16. Status of the Coral Reef Ecosystems in the U.S. Caribbean and Gulf of Mexico: Florida, Flower Garden Banks, Puerto Rico, Navassa and USVI

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Introduction

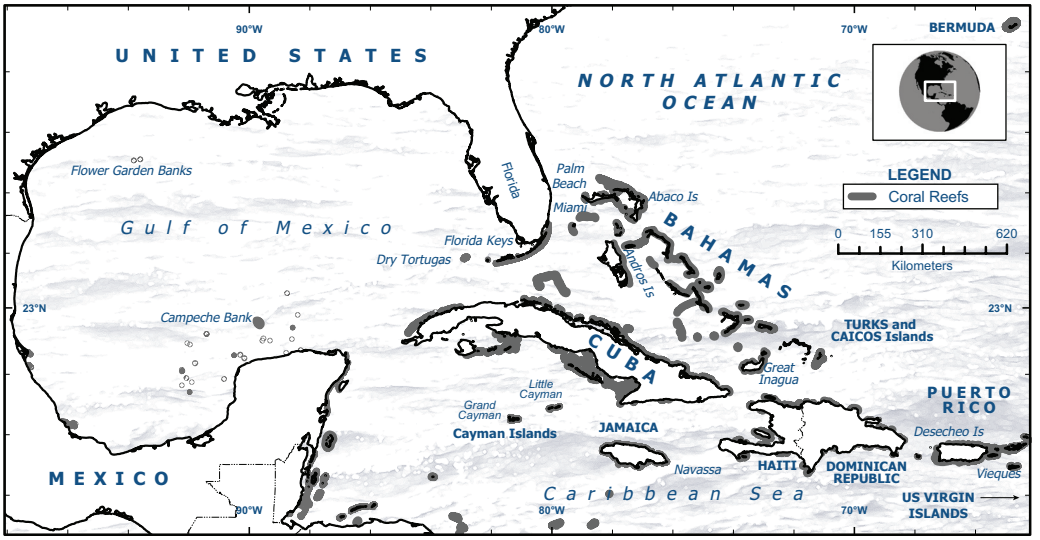
This chapter covers coral reef areas under the jurisdiction of the USA in the Wider Caribbean: Florida; Flower Garden Banks; Puerto Rico; U.S. Virgin Islands; and Navassa. The following information is condensed from six chapters of *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*. Access to the full text of this comprehensive report is available at: http://ccma.nos.noaa.gov/stateofthereefs.

Southeast Florida: The northern extension of the Florida reef tract and a complex of limestone ridges run 170 km parallel to the coast of southeast Florida, from Biscayne National Park in Miami-Dade County to the St. Lucie Inlet in Martin County. The reefs and hard bottom areas support rich and diverse biological communities. Nearshore reef habitats include hardbottom areas, patch reefs and worm reefs (*Phragmatopoma* spp.) with abundant octocoral, macroalgae, stony coral and sponge assemblages. Offshore reef assemblages grow on an old Holocene

Acropora palmata mid-shelf and shelf margin reefs extending from Miami-Dade County to Palm Beach County. The reefs from Palm Beach County to Martin County grow on Anastasia Formation limestone ridges and terraces. Southeast Florida is highly developed with more than 5 million people living close to the coast; many of the reefs are within 1.5 km of that coast. These are the highest latitude reefs on the western Atlantic coastline, but until recently, they received limited scientific and resource management attention.

Florida Keys: These form a 378 km island archipelago from Biscayne Bay to the Dry Tortugas, where the waters and climate are strongly affected by the Florida Current which brings juveniles and larvae of various marine organisms to the reefs. Parallel to the islands is the Florida reef tract consisting of almost continuous banks from Fowey Rock near Soldier Key to the Dry Tortugas. These islands and reefs are in the Florida Keys National Marine Sanctuary (FKNMS) and the Biscayne and Dry Tortugas National Parks. The FKNMS covers 9850 km^2 and includes coral reef and hard bottom habitats. The Dry Tortugas National Park covers 259 km^2, includes 7 small islands totaling 0.4 km^2 in area. The Tortugas Banks are a massive complex of submerged reefs on Pleistocene Karst limestone at depths of 21-27 m, with high coral cover but low coral diversity. The most conspicuous coral is *Montastraea cavernosa*, and the black coral (*Antipatharia* spp.) is abundant on the outer bank edges. There is a major fishery for groupers and snappers throughout the Florida Keys.

Flower Garden Banks National Marine Sanctuary: A network of banks and other submarine geologic features occur along the edge of the continental shelf south of Texas and Louisiana in the northwestern Gulf of Mexico. The banks are uplifted salt domes of Jurassic origin, rising from more than 100 m to 17 m of the surface, and some support thriving coral communities. Two of the banks, the East and West Flower Garden Banks (EFGB and WFGB), were designated as the Flower Garden Banks National Marine Sanctuary (FGBNMS) through the National Oceanic and Atmospheric Administration (NOAA) in January 1992. Stetson Bank was added to the FGBNMS in 1996, bringing the total area of the sanctuary to 145.8 km^2.



U.S. Virgin Islands: The USVI contains mosaics of coral reefs, seagrass beds, mangroves, sand and algal flats around the main islands of St. Thomas, St. John and St. Croix, and more than 60 smaller outlying cays. It is estimated that the reefs could cover 2,126 km^2, but only a small proportion of the deeper reefs have been mapped. The shallow reefs (<18 m) are estimated to cover approximately 344 km^2. As biologically rich ecosystems, they provide important goods and services to the islands in the form of shoreline protection, fishing and tourism. However, USVI coral reefs have been damaged by human activities; in response, additional fishing regulations have been enacted and MPAs designated or increased in size (see map p. 240).

Puerto Rico: The Commonwealth of Puerto Rico comprises the main island of Puerto Rico plus Culebra, Vieques, Monito, and Desecheo offshore islands in the northern Caribbean. Surrounding the islands and cays are a complex mosaic of coral reefs, seagrass beds and mangrove forests. There are also deep coral formations, including the 'Deep Terrace', 'Drop-off Wall' and 'Rhodolith' reefs down to 90 m depth. These are critical habitats for fish and invertebrates.

Navassa: This is a small (4.64 km^2), uninhabited, oceanic island approximately 50 km southwest of Haiti under the jurisdiction of the U.S. Fish and Wildlife Service. It is a raised dolomite plateau with vertical cliffs that descend to a sloping submarine terrace at about 25 m depth, with coral growing primarily on small nearshore ledges and shelves. The open ocean position of Navassa in the Windward Passage exposes it to persistent swells, especially on the eastern side, and regular storms and hurricanes.

Status of the Coral Reefs In 2008

Southeast Florida: The reefs of southeast Florida generally have low coral species richness and high cover of octocorals, sponges and macroalgae. The Southeast Florida Coral Reef Evaluation and Monitoring Project reports little change in the status of the southeast Florida reef system between 2003 and 2006. There has been no trend in stony coral species richness at the 10 sites sampled since 2003, except at the nearshore site in Palm Beach County, which was partially covered in sand in 2005 and 2006. There is a trend towards reduced coral species richness to the north with Miami-Dade County having 21 species and Broward County 24 species, while Palm Beach County has 17 and Martin County has 8 species. The most common stony corals in all counties are *Montastraea cavernosa*, *Siderastrea siderea* and *Porites astreoides*. Octocorals consistently contribute most to the bottom biota cover in Miami-Dade, Broward and Palm Beach Counties followed by macroalgae and sponges; while macroalgae dominate in Martin County. Total stony coral cover is generally between 0.5% and 2.5%, however, two nearshore monitoring sites in Broward County have 13% and 39% coral cover. The Broward County Marine Biological Monitoring Program reports coral cover and mean octocoral density have not changed significantly since 2001 at 23 sites, and multivariate statistical analysis shows that stony coral assemblages offshore of Broward County have changed little since 1997.

Florida Keys: Coral reef resources have been degraded by resource extraction as well as habitat loss and damage since the 15th century. These long-term changes to coral reefs include: 1) loss of top predators (e.g. monk seals); 2) loss of spawning aggregations and reductions in the abundance of large groupers and snappers; 3) loss of habitat structure including mangroves, corals and seagrass beds; 4) reductions in conch, lobsters and urchin populations; and 5) loss of ecosystem services provided by the aforementioned flora and fauna, including those provided by the once heavily exploited sponge fishery. Hurricanes during 2004-2005 caused some

damage to the coral reefs, but also reduced sea surface temperatures to below critical bleaching thresholds. The mean number of observed stony coral species and coral cover declined at permanent patch-, deep-, and shallow-reef sites throughout the Florida Keys from 1996 to 2006. The coral cover decline is partly due to the loss of major framework building corals, specifically the boulder star coral, *Montastraea annularis*, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*Acropora palmata*) which were once dominant in the Florida Keys. Elkhorn coral populations declined by about 50% between 2004 and 2006 at 5 upper Florida Keys reefs, primarily from hurricane and disease impacts. Staghorn and elkhorn corals were in low abundance on Upper Keys reefs in 2006; staghorn coral occurred at low densities (< 1 colony per m^2) at fewer than 18% (19 of 107) of sites and in less than 45% (5 of 11) of the habitat types surveyed. Elkhorn coral also occurred in low densities (< 2 colonies per m^2) at fewer than 17% (18 of 107) of sites and in 36% (4 of 11) of the habitat types surveyed. Data from synoptic surveys suggest that very few Acroporid corals were affected by white band disease, white pox, or tissue necrosis. However, long-term monitoring of *A. palmata* colonies indicates that disease events are highly episodic and significant impacts can occur over short time periods, as evidenced by outbreaks in 2003 and 2005.

Flower Garden Banks National Marine Sanctuary: These reefs continued to be in good condition between 2002 and 2006 with consistently high coral cover, ranging from 49.6% to 64.1%, specifically: the *Montastraea annularis* complex covered 26.8 to 40.1%; and *Diploria strigosa* (3.2% to 13.4%). Other coral species include *Porites astreoides* (3.4-8.2%) and *Montastraea cavernosa* (2.3%-7.7%), and 10 other species made up the remaining coral cover. Hurricanes Katrina and Rita passed by the Flower Garden Banks in 2005, but there were few changes in community structure in quadrat images and perimeter video assessments in November 2005.

U.S. Virgin Islands: Three long term monitoring programs provide data on USVI coral reefs: NPS/USGS Coral Disease and Benthic Cover Monitoring, Territorial Coral Reef Monitoring Program (TCRMP) and NOAA Biogeography Branch's Caribbean Coral Reef Ecosystem Monitoring Project. Mean live coral cover in northeastern St. Croix and around St. John was 5.6% (± 0.5), with 9 coral genera in St. Croix and 14 genera in St. John having cover greater than 0.01%. The three most abundant corals, *Montastraea*, *Porites*, and *Diploria* species, had mean cover of 1% (±0.09) in St. Croix and 2.4% (±0.34) in St. John. Instead, coral reef and hard bottom areas were dominated by turf and macroalgae (48.1% in St. Croix; 43.8% in St. John). However, no significant trend in the ratio between coral to algal cover was detected over 7 years of monitoring. More than 90% of coral cover at monitored sites bleached during the 2005 bleaching event on St. John with significant losses noted from the event as well as post-bleaching disease outbreaks, particularly a white plague-like condition. Within 12 months, coral cover loss at 7 sites ranged from 34.1% to 61.8% with 6,061 disease lesions noted on 23 coral species between September 2005 and July 2006. NOAA data from northeastern St. Croix revealed that approximately 51% of live coral cover was bleached in October 2005, affecting 25 of 30 observed coral species. On St. Thomas and St. Croix, TCRMP data showed that the important framework-building corals (*Montastraea annularis* complex) were hardest hit by bleaching, with some sites losing more than 70% of *Montastraea* cover.

Puerto Rico: Coral cover has been variable spatially, temporally and between studies over the years, but all studies report a general decline from bleaching and disease, as well as sediment and nutrient inputs. Up to 97% of corals bleached at monitoring sites with about 50% coral

mortality during the 2005 bleaching event; a massive white plague-like outbreak followed that resulted in 20 - 60% decline in coral cover on the east coast within 6 months. In addition, coral cover in southwest Puerto Rico is inversely correlated with increased turbidity from sediment and nutrient inputs.

Navassa: Between 2002 and 2006, coral cover at Navassa declined at deeper sites (22-32 m) by as much as 28.8% at southwest shelf sites, with similar declines in shallow areas (7-22 m) at Northwest Point. In contrast, mean coral cover at Lulu Bay has remained fairly steady at 10-25% over the same period. The major coral species are the *Montastraea annularis* complex, *Siderastrea siderea*, *Porites astreoides* and *P. porites*; however, macroalgae (especially *Lobophora variegata* with maximum cover of 34%, and *Halimeda* and *Dictyota* species as secondary components) is the dominant cover type in many reef habitats. It is not uncommon for macroalgae to cover 36-40%, or even 70% in some areas. Specific monitoring of *Acropora palmata* and *A. cervicornis* was initiated on Navassa since listing under the 2006 Endangered Species Act. Most *A. palmata* colonies in 2006 appeared healthy with only occasional recent mortality observed among 1,800 colonies along 6.8 km of the coast. While only 12 colonies of *A. palmata* were reported in 1998 in Lulu Bay, the population has increased to more than 100 colonies; in contrast, *A. cervicornis* remains extremely rare with only 5 small colonies observed in 2006.

Status of Coral Reef Fishes and Invertebrates

Southeast Florida: In general, the species composition resembles other Caribbean and tropical Atlantic sites, but with an increasing abundance of temperate species (e.g. pigfish, *Orthopristis chrysoptera*) on reefs in the northern section. There are differences in fish assemblages among the parallel reef tracts, with fish abundance and species richness increasing from inshore to offshore reefs. Grunts (*Haemulidae*) are abundant on all reef tracts but predominate on inshore reefs (<12 m depth) and in some estuaries in Palm Beach County. Juvenile fish alone can comprise 60-90% of the total fish assemblage on inshore reefs, whereas on deeper reefs, wrasses (*Labridae*), surgeonfish and doctorfish (*Acanthuridae*) and damselfish (*Pomacentridae*) become more abundant. Large groupers (*Serranidae*) and snappers (*Lutjanidae*) are relatively rare, probably because of high fishing pressure throughout Florida. For example, only 2 of 242 grouper and 219 of the 718 snapper seen during a 4-year survey were of minimum legal size in Broward County, and no goliath or black grouper were recorded. Goliath (*Epinephelus itajara*) and Nassau (*E. striatus*)grouper and queen conch (*Strombus gigas*) fisheries were closed in the 1990s. There are some signs of recovery for goliath grouper.

Florida Keys: Several exploited and unexploited reef fish populations in the Tortugas region have shown significant increases in abundance since the FKNMS Tortugas Ecological Reserve (TER) was designated in 2001. Black grouper, red grouper, and mutton snapper were significantly more abundant in the TER in 2004 than in 2000. No significant declines were detected for any exploited species in the TER, while non-exploited species showed both increases and declines. The abundance of exploited species in areas of the Tortugas Bank open to fishing either declined or did not change. In a Florida Keys-wide study, the Florida Fish and Wildlife Conservation Commission observed very little change in the mean length of several target species including *Ocyurus chrysurus*, *Lutjanus griseus*, *L. maximus*, *Epinephelus morio* and *Mycteroperca bonaci* between 1999 and 2006. Most fish observed (89%) were in the smallest size class (>5 to 20-25 cm), and few groupers and snappers observed were in the larger size classes.

The average size of lobsters has increased significantly to larger than the legal size within in the fully protected marine zones of the FKNMS since 1997, whereas the average size of lobster continues to be smaller than the legal size in exploited areas. In addition, legal-sized lobsters in fully protected marine zones were as large as or larger than those in fished areas. Lobster abundance declined in both protected and exploited areas during the open season, but less so in the reserves. The mean size of legal lobsters and the frequency of occurrence of very large lobsters increased steadily within the FKNMS Western Sambo Ecological Reserve since it was established in 1997. Adult queen conch populations in the Florida Keys have begun to recover since the fishery was closed in 1986, with conch density increasing from about 250 conch/ha in 1992 to about 700 conch/ha in 2003; it declined to about 500 conch/ha in 2005.

Flower Garden Banks National Marine Sanctuary: A total of 85 fish species were recorded in visual surveys in 2004 and 2005. The highest mean richness per diver survey was at East Bank in 2004 (mean richness = 22 species/survey). Mean fish abundance ranged from a high at the East Bank in 2004 of 251.4 per 100 m^2 to a low at the West Bank of 39.3 per 100 m^2. In 2005, the mean densities were 96.6 at EFGB and 80.0 at WFGB. Families with the most species were the Pomacentridae, Labridae, Serranidae and Scaridae, with 12 species of Pomacentridae recorded in 2005 at the East Bank. The greatest number grouper species (*Serranidae*) was 9 in 2005 at the West Bank; while 5 scarid species and 7 labrid species were regularly recorded. Long spined sea urchin (*Diadema antillarum*), spiny lobster (*Panulirus argus*) and spotted lobster (*P. guttatus*) populations were assessed in 2004 to establish a baseline. *D. antillarum* populations varied between 0.005 individuals/m^2 and 0.11 individuals/m^2 (44 individuals); but only two *P. argus* were seen in the 2004 surveys.

U.S. Virgin Islands: Five years of monitoring fish populations in northeastern St. Croix (1275 locations) and St. John (849 locations) have shown that the biomass of herbivores on St. Croix was higher than piscivores for all survey periods (except August 2001). Similarly in St. John, biomass of herbivores was higher than piscivores for all years except 2003. Fewer than 3% of snappers and groupers observed on transects between 2001 and 2006 were above legal length, and only three individual juvenile Nassau grouper were observed between 2001 and 2006 in St. Croix and nine in St. John. The largest snappers and groupers observed in St. Croix were 30-40% smaller than the maximum recorded size. Large-bodied grouper have decreased in abundance, while small-bodied grouper increased between 1979 and 2006. Similar results were obtained around St. Croix between 2002 and 2005 with herbivore biomass representing approximately 30% of the entire population, and piscivores comprising the least in biomass (10-14%) and abundance (2.7-3.1% of all fish observed). Commercially important snappers and groupers were uncommon in St. Croix. Surveys around St. Thomas between 2003 and 2006 showed no major changes in fish populations. Large-bodied serranids (red hind, *E. guttatus*; Nassau grouper, *E. striatus*; yellowfin grouper, *Mycteroperca venenosa*; yellowmouth grouper, *M. interstitialis*; and tiger grouper, *M. tigris*) were observed at offshore sites, while snappers (*Lutjanus apodus*, *L. cyanopterus* and *Ocyurus chrysurus*) were observed at nearshore and offshore sites, but were more abundant offshore. The St. Croix coral reefs support regionally important populations of queen conch (*Strombus gigas*), but with relatively few large adults. Between 2004 and 2006, significantly more legal-sized (CL ≥89 mm) spiny lobster was documented inside Buck Island Reef National Monument in northeastern St. Croix than in the adjacent, surrounding fished areas.

Puerto Rico: Shallow water reef fish abundance has generally declined; for example Nassau and goliath groupers (*E. striatus* and *E. itajara*) and queen conch (*Strombus gigas*) are being over-fished, as well as snapper and parrotfish. Fish spawning aggregations have also declined, especially for the larger, more commercially desirable species. Models developed by the University of Miami showed the majority of species are over-fished, with some substantially over-fished. The only large groupers that remain are known to cause ciguatera poisoning in humans. Although there has been a substantial decrease in fishing effort over the last 20 years, there is still an excess of fishing pressure. There has been a shift in community structure of fished groupers in southwest Puerto Rico from 2001-2006. Initially red hind (*E. guttatus*) were the most prevalent species, then the smaller Coney (*Cephalopholis fulvus*) became more prevalent, and most recently the smallest grouper (Graysby, *Cephalopholis cruentatus*) constituted well over 50% of the fished groupers in 2003, and more than 90% in 2006.

Navassa: There was a clear declining trend in reef fish biomass between 2002 and 2006, especially for piscivores, herbivores and planktivores (the dominant trophic groups). Fish sizes (mean fork length >10 cm) also showed a significant decline between 2002 and 2004 for grouper, snapper, triggerfish, parrotfish, jack, surgeonfish and squirrelfish families. On the other hand, *Diadema antillarum* abundance has increased over this 4 year interval. The mean density of urchins increased 400% between 2002 and 2006 to approximately 0.16 m^2, suggesting that recovery is underway on Navassa. Several aggregations of queen conch were observed in 2004, but there was no clear temporal trend.

Anthropogenic Threats to Coral Reefs

The top 5 threats to US Caribbean coral reefs include: elevated sea water temperature resulting in coral bleaching; coral diseases; tropical storms and hurricanes; unsustainable coastal development resulting in increased sediment and nutrient runoff; and over-fishing and damage from fishing. However the significance of each threat varies considerably. For example Florida, Puerto Rico and the USVI are heavily populated, unlike the Flower Garden Banks and Navassa.

Southeast Florida and Florida Keys: All the coral reef threats above occur along the coastline of Florida. Coastal development and pollution from the large and growing human population in southern Florida probably constitute the most significant stressors to the nearshore marine environment. Impacts associated with coastal construction, dredging for navigation, beach nourishment and infrastructure installation can reduce water quality and increase the damage to coral reefs and hard bottom communities. Wastewater effluents are pumped into the ocean near the reefs via 6 outfalls that discharge 1100 million liters/day of minimally treated wastewater. However, in April 2008, Florida passed legislation requiring effective sewage treatment in southeast Florida including discharging wastewater through ocean outfalls at higher treatment levels by December 2018 and achieving at least 60% recycling of wastewater by 2025. Wastewater management plans have also been developed for Monroe County to minimize pollution from runoff in the Florida Keys, and the state of Florida has mandated that all homes and businesses in Monroe County should be connected to centralized sewage treatment plants by 2010.

Tropical storms have and will continue to threaten coral reefs in Florida. The record-breaking 2005 Atlantic hurricane season directly affected the Florida Keys with 5 major hurricanes

within 5 months. Coral colonies were overturned or damaged, hard bottom areas were stripped of their gorgonians and sponges, and the abundance of juvenile reef fishes such as black grouper was reduced. Those hurricanes also re-suspended significant amounts of sediment and brought cold, upwelled water onto southeast Florida's reefs, dropping water temperatures by 5-10°C.

Although climate change and sea level rise are concerns in Florida, there has been no mass bleaching off southeast Florida since the last GCRMN report in 2004. The mean percentage of bleached (fully bleached, partially bleached and pale) colonies has been less than 4.5% (long-term mean <3%) off Broward County since 2000. Although there was moderate coral bleaching in the Florida Keys in 2005, the passage of several hurricanes mixed surface waters and lowered sea surface temperatures enough that Florida was buffered from the mass coral bleaching event that affected much of the Caribbean.

The occurrence of coral disease at monitoring sites in the Florida Keys has fluctuated annually since 1997, but generally has decreased since 2002. However, the reported decline in occurrence at stations could be related to the decline in coral abundance overall. Similarly the incidence of coral disease is low in southeast Florida, generally less than one diseased colony per site, or usually less than 0.5% of the corals in the community. Vessel groundings in Florida continue to occur regularly, but the numbers reported in the FKNMS have decreased annually from 721 in 2002 to 301 in 2006.

Fish stocks in Florida have been chronically over-fished since the 1970s with the fisheries showing classic 'serial over-fishing' with 23 of 35 reef fish species of groupers, snappers, hogfish, and grunts being over-fished according to federal (NMFS) standards. The average size of adult black grouper in the upper Keys was 40% of the 1940 size, and spawning stocks are now less than 5% of the historical maximum.

U.S. Virgin Islands and Puerto Rico: Scientists and resource managers perceive that the top 5 threats above are increasing, while biological resources are decreasing. However, the most dramatic recent losses were due to major coral bleaching and subsequent increased disease incidence in 2005 when sea water temperatures were the highest for the last 14 years. Bleaching conditions persisted for 12 to 15 weeks and were associated with a massive increase in coral disease lesions in the following months. In the USVI, there was a 2530% increase in disease lesions and a 770% increase in denuded skeleton caused by disease, compared to pre-bleaching levels. Bleaching and disease also occurred in deeper coral reefs. The coral bleaching in 2005 and post-bleaching mortality in 2006 also had dramatic consequences for Puerto Rican reefs, resulting in coral mortality of up to 90% at some monitoring sites. The principal reef building species, *Montastraea annularis* complex was seriously affected.

The most common diseases affecting Puerto Rican corals were white plague-II, yellow band, white band, black band, aspergillosis and coralline white band; but the distribution and prevalence was highly variable. Frequent epizootic events result in significant losses of coral cover on most reefs around the island, particularly during the summer; but bleaching and disease disappear when temperatures drop in winter.

Reporting on reef fisheries status remains a major challenge for resource managers, largely due to inadequate data on commercial and recreational fisheries. Managers report that

herbivorous fish catches around St. Croix have increased during the past decade, making parrotfish commercially important. The effects of tourist activities on the coral reefs in USVI and Puerto Rico are not well known. In Puerto Rico, commercial and recreational fisheries land more than 179 edible fish species, as well as many aquarium species. For both jurisdictions, the removal of juvenile fish, queen conch, lobster and herbivorous fish that help maintain healthy coral reefs is of particular concern.

Hurricanes have caused massive damage to coral reefs and associated communities throughout the Caribbean and are a major force structuring reef communities as evidenced by the large-scale destruction of elkhorn coral (*Acropora palmata*) in Puerto Rico. However, no major storms have affected USVI or Puerto Rican coral reefs since Hurricane Georges in 1998.

Flower Garden Banks National Marine Sanctuary and Navassa: No people live on these reefs, thus the major threats are hurricanes, or those related to climate change and fishing. Although the Flower Garden Banks are subject to threats related to oil and gas production, including the possibility of accidental spills, contamination from drilling and production effluents and discharges, and pipeline and platform construction and removal, no significant detrimental impacts have been observed on the coral reefs of the FGBNMS from these activities to date.

Since 2000, 5 hurricanes have passed near the FGB including Katrina in August 2005 and Rita in September 2005. Hurricane Rita caused significant damage to the reef including dislodging large (3-4 m diameter) coral heads, and gouging and blasting corals with rubble and sand. Many large barrel sponges were either removed or scoured, and there was catastrophic breakage and toppling of the expansive *Madracis mirabilis* field on the east side of the EFGB. Warmer temperature water sat over the reef cap for 50 days until 23 September 2005, resulting in significant bleaching, with as much as 46% of coral colonies exhibiting some bleaching. In March 2006, 4-5% of coral colonies still showed some bleaching. Severe coral bleaching was also observed on Navassa in November 2006, when little bleaching was observed elsewhere in the Caribbean. The prevalence of bleaching ranged from 15-78% of colonies of all species, with more at deep sites (>20 m) than at shallow (<10 m) sites. The most affected were *Agaricia* and *Montastraea* species, especially *M. faveolata*. Coral diseases at Navassa were rarely seen until 2004, when a severe 'white disease' event was observed affecting 15 coral species. This disease was more prevalent on larger colonies and on *Montastraea* colonies, with active disease evident on 0% to more than 15% of colonies.

Surveys conducted every two years at Navassa indicate that corals have been stressed by episodic events including a white plague-like disease outbreak in 2004 and severe bleaching in 2006. Despite Navassa's status as a National Wildlife Refuge, a lack of effective fisheries management contributes to the threat from excessive fishing pressure, primarily from Haitian artisanal fishermen who have been fishing Navassa's reefs since the 1970s. Fishing pressure may be escalating and the effects are compounded by the use of novel and more destructive gear types, including net fishing, and exploitation of queen conch and Hawksbill turtles.

Current Conservation Management Activities

Southeast Florida and Florida Keys: Coral reef conservation and management activities in southeast Florida were limited to those undertaken primarily by local county agencies until 2004. However in 2003, the U.S. Coral Reef Task Force guided the Florida Department of

Environmental Protection (FDEP) and the FWC to develop the Southeast Florida Coral Reef Initiative (SEFCRI) under the goals and objectives of the USCRTF National Action Plan to Conserve Coral Reefs. The Initiative identified key threats to the reefs and resources, and detailed priority actions to reduce those threats. The FDEP Coral Reef Conservation Program (CRCP) was established in Miami to implement the SEFCRI and this has increased awareness of the extensive and unique reef resources and the threats they face along the northern Florida reef tract. This process has led to improved management and coordination among resource agencies, and expanded the network of coral reef stakeholders. The FDEP-CRCP promotes and coordinates research, monitoring, mapping, partnerships, and stakeholder participation for reef conservation and participation in the USCRTF. It has also assumed responsibility for coordinating and leading response to vessel groundings and anchor damage on the reefs off southeast Florida.

In the Florida Keys, assessments, monitoring and research are conducted by many groups, including local, state and federal agencies, universities, private research foundations, environmental organizations and independent researchers, and much of the work is accomplished through partnerships among these groups. Sanctuary staff facilitate and coordinate research by registering researchers through a permitting system, recruiting institutions for priority research activities, overseeing data management, and disseminating findings to the scientific community and the public. For example, since 1994 the FKNMS Water Quality Protection Program has gathered data on water quality, seagrasses, and coral reef and hard-bottom communities, while the Marine Zone Monitoring Program monitors a system of 24 marine reserves located within the FKNMS to determine whether these fully protected zones effectively protect marine biodiversity and enhance human uses related to the sanctuary. Complementing the fully protected marine zones in the FKNMS, the authorization of the General Management Plan of the Dry Tortugas National Park in January 2007 included a no-take Research Natural Area covering 158 km^2 (nearly half) of the park. Lastly, complete, updated and high-resolution benthic habitat and bathymetric maps of the Florida Keys are being developed by NOAA, the FWC, the National Park Service and other collaborators. Color and panchromatic satellite imagery are now available online (http://oceanservice.noaa.gov/dataexplorer/whatsnew/welcome.html), and high resolution aerial photography is being used to map Biscayne Bay and characterize unmapped areas of the Tortugas region. In 2007, interferometric acoustic sonar and side scan sonar were used to depict the bathymetry of Hawk Channel within the FKNMS Western Sambos Ecological Reserve, where turbid conditions prevented the use of optical mapping technologies.

U.S. Virgin Islands and Puerto Rico: Since the early 1960s, many MPAs have been established in the USVI by Federal and Territorial agencies, including the recently enlarged Virgin Islands Marine National Monuments, Marine National Parks, a Marine Conservation District (MCD), several small marine reserves, Spawning Aggregation Areas (SPAGs) and 18 Areas of Particular Concern. On St. Croix, the East End Marine Park was established in 2003. Existing MPAs vary greatly in size, location and purpose and represent a wide regulatory spectrum, ranging from very little regulation (multi-use areas) to the total exclusion of extractive activities (marine reserves). The few studies inside and outside MPAs in the U.S. Caribbean have highlighted problems related to suboptimal boundary delineations, high human impacts, low resilience to disturbance and limited recovery in marine reserves. The Hind Bank Marine Conservation District south of St. Thomas was established in 1999 and became the first no-take federal

fishery reserve in the USVI, and yielded the first reported recovery of a spawning aggregation. An estimated spawning population of more than 84,000 fish was observed, and nearby grouper and snapper fisheries have improved since the area was closed. Other fish spawning aggregations are being monitored, including Grammanik Bank and Lang Bank. Long-term monitoring of coral disease and abundance, and benthic cover continue as well.

Fisheries management regulations in Puerto Rico have focused on: protecting the integrity of essential fish habitat; banning certain gears in particular locations; imposing size and bag limits; totally prohibiting the harvest of Nassau and goliath groupers; and seasonally closing spawning aggregation sites for groupers and snappers. Managers are improving data collection and obtaining socioeconomic information on the value of the ecosystem to improve decision making. Navigational markers, mooring buoys, and educational signage have been installed to inform boaters and beachgoers about reef conservation, and cleanup efforts are removing unexploded live ordnance in the former Navy training ranges on the island of Vieques. Puerto Rico has designated MPAs in several areas with extensive coral reefs as a first step towards conservation of critical coral reef resources. The Maritime Ranger Unit of 200 rangers enforces coral reef, navigation, fishery regulations and all regulations developed for the MPAs. They are also responsible for ship groundings and coral reef restoration.

Flower Garden Banks National Marine Sanctuary and Navassa: Management and regulations are focused on controlling visitor activities in these remote sites. The FGBNMS is protected under under the National Marine Sanctuaries Act, with regulations that prohibit: anchoring of any vessel within the Sanctuary; mooring of vessels greater than 30 m on Sanctuary mooring buoys; oil and gas exploration and development within the no activity zone (almost the entire Sanctuary); injuring or taking coral and other marine organisms; using fishing gear other than traditional hook and line; discharging or depositing any substances or materials; altering the seabed; building or abandoning any structures; and using explosives or electrical charges. Management of the FGBNMS is currently being reviewed to address issues identified through a public scoping process, including impacts from visitors, impacts of fishing, boundary expansion needs, pollution impacts, enforcement and education/outreach. Working groups are assisting through workshops and information gathering.

Since the Navassa National Wildlife Refuge was established in 1999, the major issue has been the increasing numbers of foreign fishers and hunters, mainly Haitians, in the refuge. This is challenging because the island is remote with no practical mechanism to efficiently or economically document, manage or address these threats. Although active management is limited, a Haitian NGO, the Foundation for the Protection of Marine Biodiversity, is educating these fishers.

Conclusions and Recommendations

Southeast Florida and Florida Keys: Awareness of the socioeconomic value of, and threats to southeast Florida reefs has increased markedly among stakeholders since 2004. New conservation, education and outreach programs, and planning have been developed and implemented, and management is addressing local resource management needs and challenges. However, the pressures of unprecedented development and growth in southeast Florida continue to outpace federal, state, local and citizen environmental protection efforts. Coral reef and hard bottom habitat losses associated with planned public projects continue and the

occurrence of coral bleaching and disease is rising. Pressures from recreational and commercial users are persistent, with serious and often severe consequences for the reef resources. Similarly, management of the FKNMS has been unable to arrest the decline in coral cover and the reduction of the major framework building corals (*Acropora palmata*, and *Montastraea annularis*) in the face of multiple anthropogenic and natural stressors that originate beyond the jurisdiction of the resource managers, such as climate change and algal blooms. Harvested reef fishes and invertebrates remain over-fished throughout Florida; however the average density and size of some stocks have increased within certain no-take areas of the FKNMS since they were established.

Action to reverse this situation is urgently needed and will require a significant increase in effort and support to conserve coral reefs in Florida. Environmental monitoring and research is currently adequate to provide the basis for sound management policy and strategy development; but improved conservation will require adequate and sustained funding for monitoring programs, law enforcement, and improvement of management plans in partnerships with local communities, visitors, and government and non-government agencies. High priority conservation projects in southeast Florida remain unfunded, including water quality monitoring, mapping of the benthic resources of Martin and Miami-Dade Counties, and research on the links between pollution from the land and coral reef degradation. In the end, successful conservation will depend on the willingness of the public, industry, and regulatory agencies to adopt the current recommendations and guidelines, and incorporate conservation in business practices and programs. Success will also depend on effective national and international programs to minimize global climate change.

U.S. Virgin Islands and Puerto Rico: Coral reefs continue to be threatened by demographic pressures, hurricanes and global climate change; the latter impacted Caribbean reefs dramatically in 2005 and 2006 with unprecedented coral bleaching and disease. While recognition of the economic, cultural, and scientific value of reefs is increasing, implementation of a community-based vision for their conservation is still needed. Fish populations have shown a declining trend of abundance and size; although the available fishery dependent and independent data have been inadequate to determine the status of some stocks, like queen conch, mutton snapper and yellowfin grouper. Catch composition continues to be dominated by herbivorous fishes, like small parrotfish, rather than large snappers and groupers that dominated fish catches 40 years ago.

Monitoring needs to be directed towards emerging issues, such as understanding bleaching and disease and assessing heat tolerant strains of corals, determining the effects of recreational activity on reefs (fishing, anchoring, boating, snorkeling, petroleum, garbage), and identifying non-point sources of pollution. Exploration, mapping, and characterization of the deeper reefs (30-50 m) are needed around the USVI and Puerto Rico, as these serve as critically important resident, foraging, reproductive and recruitment habitats for commercial fish and endangered turtles and may be an important source of coral recruits for shallower reefs.

Local government can mitigate some threats, such as reducing nutrients and sediments from development-induced erosion, agriculture and poorly maintained septic systems. Other threats from shipping, anchoring and recreational boating can be addressed by installing more navigational aids, and continuing public education and outreach. Greater inter-agency and

inter-island coordination and integration is needed to integrate management and research, improve compliance and enforcement, assess and regulate fisheries and improve coral reef monitoring programs. Management authorities and governments have many of the necessary components for an effective regulatory framework to restore coral reef health, such as establishing and improving MPA management, enforcing existing land use and resource management regulations, and accessing to long-term data from on-going monitoring programs.

Flower Garden Banks National Marine Sanctuary and Navassa: The Flower Gardens coral reefs continue to thrive, despite being in the middle of one of the largest oil and gas fields in the world. One unresolved concern is large volumes of contaminated water, or 'produced water' that is generated from offshore oil platforms; the effects of produced water on the coral reefs are unknown and need to be addressed as oil and gas activities continue to expand. These reefs are susceptible to environmental perturbations as the major deleterious impacts of 2005 clearly demonstrated with coral disease and bleaching, and major hurricanes. Current predictions are that these impacts will not be less severe in future. Because these reefs can serve as a standard for comparison to other Caribbean coral reefs and may function as a source of recruits for neighboring regions, their conservation is essential.

It is clear that the remote Navassa reefs are not remote from anthropogenic stress, and are undergoing rapid change. Fishing pressures and disturbances, such as coral bleaching and disease, have resulted in a rapid decline in coral cover, including the death of large coral colonies, and reduced reef fish size and abundance. The occurrence of severe coral disease and bleaching in this relatively deep (25-30 m) and remote location supports the hypothesis that coral loss in the Caribbean is a regional phenomenon, and there are no obvious and effective conservation and management measures to reverse this trend. The jurisdictional/management challenges for Navassa, meanwhile, do not abate.

References

A full list of references for the information provided in this chapter are provided in the full-length chapters of *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*, which can be found at: http://ccma.nos.noaa.gov/stateofthereefs.

Ault JS, Smith SG, Bohnsack JA (2005a). Evaluation of average length as an indicator of exploitation status for the Florida coral-reef fish community. ICES J. Mar. Sci. 62: 417–423.

Ault JS, Bohnsack JA, Smith SG, Luo J (2005b). Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. Bull. Mar. Sci. 76: 595–622.

Cox C, Hunt JH (2005). Change in size and abundance of Caribbean spiny lobsters *Panulirus argus*, in a marine reserve in the Florida Keys National Marine Sanctuary, USA. Mar. Ecol. Prog. Ser. 294: 227–239.

Ferro, F.M., L.K.B. Jordan, and R.M. Spieler. 2005. The Marine Fishes of Broward County, Florida: Final Report of 1998–2002 Survey Results. NOAA Technical Memorandum NMFS SEFSC 532. Miami, FL. 73 pp

García-Sais JR, Castro R, Sabater J, Carlo M, Esteves R, Williams S (2007). Monitoring of coral reef communities from natural reserves in Puerto Rico: Isla Desecheo, Rincon, Guanica, Ponce, Caja de Muerto and Mayaguez, 2006–2007. Final Report submitted to the Department of Natural and Environmental Resources of Puerto Rico. San Juan, PR. 194 pp.

García-Sais JR, Castro R, Sabater-Clavell J, Esteves R, Carlo M (2006). Monitoring of coral reef communities from natural reserves in Puerto Rico, 2006: Isla Desecheo, Rincon, Mayaguez Bay, Guanica, Ponce and Isla Caja de Muerto. Final Report submitted to the Department of Natural and Environmental Resources of Puerto Rico. San Juan, PR. 151 pp.

Gilliam DS (2006). Southeast Florida Coral Reef Evaluation and Monitoring Project 2005 Year 3 Final Report. Prepared for: Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Florida Department of Environmental Protection. 26 pp. http://www.floridadep.org/coastal/programs/coral/reports/.

Gilliam DS (2007). Southeast Florida Coral Reef Evaluation and Monitoring Project 2006 Year 4 Final Report. Prepared for: Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, Florida Department of Environmental Protection. 31 pp. http://www.floridadep.org/coastal/programs/coral/reports/.

Gilliam DS, Dodge RE, Spieler RE, Jordan LKB, Monty J (2006). Marine Biological Monitoring in Broward County, Florida: Year 5 Annual Report. Technical Report 05–01. Prepared for the Broward County Board of County Commissioners. Broward County Biological Resources Division and Environmental Protection Department. 90 pp.

McClellan DB, Miller GM (2003). Reef fish abundance, biomass, species composition and habitat characterization of Navassa Island. pp. 24–42. In: Miller MW (ed.). Status of Reef Resources of Navassa Island. NOAA Technical Memorandum NMFS SEFSC 501. Miami, FL. 119 pp. http://www.aoml.noaa.gov/general/lib/tm_501.pdf

Miller J, Waara R, Muller E, Rogers C (2006) Coral bleaching and disease combine to cause extensive mortality on reefs of the US Virgin Islands. Coral Reefs 25:418

Porch CE, Eklund AM, Scott GP (2003). An assessment of rebuilding times for goliath grouper. SEDAR6-RW-3. Sustainable Fisheries Division, NMFS Southeast Fisheries Science Center. Miami, FL. 25 pp. http://www.sefsc.noaa.gov/sedar/.

Porch CE, Eklund AM, Scott GP (2006). A catch-free stock assessment model with application to goliath grouper (Epinephelus itajara) off southern Florida. Fish. Bull. 104: 89–106.

Waddell JE (ed.) (2005). The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. Silver Spring, MD. 522 pp. available at: http://ccma.nos.noaa.gov/stateofthereefs.

Waddell JE Clarke AM (eds) (2008). The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp., available at: http://ccma.nos.noaa.gov/stateofthereefs.

Williams DE, Miller MW (2005). Coral disease outbreak: pattern, prevalence, and transmission in *Acropora cervicornis*. Mar. Ecol. Prog. Ser. 301:119–128.