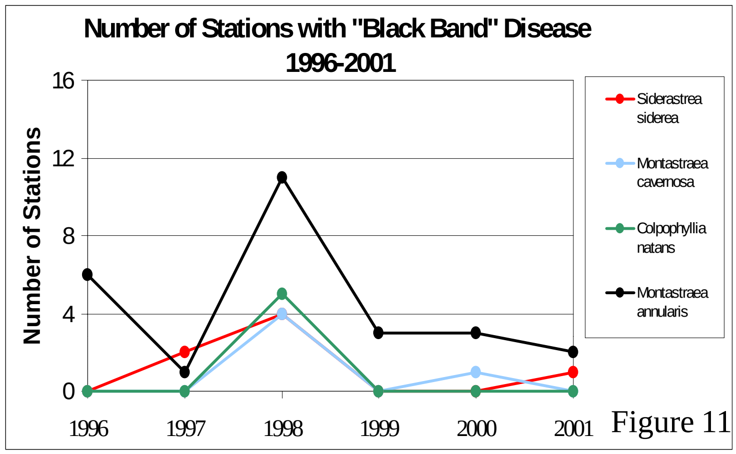


Figure 11

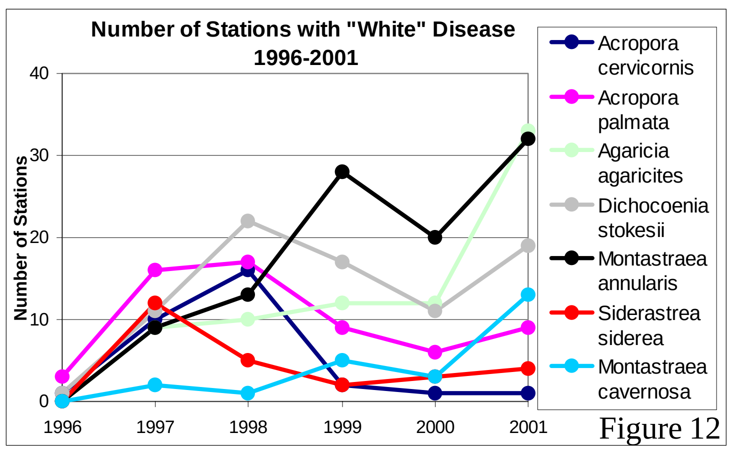


Figure 12

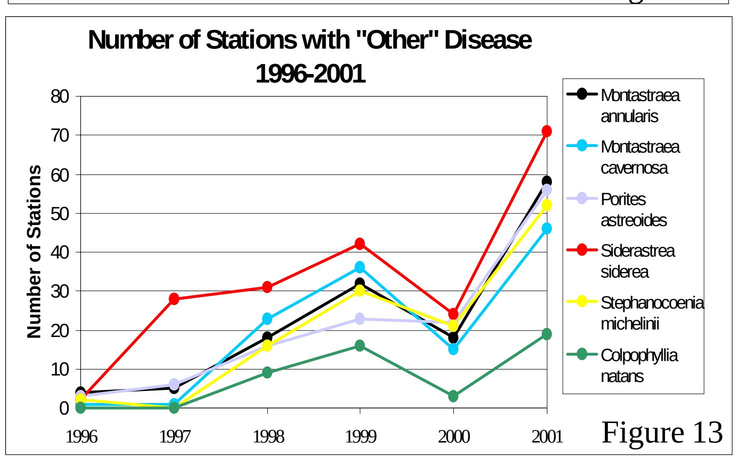
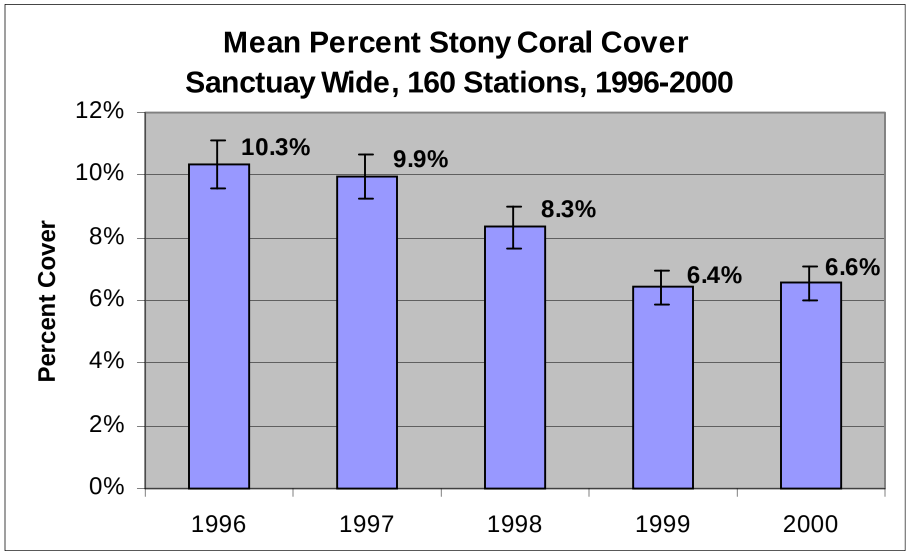


Figure 13

Stony Coral Cover

Sanctuary-wide, a general trend of decline in stony coral cover is presented in Figure 14. The decline in mean percent coral cover from 1997 to 1998 and from 1998 to 1999 was significant with a p-value of 0.03 or less for the Wilcoxon rank-sum test. The change observed from 1996 to 1997 and from 1999 to 2000 was determined to be insignificant.



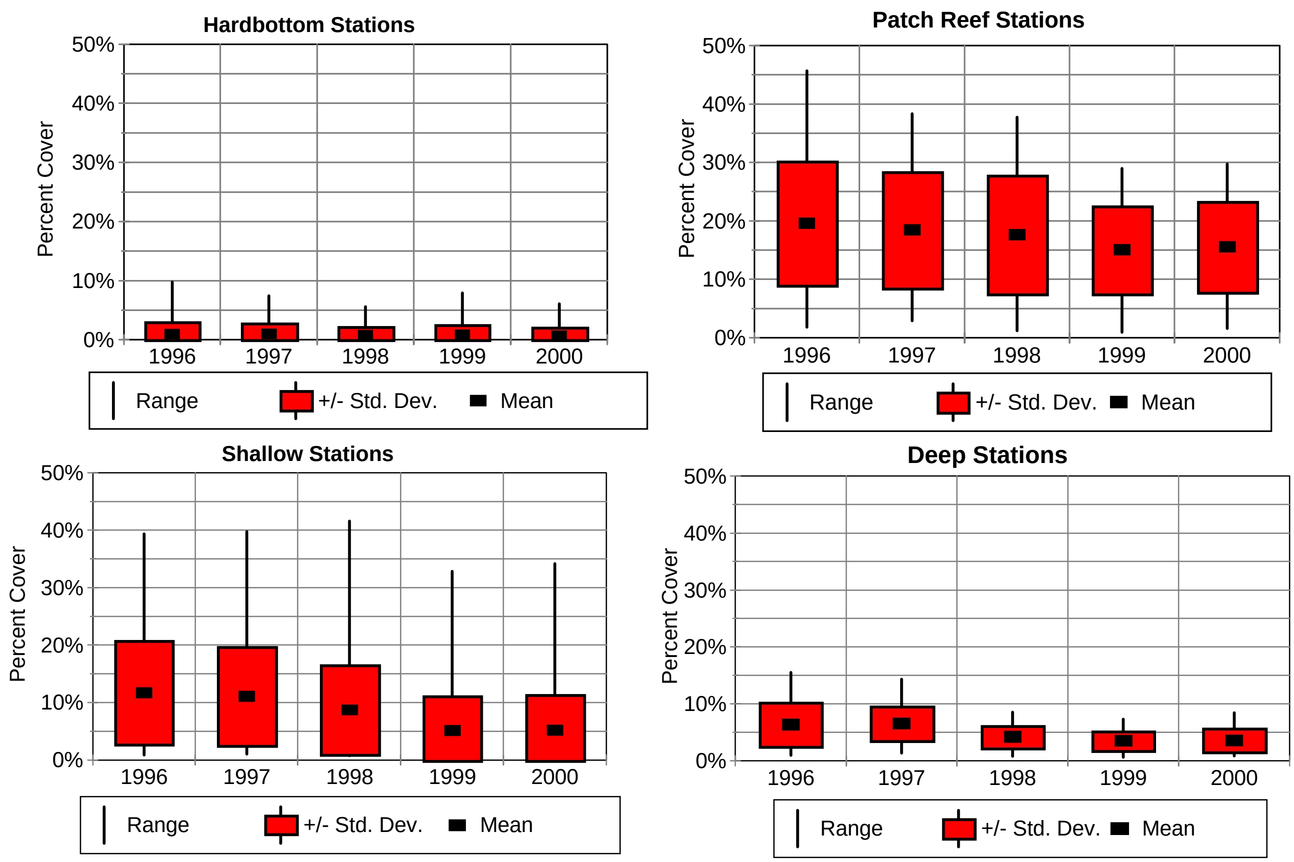


Figure 15. Mean Percent Stony Coral Cover by Habitat Type, 160 Stations, 1996-2000.

Stony coral cover by habitat type and year is provided in Figure 15. Greatest mean percent stony coral cover was consistently observed at patch reef stations. Though deep sites have the greatest number of species present, percent stony coral cover is consistently lower than at their shallow counterparts. Percent cover in hardbottom habitat is the lowest recorded for all habitat types. Sixteen of the 28 hardbottom stations had insufficient stony coral cover for hypothesis testing (<0.3% stony coral cover). Different methods are required to detect change at stations with minimal stony coral cover. Analyses of different parameters would better characterize change in these habitats.

Figure 16.

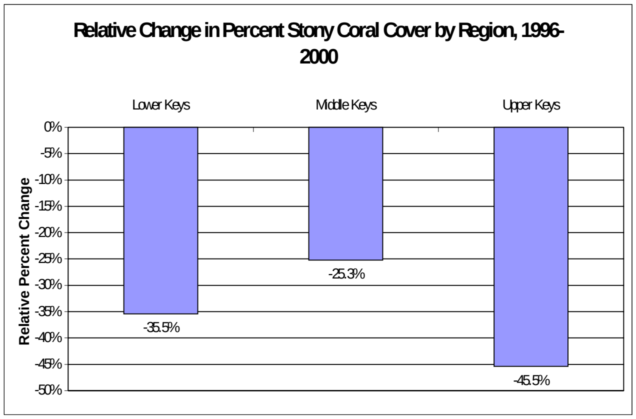
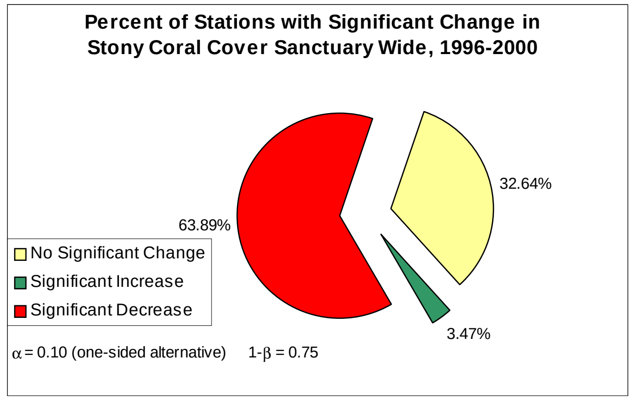


Figure 17.



Regionally, there was a greater relative change in mean stony coral cover in the Upper Keys (Figure 16). Additionally, a greater percentage of Upper Keys stations showed significant loss of coral cover compared to Lower and Middle Keys stations.

For the 144 stations with sufficient stony coral cover for analysis, 92 stations (63.9%) had a significant decrease in stony coral cover, 47 stations (32.6%)showed no significant change, and only 5 stations (3.5%) had significant gains. (Figure 17).

In the Upper Keys, 29 stations (72.5%) experienced significant loss of coral cover, 10 (25.0%) had no significant change and only 1 station experienced a significant gain in coral cover (Figure 18).

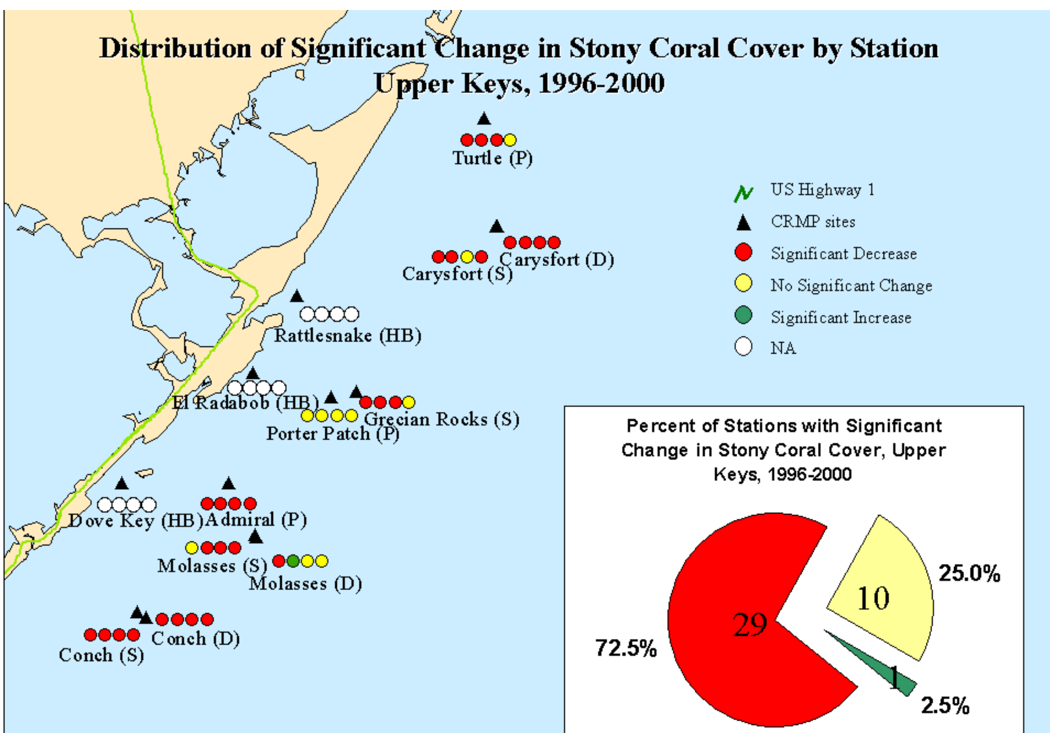


Figure 18

In the Middle Keys, 19 stations (47.5%) experienced significant coral cover losses, 20 stations (50.0%) had no significant change and only 1 station gained significant coral cover (Figure 19).

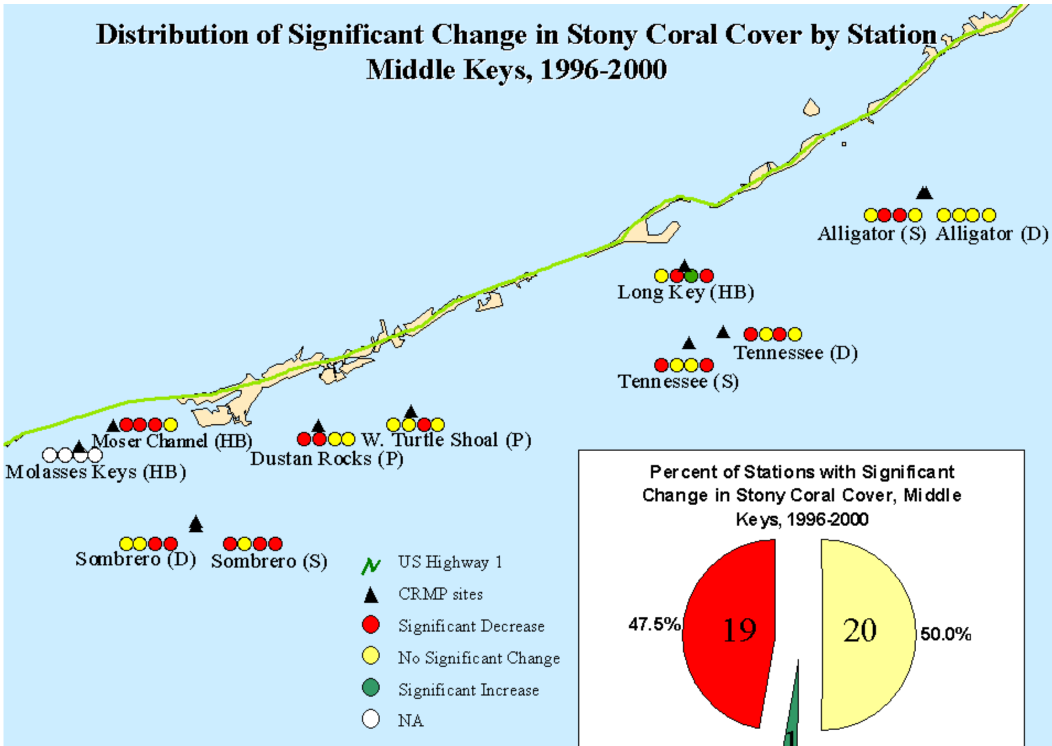


Figure 19

In the Lower Keys, 44 stations (68.8%) lost a significant amount of coral cover, 17 stations (26.6%) had no significant change and 3 stations (4.7%) showed a significant gain in coral cover (Figure 20).

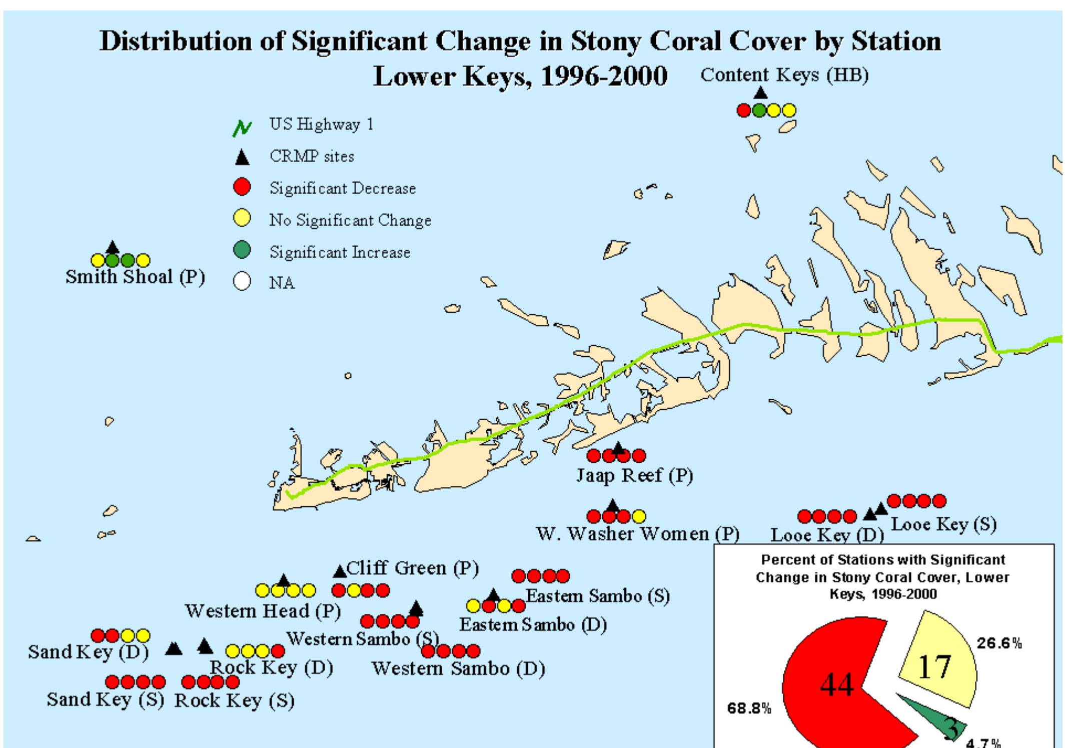


Figure 20

In the Dry Tortugas, for 1999-2000, 8 stations (66.7%) had no significant change in stony coral cover and 4 stations (33.3%) had a significant loss (Figure 21).

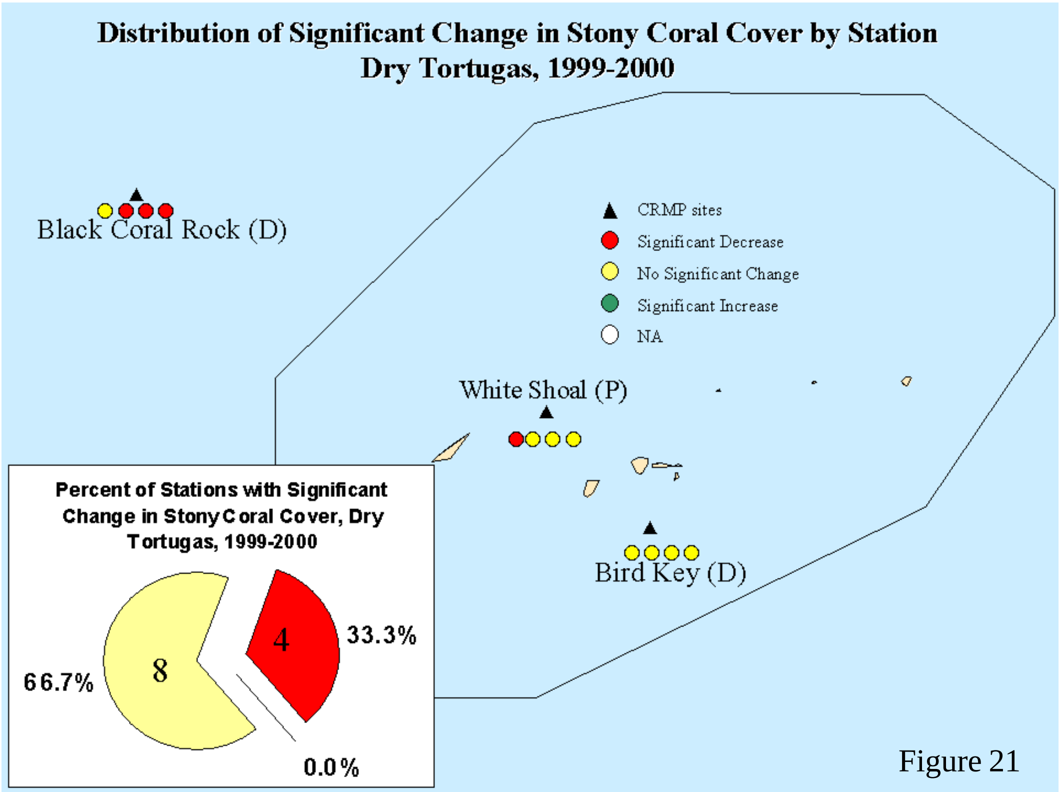


Figure 21

By habitat type, 20 patch reef stations (50.0%) had a significant loss in coral cover. Cover at 18 stations (45.0%) was statistically unchanged and 2 stations (5.0%) had a significant gain in coral cover. For offshore shallow sites, 40 stations (83.3%) had a significant loss of coral cover, 8 stations (16.7%) had no significant change in cover and no station exhibited a significant gain. In the offshore deep habitat, a significant loss in coral cover was documented at 26 stations (59.1%), 17 stations (38.6%) had no significant change in cover and only one showed a significant gain in coral cover (Table 2). For the hardbottom habitat stations hypothesis testing was only applicable for 12 of 28 stations because of sparse stony coral cover. Overall, there were significant losses in coral cover for 71.7% of offshore reef stations, both shallow and deep.

Table 2. Number of stations with statistically significant change in coral cover by habitat type, 1996-2000. (α =0.1, 1-β = 0.75)

Habitat Type	Patch Number of Stations With:			Shallow Number of Stations With:			Deep Number of Stations With:			Hardbottom Number of Stations With:			**Total Number of Stations With:**		
Comparison	No Signif. Change	Signif. Gain	Signif. Loss	No Signif. Change	Signif. Gain	Signif. Loss	No Signif. Change	Signif. Gain	Signif. Loss	No Signif. Change	Signif. Gain	Signif. Loss	**No Signif. Change**	**Signif. Gain**	**Signif. Loss**
1996 vs 1997	26	4	10	34	6	8	27	11	6	8	2	1	**95**	**23**	**25**
1997 vs 1998	27	5	8	23	1	24	18	0	26	7	1	3	**75**	**7**	**61**
1998 vs 1999	20	3	17	14	2	32	34	2	8	7	4	0	**75**	**11**	**57**
1999 vs 2000	24	11	5	37	8	3	37	5	2	10	0	1	**108**	**24**	**11**
1996 vs 2000	**18**	**2**	**20**	**8**	**0**	**40**	**17**	**1**	**26**	**4**	**2**	**6**	**47**	**5**	**2**

Functional Group Cover

Percent cover data for functional groups were analyzed for the geographic regions from 1996 to 2000 (Figures 22, 23, 24). Functional groups included: stony corals, octocorals, zoanthids, sponges, macroalgae, seagrass, and substrate (rock, rubble and sediments). Zoanthid and seagrass percent cover values were too low to represent graphically. In all three geographic regions, stony coral, sponge and octocoral cover decreased whereas macroalgae and substrate cover (Figure 25) increased over the five years. Macroalgae percent cover exhibits higher variability than all other functional groups.

Percent cover of functional groups was also analyzed by habitat type. Generally, functional group cover trends mimicked those observed at the regional level. Macroalgae percent cover increased dramatically at deep stations but declined slightly in the other three habitat types. Sponge percent cover declined more in deep and shallow stations than in patch and hardbottom stations. Zoanthid cover decreased sharply at deep and hardbottom stations, but increased slightly at shallow and patch stations.

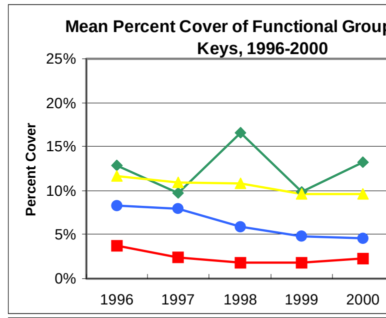


Figure 22

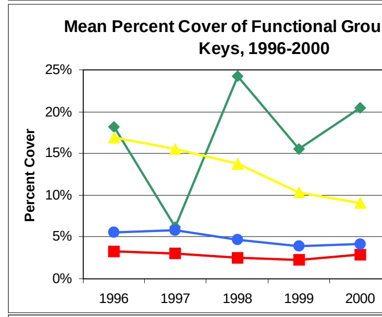


Figure 23

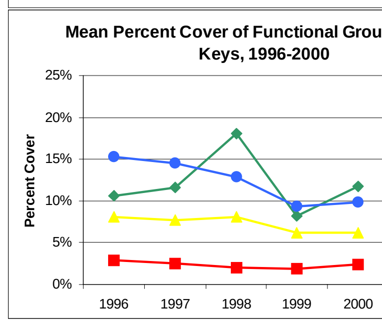


Figure 24

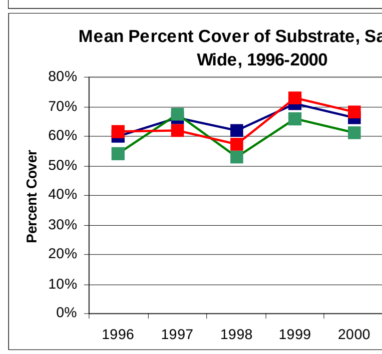


Figure 25

Stony Coral Species Cover

An understanding of the overall trend in stony coral cover can be gained through further analysis of change in percent cover of the most common species. In Figure 26, the six species with the greatest mean percent coral cover Sanctury-wide in 1996 were *Montastraea annularis* (3.39%), *M. cavernosa* (1.36%), *Acropora palmata* (0.90%), *Siderastrea siderea* (0.87%), *Millepora complanata* (0.80%) and *Porites astreoides* (0.55%). *M. annularis* represented approximately 33% of the coral cover at CRMP stations. The relative percent cover of *M. annularis* and *M. cavernosa* increased (Figure 27) although their mean cover decreased (*M. annularis* 3.39% in 1996 to 2.41% in 2000 and *M. cavernosa* 1.36% in 1996 to 1.22% in 2000). The most striking changes were declines in coral cover for *Acropora palmata*, *A. cervicornis*, and *Millepora complanata*. At shallow stations, the mean percent cover of *A. palmata* dropped from 3.01% (1996) to 0.35% (2000), representing an 88% loss. Sanctuary-wide, percent cover of *A. cervicornis* dropped from 0.20% (1996) to a barely detectable 0.006% (2000), a 97% reduction. *M. complanata* declined from a mean percent cover of 2.65% (1996) to 0.12% (2000) for all shallow stations, a loss of 95%. Only

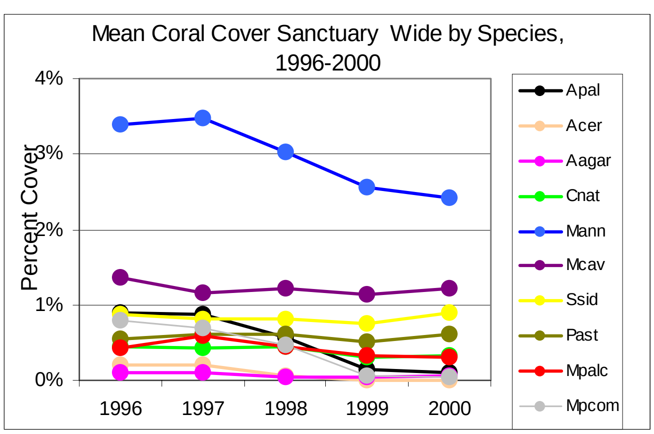
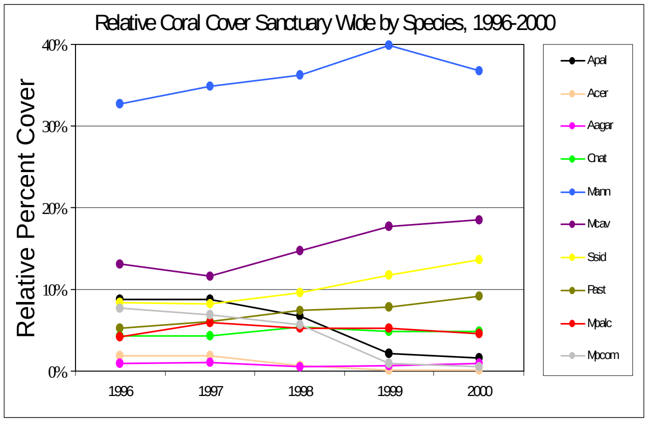


Figure 26

Figure 27

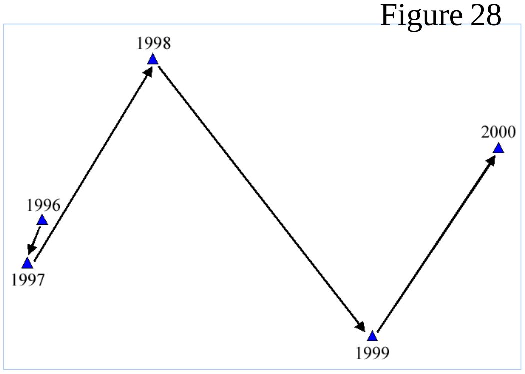


two species exhibited an increase in percent cover from 1996 to 2000. *Siderastrea siderea* increased slightly from a mean of 0.87% in 1996 to 0.89% in 2000, representing an increase of 2.5%. *Porites astreoides* showed slight increases in mean as well as relative coral cover (Figures 26, 27). The three other species shown in Figure 26, *Agaricia agaricites*, *Colpophyllia natans* and *M. alcicornis*, all experienced less dramatic declines in mean percent coral cover.

Figure 28 presents mulit-variate (MDS) analyses of data from Western Sambo Shallow. The close proximity of data points for 1996 and 1997 indicate that minimal change occurred. The greater distance between data points for 1997 & 1998, 1998 & 1999, and 1999 & 2000 indicate that, for these periods,

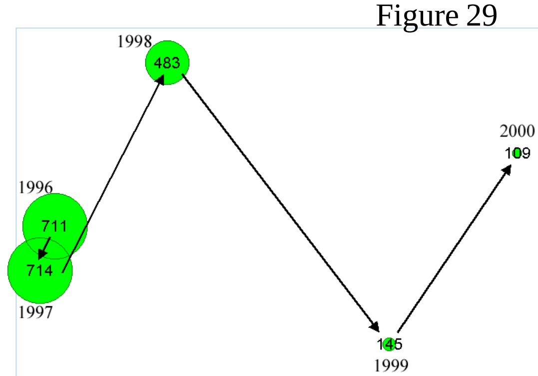
Western Sambo Shallow, MDS Ordination for Stony Corals

Figure 28



Western Sambo Shallow, MDS Ordination for Elkhorn coral

Figure 29



the stations were less similar i.e. more change occurred. The MDS bubble plot (Figure 29) and the video mosaic (Figure 30) illustrate the rapid decline of *Acropora palmata*. This was determined to be the primary cause of change at Western Sambo Shallow. From 1996 to 2000, multiple stressors acted on the Florida Keys reef tract including two hurricanes [(Georges, September 1998); (Irene, October 1999)] and major bleaching events (1997 and 1998). White and other disease increased Santuary-wide. Each of these stressors had some impact on Western Sambo Shallow. For example “white” disease infected *A. palmata* every year after 1996, and bleaching was documented in 1997 and 1998.

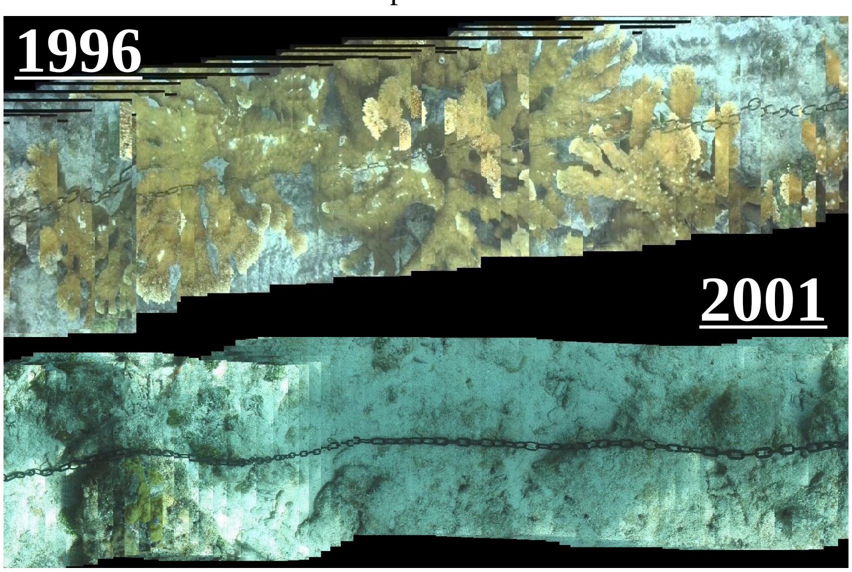


Figure 30

Western Sambo Shallow experienced a dramatic decline in a single species; however the strength of multi-variate analyses using Primer routines is the ability to distinguish between the contribution of different species when the observed change is more subtle. Primer routines can also be used to rank the significance of environmental parameters.

Discussion and Conclusions

The Coral Reef Monitoring Project (CRMP) constitutes the first successful, long-term monitoring project that has documented status and trends of coral reefs throughout the 2,800 square nautical mile FKNMS. This data set has been, and will continue to be an indispensable asset for sound resource management decisions. Between 1996 and 2000, the project reported a 37% reduction in stony coral cover Sanctuary-wide. Hypothesis testing revealed that 63.9% of project stations suffered a significant loss in stony coral cover while only 3.5% showed a significant increase. By region, the Upper Keys experienced the greatest decline with significant loss in coral cover at 72.5% of stations; followed by the Lower Keys with loss at 68.8% and the Middle Keys with a loss at 47.5% of stations. With regard to species richness, 63% of all stations lost one or more stony coral species between 1996 and 2001, 25% gained species and 12% were unchanged. These documented declines in coral cover and species richness were concurrent with an increase in disease infection. The number of stations where disease was documented increased from 26 in 1996 to 131 in 2000 and the number of species affected increased from 11 to 36.

These documented trends are alarming, however, they are reasonably consistent with trends documented by researchers elsewhere in the Caribbean basin. There is general consensus that multiple stressors acting at local, regional and global scales have negative impacts on coral reefs. It is clear that multiple stressors are contributing to coral decline in Florida.

Enhanced CRMP 2001

Following recommendations of the Advisory Panel to the Florida Keys Research and Monitoring Program (Dec. 5-6, 2000), the CRMP team conducted the following pilot studies to develop bioerosion information and census recruitment.

Dr. Mike Risk devised a rapid assessment technique to estimate presence and cover of bioeroding sponges. Large colonies of *Cliona delitrix*, an especially destructive boring sponge, capable of overgrowing and killing coral, were recorded at several of the monitoring stations. Abundance of clionids has been linked to water column concentrations of fecal bacteria. High concentrations of *C. delitrix* and closely-related *Cliona lampa*, were found at stations where coral decline was relatively high.

Stony coral recruitment data was collected because a correlation between coral recruitment rates and a capacity to recover from stress has been documented. Stony coral recruits <3cm were identified and enumerated at selected stations. The mean number of recruits was 4.46 recruits per m^2.

Future Direction

The Comprehensive Everglades Restoration Plan (CERP) aims to re-establish the historical flow of water through south Florida and Florida Bay. This project will inevitably alter biological communities and water quality in Florida Bay. Downstream of Florida Bay, the Florida Keys reef tract provides the last opportunity to quantify CERP induced changes. As water quality is impacted by changes in the volume of water delivered to Florida bay, reefs may decline in channel areas based on similar experiences in other locations (Tomascik and Sanders, 1985; Richmond, 1993; Furnas and Mitchell, 2001; Geister, 2001). Therefore, continued monitoring is crucial in order to document status and trends of coral reefs in FKNMS. In addition to the ongoing monitoring, the CRMP will expand its sampling strategy in order to better understand causes of coral decline and effects of multiple stressors under the new name, Coral Reef Evaluation and Monitoring Project (CREMP).

We propose to continue annual non-consumptive sampling at 40 established sites from Key Largo to Tortugas Banks to document status and trends in the coral reef ecosystem. Inventories of stony coral species richness and presence of disease and bleaching will be conducted. Underwater video will be analyzed to determine percent cover of stony coral and other benthic components (octocorallia, zoanthidea, macroalgae, etc.). Hypothesis testing and multivariate change analyses will be performed to quantify significant changes in these indicators.

In addition we will collect a more comprehensive suite of indicators at 11 of the established 40 sites. By following the fate of individual coral colonies, the CREMP will better understand coral community dynamics and mortality rates associated with individual stressors. For example, the density of bioeroding sponges of the genus *Cliona* is an indicator of organic enrichment in the water column. Human enteroviruses are used to distinguish the source of nutrient input (human vs other). Temperature is implicated in bleaching and disease pathogenicity. Sedimentation is associated with coastal development and is a limiting factor for larval recruitment.

The comprehensive monitoring data set on stony coral cover, species richness, bleaching, disease, bioeroders, temperature, fate tracking, human enteroviruses, recruitment and sedimentation will assist in development of landscape-seascape program models to characterize physical, chemical and biological stressors. Not only will these data assist managers in determining if the fully protected Tortugas Ecological Reserve, and other Sanctuary Protected Areas (SPA) are functioning to protect sensitive resources, it will also provide definitive feedback on the downstream effects of CERP.

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