## Executive Summary

### Circulation and Exchange of Florida Bay and South Florida Coastal Waters

The coastal ecosystem of South Florida is comprised of distinct marine environments. Circulation of surface waters and exchange processes, which respond to both local and regional forcings, interconnect different coastal environments. In addition, re-circulating current systems within the South Florida coastal ecosystem such as the Tortugas Gyre contribute to retention of locally spawned larvae.

Variability in salinity, chlorophyll, and light transmittance occurs on a wide range of temporal and spatial scales, in response to both natural forcing, such as seasonal precipitation and evaporation and interannual "El Niño" climate signals, and anthropogenic forcing, such as water management practices in south Florida. The full time series of surface property maps are posted at *www.aoml.noaa.gov/sfp*.

Regional surface circulation patterns, shown by satellite-tracked surface drifters, respond to large-scale forcing such as wind variability and sea level slopes. Recent patterns include slow flow from near the mouth of the Shark River to the Lower Keys, rapid flow from the Tortugas to the shelf of the Carolinas, and flow from the Tortugas around the Tortugas Gyre and out of the Florida Straits.

The Southwest Florida Shelf and the Atlantic side of the Florida Keys coastal zone are directly connected by passages between the islands of the Middle and Lower Keys. Movement of water between these regions depends on a combination of local wind-forced currents and gravity-driven transports through the passages, produced by cross-Key sea level differences on time scales of several days to weeks, which arise because of differences in physical characteristics (shape, orientation, and depth) of the shelf on either side of the Keys. A southeastward mean flow transports water from western Florida Bay, which undergoes large variations in water quality, to the reef tract.

Adequate sampling of oceanographic events requires both the capability of near real-time recognition of these events, and the flexibility to rapidly stage targeted field sampling. Capacity to respond to events is increasing, as demonstrated by investigations of the 2002 "blackwater" event and a 2003 entrainment of Mississippi River water to the Tortugas.

### Water Quality, Seagrass, Coral Reef, and Episodic Event Monitoring

Results from the Water Quality Monitoring Project, an element of the Water Quality Protection Program (WQPP; http://ocean.floridamarine.org/fknms_wqpp/), indicate that overall nutrient concentrations were greatest in waters on the Gulf of Mexico side of the Keys and lowest on the Atlantic side along the reef tract and in the Tortugas region. Inshore waters differed from reef tract waters mainly by having higher concentrations of nitrate. Inshore waters of the less-inhabited Upper Keys exhibited lower nitrate concentrations than the Middle and Lower Keys. Interestingly, inshore waters in the Tortugas area were similar to those of reef tract sites off the less-inhabited Upper Keys. Essentially, there was no elevation of nitrate in the inshore waters of the Tortugas, supporting the suggestion that the source of nitrate in the Keys is shoreline development.

Waters on the Gulf side of the Keys exhibited the highest total phosphorus concentrations and turbidity. Waters on the north side of the "Backcountry," extending west over the northern Marquesas Keys, exhibited the highest chlorophyll *a* concentrations. This area is most heavily influenced by advection of Southwest Florida Shelf waters.

Trends may be perceived as local when they occur regionally but at more-damped amplitudes. This spatial autocorrelation in water quality is a property of highly interconnected systems such as coastal ecosystems driven by similar hydrological and climatological forcings. There have been large changes in water quality over time, but no sustained monotonic trends have been observed. It is important to keep in mind that trend analysis is limited to the window of observation; trends may change with additional data collection. Rather than thinking of water quality monitoring as a static, non-scientific pursuit it should be viewed as a tool for answering management questions and developing new scientific hypotheses. Data from the FKNMS are integrated with other parts of a South Florida water quality monitoring network (http://serc.fiu.edu/wqmnetwork/).

Florida Bay Watch was a volunteer-driven program managed by The Nature Conservancy (TNC) in which volunteers were trained in basic methods of sampling water quality for one or more Florida Bay Watch projects (Nearshore Fixed Stations, Content Keys, and Key West Salt Ponds during this phase of the program). The Nearshore Fixed Stations project occurred at various locations along the Keys between 1994 and 2002; there were 8,510 sampling events for which five parameters were analyzed: temperature, salinity, total nitrogen (TN), total phosphorus (TP), and chlorophyll *a* (Chl. A). All five parameters were significantly greater during the wet season than during the dry season. Salinity was significantly greater for oceanside stations, while samples collected from the bayside were significantly greater for TN, TP, and Chl. A. There was no significant difference between oceanside and bayside temperatures. Temperature, TN, and Chl. A levels were significantly higher along developed shorelines (canals/boat basins) compared to natural shorelines. Temperature values were similar for all three regions of the Keys, as were salinity and TP. The Upper Keys had the highest TN and Chl. A levels.

Sampling at the Content Keys occurred from 1997 until 2000 near the surface and bottom (approximately 6 m depth). Salinity was significantly higher for samples collected near the surface, while TN, TP and Chl. A levels were significantly higher for samples collected at depth. Sampling at the Salt Ponds occurred from 2001 until 2002. Average temperature, salinity, and TN were all higher in the Salt Ponds than at Lower Keys nearshore fixed stations as expected because of the shallow depth of the Salt Ponds. The source of elevated TN may have been from stormwater, wastewater, or natural inputs such as bird droppings.

Florida Keys Watch was a canal water quality monitoring program, managed by TNC, designed to assess levels of bacterial and human-borne viral contamination in 17 canals throughout the Florida Keys. Every two weeks, a team of two volunteers and TNC staff collected environmental data and water samples from all 17 stations. Sampling also occurred following episodic events, such as a heavy rainfall. No stations exceeded the EPA recommended enterococcus maximum (104 CFU/100 ml) for samples collected following "no rainfall," while 59% of these stations exceeded the limit following a rainfall. Analysis of samples collected after there had been no rain event revealed that 12 stations were deemed acceptable by Florida Healthy Beaches standards, five stations were moderate, and no station was poor. Samples collected after heavy rain events

revealed that only three stations were deemed acceptable, four stations were moderate, and 10 stations were poor. The average dissolved oxygen level in the series of canals was determined to be 3.52 mg/l, which fell below the acceptable limit of 4.0 mg/l.

Seagrass monitoring, another component of the WQPP, is designed to determine the distribution and quantitative status of seagrasses within the Sanctuary, quantify seagrass primary production, define baseline conditions for seagrass communities, determine relationships between water quality and seagrass status, and detect trends in the distribution and status of seagrass communities. The spatial pattern of seagrass variation and agreement of these changes with model predictions of nutrient-induced modifications of the system suggest a regional-scale change in nutrient availability. Nevertheless, it appears that there have not been large-scale trends in abundance of dominant plants over the past seven years, even though increases in macroalgal abundance have occurred at several sites, consistent with an increase in nutrient availability. There have been long-term shifts in the N:P ratio in seagrass leaves, which also indicate increases in nutrient availability. It is noteworthy that these sites were relatively close to shore in the Middle and Lower Keys.

The seagrass bed that carpets 80% of the Sanctuary is part of the largest documented contiguous seagrass bed on earth, and it is vital for the ecological health of the marine ecosystem of South Florida (http://www.fiu.edu/~seagrass/). Seagrasses were completely lost at 3 of 30 permanent sites during recent hurricanes; benthic communities were relatively stable at the remaining 27 sites. The response of seagrasses to eutrophication may be on the order of decades, so long-term monitoring and further research clearly are continuing needs.

The Coral Reef Evaluation and Monitoring Project (CREMP), the third monitoring project of the WQPP (http://www.floridamarine.org/features/category_sub.asp?id=2360), documented a decline in species richness for all habitat types from 1996 to 2002. Overall, the number of stations containing diseased coral, the number of coral species with disease, and the different types of observed diseases all increased. Black band disease peaked in 1998, while “white” and “other diseases” generally have increased over the past six years, other than a dip in the number of affected stations in 2000. Between 1996 and 2002, a 38% decline in stony coral cover was observed Sanctuary-wide. However, changes between 1999 and 2002 were not statistically significant. The significant declines in coral cover observed from 1997 to 1998 (11.4% to 9.6%) and from 1998 to 1999 (9.6% to 7.4%) were concurrent with a severe mass bleaching event and strong storms including Hurricane Georges in 1998. Sanctuary-wide, in 2002, the benthic community at CREMP sites was composed of 66.8% substrate, 11.0% octocoral, 9.3% macroalgae, 7.5% stony coral, 2.5% sponge, 2.2% zoanthids, and 0.6% seagrass. The six coral species with the greatest mean percent cover Sanctuary-wide in 1996 were *Montastraea annularis*, *M. cavernosa*, *Acropora palmata*, *Siderastrea siderea*, *Millepora complanata*, and *Porites astreoides*. *Acropora palmata* (elkhorn coral) is well recognized as a primary framework species. Striking changes were documented for this species as well as *A. cervicornis* (staghorn coral) and *Millepora complanata*, a once-dominant species of fire coral. The mean percent cover of *A. palmata* decreased 91% from 1.1% in 1996 to 0.1% in 2002. Between 1996 and 2002 percent cover of *A. cervicornis* decreased 94%, from 0.20% to a barely detectable 0.01%. Also, between 1996 and 2002 percent cover of *M. complanata* declined from 1% to 0.03%.

The decline in coral cover observed on Florida reefs is similar to declines reported for reefs elsewhere in the Caribbean and Gulf of Mexico. It is important to note that declines in coral cover and numbers of species are not necessarily a recent phenomenon and are likely the result of multiple, chronic, and acute stressors acting at local, regional, and global scales over long periods. The comprehensive monitoring data set on stony coral cover, species richness, bleaching, disease, bioeroders, temperature, fate tracking, human enteroviruses, and abundance will assist in development of landscape-seascape program models to characterize physical, chemical, and biological stressors. These data will also assist managers in determining potential downstream effects of Everglades restoration.

The Marine Ecosystem Event Response and Assessment (MEERA) Project continued to log hundreds of observations reported by researchers, State and Federal personnel, and residents, as well as fishers and divers (http://www.mote.org/research/trl/MEERA.phtml). These mainly included reports of algal blooms and discolored water, sea turtle strandings, coral disease and bleaching, and fish disease or fish kills as well as various mortality events, invasive species, and a range of unusual observations. Response efforts included the collection, analysis, and shipping of samples; photo-documentation of reports or events; and providing assistance or logistical support for other researchers and organizations.

**Marine Zone Monitoring Program**

Coral reef community structure and coral population dynamics have been monitored and compared between three Fully Protected Marine Zones (FPMZs) and adjacent reference sites since 1998; a fourth pair of sites was added to the study in 2002. Coral cover remained consistently different between sites from 1998 to 2002. As in previous years, the Western Sambo Ecological Reserve (ER) shallow site exhibited considerably higher cover than the other shallow sites. The cover of encrusting octocorals increased at all shallow and deep sites from 2000 to 2001, and this trend continued at most sites from 2001 to 2002. The cover of sponges also increased from 2001 to 2002 at all shallow sites.

There appear to be very few indications that FPMZs have higher coral recruitment than adjacent reference sites. Shallow sites in both the Lower and Upper Keys have had nearly uniform recruitment rates of three to five new colonies/$m^2$/yr, with the exception of the Western Sambo ER shallow site, which has had recruitment of about 10 colonies/$m^2$/yr since 2000. The overall impression is that recruitment is highly site-specific, with an indication of higher recruitment at Lower Keys deep sites. Differences in patterns of larval settlement in the Upper and Lower Keys may indicate differences in larval supply to these regions.

Juvenile coral mortality rates are generally more consistent (20 to 40% per year) across sites and depths with little distinction between FPMZs and reference sites since 1999; no distinctions appear between the Lower and Upper Keys sites. This might indicate that factors that contribute to juvenile coral mortality are more uniformly distributed along the Florida Reef Tract than the factors that promote recruitment. However we lack any data with regard to these potential agents of coral mortality.

Very few of the massive framework-building species have recruited successfully, if at all. The fact that other broadcasting species are more successful indicates that water column processes are not limiting factors. Patterns of mortality in the marked juvenile corals did not show strong

differences between species, within years, or across depths. Also, there do not appear to be differences in mortality rates between FPMZs and reference sites.

Efforts by the NOAA National Undersea Research Center/University of North Carolina at Wilmington (NURC/UNCW) Rapid Ecological Assessment program consisted of a summer 2002 benthic coral reef sampling in the Florida Keys, which was partnered with a Keys-wide cruise of reef fishes and spiny lobster, focusing on hard-bottom and coral reef habitats from Biscayne National Park to the Tortugas region. The primary focus of the 2002 fieldwork was to obtain information on community structure and condition of reef benthos at 15-21 m depth (fore reef) along the Florida Reef Tract to compare to similar studies carried out in 1995. The fieldwork also served to supplement existing data sets on the status of reef and hard-bottom communities in Biscayne National Park, the Florida Keys, and Tortugas region. The 2002 sampling represents the fifth consecutive year of large-scale surveys of hard-bottom and coral reef habitats conducted by NURC/UNCW.

In addition to the deeper fore reef sites, the 2002 work also included patch reef, hard-bottom, and reef terrace communities offshore of Biscayne Bay, the Florida Keys, and in the Dry Tortugas. The 2002 field effort complemented Keys-wide benthic surveys of 80 sites during 1999, 45 sites across the continental shelf in the lower Florida Keys region during 2000, 86 sites Keys-wide during 2001, and 60 sites sampled in the Tortugas region during 1999-2000. During 2002, 64 sites were sampled from Biscayne National Park to the Tortugas. The deeper reef focus in 2002 was designed specifically to compare with results obtained in 1995 during a previous Keys-wide expedition. During 2002, three of the Sanctuary's 24 FPMZs were visited, with 10 additional sites surveyed just seaward of the zone boundaries in deeper water and habitats similar to sites surveyed during 1995. Benthic surveys by the NURC/UNCW project team were complemented by reef fish surveys conducted by personnel from the Rosenstiel School of Marine and Atmospheric Science (RSMAS) of the University of Miami and NOAA National Marine Fisheries Service (NMFS).

Variables measured during 2002 were similar to those sampled in previous years, namely coverage, species richness, gorgonian density, coral density and size, and coral condition. Several variables were included at some sites that were sampled during the 2001 assessment: urchin density and size; density of anemones, corallimorpharians, opisthobranch mollusks, cleaner shrimps, spiny lobster, and arrow crabs, as well as in situ measurements of topographic complexity. Several hundred underwater digital photographs were taken to further develop an archive of Florida Keys reef and hard-bottom habitats and tools for taxonomic identification of benthic invertebrates.

Key findings of the NURC/UNCW Rapid Ecological Assessment program include:

- Similar to earlier expeditions, offshore patch reefs exhibited some of the highest coral cover in the Biscayne and Florida Keys regions, ranging from 4% to nearly 28%.
- High-relief spur and groove and reef terrace habitats exhibited the highest coral cover in the Tortugas region and reef terraces exhibited the highest coral cover among all sites surveyed in 2002, ranging from 12% to 51%.

- Surprisingly, coral cover did not tend to be greater within FPMZs, contrasting with 2001 surveys of high-relief spur and groove reefs, when sites within FPMZs tended to have greater coral cover than adjacent reference sites.
- Among the four regions surveyed in low-relief spur and groove habitat, coral cover was greatest in the Dry Tortugas (20.3%), followed by the Middle Keys (7.4%), the Lower Keys (6.8%), and the Upper Keys (3%), the latter including sites east of Biscayne Bay.
- The pattern on deeper spur and groove reefs was opposite to that observed for shallower spur and groove reefs during 2001, when reefs in the Upper and Lower Keys yielded the greatest coral cover.
- A total of 46 coral, 33 gorgonian, and 80 sponge species were found.
- From Biscayne to the Lower Keys, gorgonian densities were generally similar among habitats, regions, and management protection. Scleractinian coral densities were more variable and displayed some patterns among habitats and regions.
- Similar to results from 1999-2001, all of the sampling locations yielded very low densities of urchins, particularly the long-spined sea urchin *Diadema antillarum*. Some locations had relatively high densities of other species, particularly the reef urchin *Echinometra viridis*.

Since no-take protection was initiated in 1997, significant density increases were observed by the NMFS/RSMAS team for several exploited reef fish species in FPMZs compared to fished reference areas. Among exploited species, mean densities were higher in FPMZs for Gray Snapper, Black Grouper, and Yellowtail Snapper. Concordance between FPMZs and reference areas was observed for changes in density for Stoplight Parrotfish and Striped Parrotfish, two species not directly exploited. The passage of Hurricane Georges (a strong hurricane) and Mitch (a weak hurricane) in the fall of 1998 resulted in declines of mean density at both fished and unfished sites in 1999 for the two non-exploited parrotfishes and Gray Snapper. No detrimental impacts on fish densities were noted following the passage of Hurricane Irene, a weak hurricane that passed over the Lower Keys in the fall of 1999.

Roving diver surveys by the Reef Environmental Education Foundation (REEF) Advanced Assessment Team show that black grouper has exhibited a significant increase throughout the Florida Keys between 1994 and 2002. In general, since sites were protected in 1997, black grouper have been seen with higher frequency in FPMZs than in reference areas. These findings are consistent with those of the NMFS/RSMAS team, summarized above. Nassau grouper, a protected species in Florida, has shown slight increases over time and in 2002 reached an all time high, since REEF data collection began, of 22% sighting frequency at FPMZs. Red grouper, a relatively rare species, had increased at many sites in 1999 and 2000, but sighting frequency has decreased over the last two years. The average abundances of four carnivore species (gray snapper, yellowtail snapper, schoolmaster, and hogfish) showed little difference between fully protected and reference sites. A dramatic decline in rock beauty has been seen, while other angelfish populations have remained relatively stable. This decline was associated with decreasing collections for the aquarium trade in recent years.

In 1997, investigators with the Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute (FWRI) found little difference between the number of spiny lobsters (*Panulirus argus*) inside FPMZs and reference areas, but after five years of protection there were almost twice as many lobsters inside three Lower Keys FPMZs as outside. There usually were

more lobsters in FPMZs than in reference areas during the closed fishing season, and the number of lobsters observed in reference areas always decreased dramatically during the fishing season. Since 1999, abundance of legal-sized lobsters has always been greater in two of the three FPMZs than in reference areas; however, legal-sized lobster abundance was not higher in the Looe Key Sanctuary Preservation Area (SPA) than in its reference area despite the fact that Looe Key has been a lobster reserve since 1981. This may reflect the small size of the SPA compared to the home range of lobsters denning inside it. In general, mean lobster size was below the legal limit in FPMZs and reference areas in 1997. Since implementation of marine zoning in 1997, mean lobster size in FPMZs has been larger than legal size and comparatively larger than in reference areas. Mean size of male lobsters on offshore patch reefs in the Western Sambo Ecological Reserve has increased 10 mm in five years. Abundance of very large lobsters ($\geq$100 mm carapace length) increased in the Western Sambo reserve relative to its reference area with males becoming larger as well as more abundant, suggesting that some lobsters remain in the ecological reserve for an extended period.

Queen conch (*Strombus gigas*) have been protected by State law from collection for approximately 20 years. Monitoring by FWRI staff shows that conch are distributed in well-defined aggregations that are not entirely encompassed by FPMZs, with the majority of adult conch in the Lower Keys (estimated abundance of 23,640, about 77% of the total). Over 5,000 and over 1,500 adults occurred in the Upper and Middle Keys, respectively. By contrast, juvenile conch were more evenly distributed, with the majority in the Upper Keys (estimated abundance 15,337, about 45%) and Lower Keys (12,322, 36%); about 6,400 juveniles were found in the Middle Keys. Since 1997, the total adult conch population has grown by about 46%, while juvenile abundance has increased by about 240%. From 2000 to 2001, a large amount of recruitment of juvenile conch occurred throughout the Keys. The results of the sixth year of queen conch monitoring support those of earlier years: conch are recovering, albeit slowly.

**Socioeconomic Research and Monitoring Program**

The goals of the project, "Importance and Satisfaction Ratings, A Five-Year Comparison (1995-96 to 2000-01," are to monitor and assess knowledge, attitudes, and perceptions of Sanctuary management strategies and regulations. This project monitors and assesses perceptions of the conditions of 25 natural resource attributes, facilities, and services by both residents of Monroe County and visitors to Monroe County and the FKNMS. Results show that many key natural resource attributes, facilities, and services have increased in importance to people, while satisfaction with these natural resource attributes, facilities, and services has declined. Plugging these results into a conceptual model linking the economy and environment leads to potentially dire predictions of the future natural resource-based economy if actions are not taken to reverse these trends.

Another possible consequence of negative trends in satisfaction is the cost of attracting and educating "new" visitors. The results of this project show that for many natural resource attributes, facilities, and services, satisfaction ratings are not only in decline, they are also relatively lower for more-experienced visitors. The loss of repeat visitors raises the marketing costs of attracting "new" visitors and raises the costs of educating "new" visitors on how to interact with the areas' natural resources and support sustainable tourism.

A second project, "Linking Ecological and Socioeconomic Monitoring Results, 1995-96 to 2000-01," had the goal of testing whether user perceptions of resource conditions are in agreement with what marine scientists are observing in actual conditions. There were both agreements and disagreements between user perceptions and scientific findings. Areas of disagreement may indicate needs for further efforts in education and outreach. In some cases, residents and visitors differed in their perceptions relative to scientific findings. When users perceive and scientists measure declines in natural resources, there is economic justification to make investments to solve these problems before they translate into economic losses.

A third project, "Sanctuary Preservation Areas and Ecological Reserves: Monroe County Reef-Using Residents' Opinions on 'No-Take' Zones," utilized a stratified-random sample of registered boaters with responses from nearly 600 boat users in Monroe County/FKNMS. An overwhelming majority of all reef users (78%) and recreational fishers (76%) supported the currently designed no-take zones. In contrast to expectations, results did not support a "Not In My Backyard" hypothesis; Monroe County residents were generally not in support of no-take zones in the three counties to the north, while supporting the creation of additional no-take zones in the FKNMS. Using a conservative measure, residents using Sanctuary Preservation Areas (SPAs) and Ecological Reserves (ERs) would support having 25% or more of coral reefs protected in no-take zones; non-users would support 20% or more. The current level of protection of coral reefs is 10% (6% protection across all habitats).

A fourth project is monitoring the spatial pattern and intensity of on-water recreational use, especially with regard to activities inside SPAs and ERs. Another major objective is to monitor and assess visitor and resident knowledge of Sanctuary management strategies and regulations, and their attitudes and perceptions regarding their appropriateness and effectiveness. This project established 2000-01 baselines of SPA and ER use, economic user value, and user perceptions of conditions of SPAs and ERs. A majority of resident reef users used SPAs and/or ERs (58%), compared to 44% of visitors; 16% of visitors did not know whether they had used a SPA or ER. There were almost 1.2-million person days of snorkeling and scuba diving in SPAs and ERs, nearly evenly split between residents and visitors. This project includes detailed analyses using socioeconomic profiles of users and comparative importance-satisfaction ratings. It appears that visitors already perceive SPAs and ERs as relatively higher quality areas in contrast to residents, who do not.

A fifth project seeks to determine the economic valuation of marine reserves based on diver attitudes and preferences, from late 2002 until early 2004. Preliminary results indicate that users value marine reserves and multiple-use dive sites as centers of marine resource management and recreation. Findings also demonstrate that respondents generally view all dive sites favorably, in terms of their ecological and social conditions, suggesting the efficacy of local area management, as it relates to this user group. Finally, most divers and snorkelers report congruence between expected conditions and personal experiences, which may explain the high trip satisfaction ratings.

The socioeconomic monitoring program of commercial fishing panels focuses on the commercial fishing industry in the Florida Keys, effects of FKNMS regulations on commercial fisheries, and additional impacts to the local economy. Information collected in the first five years suggests

that harvest totals and net earnings increased or remained stable in the first three years but declined in the fourth year with some recovery in the most recently surveyed year (2001-2002). Importantly, the information collected suggests that extra-Sanctuary factors may contribute strongly to interannual fishery harvests and production. Most panel members (94%) do not believe that the fully protected marine zones have increased or replenished stocks in the region, and none of the fishers believes that his group has been the primary beneficiary of the zoning strategy. These statistics are similar to results from a 1995-96 study. As in the 1995-96 study where 78% of commercial fishers interviewed opposed Sanctuary designation, a majority of the respondents (68%) remains against the establishment of the Sanctuary. Nevertheless, fishing is quite prevalent around fully protected marine zones, and many species are fished or collected near the boundaries of these zones.

**Partnership Projects with NOAA National Centers for Coastal Ocean Science**

Since 1999, scientists at the Center for Coastal Environmental Health and Biomolecular Research and several collaborating organizations have been examining corals at the cellular level, using an integrated Cellular Diagnostic System (CDS). The CDS is designed to diagnose whether an organism is stressed and to identify likely stressors. The assay, which measures changes in cellular parameters, quantifies whether the structural integrity of the cell is compromised, the type of stress, and whether defenses have been mounted against a particular stress. Results using this bioassay technique enabled scientists to determine whether a coral population was being stressed by a global stressor such as high sea surface temperatures or by a local stressor such as pesticides. When used in conjunction with other technologies and monitoring methods, this biotechnology was able to identify potential stressors. Data collected on *Montastraea annularis* at four sites supported the possibility that coral cellular damage, measured in 1999, resulted from a global stressor (La Niña sea-surface temperature effects). In contrast, in 2000 patterns of these same parameters were radically different and were not correlated with sea-surface temperatures; instead, stresses on corals noted at two sites originated from local impacts. In addition, information from the CDS can be used to make a prognosis of coral health. Levels in a single biomarker allowed the prediction of whether or not a coral colony would bleach with a 96% probability a full six months prior to the observation of bleaching in the environment.

Scientists at the Center for Coastal Fisheries and Habitat Research (CCFHR) conducted a field experiment to assess the effectiveness of installing fill material encapsulated in biodegradable fabric tubes to restore propeller scars. The experiment was designed to test the efficacy of sediment tubes, alone and in conjunction with bird stakes and *Halodule wrightii* seagrass planting units and to re-grade injuries to enhance regrowth of seagrass from the margins of propeller scars. The major findings of the study were: 1) sediment tubes are a clean and efficient means of deploying fine grained sediments into excavations in seagrass beds; 2) *Halodule wrightii* can be transplanted into sediment tubes; 3) sediment tubes degrade fast enough to allow for growth of seagrass transplants; and 4) sediment tubes do not inhibit *Thalassia testudinum* growth or algal colonization. The investigators recommend that sediment tubes be tested for use in larger blowholes where lateral growth of seagrass into excavated injuries is very slow. By installing bird stakes with sediment tubes and adding *H. wrightii* transplants it may be possible to obtain sediment-stabilizing cover of the faster-growing seagrass within two years, instead of waiting several years or even decades for seagrasses to grow in from the perimeter of a large injury. This approach needs further testing.

In a companion study, scientists at the CCFHR, in partnership with the Florida Fish and Wildlife Conservation Commission used experimental manipulation to assess effects of excavation depth and filling/regrading with carbonate pea rock on seagrass recovery into simulated propeller scars. Results of this study demonstrated that injuries to seagrass banks that exceeded 10 cm in depth had significant impacts on the densities of *Thalassia testudinum* and *Syringodium filiforme*; in some treatments those impacts persisted three years after initiation. In both experiments, *T. testudinum* short-shoot density in all treatments returned to control levels between the second and third year following injury. *Syringodium filiforme* short-shoot densities, however, remained elevated in most deep (> 20 cm) treatments through the end of the experiment. Total macroalgal cover also tended to be lower in more disturbed treatments. Although *T. testudinum* short-shoot densities and treatment depths had returned to pre-injury levels in roughly two to three years, treatments continued to impact *S. filiforme* short-shoot counts and macroalgal cover. Filling of injuries with pea gravel provides protection from erosion, does not inhibit growth of *Thalassia testudinum*, and might minimize stress of competition from *Syringodium filiforme*. The placement of fill into larger blowhole injuries that take decades to recover should diminish the probability of further erosion and enhance recovery by allowing regrowth of seagrasses.

Since 2000, a second team of scientists at the CCFHR has been investigating the refuge effect of the Tortugas Ecological Reserve (TER) by focusing on: 1) an extensive habitat characterization of the benthos in and around the TER, 2) a multiple stable isotope analysis of the food web supporting fish production in the TER, 3) an examination of the abundance and composition of reef fishes in the reserve, and 4) an examination of the effects of trawl exclusion on benthic habitats located in the TER. Analysis of a habitat map is ongoing. The majority of fish analyzed so far exhibit a C isotope signature consistent with a food web based on benthic primary producers. Additional results will help determine whether there is a significant geographic or reserve effect on food webs. Nitrogen isotope values can help to predict potential ecosystem effects of changes in average fish size as the result of no-take regulations. Six fish species (representing the most abundant species in each of six important reef fish families) increased in number and size within the Reserve compared to Dry Tortugas National Park and areas fully open to fishing. Relaxation of trawling pressure has increased benthic biomass and diversity in the Tortugas North ER. It appears that these soft-bottom communities respond quickly to relaxation of the disturbance of trawling and further changes may occur over time with development of a more stable assemblage of attached invertebrates in the more physically stable parts of the shelf.

***Diadema* Restoration Projects**

A *Diadema* restoration project conducted by The Nature Conservancy utilized “corrals” made of nylon mesh deployed around coral heads and stocked with densities of adult urchins approximating pre-die-off densities; unmanipulated coral heads served as reference sites. Corrals stocked with wild urchins quickly displayed a drastic reduction of turf algae; the percentage of corals, sponges, gorgonians, and bare substrate within corrals remained relatively level throughout the duration of the project. Three months after “seeding” with coral larvae, corralled areas contained many more juvenile corals (0.5-1.5 cm) than had been initially surveyed.

A second project was conducted in two parts: translocation of small *Diadema* from unstable rubble habitat to patch reefs (Nedimyer and Moe) and surveys of benthic communities in urchin-

addition treatments and unmanipulated reference sites (Center for Marine Science Research and NOAA's National Undersea Research Center, University of North Carolina at Wilmington). Gradual urchin losses over the year+ term of the project indicated that predation was the main cause of population decline and not mortality due to storms. This part of the study demonstrated that a translocation program of juvenile urchins from rubble zones to reef areas can establish and maintain relatively dense populations of *Diadema* in small reef areas. Translocation could substitute for natural recruitment and maintain a reproductively effective population. Urchin densities on the experimental patch reefs one year after the translocation averaged nearly 1 individual/$m^2$, similar to urchin density estimates in the Florida Keys prior to the 1983-84 mass mortality event. The coverage of stony corals and crustose coralline algae increased, while the coverage of brown foliose algae declined on experimental patch reefs. In contrast, stony coral and crustose coralline algal cover declined on control patch reefs, but increased for brown foliose algae. Juvenile coral densities increased at all sites, but density increases were markedly greater on both experimental sites, reflecting greater densities of smaller juveniles (< 1.5 cm diameter), especially *Porites astreoides* and *Siderastrea siderea*. These results are similar to previous investigations of the effects of artificially enhanced or naturally recovering urchin densities on coral reef benthos, especially as they pertain to changes in algal composition and juvenile coral densities.

**Permitted Research Projects**

This report includes lists of permitted research projects for 2002 (83 projects) and 2003 (57 projects), which show the range of investigators and topics of study in the Florida Keys National Marine Sanctuary.

## Introduction

Florida's coral reef tract is one of the largest bank-barrier reef systems in the world. All but the northernmost reefs lie within the boundaries of the National Oceanic and Atmospheric Administration's (NOAA) Florida Keys National Marine Sanctuary (FKNMS). The 9844-$km^2$ 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, hard-bottom communities, and mangrove shorelines.

The ecologically important marine resources of the Florida Keys are being impacted by a variety of stressors, both natural and human-caused. This is evidenced in a decrease in coral cover and species diversity at most reefs and an increase in coral diseases and bleaching in recent years. Boat groundings, propeller scarring of seagrass, accumulation of debris, and improper anchoring practices have been responsible for thousands of hectares of resource damage. Serial overfishing has dramatically altered reef fish and other exploited populations, contributing to an imbalance in ecological interactions that are critical to ecosystem structure and function. 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 in Florida Bay, which adjoins the Sanctuary.

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 ("no-take") 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 (23 zones) and 2001 (Tortugas Ecological Reserve) 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 ecosystem 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 and evaluation of management strategies using the best available scientific information.

Many groups, including local, state, and federal agencies, public and private universities, environmental organizations, and trained volunteers, conduct monitoring. 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. Comprehensive, long-term monitoring is conducted through the Water Quality Protection Program (WQPP) funded by the U.S. Environmental Protection Agency (EPA), and recently, NOAA, the Florida Department of

Environmental Protection, Monroe County/Tourism Development Council, and the Sanctuary Friends of the Florida Keys. The WQPP began in 1994 and consists of status and trends monitoring of three components: water quality, coral reefs and hard-bottom communities, and seagrasses. Sanctuary-wide status and trends monitoring is designed to detect large-scale ecosystem changes associated with Everglades restoration and other regional-scale phenomena.

The second scale is associated with the Sanctuary's 24 fully protected marine zones, which are monitored through the Marine Zone Monitoring Program (MZMP). 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 benthic community composition and coral population dynamics, abundance and size of fish and invertebrates, and economic and aesthetic values of the Sanctuary to its users and their compliance with regulations. The MZMP includes monitoring changes in ecosystem structure (size and number of invertebrates, fish, corals, and other organisms) and processes (such as coral recruitment and juvenile coral mortality). Human uses and perceptions of zoned areas are also being tracked. In essence, the MZMP is "nested" within Sanctuary-wide status and trends monitoring.

This report presents results from six-seven years of status and trends monitoring under the Water Quality Protection Program and four years of data from the Zone Monitoring Program. It starts with a description of circulation and exchange of South Florida coastal waters. Sanctuary-wide status and trends monitoring of water quality, seagrasses, and coral reef communities are presented next. 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, and spiny lobster and queen conch). Two reports on partnerships between the FKNMS and NOAA National Centers for Coastal Ocean Science address a Cellular Diagnostic System using corals and a study of disturbance and recovery dynamics of seagrass-coral banks. This year's annual report concludes with two studies of wastewater-derived nutrients in Florida Keys ground water. The *Sanctuary Monitoring Report 2000* is also available in downloadable format (.pdf) from the FKNMS website at http://floridakeys.noaa.gov/research_monitoring/welcome.html. We look forward to reporting future years' results and welcome your comments.