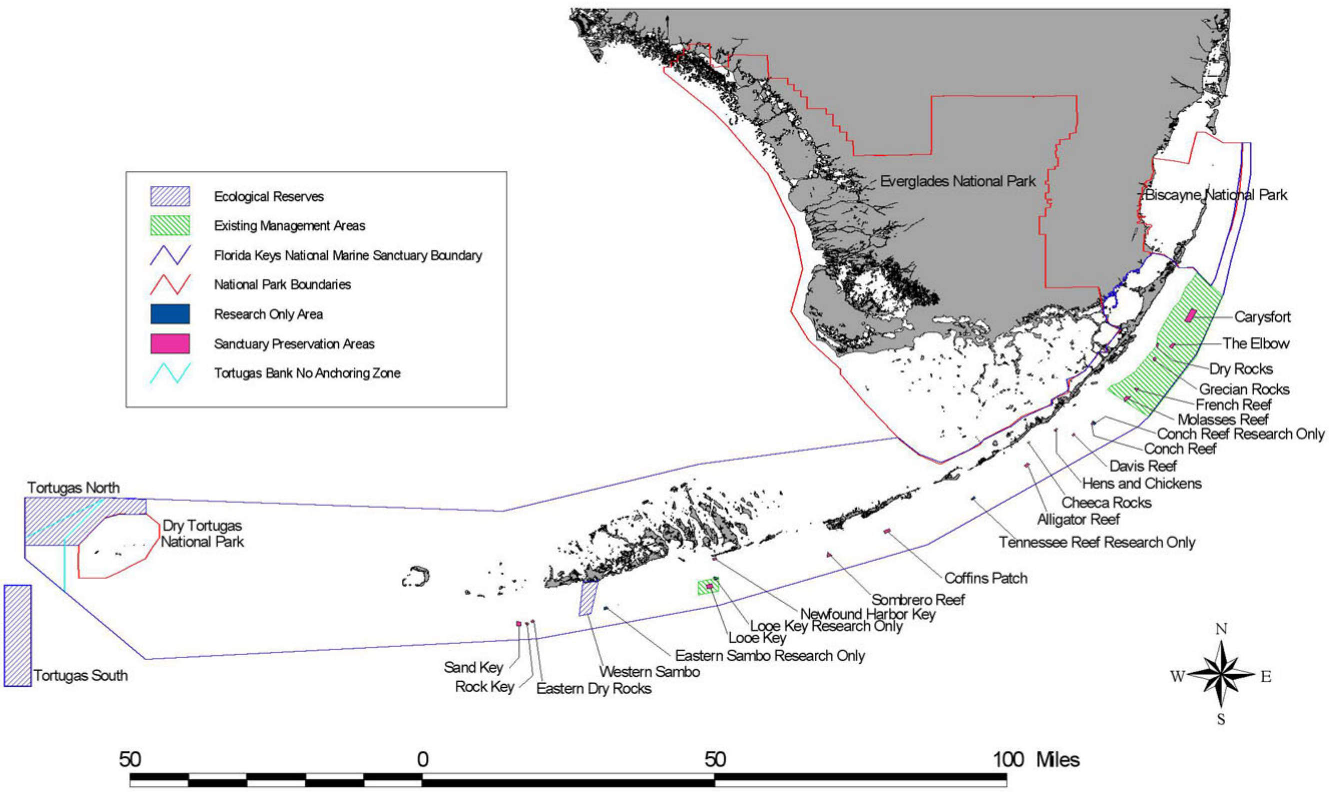
National Oceanic and Atmospheric Administration
Florida Keys National Marine Sanctuary

U.S. Environmental Protection Agency

State of Florida

Sanctuary Monitoring Report 2000



www.fknms.nos.noaa.gov/research_monitoring/welcome.html
April 5, 2002

EXECUTIVE SUMMARY

Long-term, status and trends monitoring of water quality parameters Sanctuary-wide indicates that dissolved oxygen, total organic nitrogen, and total organic carbon are higher in surface waters, while salinity, turbidity, nitrite, nitrate, ammonium, and total phosphorus are higher in bottom waters. Geographical differences include higher nutrient concentrations in the Middle and Lower Keys than in the Upper Keys and Dry Tortugas regions. Declining inshore to offshore trends along transects across Hawk Channel have been noted for nitrate, ammonium, silicate, total organic carbon and nitrogen, and turbidity.

Water quality stations located along passes between the Keys had higher nutrient concentrations, phytoplankton biomass, and turbidity than stations located off Keys landmasses, which may have long-term effects on community composition. Temporal trends in concentrations of total phosphorus, nitrate, and total organic nitrogen were also detected. There have been significant increases in total phosphorus for the Dry Tortugas, Marquesas Keys, Lower Keys, and portions of the Middle and Upper Keys, while no trend in total phosphorus has been observed in Florida Bay or areas of the Sanctuary influenced by Bay waters. Large increases in nitrate appeared to be seasonally driven. By contrast, total organic nitrogen decreased modestly at many sites, suggesting that trends may be driven by regional circulation patterns.

Seagrass monitoring is designed to identify distribution and abundance of seagrasses within the Sanctuary and track changes over time through random stations and fixed sites that are concurrent with water quality monitoring stations. Overall, at least one species of seagrass was present at over 80% of the stations monitored; approximately 12,800 km^2 of seagrass beds occur within the Sanctuary. Some variability in seagrass cover and abundance has been identified, such as seagrass loss at three of 30 fixed sites during hurricanes over the last three years. At the remaining 27 sites, benthic communities are relatively stable. There are no common trends across the sites in seagrass cover or community composition.

Decreases in coral cover and species diversity and an increase in coral diseases and coral bleaching were observed by the Coral Reef/Hardbottom Monitoring Project (CRMP). Between 1996 and 1999, over 66% of the 172 stations surveyed have exhibited losses in stony coral diversity. However, positive trends were noted in 1999-2000, when 65% of the original sampling stations increased or did not change in the number of stony coral species present. Significant gains and losses of several stony coral species have occurred both between years and over the entire sampling period, indicating interannual fluctuations in coral species richness at the scale of each station (44 m^2).

A general decline in stony coral cover has been observed Sanctuary-wide with the greatest relative changes occurring in the Upper Florida Keys. Percent coral cover was unchanged at the majority of stations in 1999-2000, again suggesting a possible reprieve from previous downward trends. Patch reef habitats have exhibiting the highest mean percent cover over time. In general, coral cover is highly variable by both habitat type and region in the Sanctuary.

Three years of monitoring of the Sanctuary’s fully protected zones indicates that some heavily exploited species exhibit differences in abundance and size between the zones and reference sites. Legal-sized spiny lobsters continue to be more abundant in Sanctuary Preservation Areas

(SPAs) than in reference sites. The average size of lobsters is larger and remains above the legal minimum size limit in the SPAs; lobsters found at reference sites remain below legal size. In the Western Sambo Ecological Reserve (WSER), the mean size of lobsters has been significantly larger than in fished reference areas in both the open and closed fishing seasons. Catch rates are higher within the WSER year-round.

Overall, a high degree of variability has been documented in reef fish abundance and size between the fully protected zones and reference sites. At this time, clear trends for all exploited reef fish species have not been demonstrated. However, some species have shown increased abundance over time due to "no-take" management. Mean densities for three of four exploited fish species are higher in the SPAs than in fished reference sites. Volunteer monitoring efforts have documented over 240 reef fish species in the Sanctuary, many for the first time.

As would be expected, changes in populations of queen conch and sea urchins (not directly exploited) and slower-growing, bottom-dwelling species such as hard and soft corals and sponges are not yet evident. No statistically significant differences in conch aggregation sizes, density, or abundance were noted between fully protected zones and reference sites. Two separate teams continue to document very low abundances of sea urchins, especially the long-spined urchin (*Diadema antillarum*).

As with the CRMP, other coral monitoring programs have documented a high degree of variability over space (habitat type and region) and time for several ecosystem parameters such as coral cover, species richness, recruitment, and density of benthic invertebrates. At this time no consistent differences in coral recruitment between the fully protected zones and reference sites have been observed. Juvenile coral mortality rates varied between habitats and years, which is likely due to the effect of several large storm events. No significant differences in the percent cover of hard corals and sponges were noted between fully protected areas and reference sites. Monitoring of macroalgal biomass indicates variability based on season, water depth, and region, with no major differences noted between zoned and reference sites. Preliminary field experiments on algal grazing rates suggest decreased herbivory within the zones, but a significant trend has not yet been established. Researchers monitoring these parameters caution that the high variability of benthic components over space and time necessitates looking at the effects of no-take regulations on a decadal time scale.

Socioeconomic monitoring indicates that zone usage is highly seasonal for both non-consumptive users (diving charters) and fishermen. Initial data suggest that compliance with "no-take" regulations is relatively high, as little illegal use of the zones has been observed. Additional socioeconomic data indicate that commercial fishermen displaced from the WSER have not suffered short-term financial losses. Estimates of use of artificial and natural reefs, market and nonmarket economic values, and user satisfaction ratings are also being compiled.

Continued status and trends monitoring of water quality, seagrasses, and coral communities are critical to establish a reference condition for these parameters within the Sanctuary such that the effectiveness of management actions can be evaluated over time. Ecological and socioeconomic monitoring of the fully protected zones is necessary to obtain a comprehensive picture of how the zones are performing in light of natural variability.

INTRODUCTION

Florida's coral reef tract comprises one of the largest communities of its type in the world. All but the northernmost extent of the Florida Reef Tract lies within the boundaries of the National Oceanic and Atmospheric Administration's (NOAA) Florida Keys National Marine Sanctuary (FKNMS). The 9800 km^2 Sanctuary was designated in 1990 to protect and conserve nationally significant biological and cultural marine resources of the area, including critical coral reef habitats, seagrass beds, hardbottom communities, and mangrove shorelines.

The ecologically important marine resources of the Florida Keys are under assault from a variety of stressors, both natural and human-caused. This is evidenced in a decrease in coral cover and species diversity and an increase in coral diseases and coral bleaching. Boat groundings, propeller scarring of seagrass, accumulation of debris, and improper anchoring practices have been responsible for thousands of acres of resource damage. Serial overfishing has dramatically altered fish and other animal populations, contributing to an imbalance in the relationships that are critical to sustaining a diversity of reef organisms. Eutrophication and inadequate wastewater and stormwater treatment have degraded nearshore waters. Altered freshwater management regimes have apparently resulted in an increase in plankton blooms, sponge and seagrass die-offs, and fish kills.

The Sanctuary addresses these threats using a variety of management programs and by applying regulations that address direct and indirect impacts to coral reef resources. In addition, a network of 24 fully protected zones, which cover approximately 6% of the Sanctuary but protect 65% of shallow bank reef habitats and 10% of coral resources overall, were implemented in 1997 and 2001 to preserve specific areas more completely. Recent, dramatic declines in reef resources highlight the importance of monitoring both status and trends of habitats Sanctuary-wide and changes within the fully protected zones. In addition, empirical cause-and-effect studies are critical to shed light on additional management tactics that will alleviate and improve overall reef health.

To monitor changes occurring in the marine environment of the Florida Keys, the Sanctuary has implemented a comprehensive monitoring program. The objectives of the monitoring program are to establish a reference condition for biological communities and water quality conditions within the Sanctuary. A research program directed at ascertaining cause-and-effect linkages complements monitoring. In this way, research and monitoring ensure the effective implementation of management strategies using the best available scientific information.

Monitoring is conducted by many groups, including local, state, and federal agencies, public and private universities, environmental organizations, and trained volunteers. The Sanctuary facilitates and coordinates partnerships with these groups, prioritizes activities, and disseminates relevant findings to the scientific community and to the public.

Monitoring within the Sanctuary occurs at two scales. The first scale and most comprehensive, long-term monitoring program underway in the Florida Keys is conducted through the Water Quality Protection Program (WQPP) funded by the U.S. Environmental Protection Agency (EPA), and recently, NOAA as well. The WQPP began in 1994 and consists of status and trends monitoring of three components: water quality, corals/hardbottom communities, and seagrasses.

Sanctuary-wide status and trends monitoring should detect large-scale ecosystem changes associated with Everglades restoration and other regional-scale phenomenon.

The second scale is associated with the Sanctuary's 24 fully protected zones, which are monitored through the Zone Monitoring Program (ZMP). The goal of this program is to determine whether the zones are effective in protecting marine biodiversity and enhancing human values related to the Sanctuary. Measures of effectiveness include the abundance and size of fish, invertebrates, and algae; and economic and aesthetic values of the Sanctuary to its users and their compliance with regulations. The ZMP includes monitoring changes in ecosystem structure (size and number of invertebrates, fish, corals, and other organisms) and function (such as coral recruitment, herbivory, predation). Human uses of zoned areas are also being tracked. In essence, the Zone Monitoring Program (ZMP) is "nested" within the Sanctuary-wide status and trends monitoring.

This report presents results from five years of status and trends monitoring under the Water Quality Protection Program and three years of data from the Zone Monitoring Program. Sanctuary-wide status and trends monitoring of water quality, seagrasses, and coral reef communities are presented first. A special program that tracks marine occurrences throughout the Sanctuary, the Marine Ecosystem Event Response and Assessment Project, is reviewed next. Individual abstracts that report results from the Zone Monitoring Program follow, grouped by topical area (coral reefs and benthic communities, fish populations, spiny lobster and queen conch, and human uses). The *Sanctuary Monitoring Report 2000* is also available in downloadable format (.pdf) from the FKNMS website at www.fknms.nos.noaa.gov/research_monitoring/welcome.html. We look forward to reporting future years' results on both monitoring programs and welcome your feedback.

Project Title: **Florida Keys National Marine Sanctuary Water Quality Monitoring Project**

Researchers**:** Ronald D. Jones and Joseph N. Boyer, Southeast Environmental Research Center, Florida International University, Miami, FL.

Goals: The Water Quality Monitoring Project for the Florida Keys National Marine Sanctuary (FKNMS) is part of the Water Quality Protection Program. The goal of this large-scale monitoring program is to assemble a holistic view of broad physical, chemical, and biological interactions occurring over the South Florida hydroscape. Water quality monitoring can be used as a tool for answering management questions and developing new scientific hypotheses, such as "Is water quality better or worse than it used to be?" This monitoring program based on quarterly sample intervals has revealed significant trends in total phosphorus (TP), nitrate (NO_3^-), and total organic nitrogen (TON) as described below, and we expect to see more trends in other variables as the database grows and we begin to tease out effects of seasonal variability.

Methods: This project began in March 1995 and includes data collected from 21 quarterly sampling events at 154 stations within the FKNMS, including the Dry Tortugas National Park. Since initiation we have added four sampling sites and adjusted six others to increase coverage in the Sanctuary Preservation Areas and Ecological Reserves. Field parameters measured at each station include salinity, temperature, dissolved oxygen (DO), turbidity, relative fluorescence, and light attenuation (K_d). Water chemistry variables measured at each station include the dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), dissolved inorganic nitrogen (DIN), and soluble reactive phosphate (SRP). Total unfiltered concentrations of organic nitrogen (TON), organic carbon (TOC), phosphorus (TP), and silicate ($Si(OH)_4$) are also measured. The monitored biological parameters included chlorophyll *a* (CHLA) and alkaline phosphatase activity (APA).

Findings to Date: Grouping stations by depth showed that temperature, DO, TOC, and TON were generally higher at the surface while salinity, NO_3^-, NO_2^-, NH_4^+, TP, and turbidity were higher in bottom waters. This slight stratification is indicative of a weak pycnocline, which is maintained by freshwater inputs and solar heating at the surface. Elevated nutrients in bottom waters are due to benthic flux and some upwelling. Stations grouped by geographical region showed that the Tortugas and the Upper Keys had lower nutrient concentrations than the Middle Keys or Lower Keys. In the Lower Keys, DIN was elevated in the Backcountry. TP concentrations in the Lower Keys transects decreased with distance offshore but increased along transects in the Upper Keys, mostly because of low concentrations alongshore. The Sluiceway had lowest salinity and highest TOC, TON, and $Si(OH)_4$ concentrations. The north Marquesas area exhibited highest phytoplankton biomass for any segment of the FKNMS. Declining inshore to offshore trends were observed for NO_3^-, NH_4^+, $Si(OH)_4$, TOC, TON, and turbidity for all oceanside transects. Stations grouped by shore type showed that those stations situated along channels/passes possessed higher nutrient concentrations, phytoplankton biomass, and turbidity than those stations off land. These differences were very small, but it is not known if they are biologically important. However, the fact that the benthic communities are different between these two habitats indicates that there may be some long-term effects.

An Objective Classification Analysis was performed in an effort to group stations in the FKNMS according to water quality. This involved a multivariate statistical approach using principal components analysis followed by k-mean clustering analysis. The result was the deconvolution of 150 stations into 7 clusters possessing distinct water quality from each other (Fig. 1). We believe this is a more functional zonation of the FKNMS as it is driven by similarities in water quality.

Probably the most interesting result of our data analysis was the elucidation of temporal trends in TP, NO_3^-, and TON for much of the FKNMS. Trend analysis showed statistically significant increases in TP for the Tortugas, Marquesas, Lower Keys, and portions of the Middle and Upper Keys (Fig. 2). These trends were remarkably linear and show little seasonality. The increases in TP were system wide and occurred outside the FKNMS on the Southwest Florida Shelf as well. Rates of increase ranged from 0.01-0.07 µM yr^{-1} which was significant considering initial concentrations to be ~0.1-0.2 µM. No trends in TP were observed in Florida Bay or in those FKNMS sites most influenced by transport of Florida Bay waters. The effect of increased TP on phytoplankton biomass has not been shown to be significant; i.e. no concurrent increases in CHLA were observed.

Trends in NO_3^- seemed to be more seasonally driven. Rates of increase ranged from 0.04-0.18 µM yr^{-1}. These are large increases in NO_3^- concentrations; in many cases NO_3^- went from <0.05 to >1 µM. Most of the increases occurred in the Shelf, Tortugas, Marquesas, Lower Keys, and Upper Keys (Fig. 3). Contrary to increases in TP and NO_3^-, TON declined at many sites over the period of record (Fig. 4). Decreases ranged from -0.7 to –2.7 µM yr^{-1} and were more modest compared to ambient TON concentrations. Most of the decreases occurred in the Shelf, Sluiceway, Lower Keys, and Upper Keys. It is possible that loss of TON was due to biological conversion to NO_3^-, but there was no significant correspondence between TON declines and NO_3^- increases. At this time we can only speculate as to the cause of these trends but believe them to be driven by regional circulation patterns arising from the Loop and Florida Currents.

Much information has been gained by inference from this type of data collection program: major nutrient sources have be confirmed, relative differences in geographical determinants of water quality have been demonstrated, and large-scale transport via circulation pathways have been elucidated. The website http://serc.fiu.edu/wqmnetwork/ integrates data from the FKNMS with other parts of the SERC water quality network (Florida Bay, Whitewater Bay, Biscayne Bay, Ten Thousand Islands, and SW Florida Shelf) and displays downloadable contour maps from these areas.

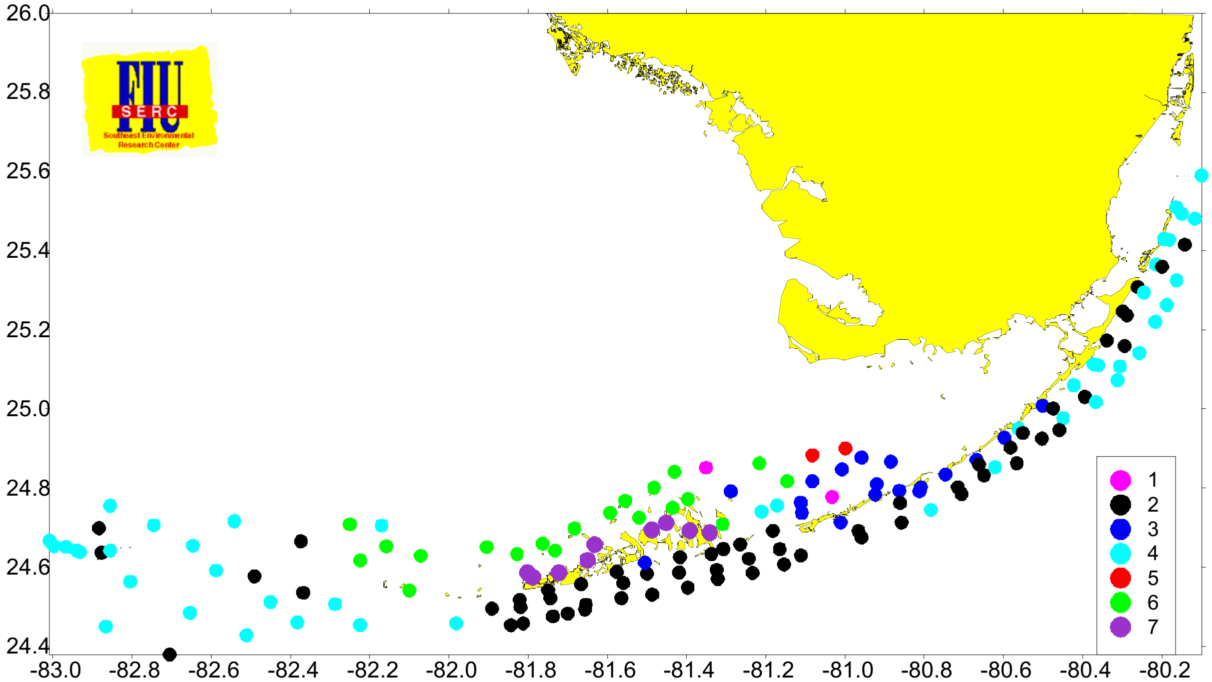


Figure 1. Map of Water Quality stations in the Florida Keys National Marine Sanctuary that are clustered according to statistical similarities in water quality parameters.

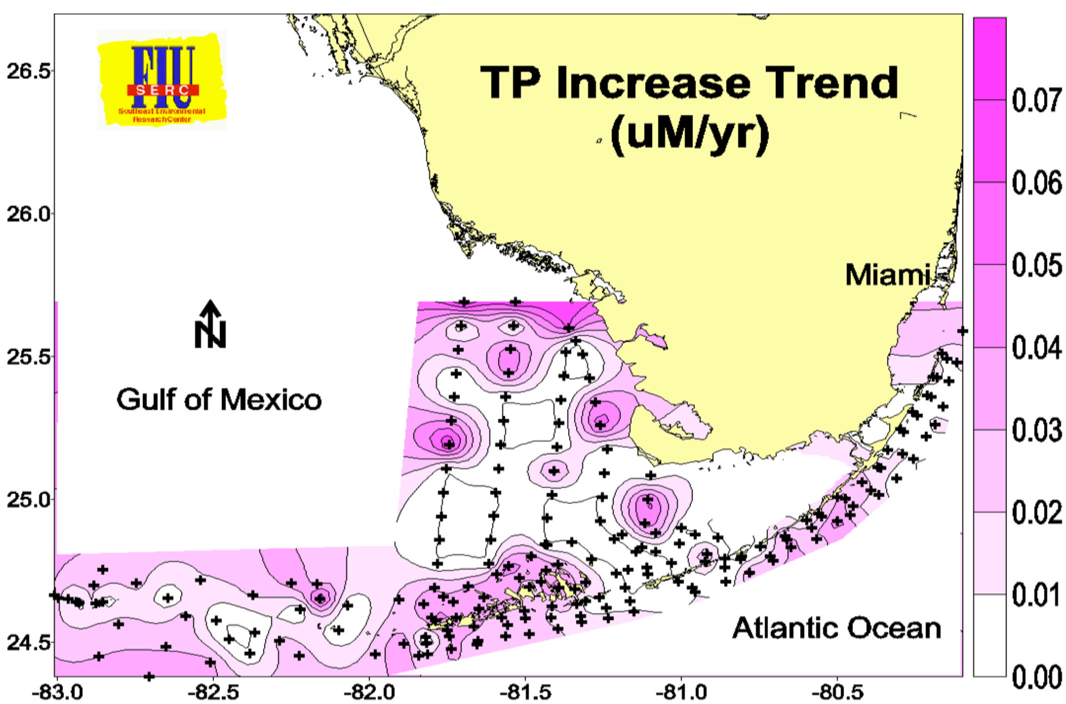


Figure 2. Total Phosphorus trends in the Florida Keys National Marine Sanctuary, 1995-2000. Note significant increases in the Dry Tortugas, Marquesas Keys, Lower Keys, and portions of the Middle and Upper Keys.

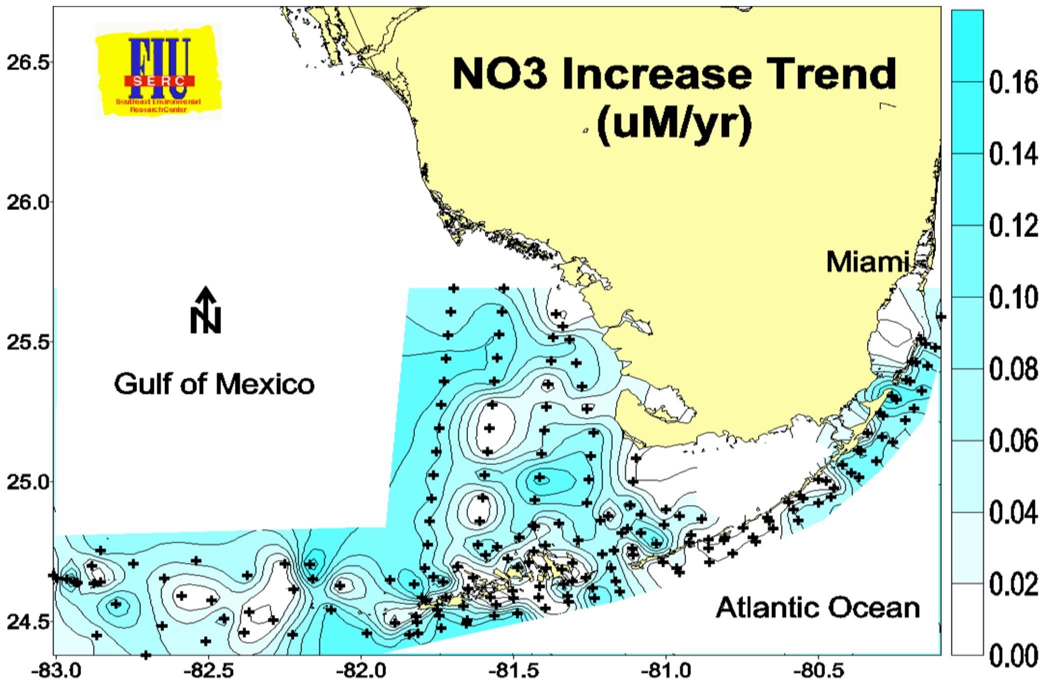


Figure 3. Nitrate trends in the Florida Keys National Marine Sanctuary, 1995-2000. Increases occurred in the Southwest Florida Shelf, Dry Tortugas, Marquesas Keys, and Lower and Upper Keys.

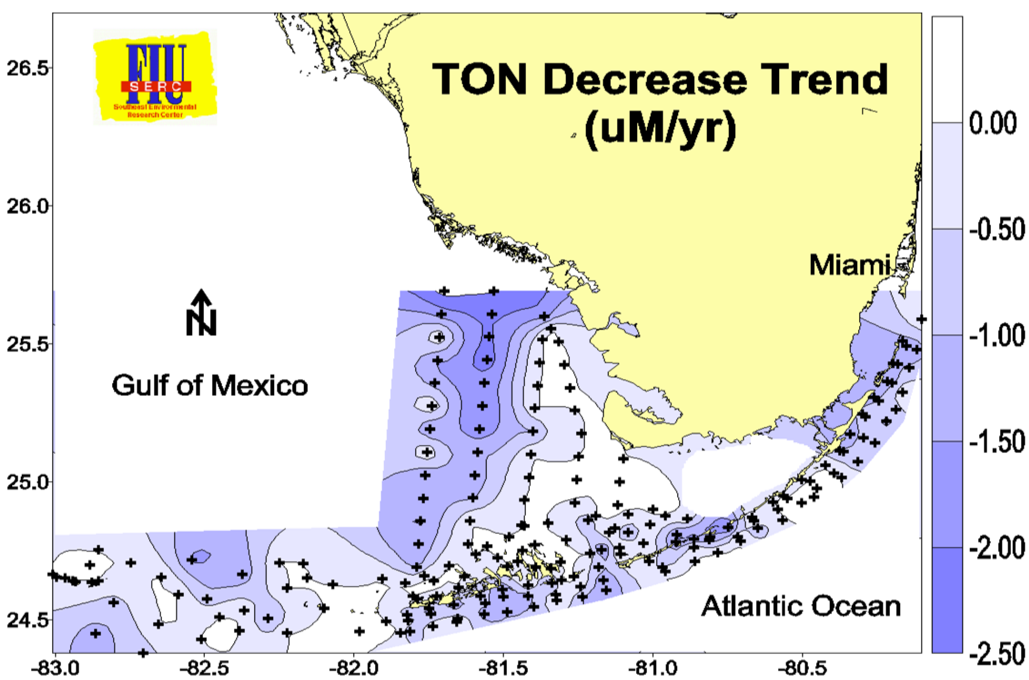


Figure 4. Total Organic Nitrogen trends in the Florida Keys National Marine Sanctuary, 1995-2000. A moderate decrease in TON occurred in some areas, in contrast to increases in TP and NO_3.

Project Title: **Seagrass Monitoring in the Florida Keys National Marine Sanctuary**

Researchers: James W. Fourqurean, Southeast Environmental Research Center and Department of Biology, Florida International University, Miami, FL; Michael J. Durako, Center for Marine Science and Department of Biology, University of North Carolina at Wilmington, Wilmington, NC; and Joseph C. Zieman, Department of Environmental Science, University of Virginia, Charlottesville, VA. ***Project Managers:*** Susie P. Escorcia and Leanne M. Rutten, Southeast Environmental Research Center and Department of Biology, Florida International University, Miami, FL.

Goals: The objective of seagrass monitoring in the Florida Keys National Marine Sanctuary (FKNMS) under the Water Quality Protection Program is to measure the status and trends of seagrass communities to evaluate progress toward protecting and restoring the living marine resources of the Sanctuary. Specific objectives are to: 1) provide data needed to make unbiased, statistically rigorous statements about the status and temporal trends of seagrass communities in the Sanctuary as a whole and within defined strata; 2) help define reference conditions in order to develop resource-based water quality standards; and 3) provide a framework for testing hypothesized pollutant fate/effect relationships through process-oriented research and monitoring. In order to meet these objectives, the following goals have been developed for the project:

- Define the present distribution of seagrasses within the FKNMS;
- Provide high-quality, quantitative data on the status of the seagrasses within the FKNMS;
- Quantify the importance of seagrass primary production in the FKNMS;
- Define the baseline conditions for the seagrass communities;
- Determine relationships between water quality and seagrass status;
- Detect trends in the distribution and status of the seagrass communities.

Methods: To reach these goals, four kinds of data are being collected in seagrass beds in the FKNMS:

1. Distribution and abundance of seagrasses using rapid assessment Braun-Blanquet surveys;
2. Demographics of the seagrass communities using leaf-scar counting and population demographics techniques;
3. Seagrass productivity of the dominant species of seagrass in the FKNMS (*Thalassia testudinum*) using the leaf-mark and harvest method;
4. Seagrass nutrient availability using tissue concentration assays.

These data are being collected at three different types of sites within the FKNMS. Level 1 Stations are sampled quarterly for seagrass abundance, demographics, productivity and nutrient availability. These stations are all co-located with the Water Quality Monitoring Project's stations. Level 2 Stations are randomly selected and sampled annually for seagrass abundance, demographics and nutrient availability. Each year, new locations for Level 2 stations are chosen. Level 3 Stations are also randomly selected and are sampled annually for seagrass abundance. Each year, new locations for Level 3 stations are chosen. Both inter-annual and intra-annual trends in seagrass communities are assessed. The mix of site types is intended to monitor trends through quarterly sampling at a few permanent locations (Level 1 sites) and to annually characterize the broader seagrass population through less intensive, one-time sampling at more locations (Level 2 and 3 sites).

From 1995-1997, we collected data from 28 permanent, Level 1 stations. Two additional Level 1 stations were established in the Western Sambo Ecological Reserves and Carysfort SPA, bringing the total number of permanent monitoring stations to 30. From 1996 to 2000, summer sampling of Level 2 and 3 sites was conducted during May-August, with the number of sites visited each year ranging from 206 to 336.

In addition, we provided spatially intensive data on benthic habitat distributions within the Western Sambo Ecological Reserve and Carysfort SPA in conjunction with the Sanctuary's Zone Monitoring Program. For each of these two zones, we sampled 40 sites within the zone and 40 sites in contiguous control areas outside of the area. Station locations for this sampling are shown in Figures 1 and 2.

Findings to Date: Our surveys have provided clear documentation of the distribution and importance of seagrasses in the FKNMS. The seagrass bed that carpets 80% of the FKNMS is part of the largest documented contiguous seagrass bed on Earth. These extensive meadows are vital for the ecological health of the FKNMS and the marine ecosystems of all of south Florida.

Synoptic surveys completed to date clearly describe the spatial extent of the seagrass beds, but do not elucidate trends at this point because sites were chosen randomly each year. A second round of sampling, to be conducted in 2003, would elucidate changes in seagrass communities that are expected to occur over this longer time scale. Second-round data will allow for the direct comparison of the status of seagrass communities at over 1000 sampling points. Also, we have begun to address the very near-shore (within 500 m of the shoreline) regions where anthropogenic effects are likely to be concentrated as part of the Florida Keys Carrying Capacity Study. In the future, monitoring efforts should put more emphasis on this region.

Our permanent monitoring sites have provided valuable data on the inter- and intra-annual variability of seagrass cover and abundance. Time series of species composition, seagrass productivity, nutrient availability and physical parameters have been developed for each permanent monitoring site. There have been some striking trends in seagrass communities at these permanent sites: seagrasses were lost completely at three of 30 sites during hurricanes over the last three years. At the remaining 27 sites, benthic communities are relatively stable. There are no common trends across the sites in seagrass cover or community composition. This can be interpreted to mean that there are no regional trends in the health of seagrass beds represented by the permanent monitoring sites that can be detected with the six years of monitoring data. But, manipulative experiments in seagrass beds in south Florida demonstrate that the time of response of seagrass beds to eutrophication is on the order of decades, and we do not understand completely the interaction humans have with the natural dynamics of these systems. Therefore, these 30 sites should continue to be monitored on a quarterly basis. Time series data and spatial maps from the monitoring effort for the period 1996-2001 are available on the internet (http://www.fiu.edu/~seagrass) and on CD-ROM.

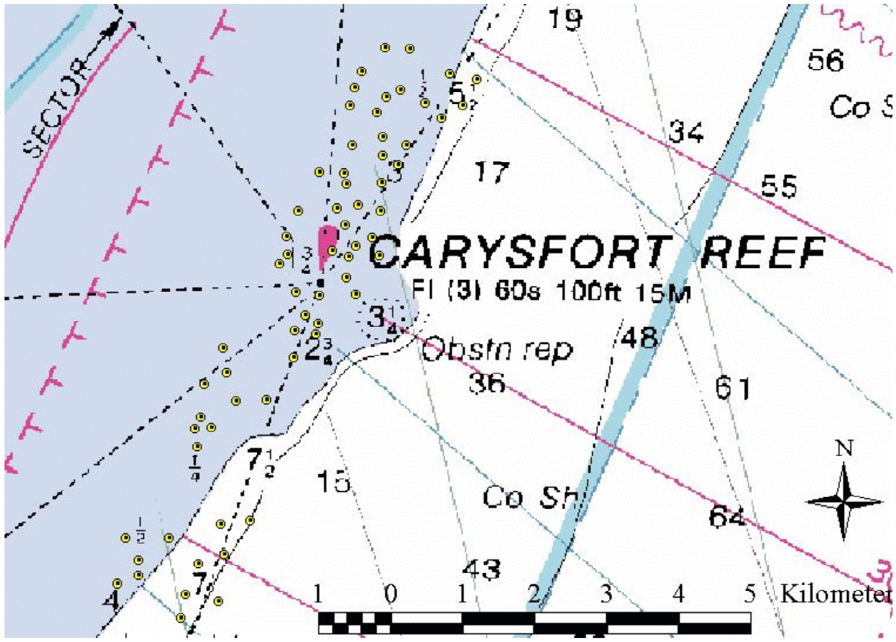


Figure 1. Intensive benthic survey sites at Carysfort SPA.

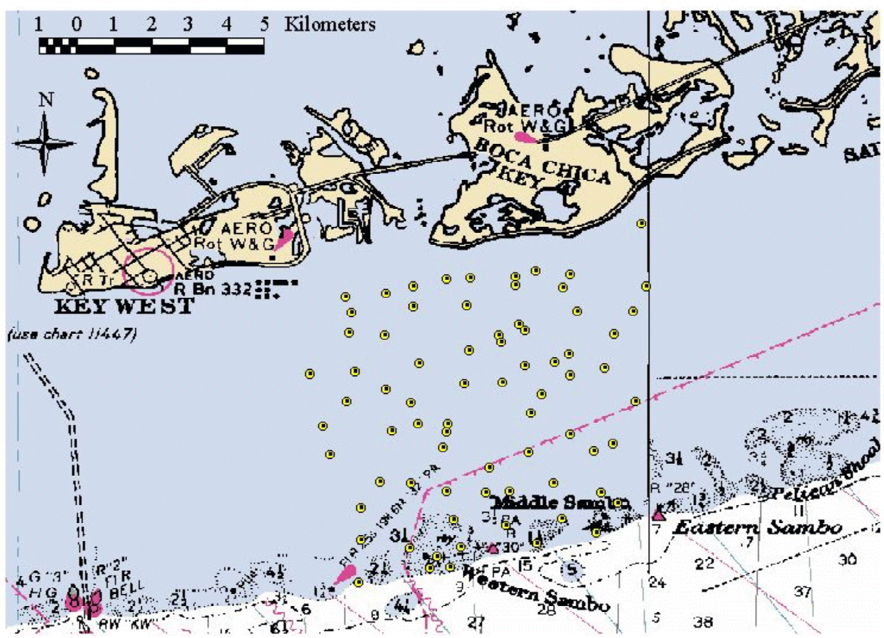


Figure 2. Intensive benthic survey sites at the Western Sambo Ecological Reserve.

***Project Title:* U.S. EPA / FKNMS Coral Reef Monitoring Project**

Researchers: Walter C. Jaap, Jennifer Wheaton, Keith Hackett, Matthew Lybolt, and M.K. Callahan, Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute (FWC/FMRI), St. Petersburg, FL; James W. Porter, University of Georgia, Athens, GA; and Chris Tsokos and George Yanev, University of South Florida, St. Petersburg, FL.

Goals: The Coral Reef Monitoring Project (CRMP) is part of the Water Quality Protection Program for the Florida Keys National Marine Sanctuary (FKNMS). The goal of this project is to utilize broad spatial coverage, repeated sampling, and statistically valid findings to document status and trends of coral communities within the Sanctuary. As coral reef monitoring is integrated with the seagrass and water quality programs, the results can be used to focus research on determining causality and to fine tune and evaluate management decisions.

Methods: Sampling site locations were chosen using stratified random (U.S. EPA EMAP) procedures. Forty reef sites located within five of the nine U.S. EPA Water Quality Segments were selected in the Florida Keys National Marine Sanctuary during 1994, and permanent station markers were installed in 1995. Sampling was initiated in 1996 and 160 stations among 40 sites were sampled through 2000. Three additional sites were installed and sampled in the Dry Tortugas beginning in 1999. The project's 43 sampling sites include 7 hardbottom areas, 11 patch reefs, 12 offshore shallow reefs, and 13 offshore deep reef sites.

Field sampling consists of station species inventories and video transects conducted at four stations within each site. Station Species Inventory (SSI) consists of counts of stony coral species (Milleporina and Scleractinia) present in each station to provide data on stony coral species richness. Two observers conduct simultaneous timed inventories within the 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. Species within a station exhibiting signs of either coral bleaching or disease are recorded as well. After recording the data, observers compare data underwater and confirm species recorded by only one observer. Taxonomic differences are addressed. Data sheets are verified aboard the vessel and forwarded to FWC/FMRI for data entry and processing.

Videography sampling occurs at a set distance above the benthos and at a constant swim speed, yielding approximately 9,000 video frames per transect. Images for all transects are frame-grabbed, written to, and archived on CD-ROM. Percent cover analysis is performed using 120 frames of digitized imagery using a custom software application, PointCount for coral reefs. Selected benthic taxa (stony coral, octocoral, zoanthid, sponge, seagrass and macroalgae) and substrate are identified. After all images are analyzed, the data is converted to an ASCII file for Quality Assurance and entry into the master ACCESS data set.

Findings to Date: The results reported here are based on hypothesis testing and statistical analysis to determine significance, and are defined by the following regions: 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). This data is also available on the internet at http://www.floridamarine.org.

Stony Coral Species Richness data indicated that between 1996 and 2000, in the Upper Keys, there was a loss of stony coral species at 32 of 52 stations (61.5%), 11 stations gained species, and at nine stations, presence of stony coral species was unchanged. In the Middle Keys, 32 of 44 stations (72.7%) lost stony coral species, six stations gained species, and six stations were unchanged. In the Lower Keys, 43 of 64 stations (67.2%) lost stony coral species, 15 stations gained species, and 6 stations were unchanged. However, positive trends were noted in the 1999-2000 survey period, when in the Upper Keys, 20 stations (38.5%) had an increase in stony coral species present, 16 stations (30.8%) showed a decrease and 16 stations were unchanged. Likewise during this period 19 stations (43.2%) lost stony coral species, 17 stations (38.6%) gained species, and 8 stations (18.2%) were unchanged in the Middle Keys. In the Lower Keys, 32 stations (50.0%) showed an increase in the number of species present, 21 stations (32.8%) had a decrease, and 11 stations (17.2%) were unchanged. In the Dry Tortugas, 8 stations (66.7%) showed a decrease in the number of stony coral species identified, 3 stations showed gains and one station was unchanged.

By habitat type, offshore deep reef and patch reef stations had the greatest numbers of stony coral taxa. The least number of stony coral species were observed at hardbottom stations. From 1996 to 2000, 16 of 28 (57.1%) hardbottom stations had stony coral species losses, five hardbottom stations gained species, and seven stations were unchanged. Twenty-nine (72.5%) of 40 patch reef stations had stony coral species losses, six stations gained species, and five stations were unchanged. For shallow reef stations, 28 of 48 (58.3%) showed stony coral species losses, 14 stations gained species, and six were unchanged. Thirty-four of 44 (77.3%) deep reef stations had stony coral species losses, seven stations gained species, and three stations were unchanged.

Significant gains and losses of several stony coral species have occurred both between years and over the entire sampling period, indicating interannual fluctuations in coral species richness at the scale of each station (44 m^2). Although the overall trend for all five years was a decline in species richness, from 1999 to 2000 about half as many stations lost species and more than twice as many stations gained species.

In general, scleractinian corals in CRMP stations Sanctuary-wide experienced a significant increase in disease infections from 1996 to 2000. All disease conditions exhibited increasing frequency of coral infection from 1996-1997 and 1997-1998. There was a significant decrease in Black Band Disease from 1998-1999, and from 1999-2000 there was no significant change in disease infections. Over the five years of the project, there was a significant increase in White Complex disease and other diseases significantly increased. Overall, there were increases in the number of stations containing diseased coral, the number of species with disease, and the different types of diseases that were observed.

A general trend of decline in stony coral cover Sanctuary-wide is presented in Figure 1. Mean percent stony coral cover declined every year from 1996 to 1999 Sanctuary-wide. A slight increase in mean percent stony coral cover was documented from 1999 to 2000, again suggesting a possible reprieve from previous years' downward trends. The decline in mean percent coral cover from 1997-1998 and from 1998-1999 was significant with a p-value of 0.03 or less for the

Wilcoxon rank-sum test. The change observed from 1996-1997 and from 1999-2000 was determined to be nonsignificant.

Regionally, there was a greater relative change in mean stony coral cover in the Upper Keys. Additionally, a greater percent of Upper Keys stations showed significant loss of coral cover compared with Middle and Lower Keys stations. In the Dry Tortugas from 1999-2000, 8 stations (66.7%) had no significant change in stony coral cover and 4 stations (33.3%) had a significant loss. As would be expected, gains and losses of coral cover have fluctuated among habitat types, with patch reef habitats suffering the least loss and exhibiting the highest mean percent cover over time (Fig. 2).

Further analysis of change in percent cover of the most common coral species indicates some striking trends, including declines in cover for elkhorn coral (*Acropora palmata)*, staghorn coral (*A. cervicornis*), and blade fire coral (*Millepora complanata*). At shallow stations, the mean percent cover of *A. palmata* dropped from 3.01% (1996) to 0.35% (2000). Sanctuary-wide, percent cover of *A. cervicornis* dropped from 0.20% (1996) to a barely detectable 0.006% (2000). *M. complanata* declined from a mean percent cover of 2.65% (1996) to 0.12% (2000) for all shallow stations. Conversely, massive starlet coral (*Siderastrea siderea*) and mustard hill coral (*Porites astreoides*) showed slight increases in mean as well as relative coral cover.

Percent cover data for all functional groups, including stony corals, octocorals, zoanthids, sponges, macroalgae, seagrass, and substrate (rock, rubble and sediments), were analyzed for the period 1996-2000. In all three geographic regions, stony coral, sponge and octocoral cover decreased (Fig. 3) whereas macroalgae and substrate cover increased (Figs. 3 and 4). Macroalgae percent cover exhibits higher variability than all other functional groups, and zoanthid and seagrass percent cover values were too low to represent graphically. Functional group percent cover data was further analyzed by habitat type, and trends generally mimic those observed regionally.

Future Plans: In 2001, the CRMP incorporated censuses of stony coral recruits by species and censuses of bioeroding sponges to further elucidate coral population dynamics questions. The total number of stations sampled was also reduced while maintaining the same broad geographical coverage and statistical rigor.

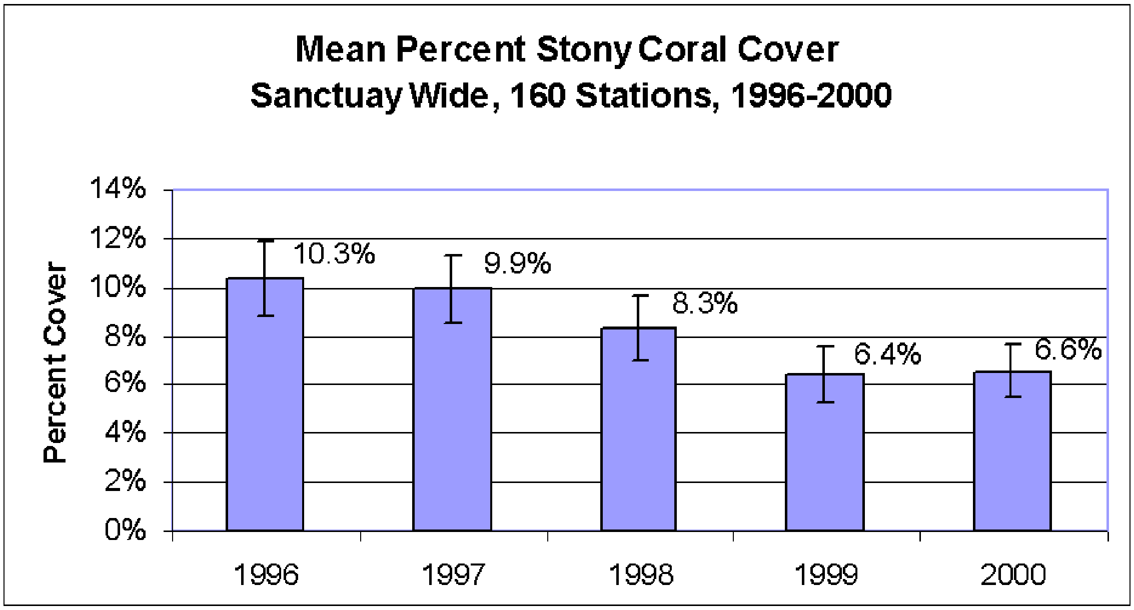


Figure 1. Mean percent stony coral cover at 160 stations from 1996-2000.

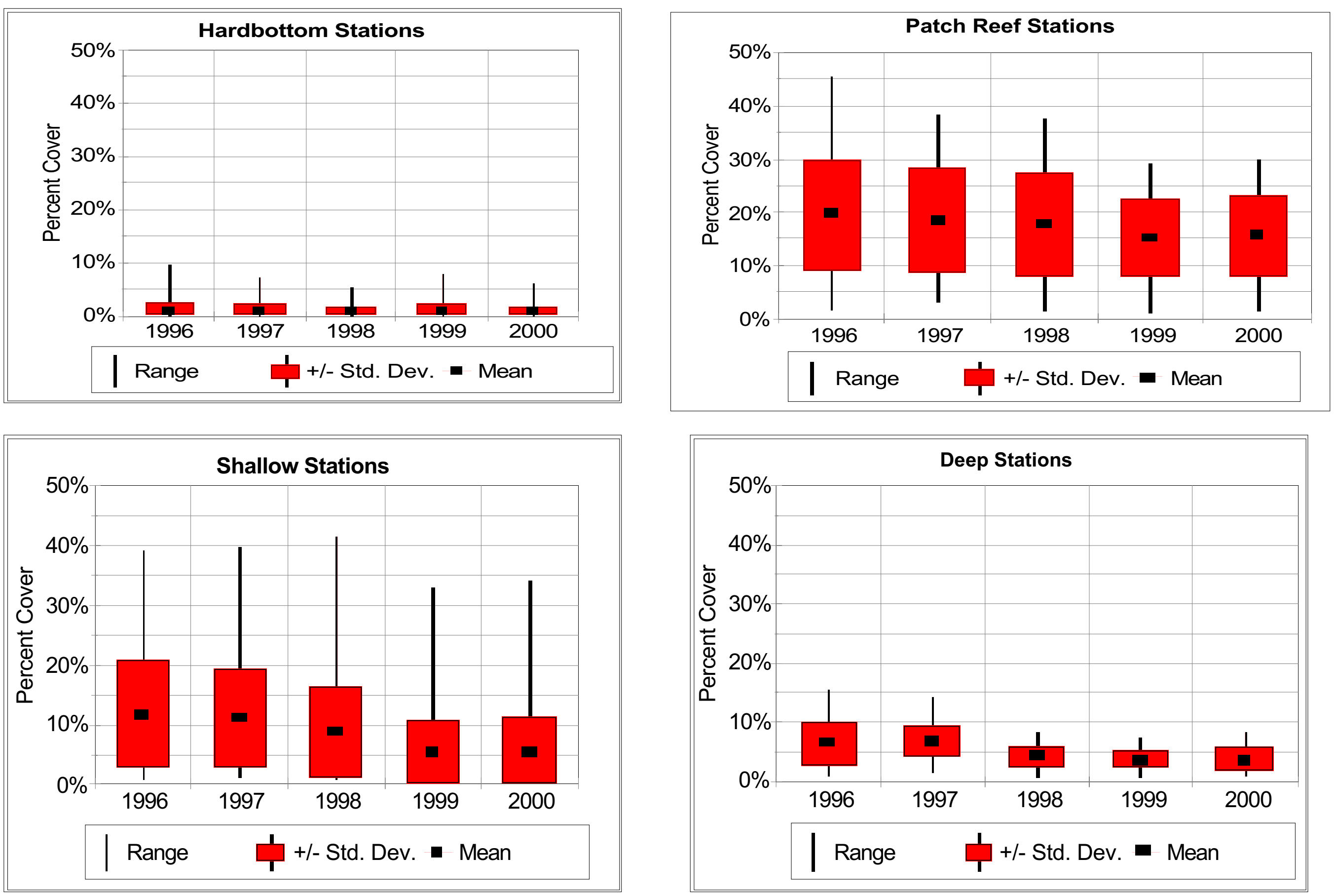


Figure 2. Mean percent stony coral cover by habitat type at 160 stations, 1996-2000.

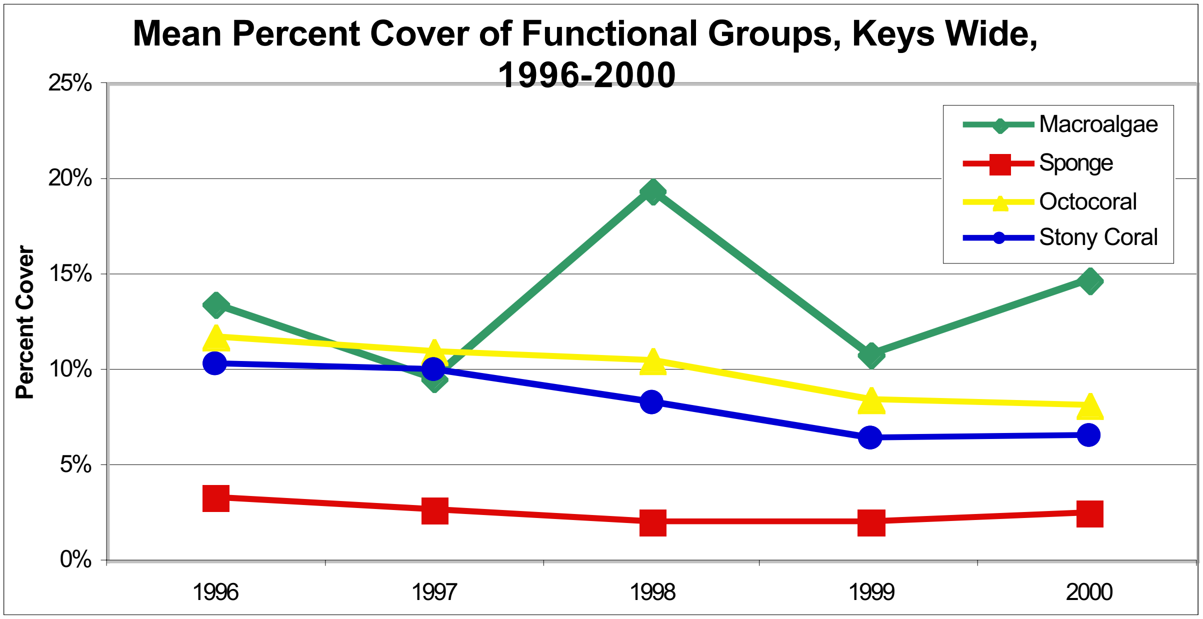


Figure 3. Mean percent cover of functional groups Sanctuary-wide, 1996-2000.

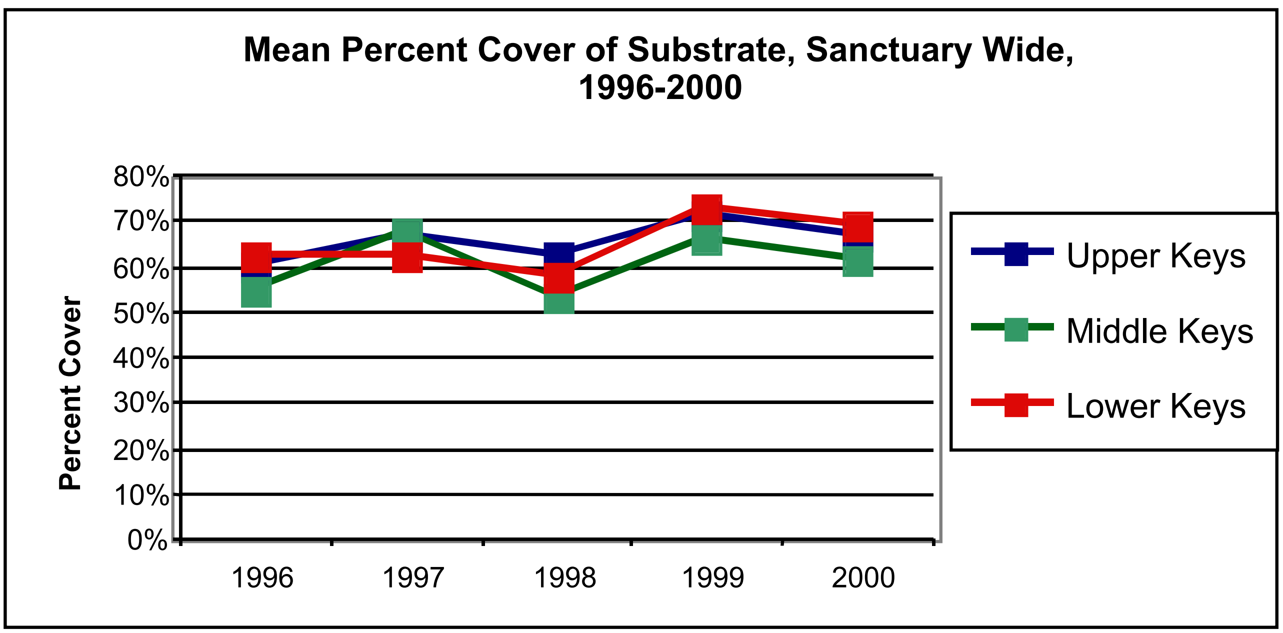


Figure 4. Mean percent cover of substrate Sanctuary-wide, 1996-2000.

***Project Title*: Marine Ecosystem Event Response and Assessment (MEERA) Project**

Researchers: Erich Mueller and Erich Bartels, Mote Marine Laboratory Center for Tropical Research, Summerland Key, FL.

Goals: Initiated in late summer, 1997 as the Rapid Biotic Assessment (RBAT) Project, this project was originally designed to provide an early warning and assessment program for biotic events on reefs of the Florida Keys National Marine Sanctuary (FKNMS). In December, 1999, the project was renamed the Marine Ecosystem Event Response and Assessment (MEERA) Project to more accurately portray the overall scope and objectives of the project, which include any event that impacts the marine environment.

Methods: Use of a Marine Observer Network continues to be the most important component of the MEERA project, whereby anyone can call, e-mail, or fax observations to the Project Coordinator for evaluation. Efforts have expanded to reach as large and diverse an audience as possible, including the following:

Fishing Guides	FWC/Florida Marine Research Institute	The Nature Conservancy
Charter Captains	Florida Keys National Marine Sanctuary	SeaCamp
Dive Operators	Florida Marine Patrol	U.S. Coast Guard Auxiliary
Commercial Fishermen	National Marine Fisheries Service	Key West Power Squadron
Tropical Fish Collectors	U.S. Fish and Wildlife Service	Key West Charter Boat Association

Findings to Date: A total of 64 reports were received in 2000 from sources including fishermen, residents, and a variety of State and Federal personnel (Table 1). Due to multiple observations included in some reports, 81 observations were logged that included mainly reports of coral disease and bleaching, “red-tide”, diseased fish, and marine mammal strandings (Table 2). Other reports included pollution, vessel groundings, macroalgal blooms, injured sea turtles, and invasive species of jellyfish.

Response efforts ranged from the collection, analysis, and shipping of samples to photo-documentation to providing assistance or logistical support for other researchers and organizations. Efforts utilized a combination of volunteers, cooperative agency work, and Mote Marine Laboratory staff and equipment. These efforts included the following:

- Collecting and analyzing water samples to investigate “red-tide” reports, including a significant bloom event in early 2000;
- Acquiring and shipping diseased fish samples to FWC/FMRI for analysis;
- Documenting coral disease and coral bleaching reports and providing logistical support and collaborative efforts on a variety of related research projects (Table 3);
- Assisting with rescue efforts and assessment of stranded and injured dolphins; and
- Forwarding reports of vessel groundings and pollution to State and Federal response agencies.

Future Plans: In the first month of 2001, more than 25 reports have already been logged, clearly indicating increasing participation of Marine Observers and the potential need for response efforts in the future. Several goals have been identified as necessary to increase the MEERA Project’s effectiveness:

- Continue to expand the Marine Observer Network and promote increased participation;

- Improve communication with State and Federal agencies, environmental organizations, and other researchers to maximize MEERA's involvement and assistance with response efforts;
- Further develop the existing MEERA website (www.mote.org/~emueller/MEERA.html) to allow researchers, resource managers, and the public access to recent reports, submit reports online, view past events, and link to related sites; and
- Increase public awareness by providing weekly news articles on recent events, and produce a quarterly newsletter to summarize the projects accomplishments and continued goals.

Table 1. Reports by source

Source	# of Reports
Guides/Captains	8
Fish Collectors	4
FMRI	6
Sanctuary	12
Other agencies	8
Mote	8
Residents	15
TNC Volunteers	3
Total	64

Table 2. Observations by type

Event Type	# of Reports
Coral Bleaching	8
Coral Mortality	5
Coral Disease	18
Fish Disease	12
Fish Kill	7
Mammal Strandings	9
Red Tide	13
Other	9
Total	81

Table 3. Related Research Efforts Focused on Coral Disease and Bleaching

Project	**Objectives**
Coral Disease Workshop	Provide training for coral disease monitoring and collection methods
CIS-NET Project	Study effects of increasing UV radiation on coral bleaching
US EPA Coral Disease Surveys	Monitor coral disease and bleaching in the Florida Keys and Bahamas
Sustainable Seas Expedition	Utilize submersible and ROV technology to monitor deep reefs
Cornell University Sea Fan Studies	Monitor abundance and distribution of diseased sea fans
EPA Special Studies	Study possible effects of reef fish feeding on coral disease distribution

Project Title: **Dynamics of Coral Reef Benthic Communities**

Researchers: John C. Ogden (Project Director); Florida Institute of Oceanography, St. Petersburg, FL; Richard B. Aronson, Dauphin Island Sea Lab, Dauphin Island, AL; Margaret W. Miller, NOAA/National Marine Fisheries Service, Miami, FL; S. Robertson Smith, Bermuda Biological Station for Research, St. George's GE01, Bermuda; and Thaddeus Murdoch, Dauphin Island Sea Lab, Dauphin Island, AL.

Goal: The primary purpose of this continuing study of ecological processes and ecosystem function is to evaluate the relationships among coral cover, coral recruitment and juvenile mortality, and algal dynamics at three fully protected ("no-take") zones and three reference sites in the Florida Keys National Marine Sanctuary (FKNMS). The fully protected zones are South Carysfort (Carysfort Sanctuary Preservation Area) in the Upper Keys, and Eastern Sambo Research-only Area and Western Sambo Ecological Reserve in the Lower Keys. The reference sites are Maitland, located near the *M/V Maitland* ship-grounding site in the Upper Keys, and Middle Sambo Reef and Pelican Shoal in the Lower Keys.

Methods: The reefs were studied in two depth ranges, shallow (7.5-10.5 m) and deep (13.5-17.4 m), using methods described in previous reports. The results reported here are for 1998-2000, the first three years of the study.

Findings to Date: Coral cover, measured by videography in May of each year was consistent within sites over the study period. In the shallow habitat, Western Sambo had considerably higher coral cover than the other sites during all three years. In the deep habitat, the two sites in the Upper Keys had consistently lower coral cover than the sites in the Lower Keys.

Coral recruitment was measured during the summer for the years 1998-1999 and 1999-2000 by censusing permanent quadrats along transects at each site. Recruitment rates (Fig. 1A) were significantly higher at the reference sites in both years, particularly in the deep habitat. Juvenile mortality (Fig. 1B) was higher in the shallow habitat at all sites during the first year as compared to the second year. This was primarily an effect of Hurricane Georges in 1998, which struck the Lower Keys directly and caused higher juvenile mortality than at the sites in the Upper Keys. Generally low rates of coral recruitment at Upper Keys sites were consistent with generally low coral cover at those sites.

Macroalgal biomass, evaluated by hand-collecting algae from randomly placed quadrats, showed clear interannual variation (Fig. 2). The spring and summer of 1998 were characterized by high algal abundance, a pattern that was also apparent in the video transects as high macroalgal cover and that other investigators reported from a number of reefs along the Florida Reef Tract. Pelican Shoal was characterized by consistently high macroalgal biomass, which could be a result of the input of nutrient-laden guano from bird colonies on the shoal. In contrast, Middle Sambo Reef had consistently low levels of macroalgal biomass, but the difference in algal biomass between Middle Sambo and Pelican Shoal did not translate to consistent differences in coral cover or coral recruitment. Herbivory assays, in which algae were affixed to lengths of rope and exposed to herbivores at the sites, suggested a possible trend toward decreased herbivory at the fully protected zones relative to the reference sites. The consistency and mechanism behind this trend require further investigation.

In summary, thus far there has been no evidence of increases in coral cover or recruitment at the fully protected zones compared to the reference areas. This is not surprising at this early stage of no-take regulations. While it is too early to draw firm conclusions for such slow-growing organisms, the possibility of correlation between coral cover and recruitment on a regional scale

(Upper versus Lower Keys) could suggest that coral populations operate on a spatial scale greater than the current sizes of the fully protected zones, but smaller than the scale of the entire reef tract. It is well established that no-take regulations have rapidly enhanced the abundance of some fish species in fully protected areas, but how that change will translate to the benthos will require a time series of data on patterns and processes longer than three years.

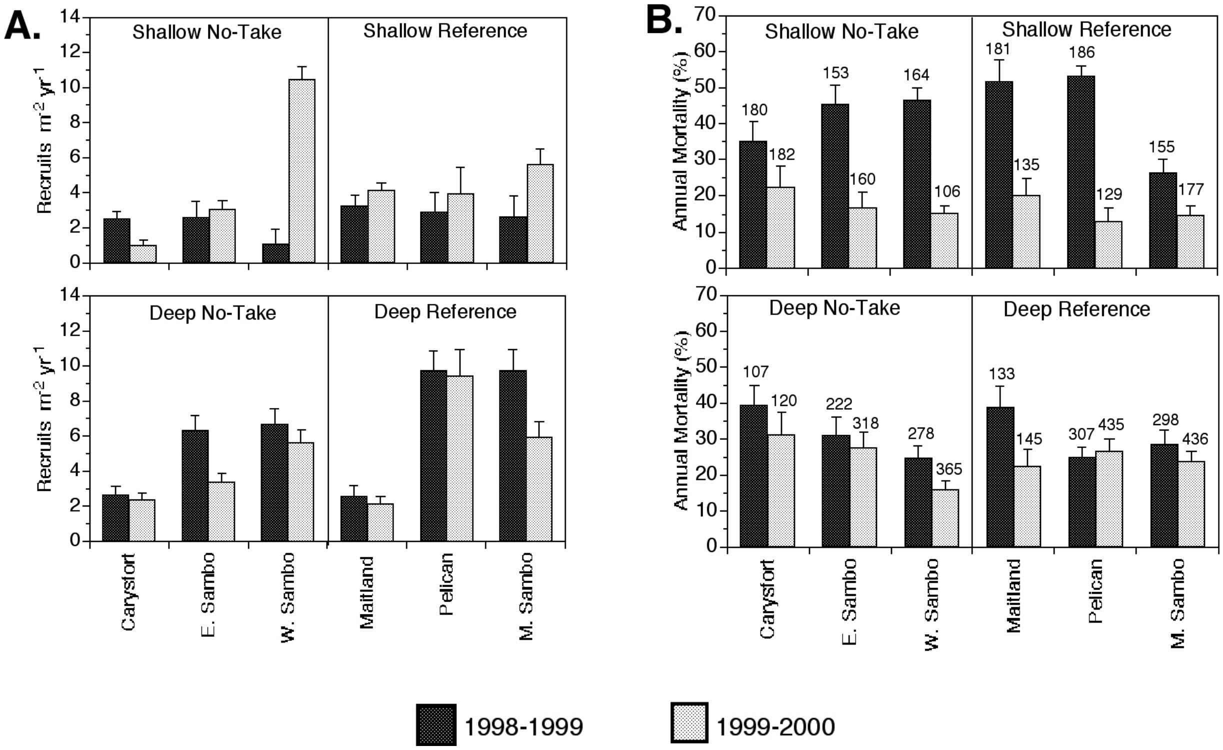


Figure 1. (**A**) Annual rates of coral recruitment in the permanent quadrats (*N*=32 quadrats per depth). Recruitment rates were significantly higher at the reference sites in both years (repeated measures nested ANOVA, with depth nested within site and site nested within reserve status). (**B**) Percent mortality of juvenile corals in permanent quadrats at each site and depth in 1998-1999 and 1999-2000 (*N*=32 quadrats per depth). Mortality rates were significantly higher at all shallow sites in 1998 (repeated measures nested ANOVA, with depth nested within site and site nested within reserve status). The numbers of coral colonies at the start of each sample period are given above the bars.

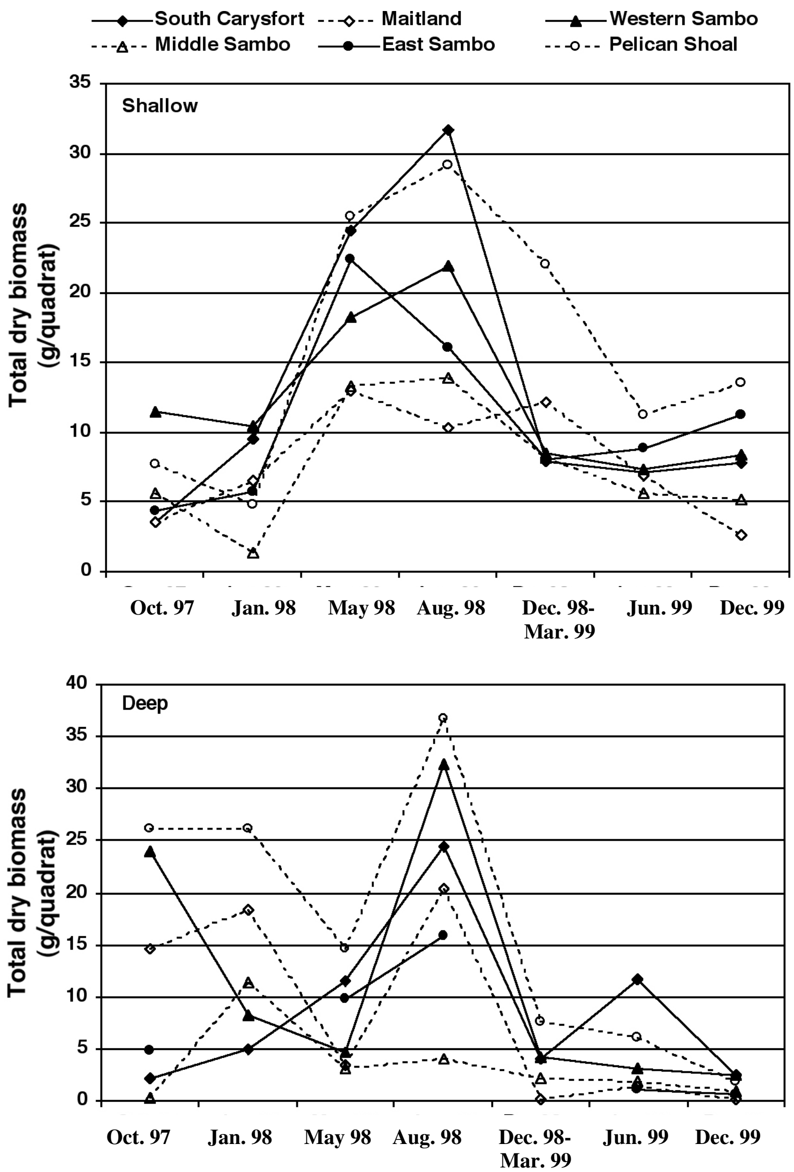


Figure 2. Mean macroalgal dry biomass (*N*=10-18 quadrats). Solid symbols represent fully protected zones; open symbols represent reference sites.

Project Title: **Rapid Assessment and Monitoring of Fully Protected Zones in the FKNMS**

Researchers: Steven L. Miller, Dione W. Swanson and Mark Chiappone, National Undersea Research Center, University of North Carolina at Wilmington, Key Largo, FL.

Goals: Our goals for sampling the response of Florida Keys National Marine Sanctuary (FKNMS) fully protected zones (Sanctuary Preservation Areas, Research-only Areas, and Ecological Reserves) to protection from fishing focus on several questions related to spatial variability at multiple scales. First, how does the structure and condition of communities vary at regional scales, given the differences in the distribution and extent of reefs in the Florida Keys? Second, to what extent do the fully protected zones and reference sites vary, and to what degree is this related to benthic habitat type and regional setting? Third, will patch reefs, which differ considerably in environmental setting, community structure, distance from shore, and human impacts, respond similarly to offshore reefs?

Methods: To address these multiple spatial scales, and given the pattern of zone configuration in the FKNMS, we employed a stratified random sampling design, following procedures discussed in detail in Ault et al. (1999). In 1999, we sampled 16 of the 23 fully protected zones in the FKNMS, mostly offshore, and were able to survey 80 sites along 200 km of the reef tract. Based on the distribution and coverage of coral reef and hard-bottom types (FDEP 1998), as well as the depth limit of most of the zones, we selected four habitat strata: offshore patch reef (one zone), inner reef line (one zone), shallow fore reef (4-7 m depth, multiple zones), and deeper fore reef (8-12 m, multiple zones). A second level of stratification was achieved by delineating three regions of the Florida Keys: Lower (southwest of Key West to Big Pine Shoal), Middle (Big Pine Shoal to Conch Reef), and Upper regions (Pickles Reef to Carysfort Reef). A suite of variables was selected to evaluate and monitor the responses of the fully protected zones relative to reference areas (Table 1). Surveys were completed using pencils, plastic slates, and SCUBA diving. Surveys in 2000 addressed cross-shelf patterns in community structure and condition at 45 sites in the Lower Keys region, including nearshore hard-bottom, patch reef, back reef, and fore reef communities.

Findings to Date:

<u>Variation by habitat type and region</u>: Table 2 provides a summary of emerging patterns from the 1999 Sanctuary-wide assessment of fully protected zones and corresponding reference sites. Of the 13 parameters reported, nearly half showed significant variations with respect to the four habitat types surveyed. Total algal cover was significantly lower on offshore patch reefs, reflecting the prevalence of sand interspersed with massive corals. Habitat variability was also evident for species richness, gorgonian density, and scleractinian coral density. Coral species richness was significantly greater on offshore patch reefs, while sponge species richness was significantly greater on both offshore patch reefs and inner reef line spur and groove. In contrast, coral cover, sponge cover, juvenile coral density and urchin density (total and by species) were highly variable at this spatial scale.

Spatial variations by regional sector (Upper, Middle and Lower Keys) were only significant for three of the 13 parameters listed in Table 2. On deeper fore reef sites (8-12 m depth), coral species richness was significantly lower in the Middle Keys compared to the Lower Keys. In contrast, sponge species richness was significantly greater on the deeper fore reef in the Middle Keys compared to both the Upper and Lower Keys. On the shallower fore reef, sponge species richness was also greater in the Lower and Middle Keys compared to the Upper Keys. Regional variations by similar habitat types or depth ranges were not apparent for various benthic cover parameters.

Zone versus reference sites: Comparisons of benthic community structure and condition between fully protected ("no-take") zones and reference sites on the deeper fore reef (8-12 m) revealed a number of significant spatial variations (Table 2). Stony coral species richness, sponge species richness, and gorgonian density exhibited differences with respect to region and management type. In contrast, coverage parameters like mean algal cover and coral cover did not exhibit these differences and were similarly high (algae 75-80%) or low (corals <5%). Coral species richness was significantly greater on Lower Keys zones compared to Middle Keys zones and reference sites, as well as Upper Keys reference sites. Sponge species richness exhibited a much different pattern, with significantly greater mean values on Middle Keys zones compared to both Upper and Lower Keys zones. Sponge species richness on Upper and Middle Keys reference sites was also significantly greater than on Upper and Lower Keys zones at 8-12 m depth.

Another spatial scale examined was between individual fully protected zones and pooled reference sites by regional sector and habitat type. Six of the 13 parameters exhibited variation at this scale, however, none of the benthic cover variables such as total algal cover and coral cover were significantly different. Species richness of stony corals, gorgonians, and sponges all varied with respect to individual zones and reference sites. Relative to reference sites, coral species richness was greater in one of three zones in the Upper Keys, only one of five zones sampled in the Middle Keys, and only one of four zones in the Lower Keys. Sponge species richness exhibited an opposing pattern to corals, exhibiting an increasing trend toward the Middle Keys relative to the Upper and Lower Keys. In the Lower Keys, no differences in species richness between zones and reference sites were apparent. In the Middle Keys, two of the five zones had significantly greater species richness than reference sites, while in the Upper Keys, two of the three zones had significantly lower species richness than reference sites.

1998-2000 Lower Keys: Three years of data are available for the Lower Keys. Two sampling efforts were conducted in 1998, before and after Hurricane Georges. Parameters measured are as described in Table 1; coral and algal cover data are presented in Figures 1 and 2. No significant differences in coral or algal cover were detected due to the hurricane in 1998, or over time through 2000.

Discussion and Future Plans: Results from our large-scale surveys in the Florida Keys show that for the variables measured and the study questions of interest, a multiple spatial scale approach is advantageous for delimiting factors related to geomorphology (i.e. reef type), environmental setting (i.e. regional variation), and management regimes. In the latter instance for the Florida Keys, the patterns observed between zones and reference sites are due to the initially biased (based on management considerations) site selection of the fully protected zones, and not to short-term effects of protection from fishing. Of course, this could change longer-term if expected changes occur in fish and mobile invertebrate community structure. Ongoing efforts include broader sampling to cover inshore to offshore habitats, work in the Dry Tortugas (we currently have 60 sites surveyed), and refinement of our sampling protocols to optimize future efforts. We also have preliminary data (not reported here) on the distribution and abundance of anemones, fishing gear and other marine debris, and we are evaluating methods for quantifying topographic complexity in new ways.

References:

Ault, J.S., Diaz, G.A., Smith, S.G., Luo, J., and J.E. Serafy. 1999. An efficient sampling survey design to estimate pink shrimp population abundance in Biscayne Bay, Florida. N. Amer. J. Fish. Mgmt. 19: 696-712.

Florida Department of Environmental Protection (FDEP). 1998. Benthic habitats of the Florida Keys. FMRI Technical Report TR-4, St. Petersburg, FL. 53 pp.

Table 1. Variables measured, methods used, and sample size (number of 25 m x 0.4 m transects) per site for the multiple spatial scale assessment of Florida Keys hardbottom and coral reef habitats within reserves and reference sites.

Variable	**Method**	**Sampling size (units)**
Cover (in situ)	Linear intercept (100 points)	4 transects (% cover)
Stony corals by species		
Algal functional groups		
Gorgonian morphology		
Sponges		
Other biota		
Abiotic components		
Cover (archival)	Video of 0.4 m x 25 m	4 transects
Species richness	0.4 m x 25 m	4 paired transects (no. species/20 m^2)
Stony corals		
Gorgonians		
Sponges		
Gorgonian and coral density	0.4 m x 25 m	2 (no. colonies per m^2)
Coral size and condition	0.4 m x 25 m	2 (size distribution, condition frequency)
Juvenile coral density and size	0.65 m x 0.48 cm quadrats	10 quadrats per transect (no. juveniles/m^2)
Other cnidarian abundance	0.4 m x 25 m	4 paired transects (no. individuals/20 m^2)
Urchin abundance and size	0.4 m x 25 m	4 paired transects (no. individuals/20 m^2)

Table 2. Summary of statistical differences of selected benthic parameters sampled at multiple spatial scales in the Florida Keys during 1999. Density estimates are in units of mean numbers of colonies or individuals per m^2, while species richness data are reported as the mean number of species per 20 m^2. ** = $P < 0.05$ and NS = $P > 0.05$.

Parameter	**Habitat**	**Habitat/ region**	**Reserve vs. reference sites (8-12 m depth)**	
			Pooled zones vs. reference	**Individual zones**
Percent cover				
Total algae	**	NS	NS	NS
Stony corals	NS	NS	NS	NS
Sponges	NS	NS	NS	NS
Gorgonians	NS	NS	NS	NS
Species richness				
Stony corals	**	**	**	**
Gorgonians	**	NS	NS	**
Sponges	**	**	**	**
Gorgonian density	**	**	**	**
Coral density	**	NS	NS	**
Juvenile coral density	NS	NS	NS	**
Urchin density				
D. antillarum	NS	NS	NS	NS
E. viridis	NS	NS	NS	NS
E. tribuloides	NS	NS	NS	NS

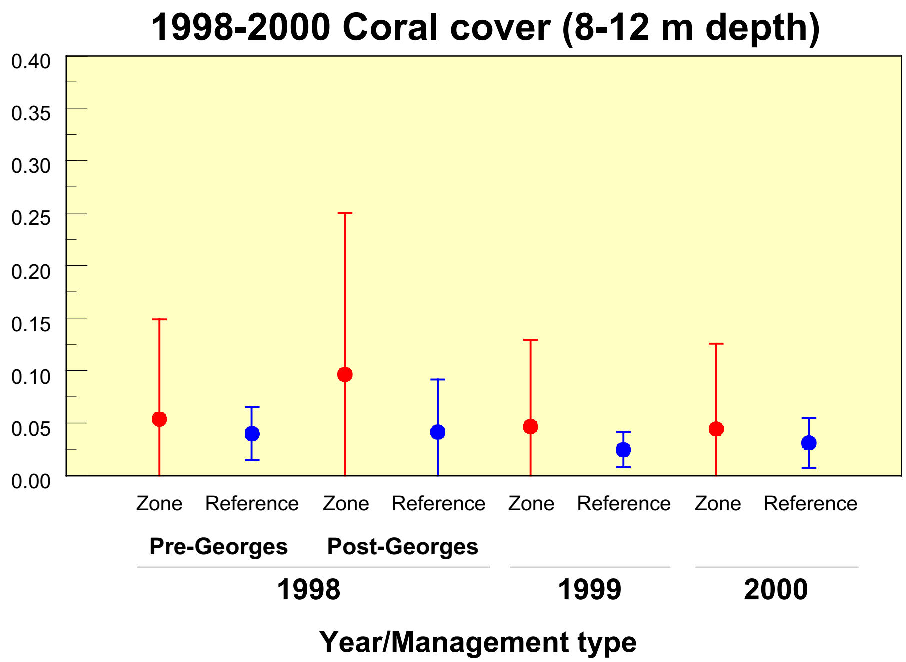


Figure 1. Coral cover (proportion) for three years in the Lower Keys comparing fully protected zones to reference sites.

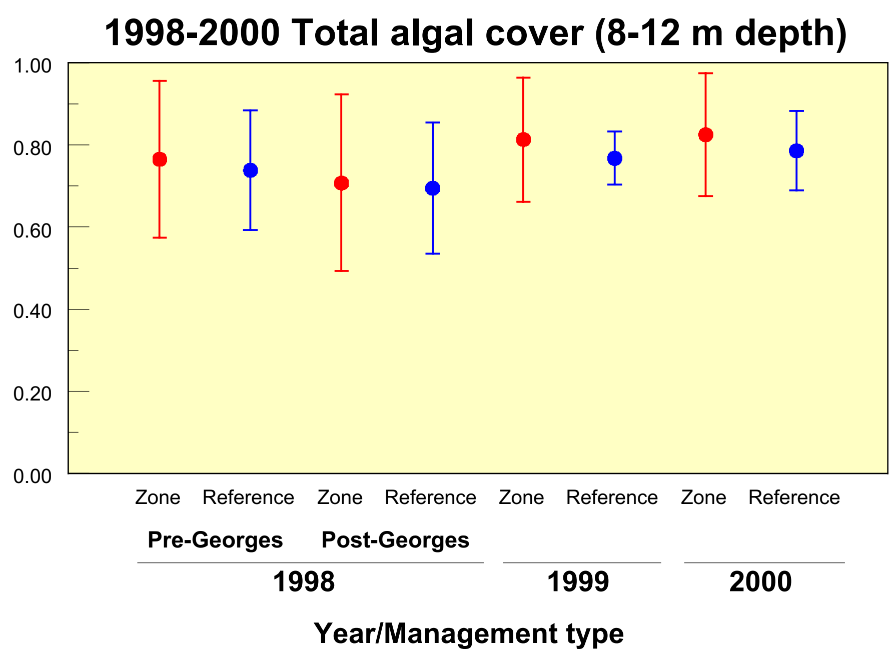


Figure 2. Algal cover (proportion) for three years in the Lower Keys comparing fully protected zones to reference sites.

Project Title: **Sea Stewards: A Volunteer Ecological Monitoring Program**

Researchers: Nicole D. Fogarty and Mary Enstrom, The Nature Conservancy, Summerland Key, FL.

Goals: In 1998, The Nature Conservancy initiated the Sea Stewards volunteer program to participate in monitoring the Florida Keys National Marine Sanctuary. The objectives of the program are to: 1) target species and ecological processes that are not being monitored by other studies, 2) contribute useful data to the evaluation of the Sanctuary's zoning program, and 3) engage Keys residents and Sanctuary users in evaluating resource condition and the effectiveness of management actions.

Methods: Ten teams of volunteer divers, boat operators, and photographers monitor assigned permanent sites in both Sanctuary fully protected zones and nearby reference areas. Selected targets include: 1) all species of reef-dwelling sea urchins (mainly *Diadema antillarum*, *Eucidaris tribuloides*, *Echinometra viridis*, and *E. lucunter*), 2) adult three-spot damselfish (*Stegastes planifrons*), 3) juvenile and adult yellowtail damselfish (*Microspathodon chrysurus*), and 4) all known fish cleaning species, mainly neon goby (*Gobiosoma oceanops*), Pederson cleaner shrimp (*Perclimenes pedersoni*), spotted cleaner shrimp (*P. yucatanicus*), scarlet-striped cleaner shrimp (*Lysmata grabhami*), juvenile porkfish (*Anisotremus viginicus*), juvenile Spanish hogfish (*Bodianus rufus*), and juvenile bluehead wrasse (*Thalassoma bifasciatum*). Teams collected data on these selected targets every year both during the dry (November-April) and wet (May-October) seasons; due to weather conditions and other constraints, not all of the teams completed data collections for each season.

Sea urchins and target damselfish were identified and counted in 20, one-m^2 quadrats radiating out from the sites' central feature in belts of five quadrats. In addition, the size of each sea urchin was categorized and recorded. Beginning in May 2000, quantitative data on the number of fish cleaners, active cleaning stations, and clients were collected within two meters on either side of each belt transect, covering a total area of 400 square meters. In addition, the location of fish cleaners and active fish cleaning stations were mapped for future comparisons.

Findings to Date: No statistically significant difference was found between the fully protected zones and reference areas for any of the four targets (Figs. 1-4). The data document an overall low density of sea urchins; due to these low numbers all sea urchin species were combined for statistical analysis (Fig. 1). The vast majority of the sea urchins recorded were slate-pencil urchins (*Eucidaris tribuloides*). Extremely low densities of long-spined urchins (*Diadema antillarum*) indicate populations have still not recovered from the 1983-1984 massive die-off.

The only target that showed a nearly significant difference ($P = 0.09$) between the fully protected zones and reference areas was adult three-spot damselfish during the 1999-2000 dry season (Fig. 2). The apparent trend for three-spot damselfish suggests greater densities in the fully protected zones. Densities of adult yellowtail damselfish appear comparable in the fully protected zones and in reference areas, while juvenile yellowtail damselfish did not seem to follow any particular pattern (Figs. 3 and 4).

Sea Stewards collected data on fish cleaners and fish cleaning stations for the first time using the belt transect method during the 2000 wet season. Six active cleaning stations with thirteen active cleaners were documented. Grunts and snappers were the only "clients" observed being cleaned. Examining the data by the two types of cleaners, obligate (relying entirely on fish cleaning for their food supply) and facultative (part-time cleaners, usually juveniles), revealed the following trend. Facultative cleaner densities were much higher than obligate cleaners; however, obligate cleaners were twice as likely to be active. The most common cleaner and most abundant obligate cleaner was the neon goby. The vast amount of juvenile bluehead wrasses made them the most abundant facultative cleaner by far. Given that these two species made up the majority of the cleaners, they were combined for the statistical analysis. The results of the t-test showed no significant difference between the fully protected zones and reference areas for the neon goby/bluehead wrasse or for all other cleaners combined.

After five seasons of data collection, some trends in urchin and damselfish densities when comparing fully protected zones and reference areas are beginning to develop; however, it is still too early to speculate about the density differences of these targets. Continued monitoring of all four targets is imperative to discern any significant differences or actual trends between the fully protected zones and reference areas.

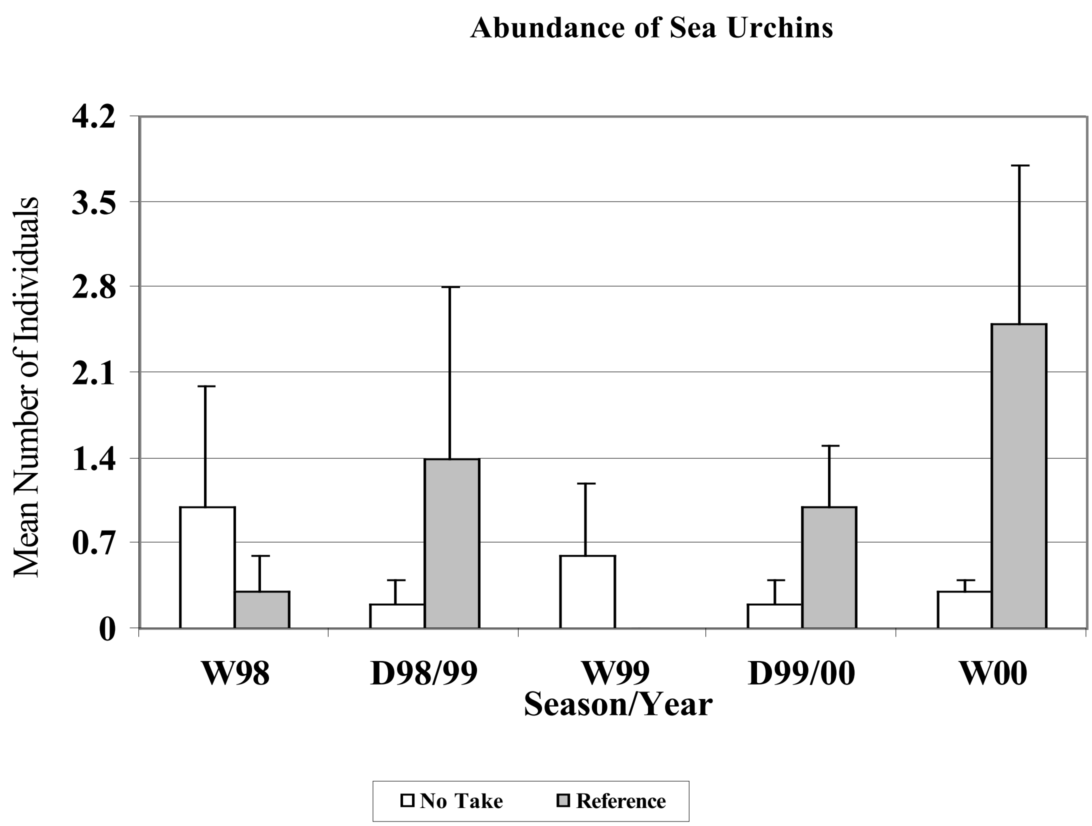


Figure 1. Mean number of individuals per 20 m^2 of sea urchins across all seasons. W: wet season (May-October); D: dry season (November-April). Results of t-test showed no statistically significant differences ($P < 0.05$) between fully protected zones and their reference sites.

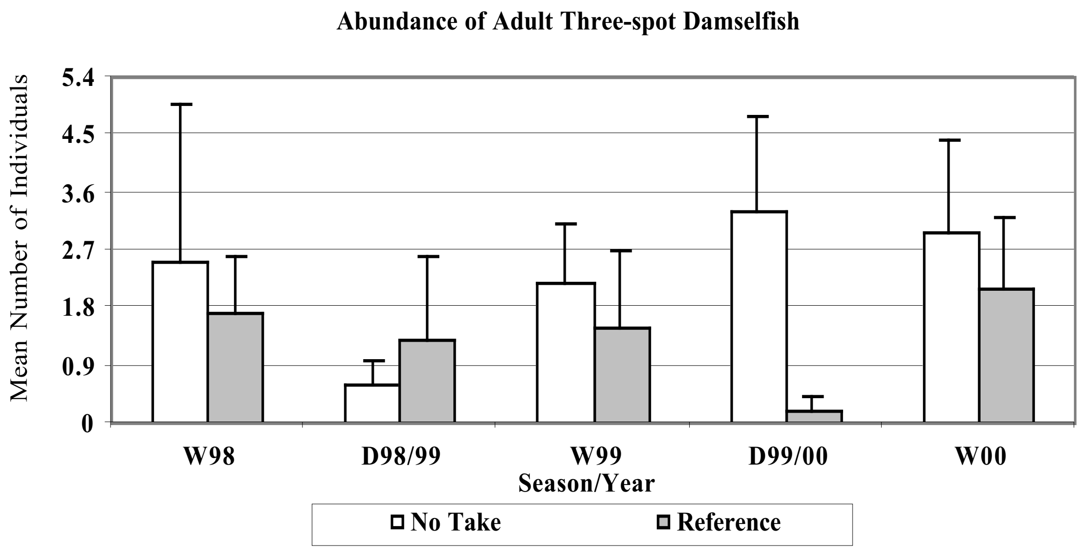


Figure 2. Mean number of individuals per 20 m^2 of adult three-spot damselfish across all seasons. W: wet season (May-October); D: dry season (November-April). Results of t-test showed no statistically significant differences ($P < 0.05$) between fully protected zones and their reference sites; however, the 1999-2000 dry season showed a nearly significant difference ($P=0.086$).

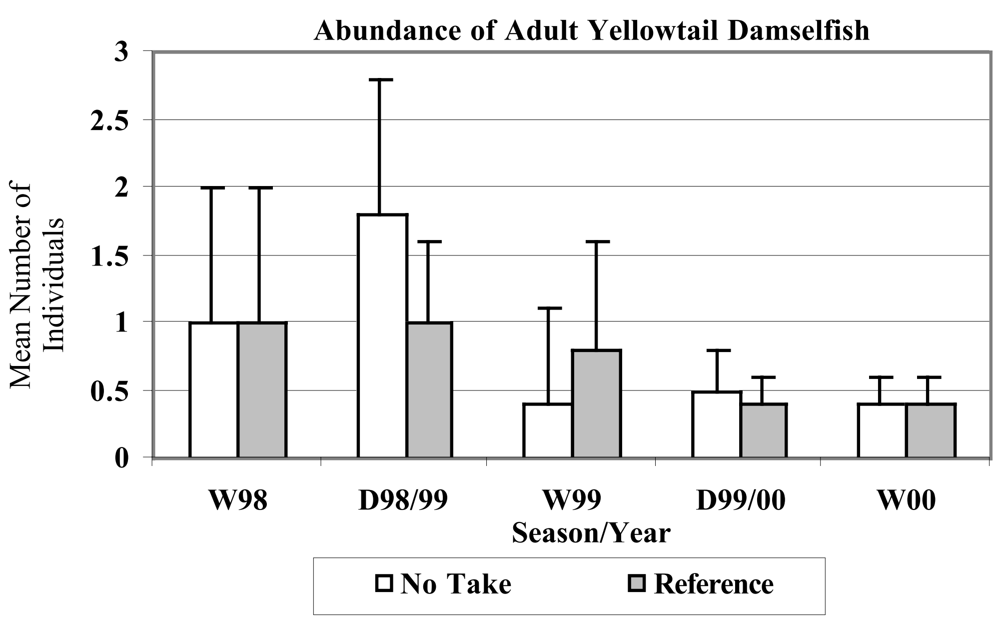


Figure 3. Mean number of individuals per 20 m^2 of adult yellowtail damselfish across all seasons. W: wet season (May-October); D: dry season (November-April). Results of t-test showed no statistically significant differences ($P < 0.05$) between fully protected zones and their reference sites.

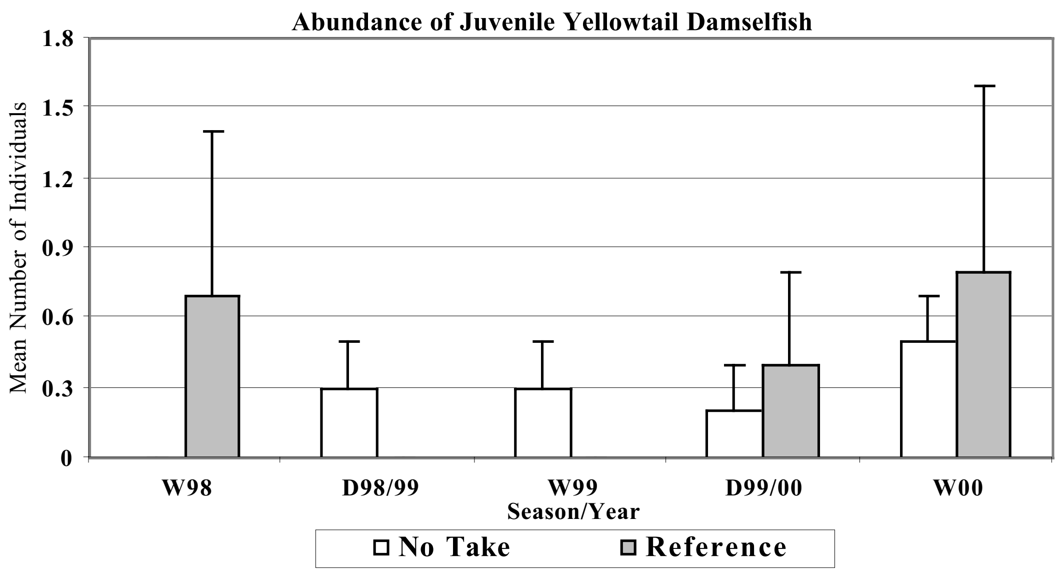


Figure 4. Mean number of individuals per 20 m^2 of juvenile yellowtail damselfish. W: wet season (May-October); D: dry season (November-April). Results of t-test showed no statistically significant differences ($P < 0.05$) between fully protected zones and their reference sites.

Project Title: **Summary of FKNMS Reef Fish Monitoring through 2000 (Year 3)**

Researchers: James A. Bohnsack, David B. McClellan, and Douglas E. Harper, NOAA/National Marine Fisheries Service, Miami, FL; and Jerry Ault, Steven Smith, Geoff Meester, and Jiangang Luo, RSMAS, University of Miami, Miami, FL.

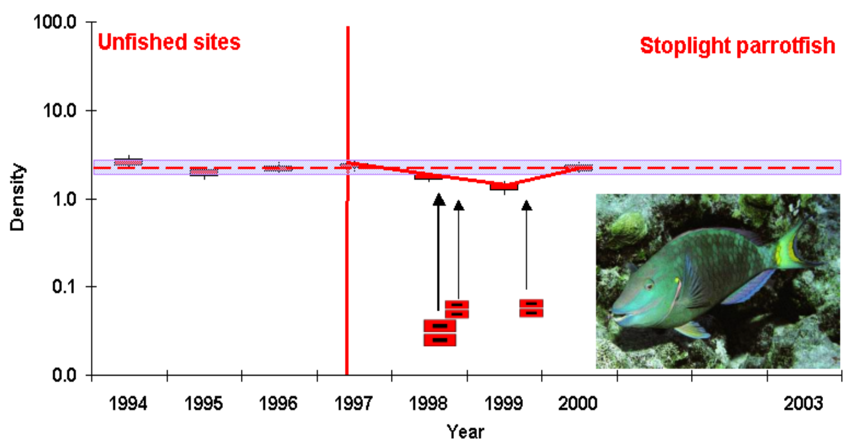
Goals: On July 1, 1997 the Florida Keys National Marine Sanctuary (FKNMS) established 18 fully protected ("no-take") Sanctuary Preservation Areas (SPAs) from Key Largo to Key West and one Ecological Reserve in the Western Sambo region of the Lower Florida Keys. Field studies since then have been directed at comparing changes in fully protected areas to nearby reference sites that are fished.

Methods: Sampling continued through 2000, the third full year of protection. Two hurricanes impacted the Lower Keys in the fall of 1998 and one struck the region in late 1999. In 1999, the sampling design included habitat-based, stratified random sampling and was expanded into other habitats to more efficiently monitor reef fish populations throughout the Florida Keys and to better assess habitat preferences by different species. This expanded effort added two additional classes of data (random samples of low relief habitat in protected and fished areas) in addition to the high relief protected and fished sites previously sampled. In 2000, sampling was expanded to include approximately 1000 visual point samples from the Tortugas region as part of a project to create a baseline for the ecological reserve implemented in this area in 2001. A total of 880 samples were collected from 233 sites in the rest of the Keys: 74 in Sanctuary Preservation Areas, 156 in fished areas, and 3 from the *R/V Columbus Iselin* restoration area. Samples were distributed throughout Biscayne National Park (36), Upper Keys (54), Middle Keys (62), and Lower Keys (81).

Findings to Date: Stoplight parrotfish, a large herbivore not normally targeted by fishing, increased in mean density (number of individuals per sample) in both fished and unfished areas in 2000 (Fig. 1a). Density in fished areas remained below the long-term 1994-1997 performance range. Striped parrotfish, a small herbivore not targeted by fishing, increased in mean density (number of individuals per sample) in both fished and unfished areas in 2000 to a level slightly above the long-term performance range (Fig. 1b). Density was similar in fished and unfished areas. Gray Snapper mean density increased in 2000 in both fished reference areas and fully protected zones to levels within the long-term performance range, but was higher in fully protected zones than in fished reference areas (Fig. 1c).

Economically important species of grouper were combined for statistical analysis. Mean combined grouper density increased in both fished reference areas and fully protected zones since 1997 (Fig. 1d). Grouper density in 2000 was approximately an order of magnitude higher in unfished sites since being protected from fishing in 1997. Yellowtail snapper mean density increased in both unfished and fished reference areas in 2000 (Fig. 1e). Density continued to be significantly higher in fully protected zones than fished sites. Mean density at unfished sites in 2000 increased above the long-term 1994-1997 performance range for the first time. Hogfish mean density increased significantly in both fished and unfished zones in 2000 to levels above the long-term performance range. Hogfish mean density was slightly lower in fully protected zones than in fished reference areas, although the relative increase was higher in fully protected zones than in fished reference areas (Fig. 1f).

In summary, three years after no-take protection was initiated, significant density changes were observed for several exploited species in the fully protected zones as compared to fished reference areas. Mean densities increased significantly in fully protected zones for gray snapper, combined grouper, and yellowtail snapper. It is likely that the passage of Hurricanes Georges (a strong hurricane) and Mitch (a weak hurricane) in the fall of 1998 resulted in declines in mean density at both fished and unfished sites in 1999 for the two non-exploited parrotfishes and gray snapper. No declines in fish densities were noted following the passage of Hurricane Irene, a weak hurricane that passed over the Lower Keys in the fall of 1999.



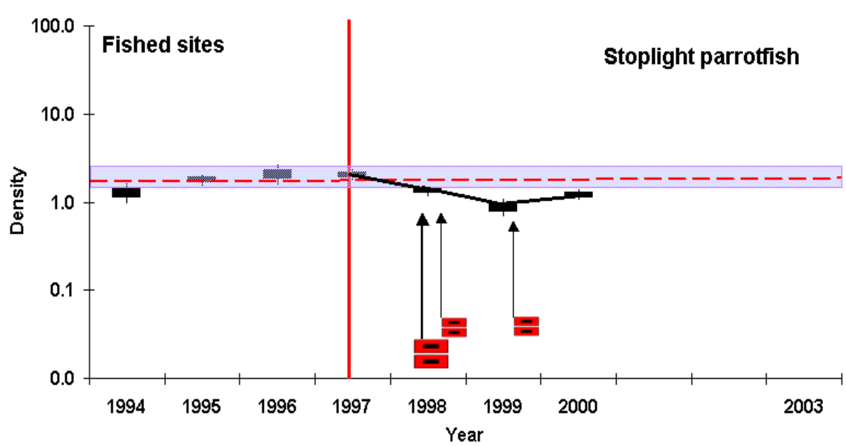


Figure 1a. Stoplight parrotfish density trends.

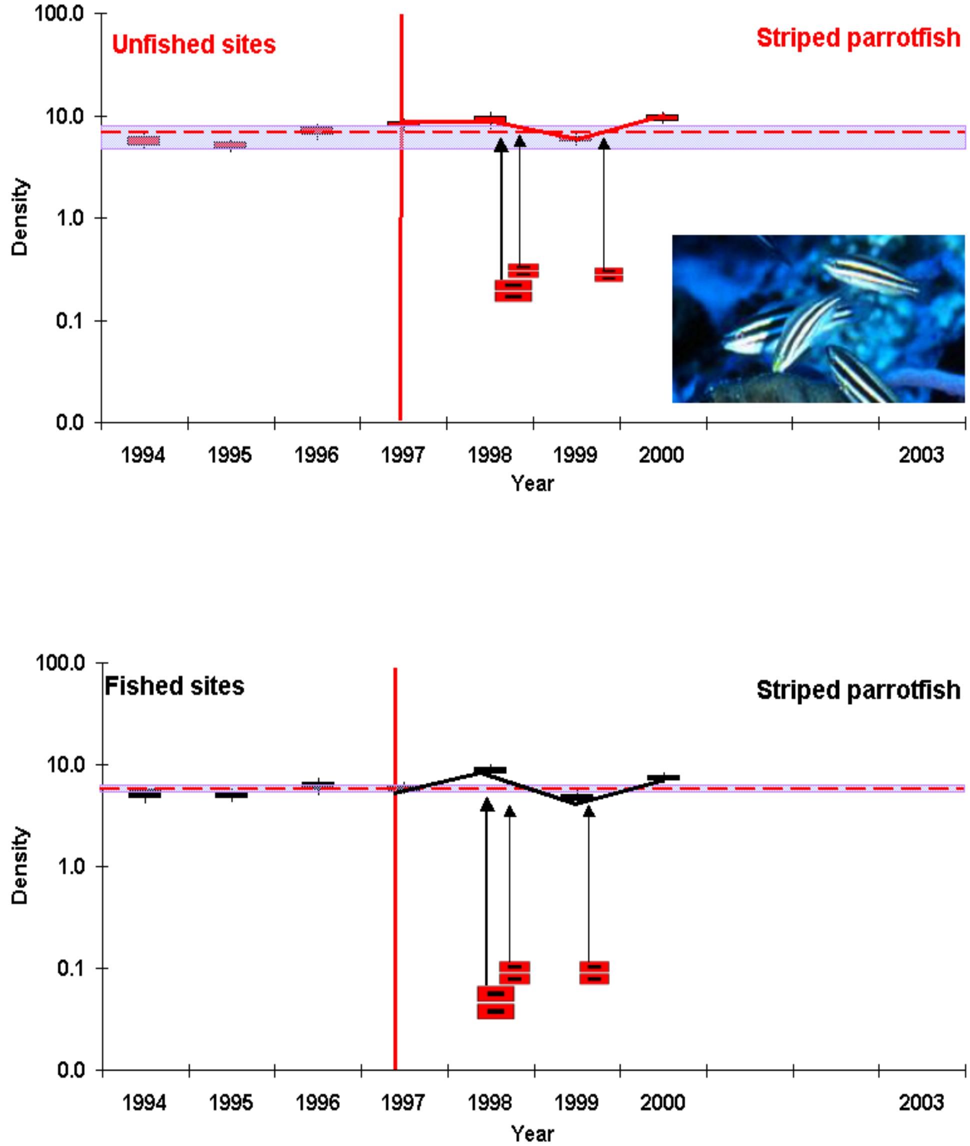


Figure 1b. Striped parrotfish density trends.

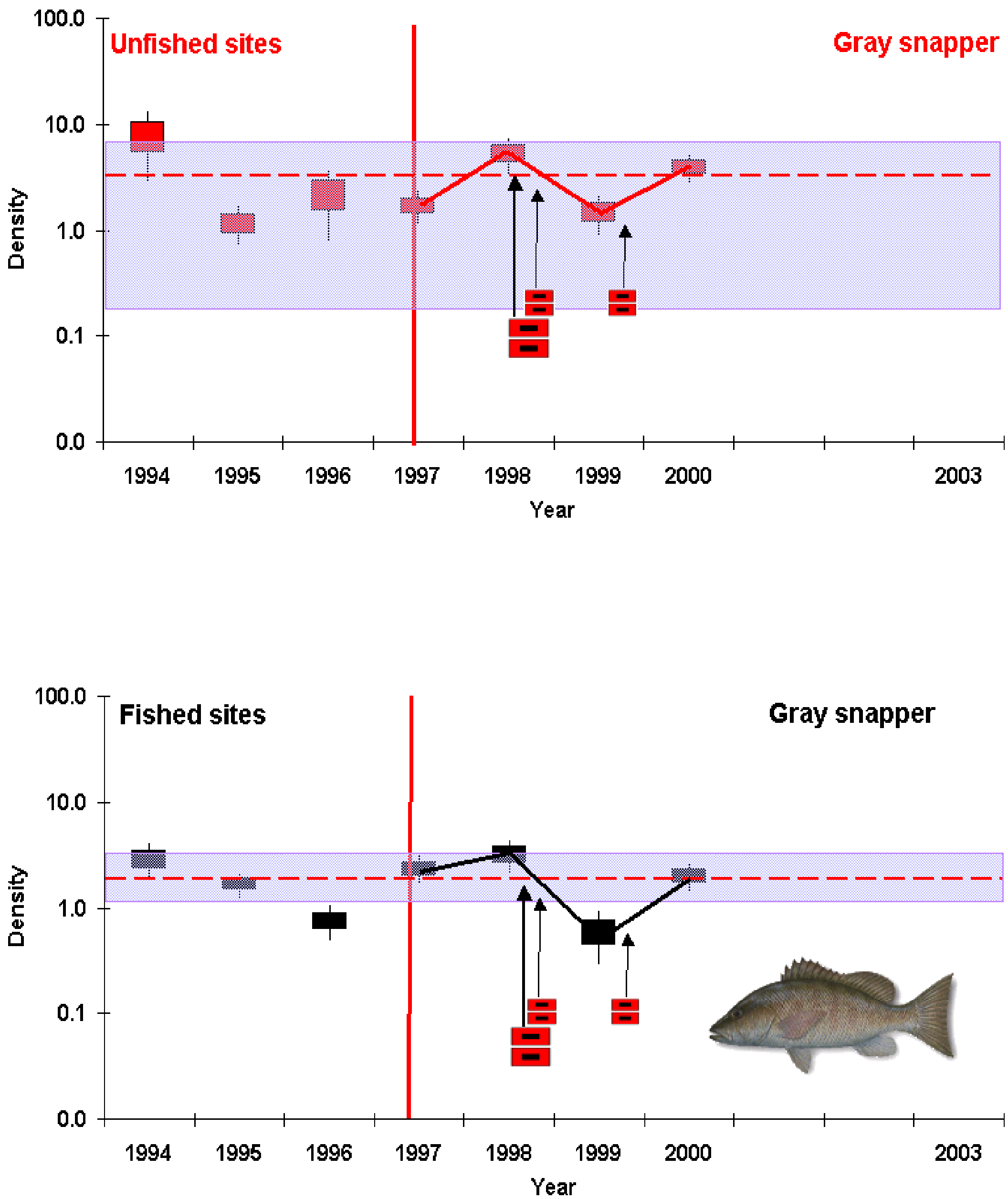


Figure 1c. Gray snapper density trends.

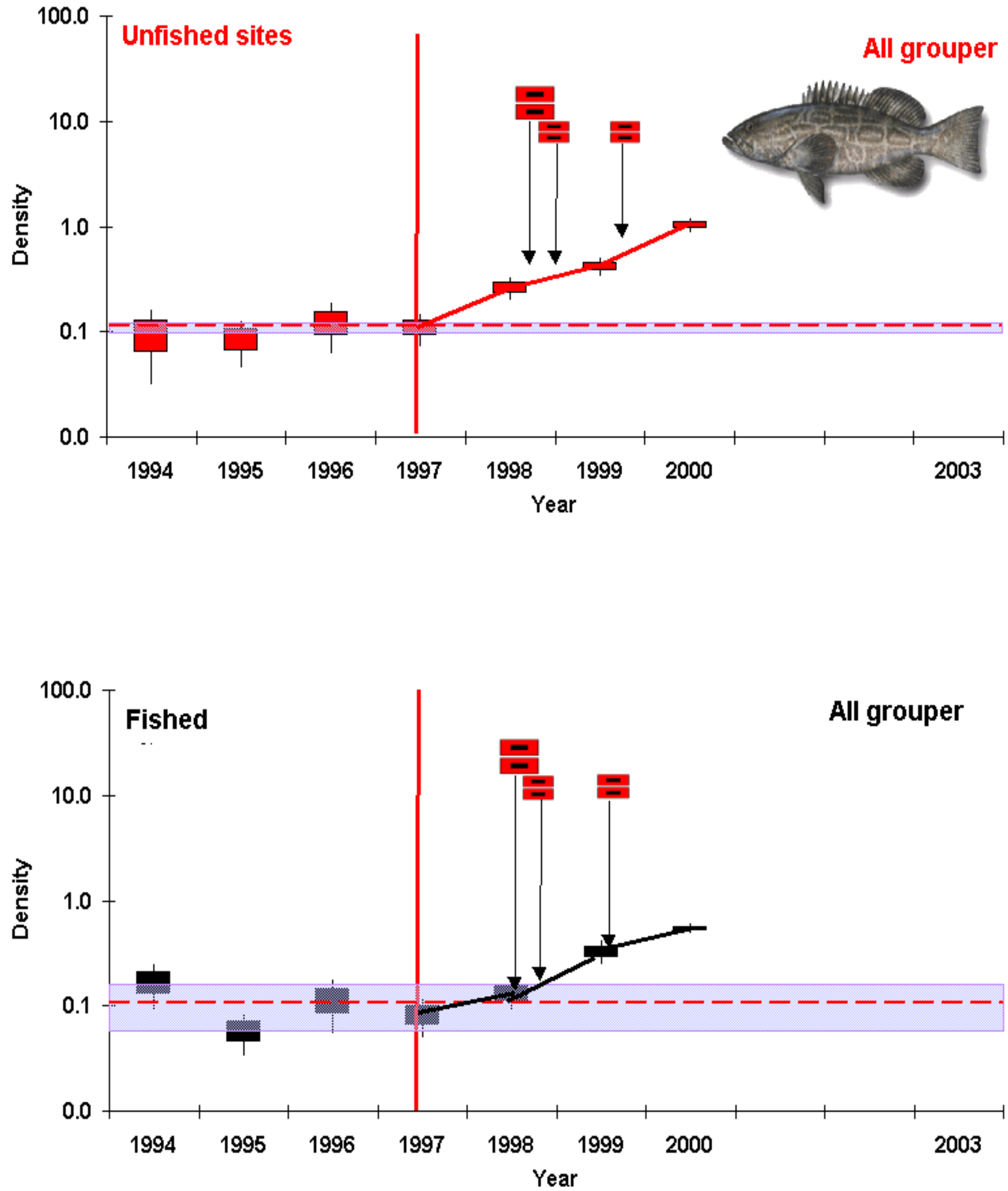
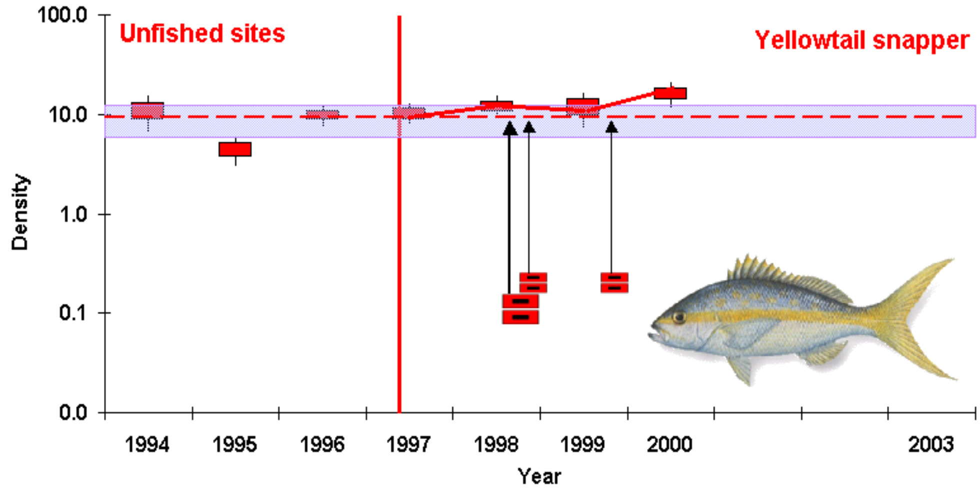


Figure 1d. Combined grouper density trends.



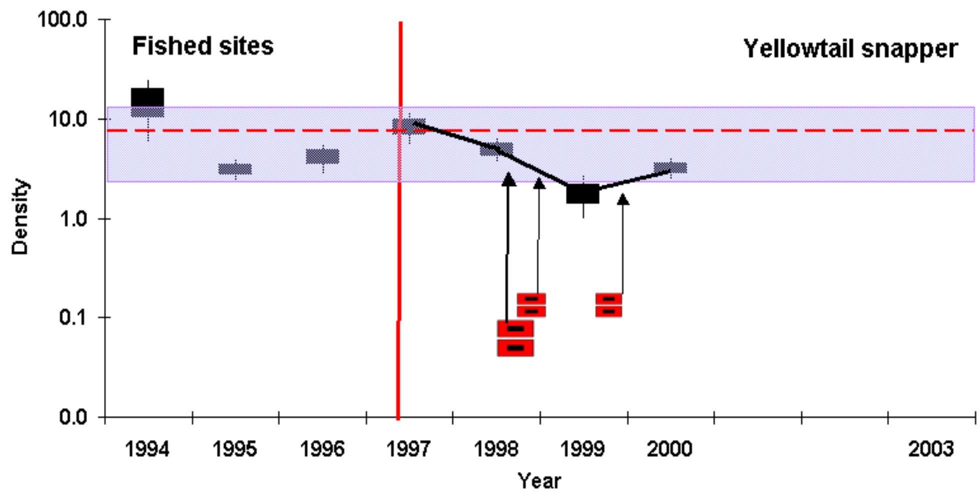
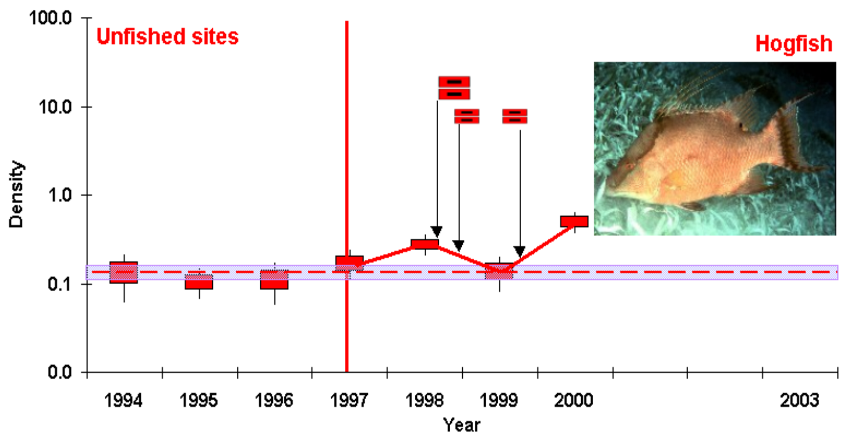


Figure 1e. Yellowtail snapper density trends.



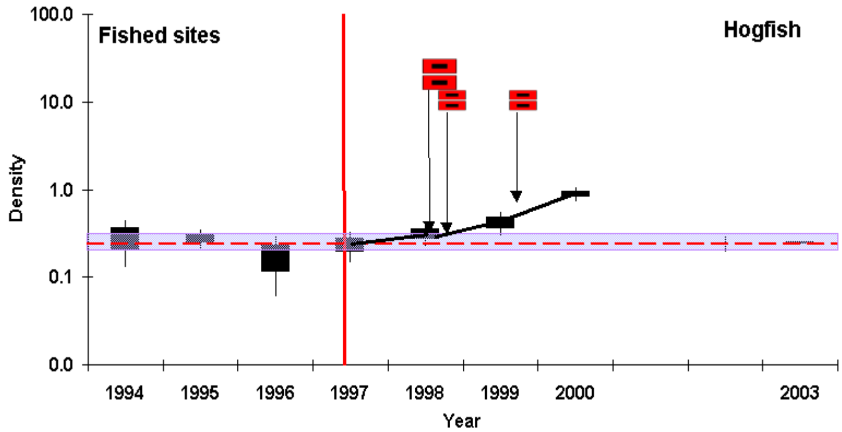


Figure 1f. Hogfish density trends.

Figures 1a – 1f. Annual mean density trends (number of individuals per sample) for selected species from fully protected sites (top) and fished reference sites (bottom). Vertical lines show 95% confidence intervals, boxes show +1 standard error, and the vertical line shows initiation of "no-take" protection in 1997. The dashed line shows mean density for 1994-1997. The gray band shows the 1994-1997 performance based on the 95% confidence intervals and is projected beyond 1997 to show predicted ranges if no changes occur. Hurricane symbols show storms impacting the Lower Keys in the fall of 1998 (Hurricane Georges, a large hurricane, and Hurricane Mitch, a small hurricane) and the Upper Keys in late 1999 (Hurricane Irene, a small hurricane).

Project Title: **Volunteer Reef Fish Monitoring in the Florida Keys National Marine Sanctuary's Fully Protected Zones**

Researchers: Reef Environmental Education Foundation (REEF) staff and the REEF Advanced Assessment Team, Key Largo, FL.

Goals: The goals of this project are to provide baseline and continual data that can be used to evaluate the effect of fishing restrictions on the fish assemblages at specific fully protected ("no take") zones in the Florida Keys National Marine Sanctuary (FKNMS) and to actively engage trained volunteers in data collection efforts.

Methods: This study employs the Roving Diver Technique (RDT), a non-point visual survey method specifically designed to generate a comprehensive species list along with frequency and abundance estimates. During RDT surveys, divers swim freely throughout a dive site and record every observed fish species. At the conclusion of each survey, divers assign each recorded species one of four $\log_{10}$ abundance categories [single (1); few (2-10), many (11-100), and abundant (>100)]. Following the dive, each surveyor records the species data along with survey time, depth, temperature, and other environmental information on a REEF scan sheet. The scan sheets are returned to REEF, and the data are loaded into the REEF database that is publicly accessible on the Internet at http://www.reef.org/.

This project supports a team of REEF's most experienced surveyors, the Advanced Assessment Team (AAT), to annually survey 37 sites in the Florida Keys National Marine Sanctuary (FKNMS), including 12 Sanctuary Preservation Areas (SPAs), 3 Research-only Areas, 1 Ecological Reserve, 10 sites in the vicinity of the new Tortugas Ecological Reserve, and 10 comparison/reference sites. A minimum of six RDT surveys is conducted at each site. This is the fourth year that the AAT has monitored most of these sites (in 2000, 4 sites in the Tortugas and 1 new reference site were included in the survey design). These data are collected during a series of cruises in October, and complement REEF's Fish Survey Project, a continual volunteer monitoring project that involves REEF volunteers conducting RDT surveys during their regular diving activities in the Florida Keys.

Findings to Date: During the 2000 field season, 300 RDT surveys were conducted by the REEF AAT documenting 244 fish species. Several species were documented within the FKNMS for the first time, including black brotula (*Stygnobrotula latebricola*), wrasse bass (*Liopropoma eukrines*), and belted sandfish (*Serranus subligarius*). Species level comparisons were performed on targeted species using all REEF data from the FKNMS. The REEF database as a whole represents a valuable source of baseline and continual data from over 223 Florida Keys sites. To date, a total of 6,974 RDT surveys have been conducted in the FKNMS, and 2,938 of those were prior to July 1, 1997, when the fully protected zones were implemented. These data were used to evaluate the change in average abundance score[*] of three species of snapper (gray, *Lutjanus griseusi;* schoolmaster, *L. apodus*; and yellowtail, *Ocyurus chrysurus*) at sixteen of the SPAs and reference sites before and after July 1, 1997. Survey effort at each site during each

---

[*] abundance score = $[(n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)] / (n_S + n_F + n_M + n_A)$ * percent sighting frequency, where n is the number of times each abundance category was assigned

time range was between 29 and 332. The general trend among the three species was an increase in average estimated abundance after zone implementation (Figure 1). Two exceptions were Molasses SPA and Middle Sambo. Sighting frequency of black grouper (*Mycteroperca bonaci*) and Nassau grouper (*Epinephelus striatus*) before and after fishing restrictions went into effect was also evaluated (Figure 2), and a similar trend was found. Sighting frequency was used in the grouper analysis because it is a more sensitive measure of change for species that, when sighted, only one or few individuals are seen.

Assemblage-level comparisons among the protected and reference sites were evaluated using the similarity of assemblages among sites. Looking at a complement of species is useful because as harvest restrictions are implemented, one would expect cascading effects, such as decreases in herbivorous damselfishes and other species as a result of increased abundances of targeted species (grouper, snapper, etc.) that are often top predators on a reef. The 2000 AAT data were used to produce correlation coefficients and a cluster diagram. Both analyses were based on rank abundance data for a sub-set of species (those seen in at least 20% of all surveys; 91 species). For each protected-reference site pair, the Spearman's coefficient is given for 1997, 1998, 1999, and 2000 (Table 1). These scores can be used to evaluate shifts in fish assemblages over time. The cluster diagram provides a visual picture of the similarity of fish assemblages among sites (Figure 3). The ten Tortugas sites formed a distinct cluster. Reefs of similar type, such as patch reefs or bank reefs, also tended to cluster together. In addition to providing a graphical view of the sites, cluster analysis may be useful in detecting shifts in assemblages that result in changes in cluster affinities. These similarity tools are expected, over a longer time scale, to provide a useful indicator of the effect of the fully protected zones.

In addition to the species-specific analyses presented here, the entire REEF FKNMS dataset was the basis of a recent NOAA technical report that evaluated the distribution and sighting frequency patterns of reef fishes within the FKNMS. The data were also used in a multi-species trend analysis method to identify sites of management concern within the FKNMS.

Future Plans: The AAT work ensures that annual data collection in the SPAs and reference areas by REEF experts occurs. REEF plans to continue this annual monitoring effort, in addition to enabling all divers to participate in its volunteer Fish Survey Project. REEF will also continue its work with NOAA's Biogeography Office to use the REEF database and the FKNMS Benthic Habitat database to investigate fish-habitat interactions, map species distributions in the FKNMS, and evaluate the effect of the fully protected zones by analyzing shifts in assemblage composition and feeding guilds over time.

References:

Jeffrey, C.F.G., Pattengill-Semmens, C., Gittings, S., and M.E. Monaco. 2001. Distribution and sighting frequency of reef fishes in the Florida Keys National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-01-1. US Dept. of Commerce, NOAA, Silver Spring, MD. 51 pp.

Semmens, B.X., Ruesink, J.L., and C.V. Pattengill-Semmens. In prep. Multi-site multi-species trends: a new tool for coral reef managers. International Coral Reef Symposium, October 2000.

Table 1. Spearman Correlation Coefficient. Scores are shown for similarity in abundance of fishes for protected-reference site pairs, based on 1997, 1998, 1999, and 2000 REEF AAT data. For example, in 1997, Carysfort Reef and Ball Buoy Reef were 71% similar, but in 1998 the fish assemblages were 53% similar. All things except harvest pressure being equal, we would expect similarity among protected-reference site pairs to initially decrease and then level off at an increased similarity when an equilibrium was reached. These scores can be used to evaluate shifts in fish assemblages over time.

The correlation analysis was performed using the rank of abundance score. In an effort to eliminate the effect of rare species, only species seen in at least 20% of surveys were included in the analysis (91 species).

	protected vs. open				
	1997	**1998**	**1999**	**2000**	
Protected Site					**Reference Site**
Carysfort Reef	0.71	0.53	0.65	0.68	Ball Buoy Reef
S. Carysfort Reef	0.77	0.60	0.68	0.67	Ball Buoy Reef
Grecian Rocks	0.76	0.78	0.72	0.72	Little Grecian
Molasses Reef	0.74	0.88	0.86	0.68	Pickles Reef
Conch Reef	0.61	0.69	0.70	0.68	Pickles Reef
Hens and Chickens	0.66	0.78	0.79*	0.77	Cannon Patch
Cheeca Rocks	0.72	0.71	0.77*	0.79	Cannon Patch
Tennessee Reef	0.63	0.24	0.63	0.41	Delta Shoals
Sombrero Reef	0.82	0.62	0.68	0.77	Delta Shoals
Coffins Patch	0.68	0.67	0.64	0.65	Samantha's Ledge
Newfound Harbor Spa	0.87	0.81	0.84	0.86	Newfound Open
Looe Key - Research	0.42	0.54	0.57	0.57	No Name Reef
Looe Key - East	0.47	0.60	0.50	0.65	No Name Reef
Eastern Sambo	0.89	0.73	0.83	0.76	Middle Sambo
Western Sambo	0.84	0.45	0.79	0.84	Middle Sambo
Sand Key	0.85	0.83	0.87	0.89	Western Dry Rocks

*In 1999, Mosquito Bank was surveyed instead of Cannon Patch.

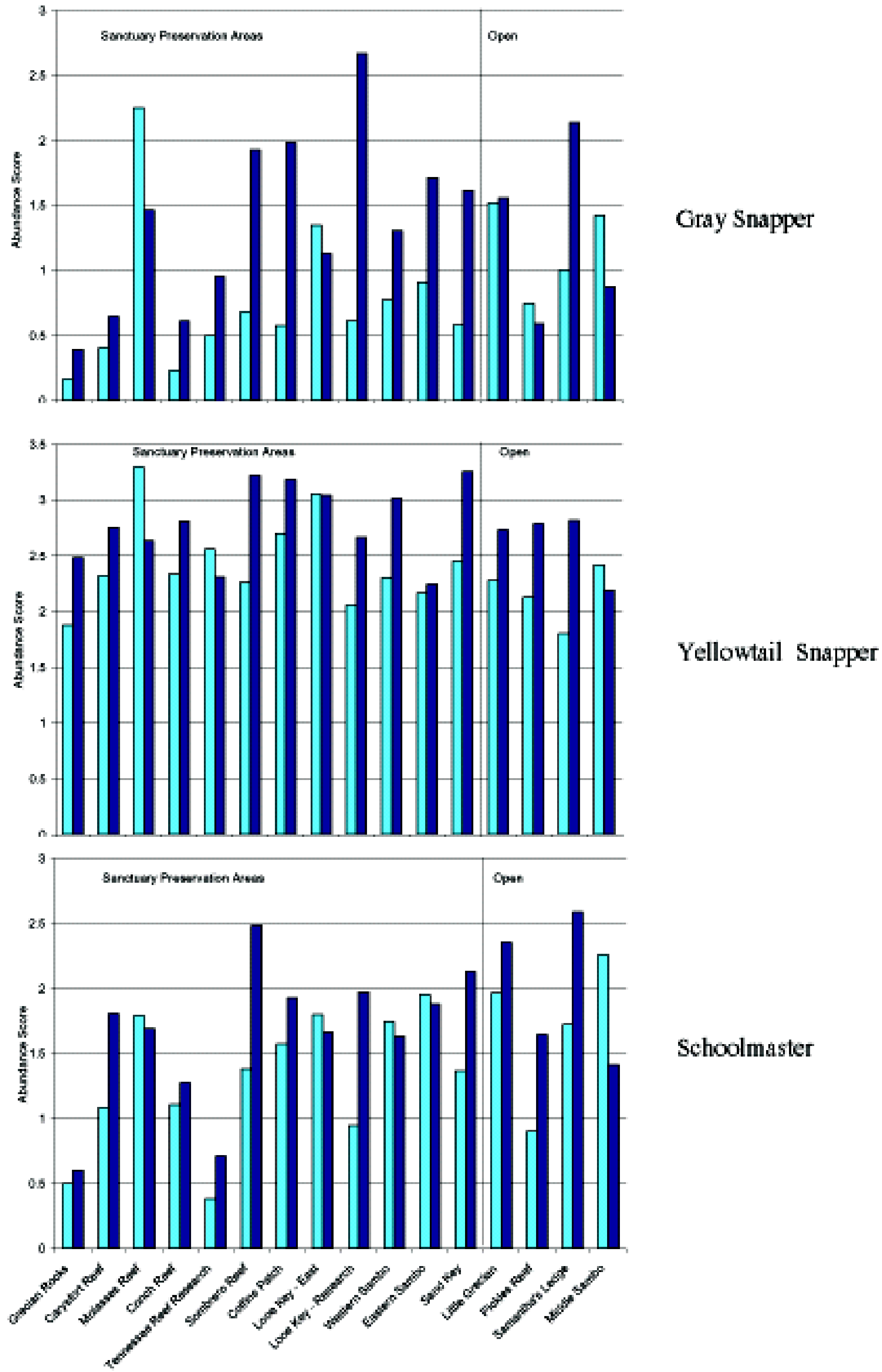
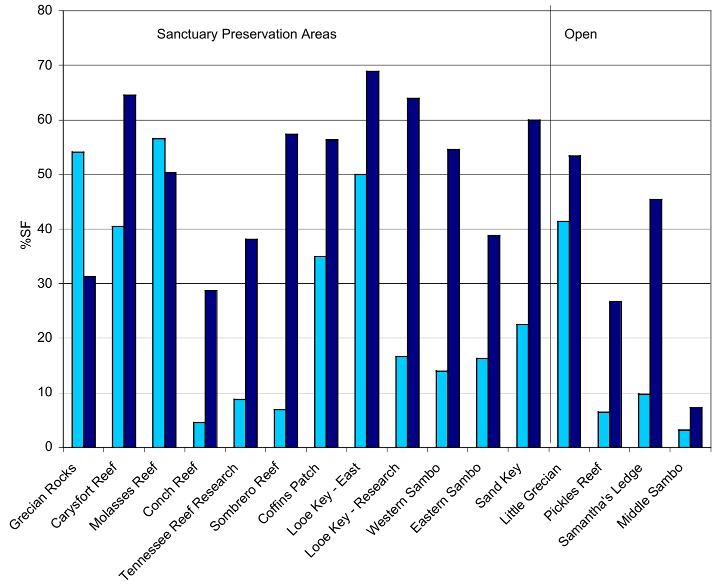
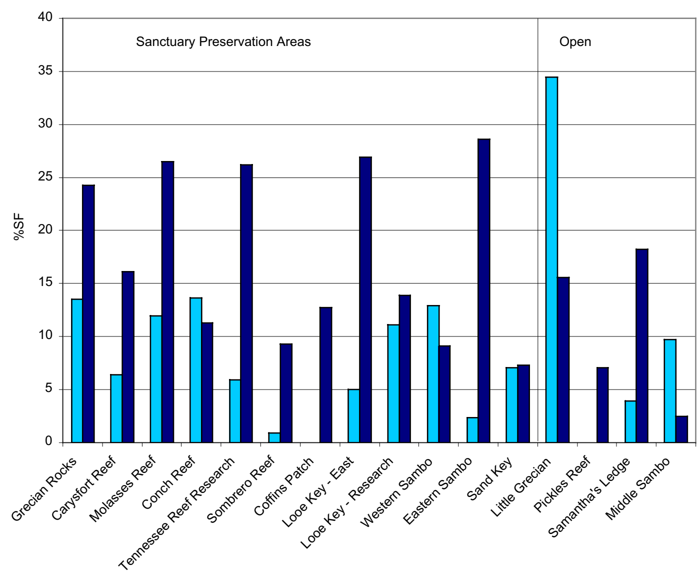


Figure 1. Average abundance score for each species is given for 16 sites in the FKNMS, before (July 1, 1993 to June 30, 1997; gray bars) and after (July 1, 1997 to April 31, 2001; black bars) fishing restrictions were implemented in the zones. Abundances generally increased or stayed the same at all sites except for Molasses SPA and Middle Sambo.



Black Grouper



Nassau Grouper

Figure 2. The sighting frequency (%SF) of black grouper and Nassau Grouper was compared at eleven sites before (July 1, 1993 to June 30, 1997; gray bars) and after (July 1, 1997 to April 31, 2001; black bars) fishing restrictions were implemented in the FKNMS fully protected zones. Frequency was used because it is a more sensitive measure of population status than abundance score for species like grouper that, when encountered, only one individual is usually seen. Frequency of sightings increased at most of the sites.

Five of the sites are part of National Marine Sanctuary's Existing Management Areas, and have been protected from spearfishing since 1975 (Grecian, Molasses, Little Grecian) and 1981 (Looe Key and Looe Key Research). Groupers are particularly vulnerable to spearfishing, and this long-term protection is likely to confound the effects of comparisons such as this.

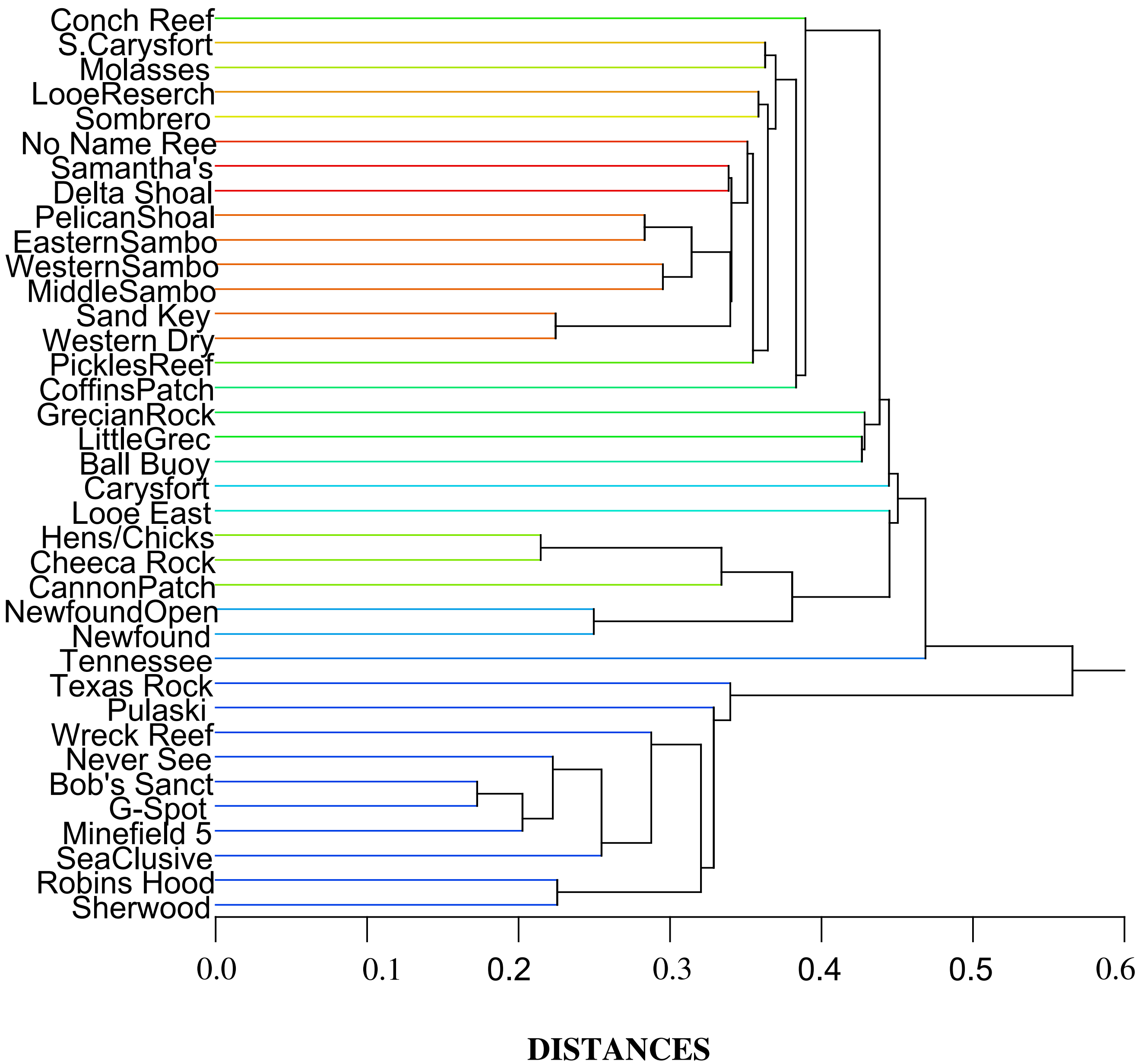


Figure 3. Cluster analysis results. The analysis used REEF's 2000 AAT data, collected at 37 sites along the Florida Keys and Dry Tortugas. Analysis used rank of the abundance score. Distance of the clusters are 1-Gamma. Only species that were seen with a %SF of at least 20% (91 species) were included in the analysis. The ten Tortugas sites (listed last) formed a distinct cluster. Patch reefs and bank reefs also tended to cluster together. This type of graphical analysis can be useful in overall site characterization. In addition, shifts in fish assemblages over time due to zone implementation may result in changes in cluster affinities.

***Project Title:* Monitoring Caribbean Spiny Lobsters in the Florida Keys National Marine Sanctuary, 1997-2000**

Researchers: Carrollyn Cox, Meaghan C. Darcy, and John H. Hunt, Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute, Marathon, FL.

Goals: We have been monitoring spiny lobsters in the fully protected zones of the Florida Keys National Marine Sanctuary (FKNMS) since their implementation in July 1997. Our goal is to determine the efficacy of the zones in protecting this highly mobile species from harvest. Protection will be evident if, over time, lobsters become larger and more abundant inside the zones than outside.

Methods: Thirteen fully protected zones and paired reference sites are sampled twice a year, in July at the end of the closed lobster season, and again in September/October during the open fishing season. Fully protected zones comprise 11 small Sanctuary Preservation Areas (SPAs) and Research-only Areas (~82 ha), a large 515 ha "Super SPA", and a 3,000 ha Ecological Reserve (ER). A single sample is taken on the predominant lobster habitat within the SPAs; three samples are taken on the forereef at the Carysfort Super SPA; and at the Western Sambo Ecological Reserve, 3 samples are taken in each of 4 habitat strata: fore reef, back reef, offshore patch reef, and nearshore patch reef. Samples consist of 60-minute timed searches during which we enumerate and attempt to catch all lobsters observed. Size, sex, molt stage, reproductive state (of females), den number, and depth are recorded for each lobster encountered.

Findings to Date: The total number of lobsters sampled varied among years with the most lobsters collected in 1999 and the least in 1998. As expected, there were fewer lobsters in reference sites during the fishing season than in July, prior to the opening of the season. However, there was also a decline in the total number of lobsters in the fully protected zones during the fishing season each year except 1998. This exception is attributed to the effect of Hurricane Georges, after which large numbers of lobsters were found at offshore reefs. During 1997, there was no difference in overall mean size of lobsters in fully protected and reference sites; mean size was below the legal size limit (76 mm carapace length [CL]). Subsequently, mean size of lobsters has been above legal-size in fully protected zones, but has remained below legal-size in reference areas. Lobster abundance (n lobsters/60 minutes) was highly variable among sites, seasons, and years. Abundance varied among habitats in the Ecological Reserve. The habitat with the greatest abundance of lobsters changed among years, reflecting the migratory nature of lobsters moving through this zone. Abundance during July was always greater at Western Sambo Ecological Reserve and its reference site than at other sites. Lobsters were always less abundant at Carysfort Super SPA than at its reference site during the closed season. In general, lobsters have been more abundant in SPAs than in reference sites during the closed season since the beginning of the study.

Overall, the fully protected zones do not totally shield lobsters from harvest as evidenced by the decline in total number of lobsters sampled from the closed to open fishing season. However, the increase in lobster size in fully protected zones is indicative of some protection. We will continue to monitor spiny lobsters in FKNMS and to look at lobster population trends after collecting five years of data.

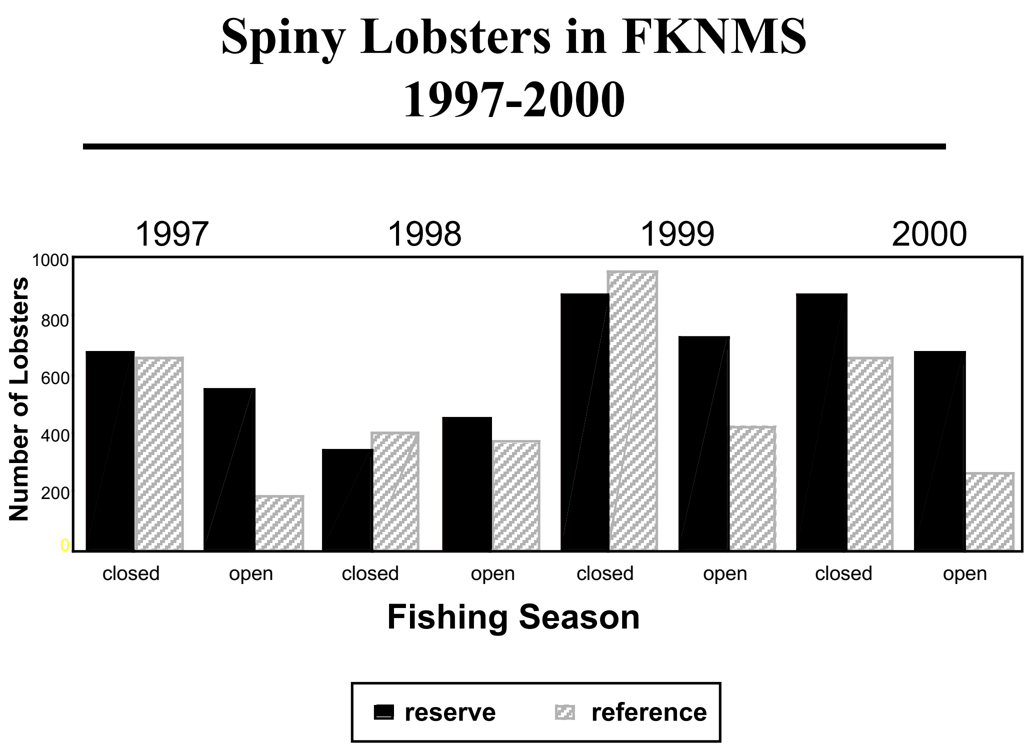


Figure 1. Number of lobsters in reserve versus reference areas, 1997-2000.

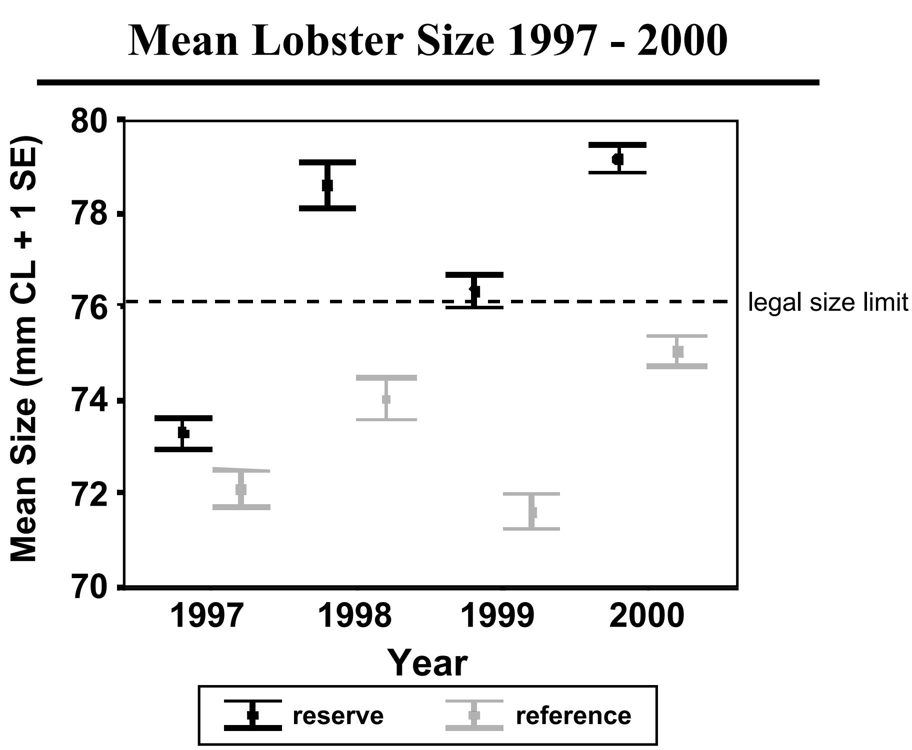


Figure 2. Mean lobster size, 1997-2000.

Abundance of Spiny Lobsters during July

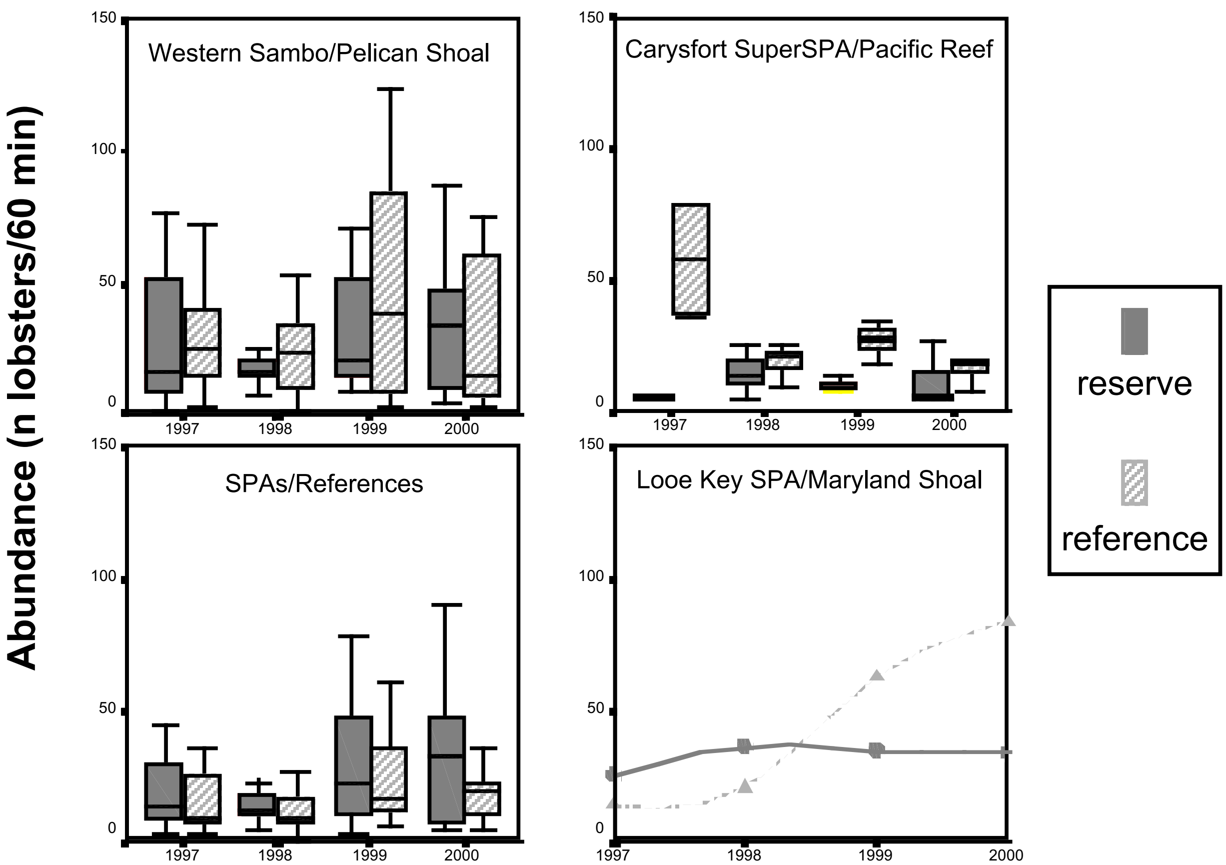


Figure 3. Lobster abundance 1997-2000 at several sites.

Project Title**: Sentinel Lobster Fisheries Project for the Florida Keys National Marine Sanctuary**

Researcher: Douglas R. Gregory, Jr., University of Florida/Florida Sea Grant, Monroe County Cooperative Extension Service, Key West, FL.

Goals: The purpose of the Sentinel Lobster Fisheries project is to use commercial fishing gear and techniques to evaluate the long-term effectiveness of the Western Sambo Ecological Reserve as a refuge for spiny lobster. The direct involvement of commercial fishermen in this project was an important factor to make the research results as relevant as possible to the commercial fishing community. This past year (2000) was the third year of the planned four-year project.

The objectives of this study are to: (1) directly involve commercial lobster fishermen in monitoring changes in lobster abundance and size effected by closure of the Western Sambo Ecological Reserve, (2) determine if trap catch per unit effort (CPUE) and the average size of spiny lobsters within the reserve increases above that of the surrounding area, and (3) determine if lobsters from within the reserve are emigrating and providing yield to fishermen fishing adjacent to the reserve.

Methods: A commercial lobster fishermen was contracted to supply and fish 90 lobster traps during the months of June and November 2000 to provide observations from both the closed and open fishing season. Four sampling trips were conducted during each sampling period with the deployment of 10 traps in each of three different areas (Western Sambo Ecological Reserve (WSER or Reserve), Middle Sambo, and Pelican Shoals) and three habitats (inshore shallows, channel patch reefs, and outer reef patch reefs, Fig. 1). A tag-recapture study was started to evaluate evidence of spillover from the Reserve. However, this portion of the study was not continued into 2000 because low tag return rates were inadequate for the amount of effort involved.

Findings to Date: During 1998-2000, a total of 5485 lobsters were observed in the WSER and adjacent areas. The tag and release effort produced 70 tag returns from fishermen, 54 with recapture locations. Four long distance recoveries to the east of the study site were from shallow water areas south of Big Pine Key, three near Looe Key, and one south of the 7 Mile Bridge. These lobsters came from both the Pelican Shoal and WSER areas. Similarly, five long-distance recoveries were from west of the study site with two from the Key West Main Ship Channel, two from south of Marquesas, and one from west of Rebecca Shoal; all of these were originally tagged in the WSER. One lobster was returned from the Gulf side, near Calda Light, that was originally tagged at the Pelican Shoal Reef site. We recaptured in research traps 32, 23, and 10 tagged lobsters in each of the three years of the project. We have not detected any movement between study areas and most of the returns are from the Ecological Reserve, indicating that some of the lobsters do tend to be non-migratory.

The mean size of lobsters in the WSER has been significantly larger than in the non-reserve areas in both the open and closed fishing seasons (Fig. 2). The only exception to this trend was that lobster size in the Middle Sambo area in the 2000 closed season was equal to that of the Reserve. The inter-annual differences in size within each area have exhibited different trends between seasons. In the open season, size in the WSER declined in 1999 (76 mm carapace length [CL]) but recovered in 2000 to 1998 levels (82 mm CL); a similar, less pronounced and non-significant trend was observed in the non-reserve areas. In the closed season, a similar significant decline and recovery trend in size was observed; however, in the Reserve the size of lobsters remained depressed during 2000. The larger observed sizes in the WSER are directly related to the greater abundance of males there. There is a direct relationship between percentage of males present and lobster size (Fig. 3; $r = 0.69$, $n=18$, $p=0.002$). During the closed season females exhibited no differences in size between Reserve and non-reserve areas.

Sex ratios were highly skewed toward males during the summer closed season, especially within the Reserve. During the winter open season sex ratios returned more toward equity. The reason for the skewed summer ratios is probably because our sample sites are inshore of the reef tract where the majority of reproduction occurs.

In all years and seasons, with consistent and comparable sampling effort, we observed more lobsters in the Reserve than in the two non-reserve areas combined. Catch rates, in number of lobsters caught per trap per day of soak time, also were greater in the Reserve than in the non-reserve areas. The only instances where significant differences did not occur between Reserve and non-reserve areas was with the Pelican Shoal area in the 1998 open season and in the 1999 and 2000 closed seasons. The Middle Sambo area consistently had lower catch rates that the other two areas. Comparison of catch rates between Reserve and non-reserve areas during the open season are confounded by the competition of active commercial fishermen in the non-reserve areas. Our research traps are at a decided disadvantage in attracting lobsters because we bait only with cowhide and commercial fishermen use live lobsters as attractants. Cowhide is a less effective bait than live lobsters so the catch rates of research traps in non-reserve areas during the open season is not an effective indication of abundance relative to that observed inside the Reserve.

Catch rates in the Reserve during the closed season have trended downward in each year since 1998; however, conversely, during the open season Reserve catch rates have done the opposite. The closed and open season catch rate trends in the WSER over the three-year period are mirror images. The combined catch rates of the two seasons results in a flat interannual trend, suggesting that overall abundance in the Reserve has remained constant since 1998. In the non-reserve areas the closed season catch rates have been similar from year to year. Non-reserve open season catch rates were similar in 1998 and 1999 but were significantly lower in 2000.

The observed increases in lobster size and catch in the Reserve does not appear to be cumulative over the three-year period of observation, but rather appears to be relatively constant. The best explanatory hypothesis at this time for the size-related observation is that those lobsters in the Reserve during the February-March pre-reproductive molting period are protected from harvest during the latter months of the fishing season and most of them probably remain in the Reserve throughout the summer. Most of the long-distance movements in lobsters tend to occur during the fall and early winter months, the non-reproductive season. Thus, it may be no coincidence that the 4 to 5 mm differences in male carapace length observed between the Reserve and non-Reserve areas during the closed season is approximately equivalent to the average increase in size of male lobsters during a single molt cycle. Females do not grow as fast as males because more of their energy is redirected to reproduction.

The limited number of returns from the tag and recapture study support only qualitative evaluations, but it seems evident that the lobsters within the study area exhibit non-migratory behavior as well as both short-distance and long-distance movements. Lobsters appear to be capable of moving in and out of the Reserve, and probably do so, to some extent, on a seasonal basis. Spillover effects may be detected through comparisons of the size and catch rate of lobsters within the WSER to both the immediately adjacent area (Middle Sambo) and the site farther away (Pelican Shoal).

The size distribution of lobsters among areas is variable (Fig. 2), with no gradation in size from the Reserve observed during the open season. The catch rate trends also did not exhibit the expected gradation if spillover were occurring. It is important to note that this lack of a trend in catch rates could be confounded by the residual effects of greater fishing effort adjacent to the Reserve (in the Middle Sambo area) relative to the Pelican Shoal area.

Future Plans: In future years, different statistical techniques for data analysis may be evaluated to ensure that within-year and within-site differences are accurately detected. If sampling continues beyond four years, then the design should be changed to provide improved statistical properties. For example, instead of fixed transects, randomly selected locations could be sampled within each study area, and quarterly sampling of the Reserve throughout the year could provide better insight into the dynamics of lobsters within this area. Lastly, it may be worth reinitiating the tag program for just one year in the Reserve area.

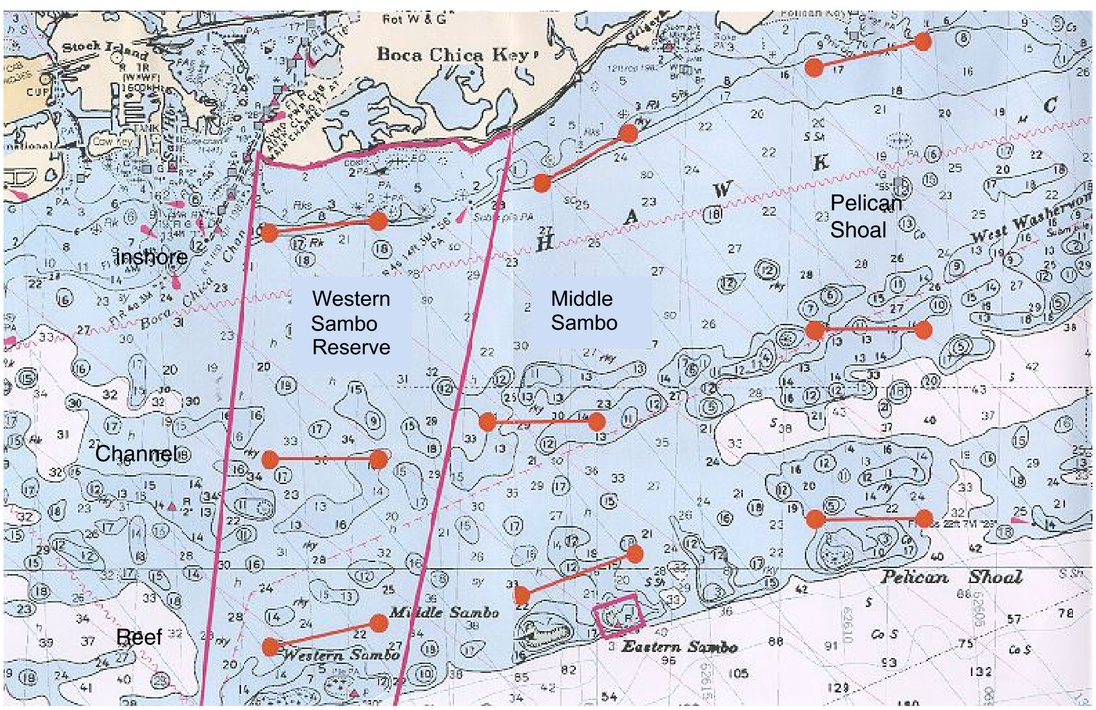


Figure 1. Location of the Sentinel Fisheries Study site. Each line represents a 10-trap string of about 1 mile in length.

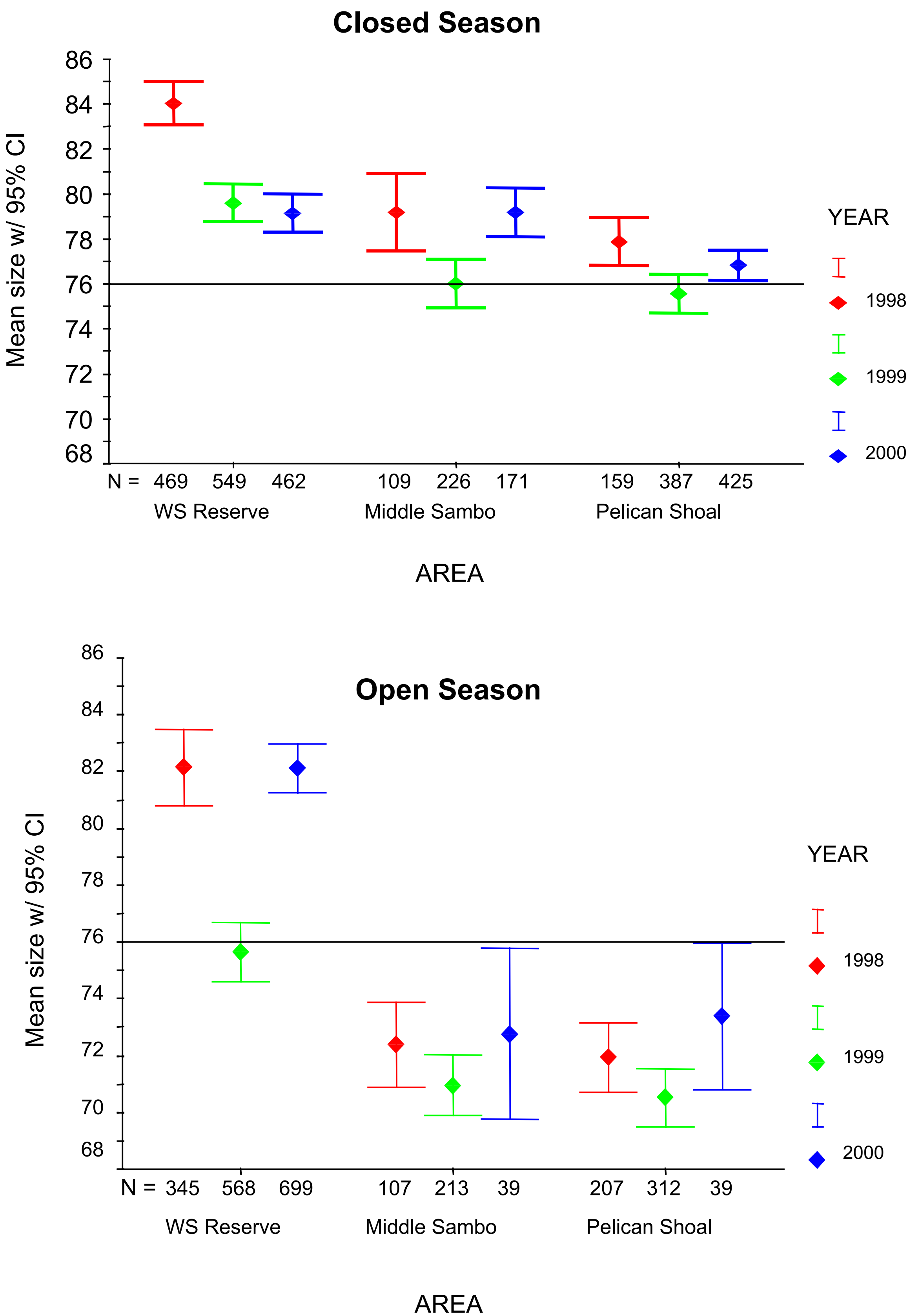


Figure 2. Lobster size (carapace length, mm) by sex, year, season, and area.

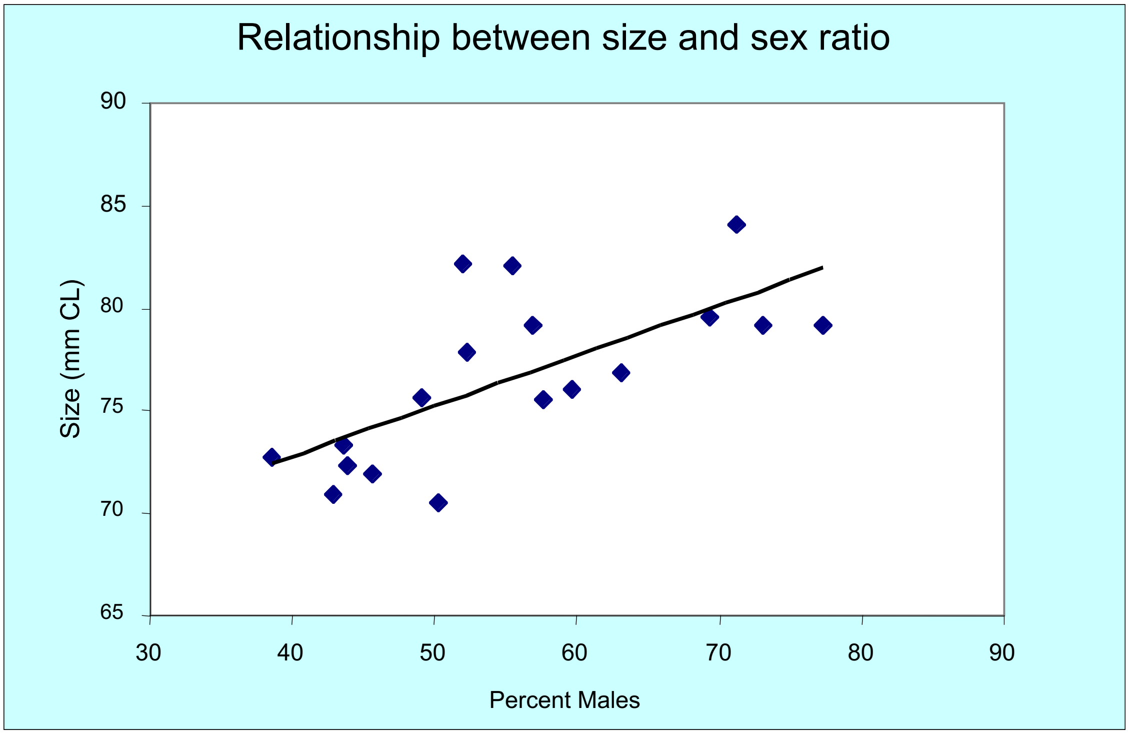


Figure 3. The larger observed lobster sizes in the Reserve are directly related to the greater abundance of males there. There is a direct relationship between percentage of males present and lobster size (r = 0.69, n=18, p=0.0016).

Project Title: **Queen Conch Population Monitoring in the FKNMS Fully Protected Zones**

Researcher: Robert Glazer, Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute, Marathon, FL.

Goals: The goal of this project is to determine the effects of the fully protected zones on the density, abundance, and area occupied by queen conch in the Florida Keys National Marine Sanctuary (FKNMS).

Methods: We conducted belt-transects using divers in locations with moderately dense aggregations of conch. Surveys were conducted in both fully protected zones and adjacent reference areas. We counted all conch within a 1-m swath along each belt and estimated densities based on these counts. Additionally, each aggregation was mapped in order to estimate the area occupied by each aggregation. The density and area estimations were used to determine population abundance. In those areas where conch were sparse, direct counts were made of all individuals present. In other areas where the aggregations occupied an extensive area, we used Global Positioning System and GIS programs to estimate the area encompassed by the aggregations.

Findings to Date: In 1997, we began monitoring fully protected zones ("reserves") and adjacent reference sites in the Florida Keys National Marine Sanctuary to assess the effects of the zones on populations of queen conch. We have now completed four annual surveys.

In 2000, we surveyed 11 reserves and 4 reference areas. All surveys were conducted during August. The median area encompassed by the aggregations associated with the fully protected reserves was 12,367 m^2, up from 7911 m^2 in 1999. In the reference areas, the median area was 6634 m^2, which was down from 9512 m^2 in 1999. The median adult conch density for aggregations associated with reserves was 0.070 conch per m^2 compared with 0.047 conch per m^2 for those aggregations associated with reference sites. We estimated that the total adult conch abundance in aggregations associated with reserves was 13,012 conch compared with 5,023 adult conch associated with reference areas. The median juvenile conch density for aggregations associated with the fully protected reserves was 0.070 conch per m^2 compared with 0.073 juvenile conch per m^2 in the reference areas.

In all of these cases, there were no statistically significant differences between the fully protected zones (reserves) and corresponding reference sites except for juvenile abundance. Additionally, there were no statistically significant changes from 1999 to 2000 in either density or areal extent for conch aggregations associated with either reserves or reference areas. However, there was a statistically significant increase in juvenile abundance within the reserves from 1999 to 2000. There has been no statistically significant change in any of the measured parameters since the beginning of the study in either the fully protected zones or reference areas.

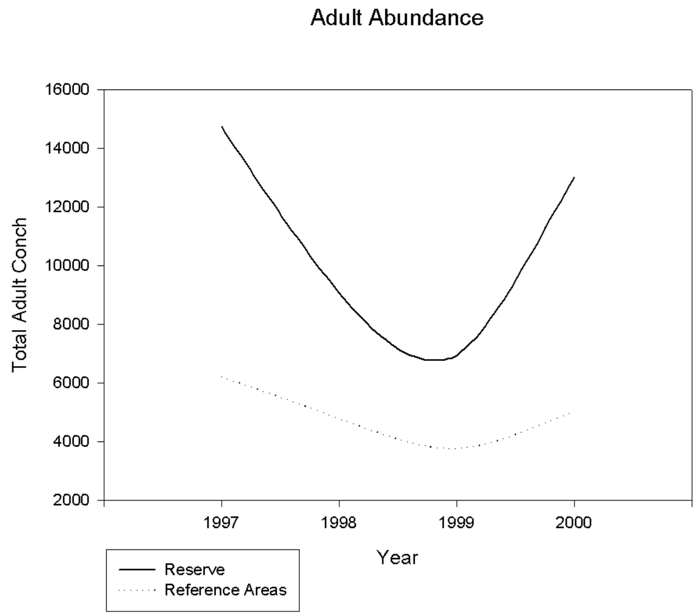


Figure 1. Conch aggregation size (m^2), 1997-2000.

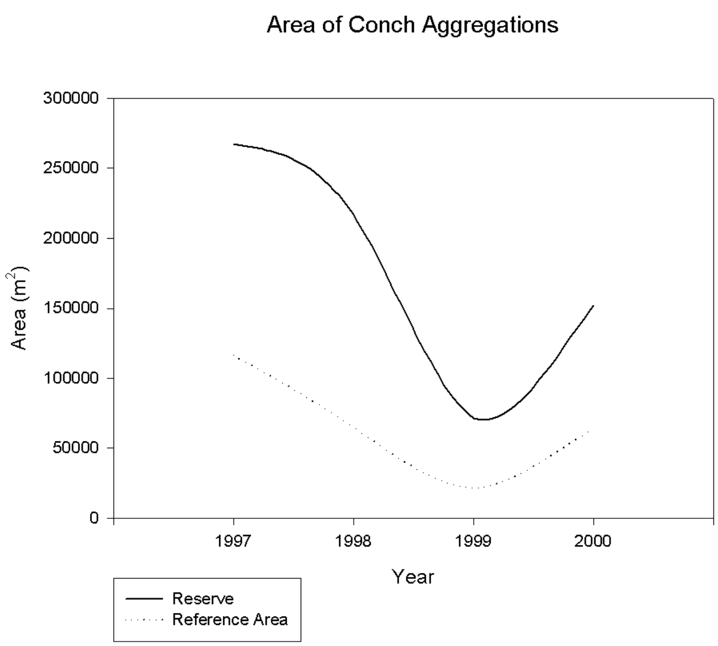


Figure 2. Adult conch abundance, 1997-2000.

Project Title: **Aerial Survey of Vessel Usage and Marine Animal Occurrences in the FKNMS, 1992-2000**

Researchers: David B. McClellan and James L. Tobias, NOAA/National Marine Fisheries Service, Miami, FL.

Goals: The goal of this project is to provide vessel usage information and marine animal sightings data to the Florida Keys National Marine Sanctuary (FKNMS). On July 1, 1997 the FKNMS implemented a series of fully protected zones that restrict consumptive activities. These zones include 18 Sanctuary Preservation Areas (SPAs), 4 Research-only Areas, and one Ecological Reserve (ER). This data will assist Sanctuary managers in assessing patterns of use in these areas.

Methods: Since September 1992, 149 aerial surveys have been conducted along the southeast Florida coast from Ft. Pierce to Key West. A cooperative agreement was established between the NOAA/National Marine Fisheries Service Miami Laboratory and the U.S. Coast Guard Miami Air Station to document marine animal occurrence and monitor vessel activity (Fig. 1). Through December 2000, 132 surveys of the Atlantic waters of the Florida Keys National Marine Sanctuary (FKNMS) have been completed.

Findings to Date: Preliminary analysis of usage of the SPAs, before and after implementation, by recreational fishermen and divers, commercial fishermen, and lobster trappers has been completed. Over 22,000 recreational vessels have been counted during the surveys. Preliminary findings indicate that dive operations occur mainly at the outer reefs during the summer. Fishing activity occurs primarily in winter in unprotected areas offshore of the reefs. Most of the 2,200 commercial vessel sightings observed were lobster vessels operating during the summer and fall. Commercial fishing operations occurred throughout the year. Other types of vessels observed include sailboats, research vessels, jet skis, and treasure salvage boats. Events that have been documented include observations of lobster and other fishing vessels fishing along the edge of the fully protected zones (Fig. 2). Little prohibited use of the zones has been seen during the surveys.

Information on marine turtle and mammal occurrences in the FKNMS has also been documented providing rough estimates of abundance. Bottlenose dolphin sightings (1992-1997) indicate year-round occurrence with no seasonality. The mean pod size was 6.06 animals (ranging from 1 – 36 individuals). Encounter rates were 18.57 per survey (range 0 – 116 animals) or approximately 0.12 animals per nautical mile in Florida Keys near shore waters. A total of 2,261 sea turtles were observed although species identification was possible for only 40% of the observations. Of the five species identified, the major species was the loggerhead turtle (33.6%). Turtles were observed all year with a mean number of 17.1 (range 0 – 153) per survey. There appears to be a spring aggregation of turtles off of the Florida Keys. Sharks, manatees, schools of manta rays, and tunas were some of the other animals observed.

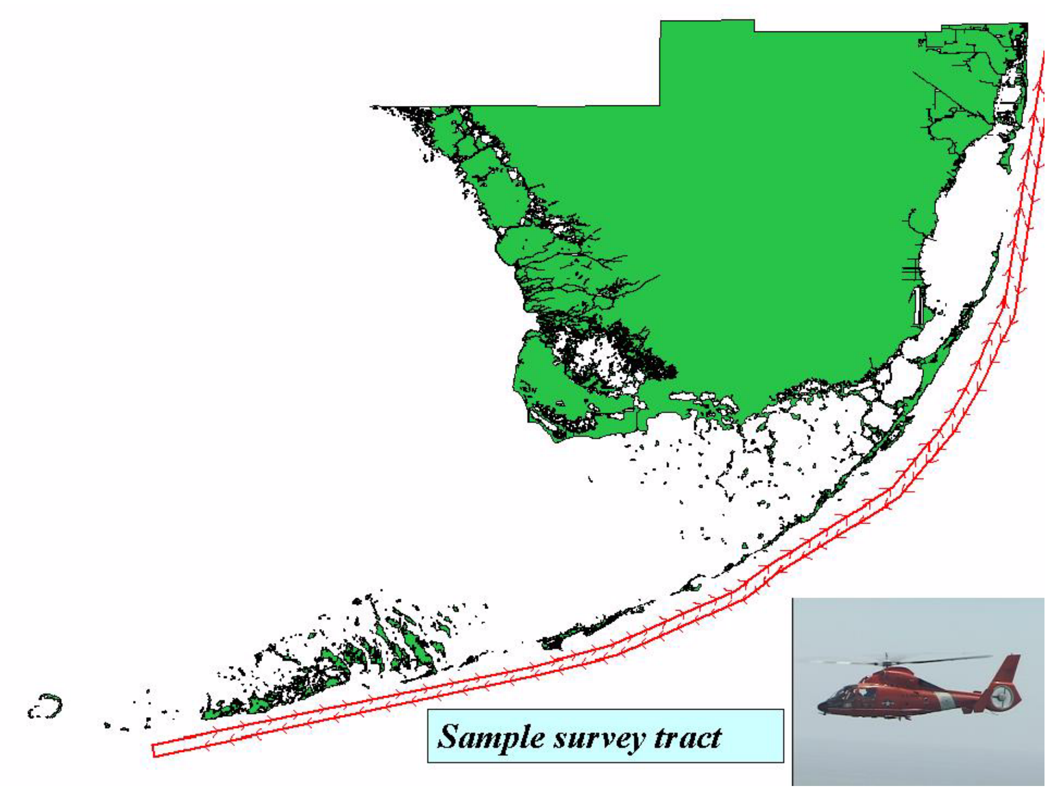


Figure 1. Sample survey tract that includes the Florida Keys National Marine Sanctuary.

Figure 2. Observations of fishing vessels "fishing the line" (fishing just outside the boundaries of the fully protected zones). Orange circles represent zone boundary buoys.

Project Title: **Socioeconomic Monitoring of Commercial Fishing Panels**

Researchers: Thomas Murray, Thomas J. Murray & Associates, Gloucester Point, VA; Manoj Shivlani, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL; and Bob Leeworthy, NOAA/NOS/Special Projects, Silver Spring, MD.

Goals: The goal of this project is to test whether fully protected zones ("no take" areas) of the Florida Keys National Marine Sanctuary (FKNMS) have short and/or long-term financial impacts (positive or negative) on commercial fishermen of the Florida Keys.

Methods: Four commercial fishing panels were selected: 1) general commercial fishermen in Monroe County (the Florida Keys) that were not displaced from the fully protected zones, 2) fishermen displaced from the Western Sambo Ecological Reserve (ER), 3) marine life collectors, and 4) Tortugas fishermen. Baseline data from the year 1997-1998 were collected. Individual catch and financial performance are monitored, as are regional fishery catches, ex vessel value, and other regulations. From these data the financial performance of the panels relative to the regional fishery and impacts of other regulations can be assessed.

Findings to Date: The first two years of data do not support the hypothesis that commercial fishermen displaced from the Western Sambo ER suffered short-term financial losses. The Western Sambo ER panel members' net earnings increased more than the general commercial fishermen's panel earnings. However, one caveat is that first-year earnings were depressed by a hurricane that led to significant losses of traps. Data from the third year will be available soon. For the Tortugas panel, we have three years of baseline data prior to implementation of "no take" regulations for the Tortugas Ecological Reserve on July 1, 2001. Fourth year data collection is also underway.

Project Title: **Monitoring of Sanctuary Use Patterns, and Market and Nonmarket Economic Values of Sanctuary Resources**

Researchers: Bob Leeworthy and Peter Wiley, NOAA/NOS/Special Projects, Silver Spring, MD; Grace Johns, Hazen and Sawyer, Hollywood, FL; Frederick Bell, Dept. of Economics, Florida State University, Tallahassee, FL; and Mark Bonn, School of Business, Florida State University, Tallahassee, FL.

Goals: The goal of this project is to demonstrate the linkage between the economy and the environment of the Florida Keys. We also seek to develop the necessary information to support public and private investments in protecting and restoring the environment.

Methods: Survey research is conducted on residents and visitors to the Florida Keys National Marine Sanctuary (FKNMS) to gather information on use estimates and type of use; user perceptions of 25 natural resource attributes, facilities, and services as measured by importance/satisfaction ratings (1 to 5 point scales); spending in the local economy; Net Economic User Value (nonmarket economic value or consumer's surplus); and, use estimates of the Sanctuary Preservation Areas (SPAs) and Ecological Reserves. Regional Economic Models are also used to translate spending into market economic impacts, such as sales/output, income, and jobs in the local economy. Travel Cost Models and Contingent Valuation are used to estimate nonmarket economic values (consumer's surplus). Standard statistical tests have been applied to some measures to compare Importance/Satisfaction and Importance/Performance Analysis for the years 1995-1996 and 2000-2001.

Findings to Date: Data from the 2000-2001 study was recently obtained and will be used to establish baseline use estimates of the SPAs and Ecological Reserves, and will support comparisons of Importance/Satisfaction Ratings on 25 natural resource attributes, facilities and services between 1995-1996 and 2000-2001. These results will be available in early 2002.

For boating residents and visitors that used either artificial or natural reefs, we have completed estimates of use and market and nonmarket economic values of reef use by type of reef (artificial and natural). In addition, we have developed estimates of use by all visitors to the Florida Keys, including non-reef users. Estimates of market economic values for non-reef using visitors have not yet been developed, but we expect this to be completed by mid-2002. Comparisons can then be made with the 1995-1996 study.

Project Title: **Monitoring Use Patterns Surrounding Sites for New Artificial Reefs**

Researchers: Robert Smith, Florida Keys Community College, Key West, FL; Thomas Maher, Marine Habitats, Inc., Tallahassee, FL; and Bob Leeworthy, NOAA/NOS/Special Projects, Silver Spring, MD.

Goals: There are two goals for this project; the first is to test the hypothesis that introducing a new artificial reef in a natural reef environment will reduce usage on the surrounding natural reefs. The second is to assess whether methods of estimating total use can be extended to implement affordable yet reliable monitoring of use in the Sanctuary Preservation Areas and Ecological Reserves.

Methods: The first test case for this project is the *U.S.S. Hoyt S. Vandenberg*, a vessel scheduled to be scuttled as an artificial reef in the Key West region of the Florida Keys National Marine Sanctuary (FKNMS). One year of pre-sinking and one year of post-sinking use information is being gathered through censuses of dive operator logbooks. Samples of on-site usage stratified by type of reef (artificial and natural), season (summer and winter), and type of day (weekday, weekend and holidays) are also collected. Types of users are identified by type of boat access (charter/party versus private/rental) and type of activity (SCUBA diving, snorkeling, glass-bottom boat viewing, fishing). Whether mooring buoys, anchoring or drifting are employed is noted. On-site samples are used to estimate the ratio of charter/party users to private/rental boat users. This ratio can then be used to extrapolate the dive operator logbook use estimates to population estimates. An Analysis of Variance method will be used to test for changes in use on surrounding natural reefs pre-sinking versus post-sinking. In addition, weather data is being gathered and a weather model is being considered for estimating use. Simple extrapolation from sample days to non-sampled days will be supplemented with a weather model to predict true zero use days.

The second test case for this project is the *Spiegel Grove*, scheduled to be scuttled in the Key Largo region of the FKNMS as an artificial reef. This phase of the study has more limited pre-sinking data from on-site observations because of a late start to the project. However, historical dive logbook data will help in this regard. The methods outlined above for the *U.S.S. Hoyt S. Vandenberg* study will also be used for *Spiegel Grove* monitoring.

Findings to Date: Both projects are underway, gathering pre-sinking data. Local dive businesses have been extremely cooperative thus far; therefore, we believe we will have a thorough census of dive logbook data.