The State of Coral Reef Ecosystems of Southeast Florida

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INTRODUCTION AND SETTING

The northern extension of the Florida reef tract and a complex of limestone ridges run parallel to the subtropical Atlantic coastline of southeast Florida. Spanning 170 km from the northern border of Biscayne National Park (BNP) in Miami-Dade County to the St. Lucie Inlet in Martin County, the reefs and hardbottom areas in this region support a rich and diverse biological community (Figure 5.1). Nearshore reef habitats in southeast Florida include hardbottom areas, patch reefs and worm reefs (*Phragmatopoma* spp.) exhibiting abundant octocoral, macroalgae, stony coral and sponge assemblages. Offshore, coral reef associated biotic assemblages occur on linear Holocene *Acropora palmata* mid-shelf and shelf margin reefs that extend from Miami-Dade County to Palm Beach County (Lighty, 1977; Figure 5.2). Anastasia Formation limestone ridges and terraces colonized by reef biota characterize the reefs from Palm Beach County to Martin County (Cooke and Mossom, 1929).

Figure 5.1. A coral reef assemblage in southeast Florida. Photo: D. Gilliam.

The coastal region of southeast Florida is highly developed, containing one third of Florida's population of 16 million people (U.S. Census Bureau, 2006). Many southeast Florida reefs are located just 1.5 km from this urbanized shoreline. Despite their unique position as the highest latitude reefs along the western Atlantic seaboard, the reefs of southeast Florida have only recently received limited scientific and resource management attention. Andrews et al. (2005) discussed the reefs of southeast Florida and the critical need to implement actions that fill resource knowledge gaps and address conservation and threats to reef health. This report further examines and updates the list of stressors imperiling the health of southeast Florida's reefs, and presents information gained from new research, monitoring and management efforts to determine the extent and condition of reef resources in this distinctive region.

1 Florida Department of Environmental Protection
2 Broward County Environmental Protection Department
3 Florida Fish and Wildlife Conservation Commission
4 NOAA, Southeast Fisheries Science Center
5 Ocean Research and Conservation Association
6 Nova Southeastern University Oceanographic Center
7 National Coral Reef Institute
8 Harbor Branch Oceanographic Institute
9 Palm Beach County Environmental Resource Management
10 NOAA, Atlantic Oceanographic and Meteorological Laboratory
11 Lithophyte Research, LLC
12 U.S. Geological Survey
13 The Nature Conservancy

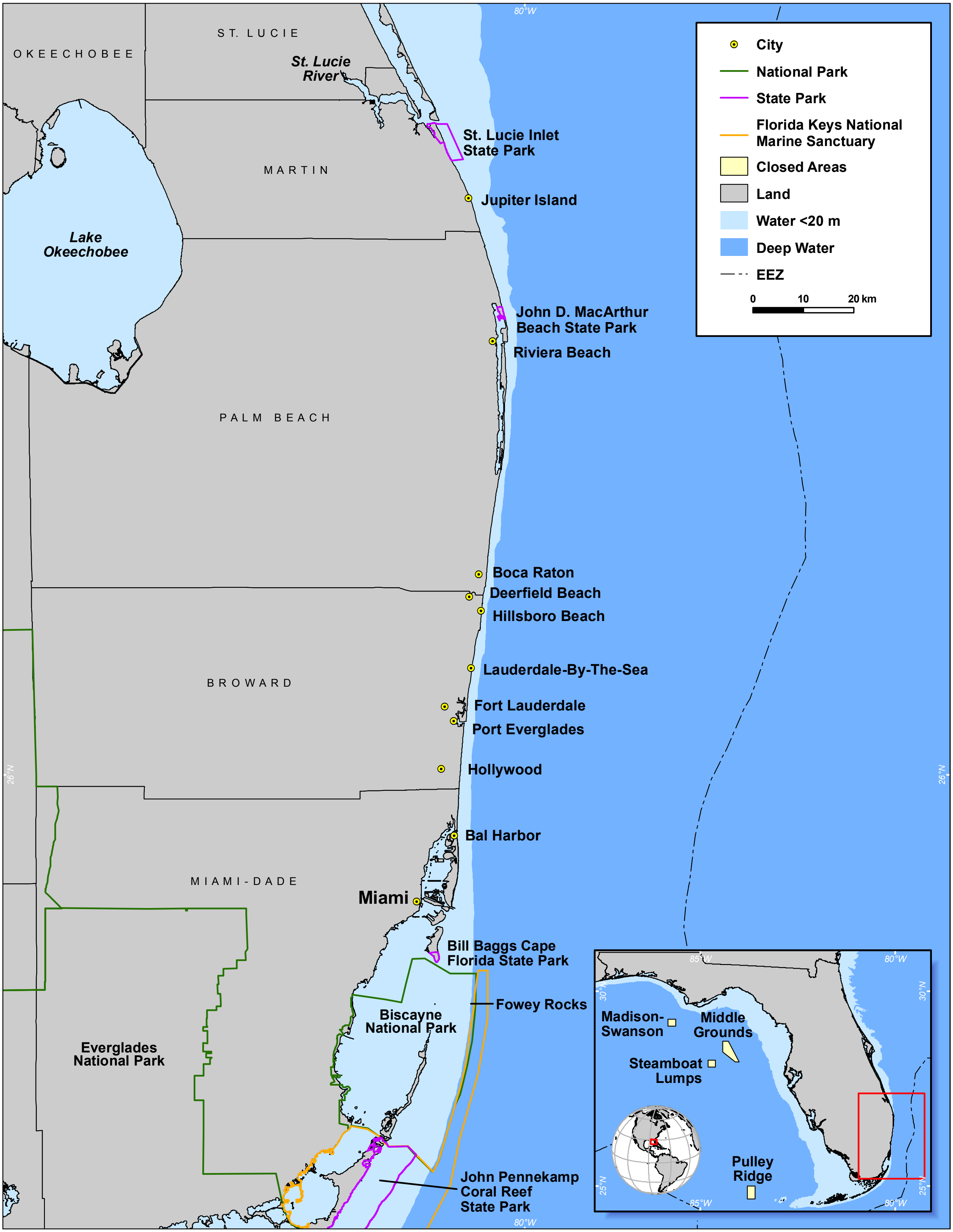

Figure 5.2. A map of southeast Florida showing locations mentioned in this chapter. Inset map shows the location of Pulley Ridge and the Florida Middle Grounds in the Gulf of Mexico. Map: K. Buja.

Pulley Ridge and Middle Grounds

The West Florida Shelf (northeastern Gulf of Mexico) carbonate platform is comprised of extensive hardbottom, ranging from low or moderate-relief rock outcrops and pavement to high-relief pinnacles and ridges. These hard substrates are colonized by sessile macrofauna such as Scleractinian corals, octocorals, black corals and sponges, which provide habitat for biologically diverse communities of invertebrates and fish, including large numbers of economically important reef fish such as snapper and grouper (Figure 5.3). The Gulf of Mexico Fisheries Management Council (GMFMC) recognized their importance by placing some of these features under protective legislation either as Marine Protected Areas (MPA), such as Madison Swanson and Steamboat Lumps, or as Habitat Areas of Particular Concern (HAPC) such as the Florida Middle Grounds (FMG) and Pulley Ridge (Gulf of Mexico and South Atlantic Fishery Management Council, 1982). The latter habitats are both dominated by shallow water coral reef communities, despite their atypical locations, and are described in more detail below.

Figure 5.3. The Florida Middle Grounds benthic community supports numerous species of algae, sponge, hydrocoral, scleractinian coral, invertebrates, long-spined urchin and fish. Photo: G.P. Schmahl.

The FMG are located 137 km off the west coast of Florida and are comprised of a series of carbonate ledges trending north to northwest at shelf depths of 40-45 m, rising up to 15 m relief from the seafloor. At a latitude of 28.50° N, these ledges represent the northern-most coral reefs in the continental United States, and in 1982 the GMFMC designated 348 square nautical miles of the primary high relief and live bottom area a HAPC. Regulations prohibit coral removal (except by special permit) and the use of bottom tending fishing gear (bottom longlines, traps, pots and bottom trawls). These areas were originally surveyed in the mid 1970's (Hopkins et al., 1977), and a resurvey of the same areas in 2003 revealed little or no changes in the sessile benthic community (algae, sponges, octocorals, Scleractinian and Hydrozoan corals); however, grouper and snapper populations have declined significantly (Coleman et al., 2003). Multibeam mapping of portions of the FMG HAPC was completed in 2006.

Pulley Ridge is a rocky feature 1-15 km wide and 1-10 m high in 60-90 m water depth between the FMG and the southern margin of the Florida shelf (Jarrett et al., 2005). This structure provides substrate for reef communities, and the southernmost 30 km of this feature supports the deepest hermatypic coral reef in the United States (Culter et al., 2006). The Pulley Ridge coral reef ecosystem has up to 60% coral cover over broad areas. The dominant zooxanthellate Scleractinia are *Leptoseris cucullata*, *Agaricia lamarcki* and *Agaricia fragilis*. Less common species include *Madracis formosa*, *M. pharensis*, *M. decactis*, *Montastraea cavernosa*, *Porites divaricata*, *Scolymia cubensis* and *Oculina tenella* (Halley et al., 2005). The area was designated an HAPC by the GMFMC in 2005. Gear restrictions and coral protection were enacted to protect the nearly 250 km^2 coral-rich zone. Sporadic remotely-operated vehicle (ROV) surveys since 1999 indicate that coral is generally healthy and there has been no evidence of bleaching or disease. A multi-institutional expedition to Pulley Reef took place in June 2005, and for the first time limited sampling was undertaken by technical divers in 65 m water depth. Samples will verify identifications that to-date have been made primarily from photographs and limited dredged material.

ENVIRONMENTAL AND ANTHROPOGENIC STRESSORS

Climate Change and Coral Bleaching

Climate change related events such as sea level rise and temperature increases may affect coral reefs. Locally or regionally, storm pattern changes may directly impact coral communities, and changes in rainfall may affect sedimentation, salinity, and nutrient and pollutant inputs (Edwards,1995). Data from 1890-2000 indicate a decline in rainfall since the 1960s, and global climate models predict a reduction in precipitation for south Florida that will ultimately decrease the volume of surface runoff (South Florida Water Management District, 1996). This may, in itself, be beneficial to reef biota. For example, Dodge and Helmle (2003) found that salinities lower than normal seawater slowed coral growth rates. However, landscape (urbanization) can influence rainfall (Pielke et al., 1999), so predicting future rainfall levels is complicated by other factors, including water use patterns by an increasing local population.

As a low elevation coastal region, sea level rise is of great concern for southeast Florida. Measured (multi-satellite altimetry) global sea level rise averaged 2.4 mm/yr between 1992-2003 (Trimble et al., 2006). Wanless (1989) reported that since 1932, sea level rise in south Florida has accelerated and more recent rates are 2-4 mm per year. Others estimate probable rates of 15±3 mm/yr over the next century (Buddemeier and Smith,1998). These high rates could directly impact corals by shifting them to a deeper, lower light position in the water column. Southeast Florida's reefs are relict *Acropora palmata* reefs colonized by reef biota and in the short term may not be as sensitive as extant acroporid reefs. However, secondary impacts, such as increased sedimentation and turbidity from flooding and erosion, could degrade water quality and affect reef growth.

Many tropical reefs live near their upper lethal temperature limits (Edwards, 1995). High latitude southeast Florida reefs have likely adapted to lower temperatures, but their ability to adapt to higher temperatures is unknown. El Niño events can cause increases in water temperature on an annual scale, and increases on a longer scale are widely predicted by scientists. In general, exposure for only a few days to temperatures of 3-4°C above normal summer ambient maxima or for several weeks to elevations of only 1-2°C above maxima can cause coral bleaching. Recovery depends on exposure time and magnitude of elevation. Coral bleaching reduces growth and impairs reproduction, and even sub-bleaching temperature rise can affect growth, reproduction and recruitment (Edwards, 1995).

Mass bleaching events similar to those reported in the Caribbean have not been reported off southeast Florida. Yearly monitoring of the reef communities off Broward County since 2000 shows that the mean percentage of bleached (fully bleached, partially bleached and pale) colonies has been <4.5%, with a long-term mean <3% (Gilliam, et al., 2006). A bleaching event affecting *Montastraea cavernosa* and *Diploria clivosa* colonies was noted near the St. Lucie inlet (Martin County) in winter/spring 2006 and may have been due to 14 months of continuous fresh water release from Lake Okeechobee (Jeff Beal, pers. obs.).

Disease

Two ongoing southeast Florida reef monitoring efforts, the Broward County Marine Biological Monitoring Program and the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP), record coral disease presence. Details on both monitoring programs and the results of their work can be found later in this chapter. Although SECREMP has identified coral diseases in three Florida counties (Miami-Dade, Broward and Palm Beach), occurrences are low, with generally less than one diseased colony identified per site (Gilliam, 2006). Since 2000, the Broward County program has documented diseased colony abundance and documented that disease prevalence is <0.5% of the community (Gilliam et al., 2006). The more common stony coral species affected by disease have included *Montastraea cavernosa*, *Siderastrea siderea*, *Solenastrea bournoni* and *Dichocoenia stokesi*. Identified diseases include black band disease, white plague and dark-spots. White band disease has been identified in the *Acropora cervicornis* thickets offshore Broward County (Gilliam, 2006); however, mortality from disease appears to be low (Vargas-Angel et al., 2003). Neither monitoring program collects quantitative data on gorgonian diseases; however, some diseased common sea fan colonies (*Gorgonia ventalina*) and sea plume colonies (*Pseudopterogorgia* spp.) have been noted with mortality caused by the fungus *Aspergillus sydowii*.

Tropical Storms

Significant new observations of the effects of tropical storms on reef environments in Florida have been made in the last decade. The placement of measurement systems within the coastal ocean in order to record environmental parameters prior to, during and after the passage of a storm has yielded new insights into storm effects. Passing storms may vary considerably in intensity, size and rain content. The distance of the storm from a reef is also important; although the eye of a storm may be distant, the region of maximum wind and storm surge could be much closer to the reef of interest.

There are several potential effects associated with passing hurricanes that have the prospective ability to affect reefs. These effects include at least the following: 1) enhanced sediment resuspension; 2) alteration of the surface wave spectrum impinging on the reefs; 3) alteration in both direction and magnitude of the ambient current field; 4) reduction in ambient light; 5) upwelling of cold, nutrient-rich, deeper ocean water; 6) an increase in runoff and water flow through inlets and cuts; and 7) direct mechanical stress on corals and associated benthic organisms.

The Florida Area Coastal Environment (FACE) program had an array of instrumentation placed in coastal waters during the busy hurricane season of 2005 and during the slow hurricane season of 2006. In the 2005 season, the reefs off southeast Florida were affected by hurricanes Katrina, Wilma and Rita. Each of these hurricanes generated significant sediment resuspension and introduced cold, upwelled water to the vicinity of the reefs. Water temperature drops of 5-10°C and more were associated with the storms (Proni, pers., comm.; FACE, unpub. data). Hurricane Wilma traveled from the west to the east over Florida while Katrina and Rita both traveled from the east to the west over Florida (Figure 5.4).

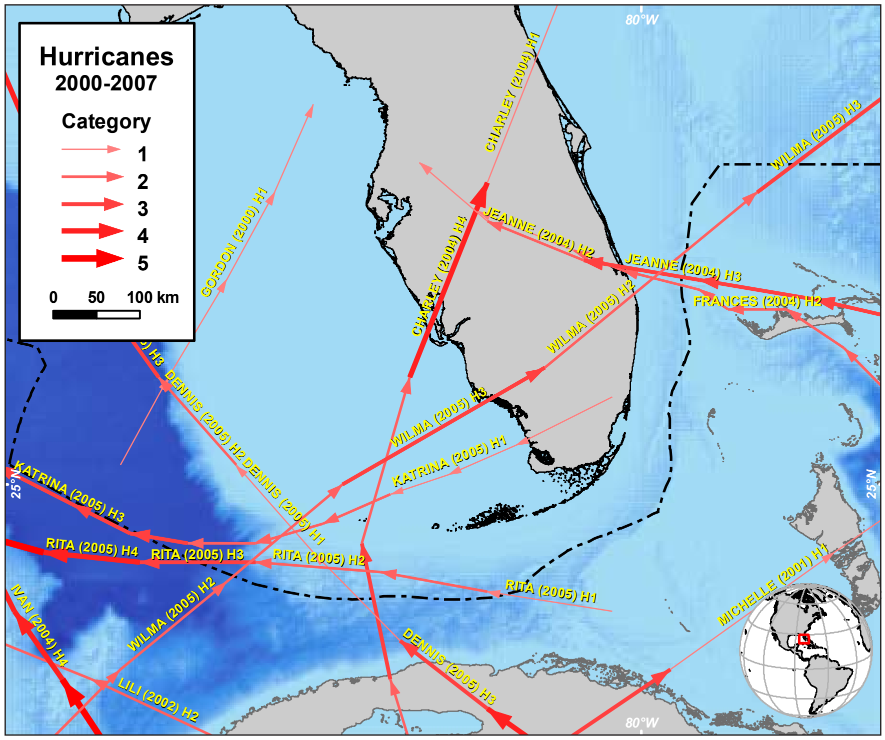

Figure 5.4. The paths and intensities of tropical storms and hurricanes affecting southeast Florida from 2000-2007. Map: K. Buja. Source: http://maps.csc.noaa.gov/hurricanes/.

Figure 5.5 shows an example of data from *in situ* instrumentation including 10 minute average wind speed in meters per second and acoustic backscatter for two frequencies measured between October 21-28, 2005 with a bottom mounted Acoustic Doppler Current Profiler in 17 m of water off Miami. Backscatter measurements can be taken to represent approximate indications of the level of sediment resuspension. The level of backscatter preceding the peak winds of Hurricane Wilma is contrasted with the level after the hurricane passed. Even four days after passage of Hurricane Wilma the backscatter levels had not returned to pre-hurricane passage levels. The extended period of elevated backscatter levels (particularly the 1200 kHz values) is coincident with the presence of long period (16 second) surface waves that radiated from Wilma after it had left the region.

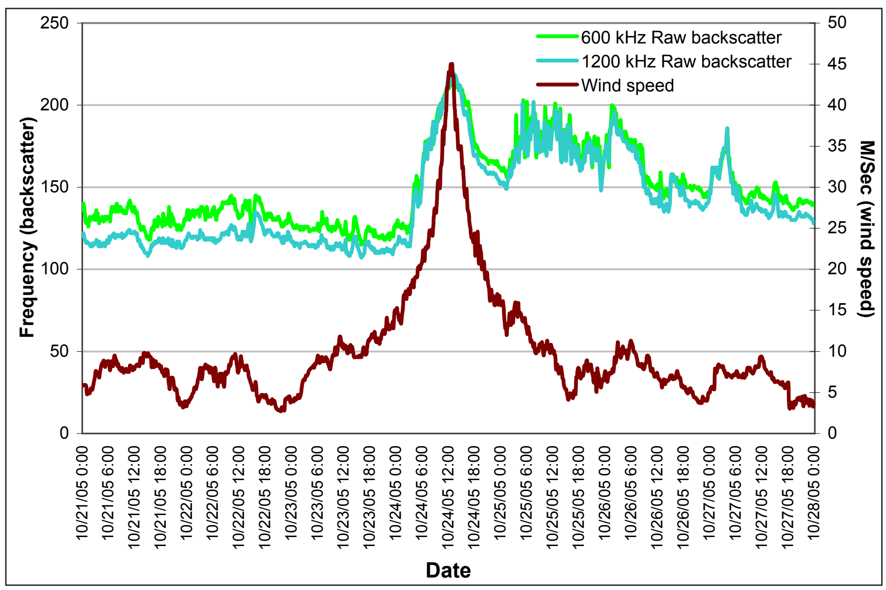

Figure 5.5. Ten minute average wind speeds compared with sediment resuspension acoustical backscatter during Hurricane Wilma of 2005. ***Note****: The data presented in this figure are for research purposes only. They are experimental products created at NOAA-AOML and must undergo additional quality control and other checks before release as official products. Source: NOAA Atlantic Oceanographic and Meteorological Laboratory, unpub. data.*

Coastal Development and Runoff

Coral reefs and related hardbottom communities of southeast Florida are located offshore and in close proximity to one of the most developed and populated areas of the United States. According to Florida Statistical Sources, the population in southeast Florida grew by 139,000 from 2003-2005 (University of Florida, 2006) demonstrating an accelerated trend. Although some development has shifted from the shoreline to 10-25 km inland, it still continues in close proximity of the coastline. Within this area, the population increased by 31-64% from 1990-2002 (U.S. Census Bureau, 2007b). These coastal areas have had continued development in diverse forms such as dredging for navigation, construction of marinas, beach nourishment, geotechnical drilling, and installation of pipelines and cables. Impacts associated with these activities can lower water quality conditions and increase the number of injuries to reef and hardbottom organisms. In addition, as the population increases, damage to coral reefs and hardbottom communities may be attributed to elevated levels of diving, snorkeling and fishing.

According to the Integrated Water Quality Assessment for Florida 2006, poor water quality was found in 50% of the river and stream miles, 60% of the lake acres (excluding Lake Okeechobee) and 60% of the square miles of estuaries (Florida Department of Environmental Protection, 2006). The same assessment states that in spite of Florida's successes in protecting its water resources, there is an alarming trend of increasing levels of phosphorus and nitrogen in surface and ground water. The growth of urban development within southeast Florida has resulted in substantial increases of surface water runoff due to increased impervious areas from construction of homes, roads, parking lots and other structures, which prevent water percolation. As a result, storm water runoff concentrates pollutants generated by an increasing population and channels it to the ocean. It has been suggested that the increased frequency of algal and cyanobacterial blooms on southeast Florida reefs is directly related to the enrichment of phosphorous, nitrogen and other nutrients attributed to terrestrial runoff. Increases in development also add to sewage impacts in nearshore waters as discussed below.

Coastal Pollution

Since the publication of The State of Coral Reef Ecosystems of Florida (Andrews et al., 2005), a number of stressors related to coastal pollution have risen to the forefront. One of the most newsworthy has been the issue of ocean wastewater outfalls and the impacts of wastewater effluent to reefs. There are four methods of effluent disposal in Florida, ocean outfalls, surface discharges, deep well injection and reuse (Trnka et al., 2006). There are six wastewater effluent outfalls in the southeast Florida region, which require secondary treatment of effluent, removing at least 85% of biodegradable organics and suspended solids. Combined, the six outfalls discharge up to 300 million gallons/day of minimally treated wastewater into the Atlantic Ocean (FDEP, unpub. data). The average monthly nutrient loading to coastal waters from these outfalls from 2000-2005 ranged from 1,327 pounds/day to 24,142 pounds/day for total nitrogen and 49 pounds/day to 3,443 pounds/day for total phosphorus (Craig, pers. comm.; FDEP, unpub. data). The large range in loading estimates can be attributed, for the most part, to differences in the average volume of water discharged, on a monthly basis, from the individual plants (Trnka et al., 2006). The fate of these nutrients in the coastal oceanographic setting is unknown but is currently under study by NOAA, as well as investigations aimed at distinguishing natural changes on the reefs from those that can be attributed to anthropogenic causes (NOAA Keynotes, 2006). Tichenor (2004b) reported a correlation between the existence of cyanobacterial blooms in Palm Beach County and an upstream wastewater outfall. Fauth et al. (2006) completed a feasibility study using enzymatic biomarkers to identify stress in *Porites astreoides* around inlets and wastewater outfalls and found that stress responses in the coral around the Hollywood wastewater outfall were consistent with sewage exposure. This project is slated to continue through 2009.

Tourism and Recreation

Tourism and recreation are two of Florida's highest grossing industries, generating a combined $62 billion in sales in 2005. Reef-based tourism and recreation are significant economic assets for the southeast Florida region inclusive of Miami-Dade, Broward, Palm Beach and Martin Counties. Results from two non-concurrent studies of natural and artificial reefs in southeast Florida (Table 5.1) indicate that a total of $2.3 billion in sales and $1.1 billion in income were generated annually from natural reef related expenditures, while supporting more than 36,000 jobs in the region (Johns et al., 2001; Johns et al., 2004). It is estimated that 15.2 million person days are spent on natural reefs in the southeast Florida region annually with primary activities including snorkeling, scuba diving and fishing (Table 5.1). Although a little less than half (7.4 million) of the estimated person days spent on reefs were by visitors, tourists contributed to $1.28 billion in sales, accounting for 72% ($791 million) of the reef-related income generated for the region. The additional high use of coral reefs by residents of southeast Florida is explained by the fact that they lie adjacent to three of the four most populous counties in Florida (U.S. Census Bureau, 2007a), and >20% of all 2005-2006 state recreational saltwater fishing licenses were purchased by residents within these counties.

Table 5.1. Estimate by county of socioeconomic value of recreation and tourism related activities occurring on natural coral reef ecosystems of southeastern Florida. Data for Broward, Miami-Dade, and Palm Beach counties from Johns et al., 2001. Data for Martin County from Johns et al., 2004.

ATTRIBUTE	BROWARD	MIAMI DADE	PALM BEACH	MARTIN	TOTAL
Total Person Days (millions)	5.40	6.30	2.80	0.70	**15.2**
Snorkeling and Diving Person Days (millions)	2.84	2.24	1.68	0.08	**6.84**
Fishing Person Days (millions)	2.58	3.96	1.14	0.45	**8.13**
Sales (millions of $)	1,108	878	354	6	**2,346**
Income (millions of $)	547	419	141	3	**1,110**
Jobs	18,600	12,600	4,500	84	**35,784**

Fishing

Total fishing activity in the southeast Florida region reflects Florida's increasing population. The southeast Florida region accounted for more than 20% of all resident recreational saltwater fishing licenses sold in Florida in 2005-2006. Precise data on fishing effort on coral reefs do not exist, but are reflected by state-wide and regional fishing statistics (Ault et al., 2005). Since 1964, the number of registered recreational boats in the southeast Florida region has grown approximately 350% (Figure 5.6). Although the number of registered vessels actually used for fishing is unknown, the number of recreational saltwater fishing licenses purchased annually in Florida by both residents and non-residents has risen by 25% since 1992 (Figure 5.6; McDevitt, pers. obs.). Florida recreational fishery estimates from 2001-2005 indicate that more than 6.4 million anglers average 27.2 million marine fishing trips annually (NMFS, 2005). In the southeast Florida region alone, two recent (2000-2001, 2003) non-concurrent studies estimate that 6.029 million person days were spent fishing on the natural reefs annually (Johns et al., 2001; Johns et al., 2004). The number of commercial vessel registrations in the southeast Florida region has grown at a lower rate (about a 100% increase) since 1964, but the number of state-issued individual and vessel commercial licenses has been decreasing over the last decade (Figure 5.6; Fish and Wildlife Research Institute, unpub. data). Fishing power (the proportion of stock removed per unit of fishing effort) has probably increased substantially in recent decades because of technological advances in fishing tackle, hydroacoustics (depth sounders and fish finders), navigation (charts and global positioning systems), communications and vessel propulsion (Bohnsack and Ault, 1996; Mace, 1997).

Fishing can impact coral reefs by removing targeted species and by killing non-target species as bycatch, both of which may decrease abundances of important keystone species and cause cascading ecological effects. Several fishing techniques (e.g., trawling and trapping) cause habitat damage and because fishing is often size-selective, concerns exist about the long-term viability of heavily exploited stocks (e.g., groupers and snappers) especially when fishers target spawning aggregations. Fishing stress can be compounded when combined with other stressors such as pollution and habitat damage (Wilkinson, 1996).

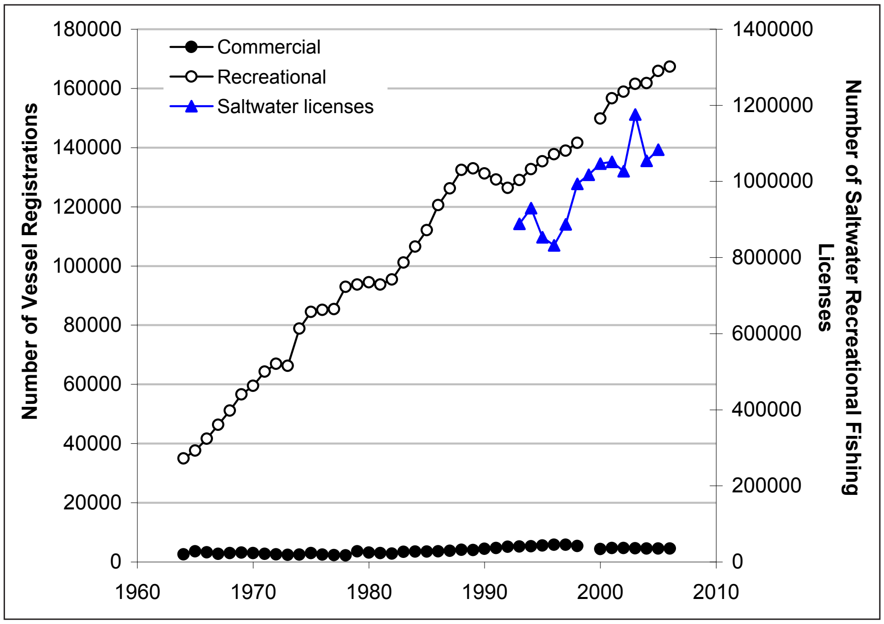

Figure 5.6. The number of commercial and recreational vessel registrations by year for the southeast Florida region. No data were available for 1999. Number of saltwater recreational fishing licenses purchased in Florida, both residential and non-residential, for the period of 1993-2006. Source: Florida Fish and Wildlife Conservation Commission, unpub. data.

Trade in Coral and Live Reef Species

Florida Administrative Code rule 68B-42 and the Federal Fishery Management plan prohibit the removal and possession of wild live rock, coral (hard, stony, fire and black corals), and common and Venus sea fans in state waters and the adjacent Exclusive Economic Zone with few exceptions allowed for research collections. The recreational and commercial collection of wild octocorals (except the two prohibited species of sea fans) and numerous tropical-ornamental reef species is regulated by state and federal fishery management agencies. Several species of coral and seahorses indigenous to Florida are listed as Convention on International Trade in Endangered Species (CITES) species, and their international trade is regulated by the U.S. Fish and Wildlife Service. Few reef species that are indigenous to Florida are used in food, curio or pharmaceutical industries, which significantly decreases their demand in international markets. Florida reef species are primarily utilized in the tropical-ornamental aquarium industry within the United States. Although regulated, the extraction of reef species may still threaten the health of coral reefs because there is a general lack of research and scientific knowledge to support the current management plans, limited enforcement and ecological implications that may extend from over-fishing.

Ships, Boats and Groundings

Impacts from large vessel groundings and anchor or cable drag events can result in immediate and extensive long-term injuries to coral reefs and associated organisms. Vessel hulls, anchors and propellers can fracture and crush coral reef framework (Figure 5.7), scrape the reef substrate, and dislodge corals and sponges, often leading to total loss of all biota (U.S. Coral Reef Task Force, 2000).

The southeast Florida region has experienced a high number of vessel groundings and anchor and cable drag cases over the last 30 years. Most notably, Broward County experienced 11 known ship groundings and six known anchor drag cases from 1994–2006, which resulted in over 11 acres of damaged reef habitat (Figure 5.8; Collier et al., 2007). The majority of these cases have been associated with the Port Everglades anchorage which services cruise ships, cargo vessels and petroleum carriers. Many large commercial carriers use the offshore Port Everglades anchorage while waiting for berths inside the Port. The Port Everglades' anchorage consists of two anchorage areas which are located north of the Port Everglades entrance channel, situated between the second and third reef tracts, and east of the third reef tract, respectively (Figure 5.8). The proximity of the anchorage areas to reefs, coupled with navigational error, has resulted in the high number of groundings in this area. In October 2007, the U.S. Coast Guard issued a Notice of Proposed Rulemaking to eliminate Port Everglades anchorage area A, expand anchorage area B into deeper waters and away from the reefs, and limit the time a vessel may remain in the anchorage. The proposed action was a direct result of recommendations by the Port Everglades Harbor Safety Committee, which includes representatives from federal, state and county agencies, and local maritime and environmental stakeholders.

In addition to damage created by large vessel groundings and improper anchoring, chronic damage caused by anchors from smaller recreational vessels also result in widespread cumulative damage. In 2006, there were over 165,000 recreational boats registered in the southeast Florida region, many of which anchor on the reef to fish, dive, and snorkel (Johnson et al., 2007). Several large-scale marine spectator events held in southeast Florida each year draw thousands of recreational vessels that congregate in relatively small areas and anchor on reefs to observe the events (Bingham, pers. comm.). In March 2007, a 73 ft. motorized catamaran attempted to anchor, partially sank, then ran aground in 6 m of water off northern Miami-Dade County, causing extensive damage to corals and hardbottom habitat. Through the Southeast Florida Coral Reef Initiative (SEFCRI), a document was produced to provide guidance and recommendations for rapid response to, and restoration of, coral reef injuries in southeast Florida (Collier et al., 2007).

Figure 5.7. Divers assess coral injuries from a vessel grounding. Photo: D. Gilliam.

Marine Debris

With increasing anthropogenic pressure on reefs, specifically fishing and diving, reef debris has become an increasing problem. In 2006, during one volunteer waterway cleanup, 446 bait containers, 274 buoys, 920 fishing lines, 404 fishing lures/light sticks and 1,854 pieces of rope were recovered, which represents a third of the categories attributed to boating operations (Ocean Conservancy, 2006). Another cleanup operation estimated fishing line, lures and light sticks as 77.9% of the debris removed during an underwater cleanup (Ocean Conservancy, 2005). Hook-and-line fishing gear accounted for 87% of all debris reported in the Florida Keys responsible for tissue abrasion and causing partial or entire mortality of many benthic organisms, such as branching gorgonians (Chiappone et al., 2005). Since 2005, several debris cleanup events have been conducted within St. Lucie Inlet Preserve State Park in Martin County through partnerships with state agencies, commercial fishermen and a local non-profit organization. During a one-day event, over 300 gallons of debris (mostly netting) were collected (Herren et al., 2007). Derelict nets used to catch bait and Spanish mackerel remain a source of debris in the park and impact corals and other benthic invertebrates.

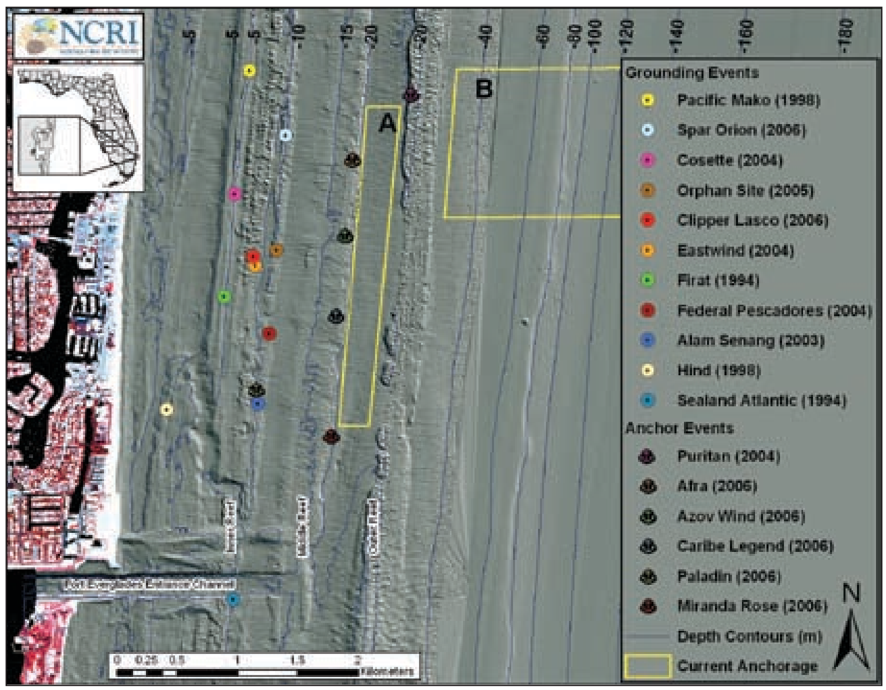

Figure 5.8. U.S. Coast Guard designated anchorages at Port Everglades outlined in yellow, with locations of recent vessel groundings and known anchoring events. Image: B. Walker.

Aquatic Invasive Species

Florida's marine environment has become a haven for many non-indigenous species, particularly those imported for aquaculture, the aquarium trade or introduced by ships from other tropical and sub-tropical regions. Some of these species are ephemeral and do not survive because they are consumed by predators or cannot acclimate to a new habitat. The species that thrive, however, negatively impact reef ecosystems by competing with and displacing native species. Established invasive species in southeast Florida include macroalgae, mollusks, crustaceans, cnidarians and fish.

Macroalgal invasions pose the greatest risk to southeast Florida's coral reefs. Since 1990, a succession of native and non-native macroalgae in the genera *Caulerpa* and *Codium* formed widespread blooms on reefs in Palm Beach and Broward Counties, resulting in mortality of reef biota (Lapointe, 1997; Lapointe et al., 2005a). In 2001, the Pacific species *Caulerpa brachypus f parvifolia* was discovered on reef communities off Riviera Beach (Lapointe et al., 2005b). This invasion expanded northward to Ft. Pierce, forming thick mats that covered up to 90% of reefs in northern Palm Beach County and resulted in loss of biodiversity and fisheries habitat. In August 2004, hurricanes Frances and Jeanne temporarily removed the *C. brachypus* blooms, but the species reestablished itself in winter 2007 (Lapointe et al., 2006). The extent of cyanobacterial blooms on the reefs of Broward County, reported by Paul et al. (2005), has lessened, although they persist at the site studied by Tichenor (2004b) in Palm Beach County. Periodic, short-lived blooms continue to occur offshore of Broward County, however. Land-based nutrient pollution may facilitate the expansion of native and non-native species to levels that cause environmental degradation.

A majority of non-indigenous fish in Florida have been freshwater or freshwater/marine introductions (157), but 21 marine species have been recorded as well. The number of introduced species in Florida has steadily risen each decade (South Florida Information Access, http://sofia.usgs.gov). Two Indo-Pacific lionfishes have established themselves on the east coast of the U.S. (Whitfield et al., 2002; Semmens et al., 2004). Both the Red Lionfish (*Pterois volitans*) and its congener, the Devil Firefish (*P. miles*), have been imported extensively for the aquarium trade and were first observed on local reefs in 2002 (Whitfield et al., 2002). Lionfish were most likely introduced as a result of an aquarium trade release (Semmens et al., 2004) and although they are not abundant on southeastern Florida reefs, they have established large populations on northern U.S. temperate reefs (Whitfield et al., 2007). A list of other exotic reef fishes inhabiting southeast Florida's reefs can be found on the Reef Environmental Education Foundation (REEF) Web site (http://www.reef.org/programs/exotic).

There are at least 60 non-native species of invertebrates that have been reported in the marine and freshwater habitats of Florida. These species belong to the phylla Mollusca (26 species), Crustacea (21 species), Cnidaria (six species), Annelida (three species), Entoprocta (Bryozoa; two species) and Chordata (tunicates; two species). Invertebrate non-indigenous species are often introduced by ship ballast rather than the aquarium trade. The green mussel, *Perna viridis*, is native to the Indo-Pacific but has invaded estuaries on both coasts of Florida, specifically in Tampa Bay and St. Augustine (Baker et al., 2003). Although not necessarily invasive to southeast Florida at present, the Australian spotted jellyfish, *Phyllorhiza punctata*, is cause for concern because a bloom of these jellyfish had a significant economic impact on the shrimp fishery in the Gulf of Mexico in 2000 (Perry et al., 2000). While this outbreak was relatively confined, there is the possibility that future blooms may occur over broad areas and potentially affect fish spawning success because the jellyfish preys on the eggs and larvae of many species (Graham et al., 2003).

For additional information on the status and trends of invasive and non-indigenous species in Florida please visit http://www.ccfhr.noaa.gov, http://nas.er.usgs.gov and http://sofia.usgs.gov. The U.S. Geological Survey's Nonindigenous Aquatic Species Alert System allows the public to report alien species sightings and functions as an early alert system for managers.

Security Training Activities

Military security training activities are not recognized as a threat to coral reefs in southeast Florida.

Offshore Oil and Gas Exploration

There continues to be no oil or gas drilling operations in the state waters of southeast Florida.

Other

Subsea Engineering Projects: Gas Pipelines and Fiber Optic Cables

Installation of fiber optic cables and construction of gas pipelines can have a major impact on coral reefs. Stony corals, gorgonians and sponges can become abraded or dislodged during pipeline installation, increased sedimentation and leaks of drilling mud and lubricants during horizontal directional drilling (HDD) can smother corals, and resultant increases in turbidity reduces the amount of light necessary for healthy function. Although cables have a small impact footprint, corals and other reef organisms can be chronically impacted by shading and abrasion (PBS&J, 1999). Storm events can lead to movement of cables on the substrate, which can result in abrasion of corals and reef substrate. Over the last twenty years there has been over 12 acres of nearshore reef damaged during pipeline installation in southeastern Florida (U.S. Fish and Wildlife Service. SE Region, 2004). There are two gas pipeline projects currently being reviewed for permits in the southeast Florida region, AES Ocean Express and Calypso U.S. Pipeline, LLC, and they are expected to incur greater than seven acres and 4.5 acres of reef damage, respectively. Both of these projects plan to pipe liquid natural gas from facilities in the Bahamas to exit points in Broward County. However, as an alternative, Calypso is proposing a deepwater port approximately 10 miles offshore from Port Everglades.

There have been no new fiber optic cable permits issued since 2001 for the southeast Florida region (Vince, pers. comm.). Since 2003, recommendations have been made to minimize impacts to reef systems, such as decreasing turbidity thresholds, using reef gaps to lay cables, implementation of tunneling and elimination of HDD, coral relocation for corals at risk, and increased monitoring and mitigation. Through the Southeast Florida Coral Reef Initiative, a best management practices document for construction, dredge and fill and other activities near coral reefs is in development (Collier, pers. obs.).

CORAL REEF ECOSYSTEMS—DATA-GATHERING ACTIVITIES AND RESOURCE CONDITION

Current coral reef monitoring and assessment activities in southeast Florida, including activities that are discussed below, are listed in Table 5.2. Figure 5.9 presents both water quality and biological monitoring sites in Southeast Florida.

Table 5.2. Coral reef monitoring programs in the Southeast Florida region. See next page for funding/partner acronym definitions. Source: FDEP.

PROGRAM	OBJECTIVES	START	FUNDING	PARTNERS
Miami-Dade County Water Quality Monitoring Network (MDCWQMN; DERM)	Monitor status and trends in water quality parameters to evaluate progress toward achieving/maintaining water quality standards and protecting/restoring living marine resources in South Florida coastal waters. Limited to Biscayne Bay and associated canals and tributaries.	1979	SFWMD, DERM	24 municipalities of Miami-Dade County, SFWMD, FDEP
Palm Beach County Environmental Resource Management Reef Monitoring Program (PBCERM)	Long-term non-destructive *in situ* monitoring of fish composition, abundance and size structure on artificial reefs. Benthos monitoring added (1998) and fish and benthos on natural reefs added (2004). Offshore reef monitoring expanded (2006). Nearshore aerials flown/digitized county-wide annually. Pilot coastal water quality monitoring program targeting wastewater outfalls and Lake Worth Inlet begins 2008.	1983	PBCERM, FDEP, FWC	PBCERM, FDEP, FWC, Volunteers
Water Quality Monitoring Network (FIU/SERC)	Status and trends of monitoring of water quality parameters to evaluate progress toward achieving/maintaining water quality standards and protecting/restoring living marine resources in South Florida coastal waters. 340+ sites in Florida, 35 of which are located in Biscayne Bay in southeast Florida. Discrete sampling locations from MDCWQMN.	1991	SFWMD, USEPA	FIU-SERC
The Reef Environmental Education Foundation (REEF)	Scuba divers and snorkelers collect information on marine fish populations using Rover Diver Survey method.	1993	DWCF, EODF, HF, RHGFF, KF, JEMF, MF, MML, NFWF, NC, NWP, NWF, OF, RFF, SS, TF, WSA, WSG	Volunteers
Broward County Marine Biological Monitoring Program (BCEPD)	Long-term fish and coral monitoring program to check relative health of the reef community habitats offshore of Broward County.	1997	BCEPD	BCEPD, NSUOC-NCRI
Bal Harbour Mitigation Monitoring Project	Long-term monitoring documenting benthic and fish assemblages on a limerock boulder and module reef with comparisons to adjacent natural reefs. Currently in year 8 of a 20 year monitoring plan.	1999	DERM	USACE
Biscayne Bay Submerged Aquatic Vegetation (SAV) Monitoring (DERM)	Annual assessment of SAV at 100 stations within central and southern Biscayne Bay and 11 "fixed' stations within central and northern Biscayne Bay.	1999	SFWMD, DERM	SFWMD, FDEP
Southeast Florida Coral Reef Evaluation and Monitoring Program (SECREMP)	Long-term monitoring of benthos within southeast Florida; northern Miami-Dade through Martin Counties.	2003	NOAA, FDEP, FWC, NSUOC-NCRI	FDEP, FWC, NSUOC-NCRI
Palm Beach County Reef Rescue Monitoring (PBCRR)	Monitoring algal blooms, coral condition and *Acropora* spp. locations. Area of monitoring is between points shown on Figure 5.9.	2003	Various	Volunteers
Harbor Branch Oceanographic Institute Comparative Ecology of Harmful Algal Blooms (HBOI)	Track the spread of *Caulerpa brachypu*s and better understand the role of nutrients in facilitating this invasion.	2004	Current: FWRI 2003-04: USEPA ECOHAB	FWRI, HBOI
Broward County Coastal Water Quality Monitoring Program (BCEPD/NSUOC)	Pilot coastal water quality monitoring program collecting monthly surface and bottom water samples.	2005	BCEPD	BCEPD, NSUOC
Florida Reef Resilience Program Disturbance Response Monitoring (FRRP/ TNC)	Disturbance response monitoring to improve understanding of reef health and to identify factors that influence the long-term resilience of corals, reefs and the marine ecosystem.	2005	FDEP, TNC and Others	TNC, FDEP, GBRMPA, NOAA and others
Florida Area Coastal Environmental Initiative (NOAA/FACE)	Extensively measure and quantify a variety of known nutrient sources for comparison with levels of anthropogenic quantities delivered to the coastal ocean via inlets, outfalls and other routes in southeast Florida.	2006	BC, CoH, CoBR, MDWSD, NOAA, SCRWTDB	NOAA, EPA, USACE, FDEP, USGS, FWC and others
Florida Fish and Wildlife Conservation Commission (FWC)	Population dynamics of gray snapper and snook; monitoring diversity and spawning locations of recreational fisheries species, sea temperatures, frequency and severity of upwellings.	2006	FWC	FWC
Baseline Limerock Boulder Reef Monitoring	Evaluation of benthic and fish assemblages on five multi-layered limerock boulder reefs throughout Miami-Dade County	2006	DERM, FWC	FWC

BC -- Broward County
BCEPD -- Broward County Environmental Protection Department
CoBR -- City of Boca Raton
CoH -- City of Hollywood
DERM -- Miami-Dade County Department of Environmental Resource Management
DWCF -- Disney Wildlife Conservation Fund
ECOHAB -- Ecology and Oceanography of Harmful Algal Blooms
EODF -- Elizabeth Ordway Dunn Foundation
EPA -- Environmental Protection Agency
FDEP -- Florida Department of Environmental Protection
FIU -- Florida International University
FWC -- Florida Fish and Wildlife Conservation Commission
FWRI -- Florida Fish and Wildlife Research Institute
GBRMPA -- Great Barrier Reef Marine Park Authority
HBOI -- Harbor Branch Oceanographic Institute
HF -- The Henry Foundation
JEMF -- The J. Edward Mahoney Foundation
KF -- The Korein Foundation
MDWSD -- Miami-Dade Water and Sewer Department
MF -- The Meyer Foundation
MML -- Mote Marine Laboratory
NSUOC -- Nova Southeastern University Oceanographic Center
NC -- The Nielsen Compan
NCRI -- National Coral Reef Institute
NFWF -- National Fish and Wildlife Foundation
NOAA -- National Oceanic and Atmospheric Administration
NWF -- Norcross Wildlife Foundation
NWP -- New World Publications
OF -- The Ocean Foundation
PBCERM -- Palm Beach County Department of Environmental Resources Management
RFF -- The Russell Family Foundation
RHGFF -- Robert J. and Helen H. Glaser Family Foundation
SCRWTDB -- South Central Regional Wastewater Treatment and Disposal Board
SERC -- Southeast Environmental Research Center
SFWMD -- South Florida Water Management District
SS -- Seaspace
TF -- Triad Foundation
TNC -- The Nature Conservancy
USACE -- United States Army Corps of Engineers
USGS -- United States Geological Survey
WSA -- Washington Scuba Alliance
WSG -- Washington Sea Grant

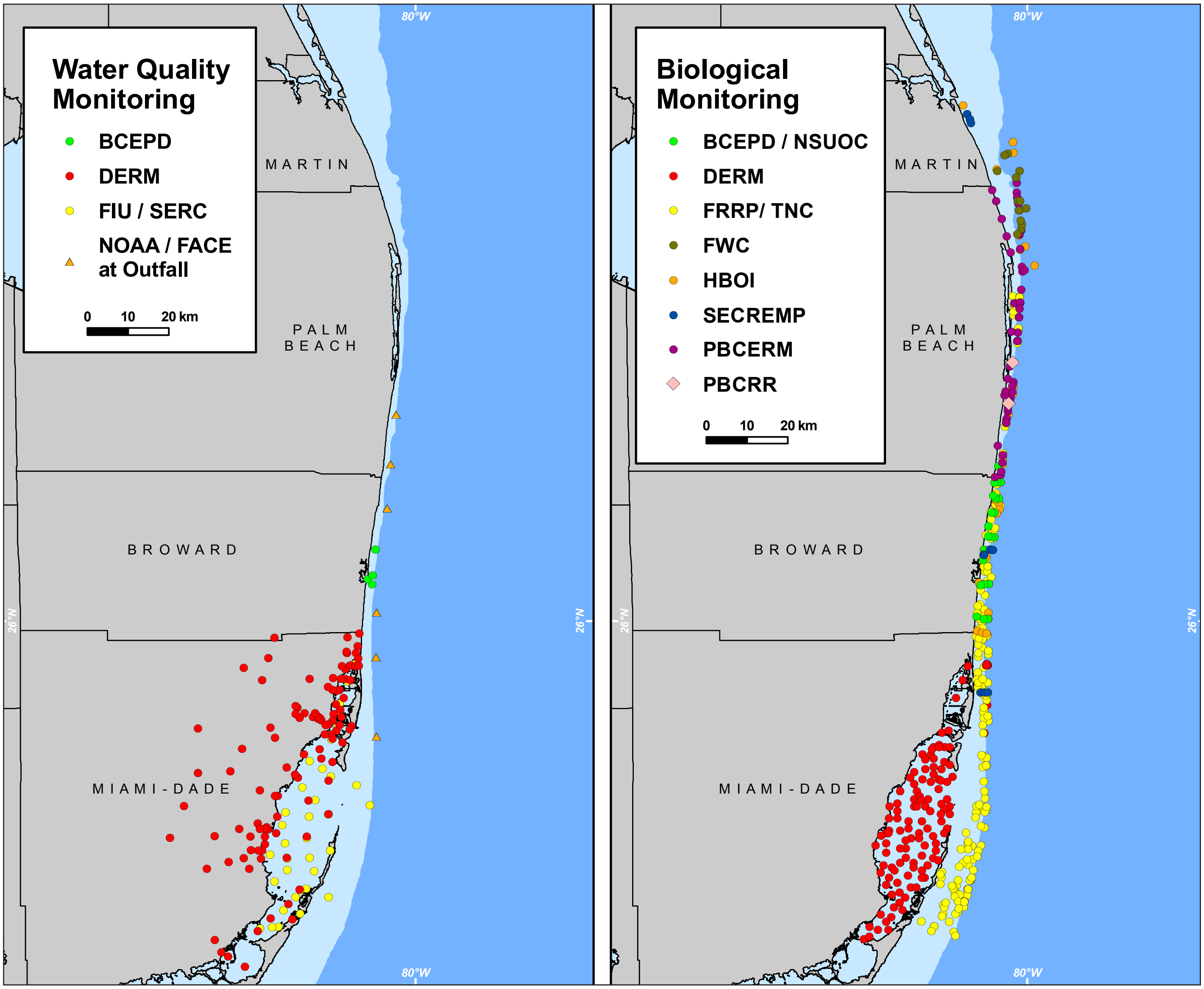

Figure 5.9. A map of the monitoring locations across southeast Florida discussed in this chapter. The PBCRR project samples the area between the two points shown. Map: K. Buja.

WATER QUALITY AND OCEANOGRAPHIC CONDITIONS

Land-based sources of pollution and poor water quality are recognized as a key threat to marine resources in southeast Florida (Florida Department of Environmental Protection, 2004). However, there are no regional, comprehensive, coordinated or long-term water quality monitoring programs in southeast Florida. The information that follows summarizes the limited activities in place, and new initiatives in development.

Water Quality Monitoring Across the Southeast Florida Region

Coral reefs off southeast Florida have experienced unprecedented blooms of macroalgae and cyanobacteria during the past two decades. Beginning in 1989, extensive blooms of *Codium isthmocladum* impacted deep (27-45 m) reefs off northern Broward County and Palm Beach County. Sea Grant-funded monitoring studies established that these blooms were adapted to low light levels and developed seasonally in the late spring and summer (Lapointe, 1997). Water column sampling for dissolved inorganic nutrients and tissue analysis for carbon:nitrogen:phosphorus (C:N:P) ratios further indicated that the *C. isthmocladum* blooms were related to nutrient enrichment (nitrogen and phosphorus) from both natural and anthropogenic land-based sources (Lapointe et al., 2005a).

Studies assessing stable nitrogen isotopes in macroalgal tissue were conducted at a network of shallow, mid-depth and deep reefs in Palm Beach and northern Broward counties in 2001 to address possible linkages of macroalgal blooms with land-based nutrient source (Lapointe et al., 2005b). This study, which compared a dry season without upwelling versus a wet season with strong upwelling, indicated that land-based sources of nitrogen enrichment, including sewage outfalls, were a more important source of nitrogen enrichment than natural upwelling to blooms of *Codium isthmocladum* and *Caulerpa* spp. During this study, scientists discovered the invasive *Caulerpa brachypus f. parvifolia* (Pacific native) overgrowing deep reef communities in northern Palm Beach County.

To track the spread of *Caulerpa brachypus* and better understand the role of nutrients in facilitating *C. brachypus* proliferations, the Florida Fish and Wildlife Research Institute (FWRI) and Harbor Branch Oceanographic Institution (HBOI) initiated an expanded reef monitoring program in a study area extending from northern Dade County to St. Lucie County in 2004. This monitoring program initially included 88 randomly selected reef sites throughout the study area that were stratified into shallow, mid-depth, and deep reefs and sampled in the wet (June-October) and dry (November-May) seasons. At each site, replicate samples of near bottom water were collected for determination of dissolved inorganic and organic nitrogen and phosphorus concentrations. Abundant macroalgae from each site were also collected for determination of C:N:P ratios and stable nitrogen isotopes. Water samples were collected from various natural (rainfall and upwelling) and anthropogenic (sewage outfalls and inlet discharges) nutrient sources for determination of nutrient concentrations and stable nitrogen isotope ratios. Divers also collected underwater digital video imagery from replicate transects to quantify benthic biota, especially blooms of macroalgae and the cyanobacterium *Lyngbya* spp. Shortly after initiating this monitoring effort in August 2004, hurricanes Frances and Jeanne made landfall in northern Palm Beach County and temporarily removed the invasive *C. brachypus* blooms (Lapointe et al., 2006).

On relatively oligotrophic coral reefs in Dade and Broward counties off southeast Florida, blooms of the phaeophyte *Dictyota* spp., the calcareous chlorophyte *Halimeda* spp. and the cyanobacterium *Lyngbya* spp. have developed. On more northern coral reefs off Palm Beach County, blooms of the chlorophytes *Codium* spp. and *Caulerpa* spp. have recurred since 1990. Monitoring of the water column for dissolved inorganic and organic nutrients and algal tissue for C:N:P ratios suggests that the observed taxonomic shifts in these macroalgal blooms are related to N:P availability. For example, relatively high tissue N:P ratios (35:1-70:1) occur in Dade and Broward counties compared to lower values in Palm Beach County (33:1). These differences in N:P ratio result from both natural patterns in geological substrata as well as anthropogenic nutrient enrichment of the watershed.

The Florida Area Coastal Environment Program

The FACE program is an ongoing, long-term effort to gather a broad range of data needed for understanding the coastal environment, for evaluating potential anthropogenic impacts, for guidance in the operation and development of water and sewer infrastructure, and for the formulation of science-based regulation. FACE is a focused measurement and analysis program designed to address the scientific aspects of societal questions of pressing importance in the general areas of wastewater discharge and water provision. FACE program data are also of substantial use in dredged material discharge studies (McArthur et al., 2006). In the longer term, the FACE program may evolve into a unified water study program including not only coastal ocean water but fresh waters as well for a “unified” study of south Florida waters.

There are multiple routes whereby human generated substances may find their way to coral reef ecosystems. Agricultural nutrients, septic tank leakages and storm water discharges may find their way to coastal ocean coral reef sites via inlets, cuts or even groundwater discharges. Secondarily treated wastewater effluent outfalls are also a source of nutrients and other pollutants to the coastal ocean. Nature is a prospective supplier of significant amounts of nutrients via upwelled oceanic water. In the Florida Keys (Leichter et al., 2003), internal bores have been suggested as a mechanism for the transport of nutrients from nearby nutrient rich deeper ocean water. Also in the Florida Keys, Hitchcock et al. (2005) have suggested that transport of deeper waters may occur with Gulf Stream eddies. Some (Lapointe, 1997) have suggested that anthropogenic nutrients are related to algal growth on the reefs, while others (Szmant, 2002) have suggested alternate causes. Long-term reef observations carried out using accepted scientific protocols at multiple locations are needed to understand the natural variation in the populations of algae and other reef species.

The FACE program's primary area of observations includes the coastal ocean off southeast Florida as well as adjacent waters and groundwater. The program includes nutrient, stable isotope, sediment, algal, coral, physical oceanographic, chemical, meteorological, genetic and microbiological measurements. Atmospheric input measurements are also planned. Related/cooperating programs include the Integrated Coral Observation System (ICON) and the Florida Bay measurement program. Existing and planned measurement systems include long-term *in situ* sensors, large-ship borne sensors and regular sampling from small ships. Continuous temperature data gathered at several sites during 2005 and 2006 off Miami-Dade, Broward and Palm Beach counties have shown the existence of correlated temperature decreases in ambient water temperatures. Comparison of 2005 and 2006 data has shown that while significant appearances of cold water occur during hurricane passage, significant cold water appearances are seen to occur in the absence of local meteorological forcing. The FACE fact sheet (NOAA Keynotes, 2006) displays some of the temperature data. More FACE data will become available in subsequent years.

Broward County

Broward County's Environmental Monitoring Division, Environmental Protection Department (EPD) implemented a pilot coastal water quality monitoring program in December 2005. This initial effort targets Port Everglades and adjacent areas on the north and south since Port Everglades represents one of the major inputs to Broward County's coastal waters. Surface and bottom water samples are collected from four stations at Port Everglades and three stations where the Biological Resources Division and EPD conduct coral monitoring activities and/or has thermographs. Efforts will be made to sample on a monthly basis. Samples are analyzed for chlorophyll, turbidity, and nutrients including: ammonium (NH_4), nitrate (NO_3), nitrite (NO_2), total dissolved nitrogen (TDN), total nitrogen (TN), soluble reactive phosphate (SRP), total dissolved phosphorus (TDP), total phosphorus (TP), silicate ($Si(OH)_4$), dissolved organic carbon (DOC) and total organic carbon (TOC). In addition to water samples, secchi depth is measured, field conditions noted and vertical profiles of temperature, depth, chlorophyll a (Chl_a), dissolved oxygen (DO), pH, specific conductivity and turbidity are collected at each site using a YSI sonde. EPD plans to expand monitoring efforts to ten stations by the end of 2008.

Palm Beach County

Palm Beach County's Department of Environmental Resources Management (ERM) is in the process of implementing a pilot coastal water quality monitoring program. The initial effort will target wastewater outfalls and the Lake Worth Inlet. Discharges from these sources represent the major contributors of freshwater effluent into Palm Beach County's coastal waters. Surface and bottom water samples will be collected from ten stations, the Lake Worth Inlet and nine additional stations, where ERM conducts reef monitoring activities. Samples will be analyzed for chlorophyll, turbidity, and nutrients including NH_4, NO_3, NO_2, TDN, TN, TP, $Si(OH)_4$, DOC and TOC. In addition to water samples, secchi depth will be measured, field conditions noted and vertical profiles of temperature, Chl_a, DO, pH, conductivity and turbidity will be collected at each site using a Hydrolab. Consideration is being given to expanding monitoring through a joint effort with NOAA.

St. Lucie State Park

The inshore reef associated with St. Lucie Inlet Preserve State Park is unique in terms of its setting in the coastal landscape, with open ocean to the east, undeveloped barrier island dunes and mangrove swamps to the west (a state park), and a maintained inlet (St. Lucie Inlet) and major outfall for surface water (St. Lucie River and Indian River Lagoon) to the north. These regional features shape the hydrodynamics and water quality along the 7 km reef tract, creating an obvious zonation of effects. The northern half of the reef is predominantly worm rock (*Phragmatopoma* spp.) with very few hard corals due to the influence of the surface water input through the inlet. The watershed of the St. Lucie River has tripled in size during the past century, including a connection to Lake Okeechobee. The water quality in the reef's northern half is characterized by high levels of total suspended solids (TSS), color (tannins) and certain nutrients (e.g., nitrogen and phosphorus), and wide fluctuations in salinity, making conditions suitable for worm rock growth. The reef's southern half is influenced greatly by oceanic waters with acute changes in water quality during periods of high flow from the inlet as longshore transport brings estuarine water southward. During 2006, the Florida Fish and Wildlife Conservation Commission held a symposium for the St. Lucie reef, including a panel discussion regarding the need for a unique water quality monitoring effort addressing these issues and the influence of water quality on benthic organisms and fish communities.

BENTHIC HABITATS

The Southeast Florida Coral Reef Evaluation and Monitoring Project

Since 1996, the Coral Reef Evaluation and Monitoring Project (CREMP) has documented changes in reef resources throughout the Florida reef tract from the northern Florida Keys to the Dry Tortugas. In 2003, CREMP was further expanded to include 10 sites offshore of southeast Florida in Miami-Dade (three sites), Broward (four sites) and Palm Beach (three sites) counties. This CREMP expansion, named the Southeast Florida Coral Reef Evaluation and Monitoring Project (SECREMP) was expanded again in 2006 with the addition of three sites in Martin County. Usually, monitoring efforts along the southeast coast are associated with environmental impact and mitigation studies at specific sites (dredging, ship groundings, pipeline and cable deployments and beach renourishment). Monitoring efforts that are part of marine construction activities are generally of limited duration (1-3 years) and focus on specific project areas. However, monitoring conducted by SECREMP is not tied to other activities and was designed to be a region-wide, long-term project that fills gaps in monitoring of coral reef ecosystems as part of a nation-wide effort. SECREMP complements the goals of the

National Coral Reef Ecosystem Monitoring Program (NCREMP) to monitor a minimum suite of parameters at sites in the network.

SECREMP follows the established Florida Keys CREMP protocols (Johnson et al., 2008). Monitoring consists of four stations at each of 12 sites where, at each station, a stony coral species inventory, video transect and bio-eroding sponge survey are conducted. The stony coral species inventory provides a species list for each station and includes longspine sea urchin, *Diadema antillarum*, abundance and information on diseased and bleached stony coral colonies. The video transects are used to determine the cover of stony coral species, gorgonians, sponges and macroalgae. A thirteenth monitoring site in Martin County (MC3) was established in 2006 with a unique purpose. Forty-nine individual coral colonies, representing six species were mapped within this site, and images of the colonies will be used to estimate growth and track colony condition. In 2007, benthic temperature data loggers were deployed at all SECREMP sites.

Results and Discussion

With four years of data (2003-2006) the SECREMP sites indicate that, in general ,there appears to be little change in the status of the southeast Florida reef system. The stony coral species inventory shows no trend in species richness changes within the 10 sites sampled since 2003 (excludes Martin County), except the nearshore site in Palm Beach County (PB1) which was partially covered in sand in 2005 and 2006 (Figure 5.10). There is a trend towards reduced richness in the northern part of the region with Miami-Dade County (21 species) and Broward County (24 species) having more species than Palm Beach County (17 species) and Martin County (eight species). The three most common hard coral species were *Montastraea cavernosa*, *Siderastrea siderea* and *Porites astreoides*, and they were found in all four counties and at least 12 sites (Gilliam, 2007).

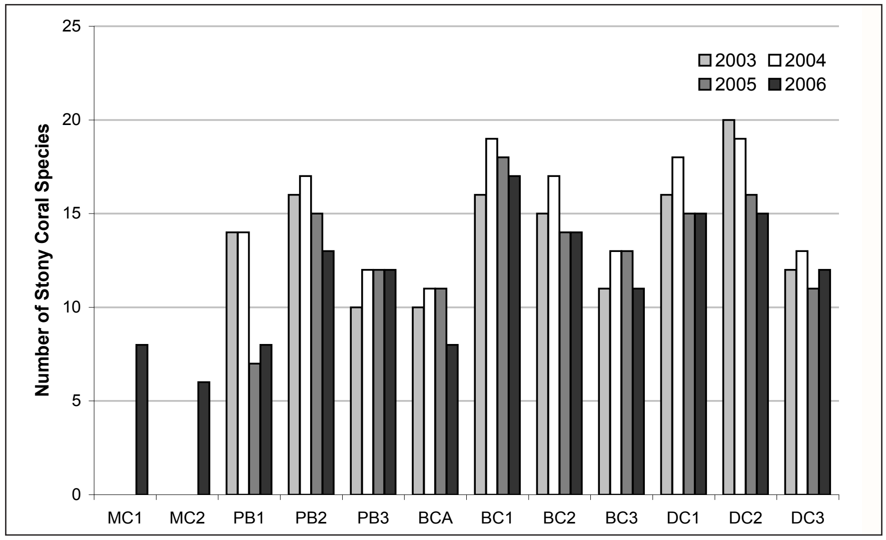

Figure 5.10. Number of stony coral species identified within each of the SECREMP sites 2003-2006 (MC = Martin County, PB = Palm Beach County, BC = Broward County, DC = Miami-Dade County). MC sites were not established until 2006. Source: SECREMP, unpub. data.

There also do not appear to be any consistent temporal changes in functional group cover between 2003 and 2006. Octocorals consistently contribute most to community cover in Miami-Dade, Broward and Palm Beach Counties followed by macroalgae and sponges (Table 5.3); while in Martin County, with only 1 year of data, macroalgae contributes most to cover. Stony coral cover in the region is generally between 0.5% and 2.5%. Two Broward sites (BC1 and BCA) were specifically included in the project to capture information on reef areas with unusually high stony coral cover. BC1 is within an area that has a high density of larger (>1 m diameter) *M. cavernosa*, *Montastraea faveolata* and *Colpophyllia natans* colonies and a stony coral cover of nearly 13%. BCA was specifically added to the project for the purpose of monitoring one of the unique *Acropora cervicornis* patches that occur offshore Broward County. This is especially important with the recent federal listing of *A. cervicornis* as a threatened species. *A. cervicornis* cover at BCA increased slightly from 31% in 2003 to 39% in 2005 but decreased in 2006 to 25%. This reduced *A. cervicornis* cover in 2006 was also identified during the Broward County Marine Biological Monitoring Project (Gilliam et al. 2007). Through fragmentation, *A. cervicornis* patches are dynamic in live tissue cover and boundaries. Increased effort is planned to map patch boundaries and track cover and condition beyond the permanent stations.

Broward County Marine Biological Monitoring Program

The present configuration of the Broward County Environmental Protection Department's Marine Biological Monitoring Program began in 1997 with the installation and initial monitoring of 18 offshore reef community transect sites. The sites were distributed such that there were three offshore of each of the following municipalities (from south to north): the City of Hollywood Beach, John U. Lloyd Beach State Park, the City of Fort Lauderdale, the Town of Lauderdale-By-The-Sea, The Town of Hillsboro Beach and the City of Deerfield Beach. Each latitudinal location had one permanent transect on each of the three reef tracts. These original 18 sites were established to initiate a long-term monitoring program to check relative health of the reef community habitats offshore of Broward County. Additionally, in anticipation of reef monitoring requirements that would become part of permits issued for the Broward County Shore Protection Project, it was proposed to federal and state agencies that monitoring of these sites become part of the Biological Monitoring Plan for the Project. Subsequent review by those agencies prompted the installation of five additional transect sites in 2001 and an additional two transect sites in 2004 for a total of 25 sites. The sites each have a 20 m belt-quadrat transect (30 m^2 total area) and sediment collector ringstands, each containing three replicate sediment traps. Sediment traps are changed out and analyzed every 60 days for sediment fallout rate calculation (mg/cm^2/day) and grain-size distribution, while the transects are visited annually during the months of September and October. Transects are examined for stony coral species density (colonies/m^2), diversity and evenness (Shannon indices), percent of live coral cover, and density of octocorals and sponges. In conjunction with the coral surveys, fish populations are assessed annually following methodology published by Bohnsack and Bannerot (1986) and Bortone et al. (1989). The 18 original sites have been monitored for ten years, 23 sites have been monitored for six years, and all 25 sites have been monitored for four years.

Table 5.3. Functional group percent cover (mean and range) within each of the SECREMP sites 2003-2006 (Broward County has four sites, Miami-Dade County has three sites and Palm Beach County has three sites. Martin County has two sites, which were established in 2006. Source: Gilliam, 2007; http://www.dep.state.fl.us/coastal/programs/coral/reports/.

	STONY CORALS		OCTOCORALS		SPONGES		MACROALGAE	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Broward Co.								
2003	11.2	31.7 - 0.3	7.2	13.5 - 2.3	1.9	2.8 - 0.3	1.9	3.7 - 0.3
2004	13.1	39.6 - 0.4	7.8	16.0 - 2.0	2.4	3.6 - 0.5	1.7	4.0 - 1.0
2005	13.3	39.9 - 0.3	8.9	17.9 - 1.5	2.9	4.2 - 0.4	6.5	11.9 - 1.8
2006	9.8	25.4 - 0.4	7.1	14.1 - 1.4	3.5	5.1 - 1.1	15.4	34.6 - 6.8
Miami-Dade Co.								
2003	1.1	2.4 - 0.2	12	15.5 - 5.9	3.2	5.1 - 0.9	8.5	13.3 - 2.3
2004	1.1	2.6 - 0.2	10.4	12.3 - 7.3	2.6	4.0 - 1.1	12.9	31.4 - 3.3
2005	1.2	2.8 - 0.3	13	15.9 - 8.0	2.9	4.0 - 1.5	5.7	12.8 - 1.8
2006	1.3	3.0 - 0.2	10.1	12.2 - 7.7	3.2	4.8 - 2.1	15.7	20.5 - 10.3
Palm Beach Co.								
2003	1.3	1.8 - 1.0	20.1	30.3 - 2.7	8.1	10.5 - 3.5	0.1	0.3 - 0.0
2004	1.2	1.8 - 0.9	21.3	31.2 - 2.9	7.6	9.8 - 4.2	1.4	2.5 - 0.3
2005	0.9	1.6 - 0.1	17.5	27.5 - 0.0	4.2	9.5 - 0.2	1	1.5 - 0.7
2006	1	1.8 -0.4	14.3	23.4 - 0.0	4.8	9.3 - 0.1	7.9	12.4 - 3.9
Martin County								
2006	1.3	1.6 - 1.0	0	0.0 - 0.0	1.8	2.6 - 1.1	38.3	42.0 - 34.5

Average coral cover for all 25 sites in 2006 was 4.2% (±7.7%) and the average coral cover for the original 18 sites (10 year average) was 1.7% (±1.1%). Included in the 2006 figure are three very high coral cover sites (34.0%, 15.8% and 19.2%) located on the first (inner) reef tract offshore of Fort Lauderdale. If these values are removed from the 2006 calculation, live coral cover (22 sites) was 1.6% (±1.2%), a value not significantly different from the 10-year average for the original 18 sites. Among the 23 sites monitored since 2001, mean coral density, stony coral cover and mean octocoral density have not significantly changed (Gilliam et al., 2007; Gilliam et al., in prep.). Results of multivariate statistical analysis indicate that the stony coral assemblages offshore of Broward County have changed little from 1997 to 2006. The analysis has also shown that the coral communities within the third (outer) reef and second (middle) reef sites have greater similarity than the sites within the first reef. The 2006 survey for fishes revealed that significantly fewer fish were counted on the first reef compared to either the second reef or the third reef. Haemulidae (grunts) was the predominant family on the first reef, Labridae (wrasses and damselfishes) and Carangidae (jacks) were predominant on the second reef, and fish in the Labridae family dominated the third reef. Sediment rate analysis since 1997 has consistently shown that the first reef sites exhibit a statistically significant higher sedimentation rate than both the second and third reefs and that the second reef sedimentation rate is significantly higher that the third reef rate. Additionally, there appears to be a seasonal trend with the highest annual rates of sedimentation occurring during the late fall/early winter.

Palm Beach County Monitoring

Characterization of benthic assemblages in Palm Beach County is ongoing for inshore, artificial, and some offshore reefs associated with beach nourishment projects (Continental Shelf Associates Inc., 1983; Continental Shelf Associates Inc., 1985; Palm Beach County Department of Environmental Resources Management, 1993; Palm Beach County Department of Environmental Resources Management, 1994; Coastal Planning & Engineering Inc., 2007) and for artificial reefs (Continental Shelf Associates Inc., 2006). The Palm Beach County Reef Research Team has performed routine monitoring and assessment of benthic communities on artificial reefs for 10 years and initiated work on the natural, deeper reefs in 2006. Monitoring methods include use of photoquadrats with post-processing of point counts (Palm Beach County Reef Research Team, 2004), videography with post-processing of line transects (Continental Shelf Associates Inc., 2006), in-water quadrat assessment with videography of line transects (Coastal Planning & Engineering Inc., 2007) and line intercept transects (Phipps, pers. comm.). Palm Beach County Reef Rescue, a volunteer, non-profit group of divers, has been monitoring the occurrence of algal blooms in southern Palm Beach County for several years (Tichenor, 2003; 2004a; 2004b; 2005).

Nearshore shallow (<4 m) reef habitats are dynamic and vary widely in benthic cover. Macroinfaunal communities have high species richness and diversity with 133 species representing 13 phyla counted in one study (Continental Shelf Associates Inc., 1983). Species numbers of epifaunal invertebrates range from 60 for Ocean Ridge to 25 for Jupiter Island (Continental Shelf Associates Inc., 1985; Palm Beach County Department of Environmental Resources Management, 1994). Macroalgal coverage is typified by low-growth plants, generally filamentous or encrusting forms representing approximately 23 to 31 species countywide (Palm Beach County Department of Environmental Resources Management , 1994). Worm rock (*Phragmatopoma* spp.) coverage averaged 30% countywide (Vare, 1991). *Siderastrea radians* is the most frequently encountered scleractinian coral, but five species of hard coral with approximately 5% coverage represented the nearshore reefs (Continental Shelf Associates Inc., 1985). Nearshore, softbottom benthic macroinfaunal samples yielded 33 species of macroinvertebrates dominated by polychaetes (Palm Beach County Department of Environmental Resources Management, 1994).

Offshore reefs in Palm Beach County are dominated by octocorals (Gorgonacea) and sponges (Porifera; Continental Shelf Associates Inc. 1985; Palm Beach County Department of Environmental Resources Management 1994). Goldberg (1970) identified 39 species of octocorals and 27 species of hermatypic corals. Forty species of sponge were recorded in North Boca Raton and on offshore reefs (Continental Shelf Associates Inc., 1985).

Artificial reefs constructed from concrete can develop complex benthic communities with diverse Scleractinian and octocoral assemblages. Hydroids, specifically the algae hydroid (*Thyroscyphus ramosus*), can be the principal colonizer of artificial reefs. Compared to natural reefs, artificial reefs have less algal diversity and fewer scleractinian and octocoral species (Palm Beach County Reef Research Team, 2004).

ASSOCIATED BIOLOGICAL COMMUNITIES

FISH

Three main reef tracts run roughly parallel to shore in Dade and Broward Counties while in Palm Beach and Martin Counties the inner and middle tracts disappear. The outer reef tract continues to run parallel to shore until the Lake Worth Inlet in Palm Beach County, where it terminates. A series of shore-parallel ridges continue northward into Martin County (Banks et al., 2007). In Miami-Dade, Broward, and most of Palm Beach Counties the third (outer) reef tract lies 1.5-2.5 km offshore, but the distance of the ridges increases to 3 km in north Palm Beach County and up to 9-13 km in northern Martin County.

Numerous stationary and roving visual fish surveys have been performed by SCUBA divers to assess reef fish populations (<30 m depth) in the southeast Florida region. In Broward County, an additional 20+ hours of ROV surveys have been completed between the depths of 50-200 m. Broward County conducts, on average, 300 surveys annually and has recorded 300 species in <30 m depth (Ferro et al., 2005; Bryan 2006). Since its inception in 1993, the REEF database (REEF, 2007) has received over 3,500 surveys for Palm Beach County and recorded a total of 404 species from 108 sites. Fish counts by Palm Beach County Environmental Resources Management and Palm Beach County Reef Research Team (PBCRRT) on both natural and artificial sites have recorded 193 species representing 48 families (Palm Beach County Reef Research Team 2004). In Martin County, the Florida Fish & Wildlife Conservation Commission (FWC) completed 101 surveys in 2006. Only fish >10cm in length were counted, but a total of 118 species were observed on four sites between 15-25 m depth (McDevitt, pers. comm.). Within the St. Lucie Inlet Preserve State Park, FWC has recorded 244 species including the endemic striped croaker, *Bairdiella sanctaeluciae* (Beal, pers., comm.). For southern Miami-Dade County, a study spanning more than 25 years of fishery-dependent and fishery-independent data has documented 318 fish species in BNP (Ault et al., 2001).

In general, species composition resembles other Caribbean and tropical Atlantic sites with an increasing abundance of temperate species (e.g., pigfish, *Orthopristis chrysoptera*) on reefs of the northern southeast Florida region. The 20 most commonly observed fish species in the southeast Florida region identified in the REEF database are listed in Table 5.4. There are differences in assemblage structure among the reef tracts, with increasing fish abundance and species richness moving from inshore to offshore reefs. Grunts (Haemulidae) are abundant on all reef tracts but predominate on inshore reefs (<12 m depth) and some estuaries (e.g., Lake Worth Lagoon) in Palm Beach County. Juvenile populations alone can comprise 60-90% of the total assemblage on inshore reefs (Ferro et al., 2005). On deeper reefs, wrasses (Labridae), surgeon and doctor fishes (Acanthuridae) and damselfish (Pomacentridae) become more abundant (Ferro et al. 2005). Most likely due to high fishing pressure, large groupers (Serranidae) and snappers (Lutjanidae) are relatively rare throughout the southeast Florida region (Ault et al., 2001; Ferro et al., 2005). For example, in Broward County, only two of the 242 grouper and 219 of the 718 snapper recorded during the four year survey period were of minimum legal size (Ferro et al., 2005).

Numerous artificial reefs have been deployed in the southeast Florida region. Artificial reefs consist of ships, limestone boulders, concrete demolition pieces and/or prefabricated structures, and they have been deployed for habitat and fishery enhancement as well as for experimental studies (Sherman et al., 1999; Sherman et al., 2001; Arena et al., 2002; Arena et al., 2007). A cumulative review of data collected by the PBCRRT from 1997 to 2003 shows that fish assemblages cluster into groups based primarily on depth (<9 versus >18 m) and secondarily on structural material (Harkanson, in prep.). Derelict ships can have higher species richness and abundance than neighboring reefs with species-specific differences in composition or aggregation size (Arena et al., 2007). Ships that have been deployed in 50-120 m depth have different assemblages of fishes than shallower vessel-reefs (Bryan, 2006). For example, the abundance of herbivorous species is higher on shallower, sunken artificial reefs, while the presence of planktivorous species is greater on deeper ones (Beal, pers. comm.; Arena et al., 2002; Bryan, 2006).

FISHERIES

Both recreational and commercial fishing occur in southeast Florida waters. Recreational fishers of southeast Florida counties land more than 200 species (Johnson et al., 2007) and account for roughly 20% of statewide recreational fishing licenses indicating a significant local contribution to fishing pressure. Visitors to southeast Florida also contribute to this fishing demand as many tourists wish to experience the "Fishing Capital of the World", as the state of Florida promotes itself (Florida Fish and Wildlife Conservation Commission, 2007). Along the reef tract, the most commonly targeted species are members of the snapper-grouper complex, including snappers (Lutjanids), groupers (Serranids), grunts (Haemulids) and porgies (Sparids). Commercial fisheries in southeast Florida target reef and pelagic fishes, spiny lobster (*Panulirus argus*), stone crab (Menippe mercenaria), blue crab (*Callinectes sapidus*), pink shrimp (*Farfantepenaeus* spp.) and ballyhoo (*Hemiramphus brasiliensis*).

Table 5.4. The 20 most commonly observed fish species on southeast Florida reefs according to the REEF database. Frequency of sightings is compiled from 6,271 surveys completed between 1993 and 2007. Source: REEF database, www.reef.org.

RANK	COMMON NAME	SPECIES	FAMILY	FREQUENCY OF SIGHTING (%)[1]
1	Porkfish	*Anisotremus virginicus*	Haemulidae	84.0
2	Bluehead wrasse	*Thalassoma bifasciatum*	Labridae	83.5
3	Sergeant major	*Abudefduf saxatilis*	Pomacentridae	76.7
4	French grunt	*Haemulon flavolineatum*	Haemulidae	72.5
5	Blue tang	*Acanthurus coeruleus*	Acanthuridae	71.0
6	Bicolor damselfish	*Pomacentrus partitus*	Pomacentridae	66.4
7	Ocean surgeon	*Acanthurus bahianus*	Acanthuridae	65.7
8	Doctorfish	*Acanthurus chirurgus*	Acanthuridae	63.9
9	Bluestriped grunt	*Hemulon sciurus*	Haemulidae	63.5
10	Spotted goatfish	*Pseudupeneus maculatus*	Mullidae	60.2
11	Stoplight parrotfish	*Sparisoma viride*	Scaridae	60.0
12	Tomtate	*Haemulon aurollneatum*	Haemulidae	59.7
13	Redband parrotfish	*Sparisoma aurofrenatum*	Scaridae	59.5
14	Bar jack	*Caranx ruber*	Carangidae	57.3
15	French angelfish	*Pomacanthus paru*	Pomacanthidae	56.8
16	White grunt	*Haemulon plumieri*	Haemulidae	56.6
17	Spanish hogfish	*Bodianus rufus*	Labridae	55.5
18	Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	52.6
19	Gray snapper	*Lutjanus griseus*	Lutjanidae	50.9
20	High hat	*Equetus acuminatus*	Sciaenidae	49.7

[1] Frequency of Sighting = the number of dives in which the species was observed divided by the total number of dives completed.

Little information exists on the historical levels of fishery resources in the southeast Florida region. NOAA's National Marine Fisheries Service classifies 11 species landed in southeast Florida as regionally overfished and 11 species as subject to overfishing, with some species in both categories (NMFS, 2005). These include grouper species: gag (*Mycteroperca microlepis*), black (*M. bonac*i), red (*Epinephelus morio*), snowy (*E. niveatus*), warsaw (*E. nigritus*), goliath (*E. itajara*) and Nassau (*E. striatus*), speckled hind (*E. drummondhay*i), and the red (*Lutjanus campechanus*) and vermilion snapper (*Rhomboplites aurorubens*). Fisheries for goliath and Nassau grouper and for queen conch (*Strombus gigas*) were closed in the 1990s and remain closed today, although the goliath grouper stock shows signs of recovering (Porch et al., 2003; Porch et al., 2006). This has prompted discussions about the possibility of re-opening the goliath grouper fishery.

In southeast Florida, Ferro et al. (2005) inventoried fishes associated with reefs in Broward County over four years and noted a general scarcity or absence of groupers and snappers. Although juvenile red grouper were frequently seen (n = 232 at 667 sites), only two were above legal minimum size. A total of 10 gag, yellowfin or scamp grouper were observed, but none were of legal size. No goliath or black grouper were recorded. Of the 718 snappers in six species that were recorded, only 219 (30%) were of legal size.

Johnson et al. (2007) assessed trends in recreational and commercial fisheries in the southeast Florida region from 1990-2000 and determined that recreational and commercial fisheries combined landed over 260 species of finfish and invertebrates. Total average annual landings were 21.4 million lbs. (range 17.7-26.9) and were composed of 62% recreational, 35% commercial and 3% headboat landings. Recreational landings included 27% reef fishes, 23% coastal migratory fishes and 50% offshore pelagic fishes. Commercial landings included 17% reef fishes, 43% coastal migratory fishes, 20% offshore pelagic fishes, and 20% invertebrate species. Headboat landings were 38% reef fishes, 30% coastal migratory fishes, and 32% offshore pelagic fishes. Total commercial landings declined 33% (9.3 to 6.2 million pounds) between 1990 and 2000, although total commercial landings of invertebrates increased from 0.6 to 2.3 million pounds, primarily because of increased catches of shrimp and blue crab.

Total finfish landings averaged 20.7 million pounds per year and declined significantly (22%) from 1990 through 2000. The recreational sector contributed 66% of the total reported finfish landings, followed by 31% from the commercial sector and 3% from the headboat sector. Total finfish landings varied without trend for the recreational sector, but declined significantly for both the commercial and headboat sectors (Figure 5.11). The net result was that the relative proportion of total finfish landings increased over time for the recreational sector, but declined for the commercial and headboat sectors (Figure 5.11). Average annual total recreational fishing effort was 4.2 million angler trips from 1990-2000.

Total reef fish landings in the southeast Florida region averaged 4.8 million pounds annually over the 11 year period and were composed of 68% recreational, 27% commercial and 5% headboat landings. Reef fishes represented 27% of total recreational landings, 38% of total commercial landings and 17% of headboat landings. Total reef fish landings varied without trend for the recreational fishery (mean = 3.27 million lbs/yr), but declined significantly for headboat and commercial fisheries. Headboat landings of reef fish, for example, declined 65% from 0.32 to 0.11 million pounds between 1990 and 2000 concomitant with a 48% reduction in the number of angler days fished, and from 1993 to 2000, a 60% decline in catch per unit effort (lbs/angler/day). Total commercial reef fish landings declined 55% from 1.9 to 0.8 million pounds over the study period. Research is needed to determine whether these declines are associated with reductions in fish populations or fishing effort, or to other possible causes.

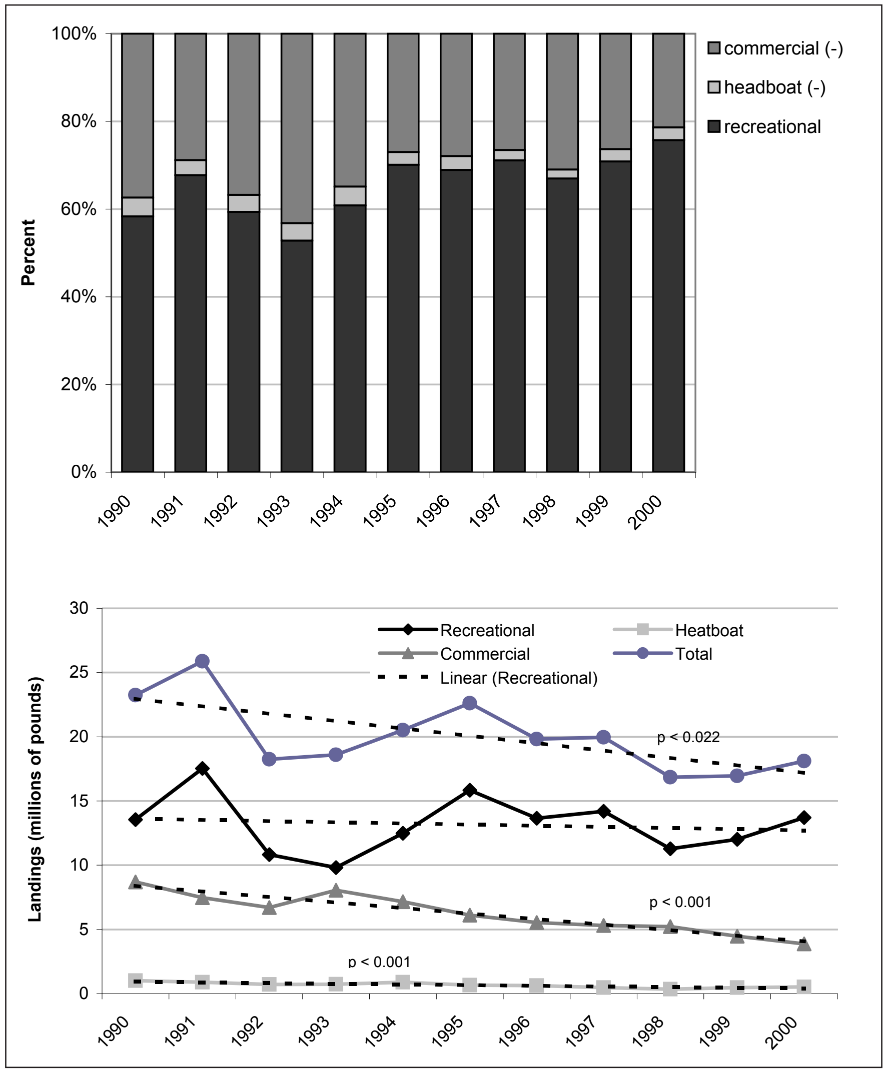

Figure 5.11. Total annual finfish landings in the southeast Florida region by fishing sector (top) and by source (bottom). Dashed lines show significant ($p < 0.05$) linear trends. Source: Johnson et al., 2007.

INVERTEBRATES

Annual reported commercial invertebrate landings in the southeast Florida region averaged 1.6 million pounds between 1990 and 2006 (Figure 5.12). Four fisheries comprised over 80% of the invertebrates landed during that time span: spiny lobster (33%), stone crab claws (3.4%), blue crab (11%), and combined food and bait shrimp (36%). Both commercial landings of spiny lobster and stone crab claws declined significantly over the reporting period while blue crabs and combined shrimp exhibited no statistically significant landings trend.

Of the four principal fisheries, only spiny lobster has an intensive recreational fishery. From 1993-2002 the recreational harvest averaged approximately 0.47 million pounds annually (Sharp et al., 2005). By comparison, commercial landings averaged about 0.57 million pounds per year over the same reporting period. Of note is a significant increase in the landings of miscellaneous invertebrates such as squid, octopus, slipper lobster and sponges . The increased harvest of these species may be due to commercial fishers being displaced from other fisheries (e.g., enactment of Florida's net ban in 1995 or increased management restrictions in other fisheries).

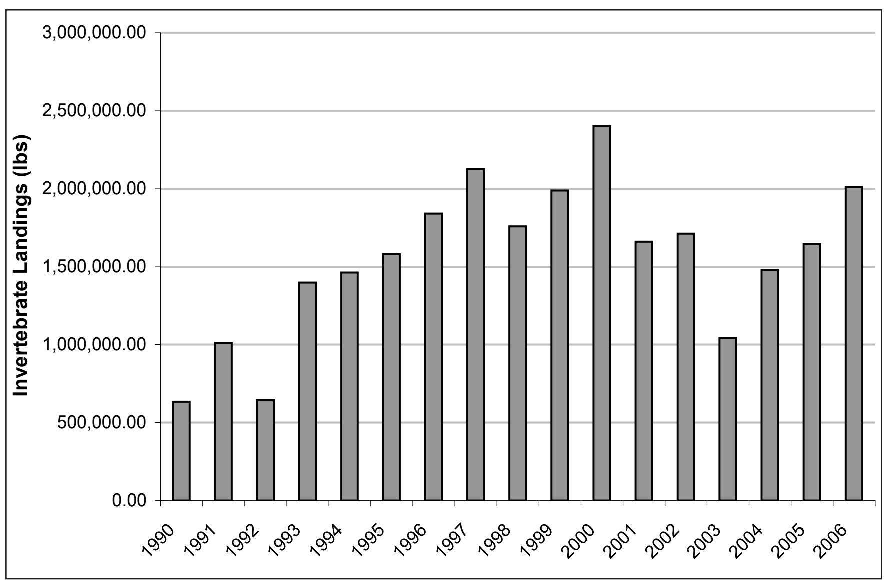

Figure 5.12. Combined annual invertebrate landings for blue crab, stone crab claws, combined shrimp, lobster and miscellaneous invertebrates in the southeast Florida region from 1990 through 2006. Source: Johnson et al., 2007; FWC, unpub. data.

CURRENT CONSERVATION MANAGEMENT ACTIVITIES

Until 2004, coral reef conservation and management activities in southeast Florida were limited and activities in the region were led primarily by local county agencies. However, in 2003, with guidance from the U.S. Coral Reef Task Force (USCRTF), the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Conservation Commission coordinated the development of the Southeast Florida Coral Reef Initiative (SEFCRI). Linked to the goals and objectives of the USCRTF National Action Plan to Conserve Coral Reefs, SEFCRI is a local action strategy (LAS) that identifies key threats to the reefs and associated reef resources of southeast Florida, and priority actions needed to reduce those threats. SEFCRI is a locally-developed and driven roadmap for collaborative and cooperative action among federal, state, local and non-governmental partners. SEFCRI spans Miami-Dade, Broward, Palm Beach, and Martin Counties, targeting the reefs from the northern border of Biscayne National Park to the St. Lucie Inlet (Figure 5.2). This region was chosen because its highly valued reefs lie close to an intensely developed coastal region with a large and diverse human population. Even though these reefs are exhibiting the same signs of degradation that have been documented in other parts of the world, prior to development of the SEFCRI, there was no coordinated public education or management plan proposed for the reefs located north of Biscayne National Park. Numerous stakeholders were, and continue to be, involved in developing southeast Florida's LAS through a facilitated process including public review and input. The SEFCRI LAS is comprised of 140 projects targeting four focus areas: 1) land-based sources of pollution; 2) fishing, diving, and other uses; 3) awareness and appreciation; and 4) maritime industry and coastal construction impacts (Florida Department of Environmental Protection, 2004). SEFCRI was created in tandem with the development of similar local action strategies in Hawaii, Guam, American Samoa, Commonwealth of the Northern Mariana Islands, U.S. Virgin Islands and Puerto Rico.

In 2004, FDEP established a Coral Reef Conservation Program (CRCP), based in Miami, to complete the development of the LAS, and to plan, direct and coordinate the implementation of SEFCRI. Through the LAS process, the FDEP-CRCP has increased awareness of the extensive and unique resources of, and threats to, the northern extension of the Florida reef tract. The LAS process also provided the framework which has led to improved management and coordination among resource agencies, and expanded the network of stakeholders working on coral reef issues in southeast Florida. Today, in addition to managing and administering SEFCRI, the FDEP-CRCP promotes and coordinates research, monitoring, partnerships, and stakeholder participation for the protection of southeast Florida's reefs, and continues to develop and support the state's efforts through Florida's membership on the U.S. Coral Reef Task Force. In 2006, the FDEP-CRCP also assumed responsibility for coordinating and leading response to vessel groundings and anchor damage incidents in southeast Florida.

Mapping

Mapping activities in southeast Florida have progressed substantially in the last three years (Figure 5.13). High resolution laser bathymetry has been obtained for the nearshore seafloor (<30 m depth) from Fowey Rocks in South Miami-Dade County to the north Palm Beach County line. In addition to bathymetry, benthic habitats have been mapped for all of Broward and Palm Beach Counties. The benthic habitat mapping efforts employed a multi-technique approach incorporating laser bathymetry, aerial photography, acoustic ground discrimination, video groundtruthing, sub-bottom profiling and expert knowledge (Walker et al., in review). Nova Southeastern University's Oceanographic Center (NSUOC) and the National Coral Reef Institute (NCRI) led this effort with interagency funding by NOAA, the Florida Department of Environmental Protection and the Florida Fish and Wildlife Conservation Commission. The maps were produced by outlining the features in the high resolution bathymetric data and classifying the features based on their geomorphology and benthic fauna. *In situ* data, video camera groundtruthing and acoustic ground discrimination (AGD) were used to help substantiate the classification of the habitats using aerial photography and geomorphology. AGD was also used to further discriminate the sea floor based on the density of organisms. In short, AGD evaluates the shape of sound waves bounced off the seafloor from which different categories of wave shapes are classified. These different wave shapes correspond to different habitats. Many improvements have been made in the acoustic discrimination of coral reef habitats during the southeast Florida mapping, enabling better evaluation of the data. The Broward AGD supplied an additional map layer of relative estimated benthic cover density, whereas the Palm Beach effort has been enhanced to show relative benthic cover density of specific benthic groups- gorgonians and macroalgae. These data supplement the geomorphology-based layer to include not only mapping between features, but also the variability of habitat within features. Accuracy assessment of the map showed high levels of accuracy comparable to that of using aerial photographs in clear water (Walker et al., in review).

The mapping completed thus far supports management of marine resources and scientific research. For example, a GIS evaluation of the nearshore anchorage at Port Everglades has enabled resource managers, commercial interests, enforcement agencies, and scientists to agree on an amendment of the anchorage configuration to help lessen the occurrence of ship groundings and reef impacts by ship anchors. The data are also being used by resource managers to guide decisions on many other proposed construction activities and their associated environmental impacts in the area as well. Future goals for mapping in the area include the continuation of these efforts to the south into Miami-Dade County (gray area in figure) and to the north into Martin County (hatched area in Figure 5.13)

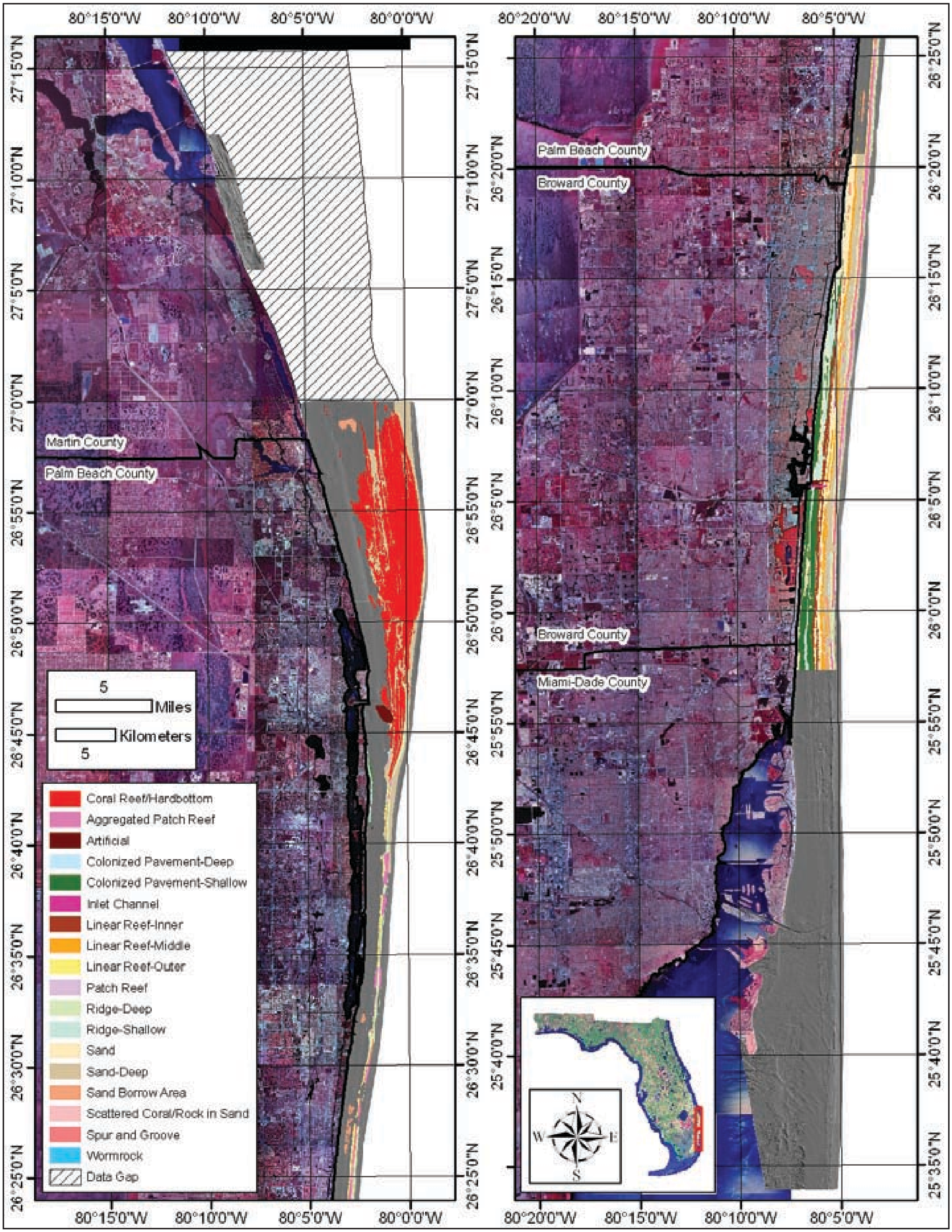

Figure 5.13. A map of the present state of southeast Florida nearshore (<30m depth), seafloor and benthic habitat mapping activities. Benthic habitats have been characterized from southern Martin County to northern Miami-Dade. High resolution bathymetry has been completed from southern Martin County to southern Miami-Dade and a nearshore strip in central Martin County (gray areas). Data gaps are benthic habitats for Miami-Dade County (gray area) and benthic habitats and high resolution bathymetry for Martin County (black hatched area). Image: B. Walker.

Monitoring, Assessments and Research

Considerable monitoring and assessment activity is taking place in southeast Florida. The Southeast Florida Coral Reef Evaluation and Monitoring Program (SECREMP) now spans all four counties. The sites provide a needed baseline of information using methods similar to those used for the Florida Keys CREMP program. More sites are needed. The Florida Reef Resilience Program conducts annual surveys for bleaching and disease at sites throughout the four county areas as well. Other monitoring projects conducted by or under the auspices of county and state agencies, academic institutions, or volunteers occur throughout the region. These include temporary (less than five years) benthic organism and reef fish monitoring projects of beach nourishment programs (pre-construction, post-construction). These provide valuable statistical data on status and dynamics of hardbottom communities and reefs. Programs in 2006 included: two in Martin County, seven in Palm Beach County, and one in Broward County. Fish studies in Broward County include assemblage comparison of pre and post nourishment sites and on natural and boulder (mitigation) reefs. Other monitoring efforts include: coral transplants on mitigation artificial reefs in Broward, benthic and fish communities of artificial substrates (limestone boulders and prefabricated artificial reef modules) and of natural reef areas in Broward and Miami-Dade Counties, fish populations of Sabellariid reefs in Palm Beach Counties, fish spawning and algal blooms and *Acropora* spp. in Palm Beach County, benthic and fish communities of artificial and natural reefs in Palm Beach County, and an Annual Fish Count by volunteers in Martin County. There were at least 12 monitoring programs in 2006 (excluding beach renourishment).

Likewise, there are diverse ongoing research projects. Studies in Broward and Miami-Dade Counties involve investigation of efficacy of reef restoration using artificial substrates. In Broward County, benthic recruitment in injury and non-injury areas, coral reproduction and sponge recovery, coral nursery transplantation survival, and *Acropora* spp. expansion are being studied. Since 2004, research has been conducted on recurring benthic cyanobacterial *Lyngbya* spp. blooms on the Broward reefs including seasonality, natural products, and the ecological role of nutrients. Miami-Dade and Broward Counties are or have been involved in investigations into effectiveness and impact of mooring buoys. Palm Beach County studies involve the effectiveness of mitigation reefs, population assessments of hawksbill turtles, and research on gray snapper and snook. Martin studies include evaluating coral condition and water quality impacts using photochemistry

Marine Protected Areas

Current coral reef management efforts in Florida have primarily focused on the reef tract south of Miami including Biscayne National Park (BNP), the Florida Keys National Marine Sanctuary, John Pennekamp Coral Reef State Park and the Dry Tortugas National Park. No coordinated management plan exists for the 170 km long northern portion of the Florida reef tract extending from BNP to the St. Lucie Inlet in Martin County. Three state parks within the southeast Florida region; John U. Lloyd, John D. MacArthur, and Bill Baggs Cape Florida have boundaries extending 122 m seaward and include hardbottom communities such as limestone, worm rock and coral patch reefs. The 14.5 km^2 aquatic portion of the St. Lucie Inlet Preserve State Park (SLIPSP) in Martin County contains extensive coral communities. All state parks in the region afford submerged natural resource protection by prohibiting spearfishing and collecting, although all other recreational and commercial fishing rules apply. Waters within the boundaries of these state parks also received the designation of Outstanding Florida Waters (OFW) which prohibits the pollution of these water masses under Florida Statute 403.061. In 2006, SLIPSP received additional protection through the installation of boundary and mooring buoys. The Broward County Environmental Protection Department maintains 125 mooring buoys on the County's shallow terrace reefs, and a joint effort led by the Florida Fish and Wildlife Conservation Commission, the Wildlife Foundation of Florida, and Palm Beach County Environmental Resource Management was launched in 2006 to establish a mooring ball program for the shallow water reefs in Palm Beach County. Miami-Dade County Department of Environmental Resource Management is also developing a plan to install moorings off the county's reefs.

The Southeast Florida Coral Reef Initiative (SEFCRI) Local Action Strategy, described above, serves as the guidance document for coordinating public education, mitigating threats to southeast Florida reefs and developing recommendations for a management plan for the reefs north of BNP. Several of the local action strategy projects outlined in the Fishing, Diving and Other Uses Focus Areas of SEFCRI will aid the development of an effective strategy to help expand management options beyond OFW and state park efforts.

Gaps in Monitoring and Conservation Capacity

Research, Monitoring and Mapping

Despite continuing research and progress in implementing benthic habitat monitoring and mapping, many gaps remain in research, mapping and monitoring southeast Florida. Basic management tools such as benthic habitat maps for northern Miami-Dade County, and both bathymetric and benthic habitat maps for Martin County, do not exist. Martin County is the northern limit of shallow water reef building corals along the southeast Florida reef tract and has been given little attention in the past. The only data sets used for mapping in Martin County thus far are limited bathymetry from a NOAA coastal LIDAR survey and coastline aerial photography. Changes in the water flow out of the St. Lucie River from the Everglades restoration project are expected to have a positive impact on the recruitment of reef building corals and reef development in the next several years. Martin County needs to be mapped and monitored for these changes.

A comprehensive, coordinated, long-term regional water quality monitoring program is also essential for reef resource managers to understand the influence of land-based sources of pollution on southeast Florida reefs, and to develop and evaluate effective management to address these threats. The number of SECREMP benthic habitat monitoring sites needs to be increased and linked to water quality monitoring. Reef fish habitat and community monitoring is also needed.

Research priorities include studies to trace nutrients being transported to reef communities from both natural and anthropogenic sources. Research on coral growth, reef succession and recovery rates is needed to establish mitigation protocols for projects impacting reef resources and to ensure appropriate compensation is awarded for lost ecological services resulting from injured coral reef and hardbottom communities. Innovative ways to address the impacts of climate change on coral reefs are also becoming increasingly important.

Enforcement

Enforcement efforts related to coral reef and hardbottom habitats in southeast Florida are limited due to the lack of state statutory authority governing damage caused by recreational vessel anchoring and the lack of Special Management Zones prohibiting anchoring over coral reefs. While section 68B-42.009(1) of the Florida Administrative Code addresses the take, destruction, possession and sale of coral, there are no provisions with adequate specificity to restrict recreational anchoring or address unintentional damage to the reefs.

The lack of statutory authority is a problem because it is standard practice throughout all of the coastal counties of Florida, with the exception of Monroe, for recreational vessels to anchor anywhere. Furthermore, in some instances, significant recreational anchoring impacts occur during large-scale marine events that designate vessel spectator areas on the reef tracts. One such annual event is the McDonalds Air and Sea Show that draws close to 3000 anchored boats per day for the two-day event. Other large-scale events include Fourth of July firework shows with offshore presentations. The location of the reefs is not posted, and the current law requires proof that the violator intended to commit damage. The subsequent result is that little enforcement action can be initiated. Due to a shortage of time and resources, inadequate training, and enforcement costs outweighing the potential benefits, officers are unable to make the necessary inspection dives to sufficiently document the damage committed.

Overtaxed manpower also inhibits adequate enforcement. When Florida Fish and Wildlife Conservation Commission (FWC) law enforcement officers are assigned to protect homeland security assets or participate in specialized training programs for homeland security, they are removed from their assigned duties with regard to resource protection. Reduced staff levels due to long-term vacancies further reduce resource protection at all levels. This is of particular concern due to the recent listing of two Acroporid coral species under the Endangered Species Act. Continued shortages in FWC law enforcement will greatly hinder enforcement efforts to protect these threatened species.

Management

The SEFCRI LAS has established the need for a comprehensive management plan to conserve, protect and manage the significant coral reef, hardbottom and associated reef resources found along the northern extension of the Florida Reef Tract (FDEP, 2004). However, state and local capacity to develop and implement a new management plan is limited. Increased staff and facilities are needed to support increasing demands on existing programs, as well as to enable and enforce new or expanded efforts. Public and political support for a management plan will also be critical for success and effective action.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

Since 2004, through the collaborative efforts of local resource managers, scientists and stakeholders, awareness of southeast Florida's reefs, appreciation for their socioeconomic value, and concern for the threats to reef health have markedly increased. New conservation, education and outreach programs and planning have been developed and implemented; and new resource management tools have been created and applied to address local resource management needs and challenges in the region.

However, the unprecedented development of southeast Florida and the multiple pressures from its growing urban population continue to outpace environmental protection efforts at federal, state, local and citizen levels. The loss of coral reef and hardbottom habitats and communities associated with planned public projects continues and the occurrence of coral bleaching and disease is rising. Additionally, pressure on reef resources from recreational and commercial users in southeast Florida is persistent, and the ecological consequences of extractive and non-extractive user activities are serious, and in some cases severe. The urgency of this situation requires a serious increase in effort and support at all levels.

Continued support, adequate funding and increased capacity are critical for ongoing implementation and completion of LAS projects identified in the SEFCRI. High priority LAS projects which remain unfunded require immediate action. These include establishing and maintaining a long-term water quality monitoring program linked to an expanded benthic habitat/community monitoring program, mapping the benthic resources of Martin and Miami-Dade Counties, and conducting research that definitively links land-based sources of pollution to coral reef degradation and quantifies the relative contributions pollution sources.

Florida Reef Resilience Program

The Florida Reef Resilience Program (FRRP) is a multiyear effort to develop management approaches and tools to better cope with climate change impacts and other stresses on south Florida's coral reefs. The program started in 2004 after creation of a Memorandum of Agreement to facilitate sharing knowledge and best practices for resilience-based management among the state of Florida, NOAA and Australia's Great Barrier Reef Marine Park Authority. The Nature Conservancy is coordinating the FRRP in conjunction with these three agencies and a steering committee of reef managers, scientists, reef user-group representatives and other non-governmental organizations.

The FRRP is designed to improve understanding of reef health in the Florida Keys and southeast Florida region and to identify factors that influence the long-term resilience of corals, reefs and the entire marine ecosystem. With this knowledge in hand, coral reef managers and users can work toward resilience-based management strategies that maximize the benefits of healthy reefs while seeking to improve the condition of those that are less healthy. Ultimately the FRRP seeks to improve ecological conditions on Florida's reefs, economic sustainability of reef-dependent commercial enterprises and compatible recreational uses of reef resources.

A focal area of the FRRP has been filling spatial and temporal information gaps for stony coral bleaching and other bio-indicator monitoring data. The first step in this process was characterization of the 400 km long reef tract from Martin County to the Dry Tortugas into 58 distinct zones. This spatial framework was then used to develop a disturbance response monitoring plan, initially focused on coral bleaching. A sampling design and monitoring protocol were developed by members of the FRRP Benthic Working Group. Reef managers and scientists were trained in the sampling methods which were piloted during the peak bleaching months of 2005, 2006 and 2007. The large number of sample sites (>180) combined with the large geographic area necessitated the involvement and coordination of 12 teams and over 70 divers from multiple agencies, universities and non-governmental organizations. Preliminary results from these surveys indicate spatial and temporal patterns in coral bleaching, disease and mortality, and demonstrate that some coral species and reef types may be more vulnerable to disturbance than others (Figure 5.14). To increase the predictability of thermal stress, these results are also being used to help calibrate remotely-sensed, high resolution (about 1 km) sea surface temperature maps.

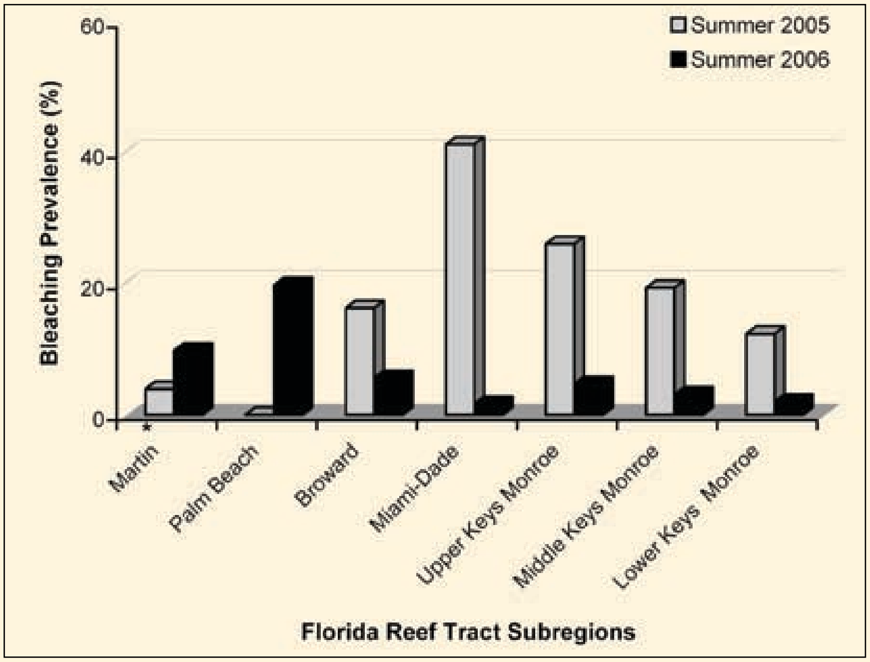

Figure 5.14. Coral bleaching results from the Florida Reef Resiliency Program surveys completed during the summers of 2005 and 2006. Data for bleaching prevalence is sub-divided into the four counties representing the southeast Florida region and three subregions for Monroe County. Bleaching prevalence is defined as the number of completely and partially bleached corals divided by the total number of corals recorded within each county or subregion. Source: FRRP, unpub. data.

Another vital aspect of the FRRP is improvement of the information base concerning how people use and value the coral reef ecosystem. Surveys of over 4,000 divers and fishers were conducted in the Florida Keys and the FRRP Human Dimensions Working Group is integrating these results with other socioeconomic and behavioral studies underway in the region. Human dimensions survey results will be related to biophysical study results to provide managers and decision makers with an integrated product to examine different management alternatives.

For more information on the FRRP visit http://www.nature.org/wherewework/northamerica/states/florida/preserves/art17499.html.

Success for many SEFCRI LAS projects is also dependent on the subsequent willingness of the public, industry, and regulatory agencies to adopt the recommendations, guidelines, tools and best management practices developed through SEFCRI and incorporate these conservation strategies into their actions, business practices and programs. However, it is important to recognize that LAS alone are not a complete solution to coral reef conservation and management. A comprehensive management plan, supported by a strengthened outreach and education program and appropriate levels of management capacity, is needed for the reefs of southeast Florida. Improved statutory authority and increased manpower are needed to support and improve coral reef protection and enforcement capacity. New, innovative and compatible, regional, national and international strategies and regulations must also be developed and implemented to address the impacts associated with land-based sources of pollution, climate change and destruction of coral reef resources associated with coastal development and globalization.

Residents, business leaders, visitors, elected officials, scientists and resource managers alike must acknowledge the real threats to both global and local human communities that are associated with the loss of coral reef communities, and be willing to work together to create, support and act on solutions that effectively protect these limited natural resources. As mandated by Presidential Executive Order 13089 (Clinton, 1998), federal agencies whose actions may affect U.S. coral reef ecosystems must: 1) identify such actions; 2) utilize their programs and authorities to protect and enhance the conditions of such ecosystems; and most importantly 3) to the extent permitted by law, ensure that any actions they authorize, fund, or carry out will not degrade the conditions of such ecosystems. State and local government leaders and agencies must act in kind. Stewardship for coral reef resources in Florida, and across the globe, is a responsibility that must be shared.

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