The State of Coral Reef Ecosystems of the U.S. Virgin Islands

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INTRODUCTION AND SETTING

This report is the third in a series of assessments of the status of coral reef ecosystems in the U.S. Virgin Islands (USVI). The first assessment (Catanzaro et al., 2002) provided a broad overview of the status of USVI coral reef ecosystems, reported them to be in serious decline, and recommended enforcement of existing regulations and creation of no-take areas as the best actions to help reverse ecosystem declines. The second assessment (Jeffrey et al., 2005) identified several threats faced by coral reef ecosystems in the USVI, reported a continued overall decline in marine resources, and recommended for a second time that enforcement of existing regulations was the essential first step needed to address declining water quality, benthic habitats, and associated biological communities. This third assessment presents the current condition of coral reef ecosystems, describes the threats these marine ecosystems face and recommends additional actions based on data gathered between 2003 and 2007 by federal and territorial government agencies, non governmental organizations, academic institutions, and other stakeholders working in USVI coral reef ecosystems.

Coral reef ecosystems in the USVI comprise a mosaic of habitats, e.g., coral and other hardbottom areas, seagrasses, and mangroves, which house a diversity of organisms. Island communities depend on these biologically rich ecosystems for the important ecosystem services they provide such as shoreline protection and the support of valuable socioeconomic activities (e.g., fishing and tourism). However, human activities can and have destroyed or seriously degraded these same marine habitats upon which so much depends.

Coral reefs generally form fringing, patch, or spur and groove formations that are distributed in patches around three main islands of St. Croix, St. John, and St. Thomas and several smaller islands (Figure 2.1). The geology of these islands is dissimilar and has been previously described in great detail (Adey et al., 1977; Hubbard et al., 1993). Recent estimates of the spatial extent of coral reef ecosystems from Landsat satellite imagery indicate that coral reef ecosystems in the USVI cover approximately 344 km^2 (to 18 m depth) or 2,126 km^2 (to 183 m depth; Rohmann et al., 2005).

According to benthic habitat maps released by NOAA in 2001, coral reef and hardbottom habitats comprise 61%, submerged aquatic vegetation covers 33%, and unconsolidated sediments comprise 4% of shallow water areas less than 30 m deep in the USVI (Kendall et al., 2001; Monaco et al., 2001; http://ccma.nos.noaa.gov/about/biogeography/).

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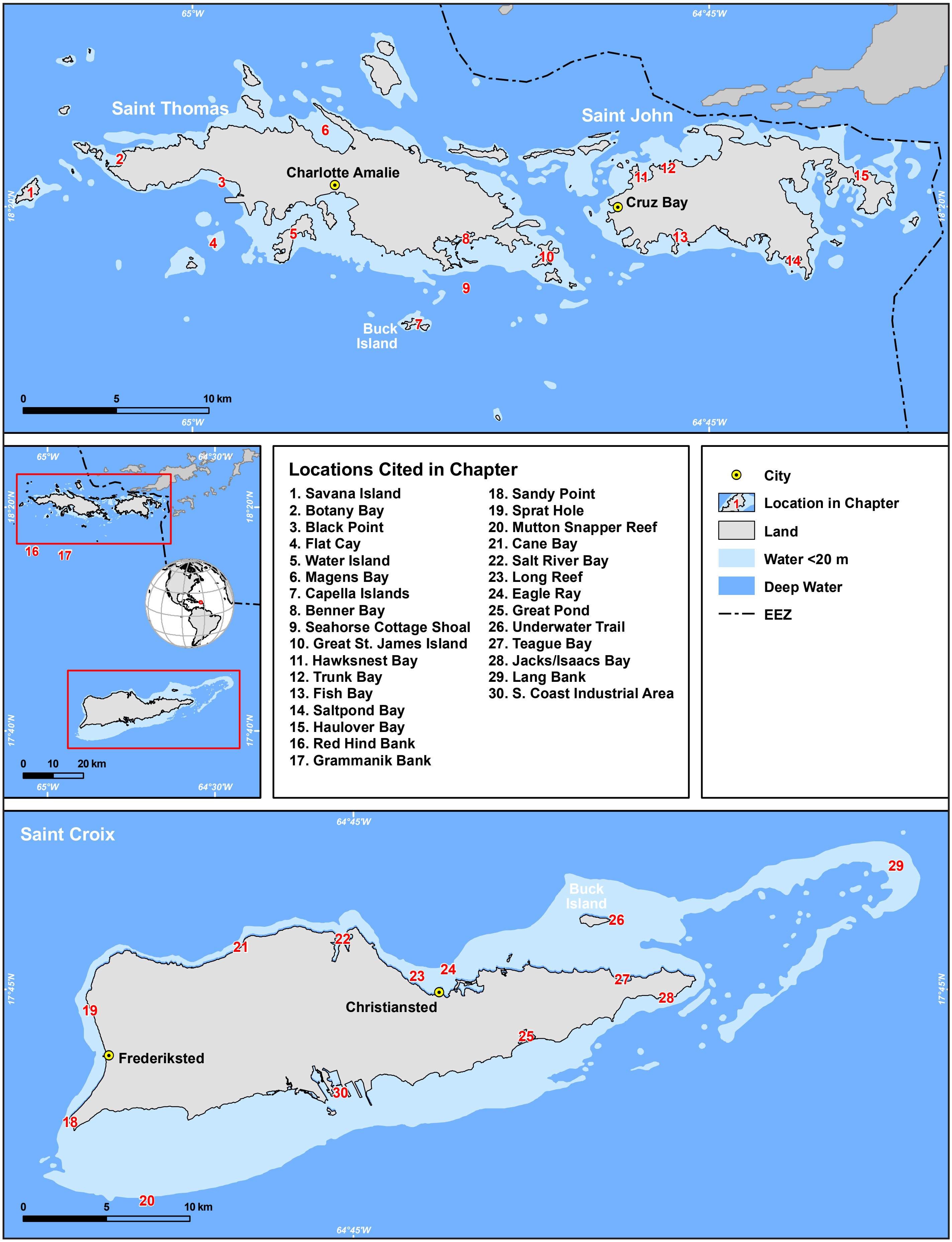

Figure 2.1. Map of the U.S. Virgin Islands showing locations mentioned in this chapter. Map: K. Buja.

ENVIRONMENTAL AND ANTHROPOGENIC STRESSORS

Threats and pressures affecting USVI coral reef ecosystems have been reviewed extensively by Rogers and Beets (2001), Catanzaro et al. (2002), Jeffrey et al. (2005) and Rogers et al. (in press). This section summarizes the major pressures on USVI coral reef ecosystems since 2003. Stressors that were described previously and have not produced major impacts since 2003 have been excluded from this report.

Climate Change and Coral Bleaching

Increasing sea surface temperatures (SST) continue to stress USVI coral reefs (Figure 2.2). A major coral bleaching event occurred in the Caribbean during summer and fall 2005 and was associated with elevated SSTs that persisted for a period of 12 to 15 weeks, depending on location (http://www.osdpd.noaa.gov/PSB/EPS/SST/data2/dhwa.11.5.2005.gif). Reefs in the USVI experienced extensive and widespread bleaching during 2005, with more than 90% of coral cover bleached in some areas. On average, water temperatures surrounding the reefs were much higher than anytime during the previous 14 years (Miller et al., 2006; Lundgren and Hillis-Starr, in revision). Modeling of the SSTs that precipitated this event indicated that anomalously high SSTs were most likely a result of unprecedented forcing from modern climate change (Donner et al., 2007). A response was initiated by federal and territorial monitoring agencies when the potential impacts from the event became apparent. These efforts included teams from the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), National Park Service (NPS), Virgin Islands Department of Planning and Natural Resources (DPNR) and the University of the Virgin Islands (UVI). What began as ad hoc monitoring at permanent and random study sites now forms the basis for one of the most intensively and extensively characterized coral bleaching events on record. Monitoring efforts from the event recorded not only the severe nature of the bleaching and subsequent disease and mortality, but variability in the response of corals across the USVI seascape. Although there was some recovery, episodic monitoring by NPS's South Florida Caribbean Network (SFCN) at four reefs in St. John and one at Buck Island Reef National Monument (BIRNM) in St. Croix after the bleaching event showed that bleached coral frequently became affected by white plague disease, ultimately resulting in > 50% loss of coral cover (Miller et al., 2006; NPS unpub. data) at long-term monitoring sites. Extensive monitoring by UVI as part of the DPNR Territorial Coral Reef Monitoring Program (TCRMP) at 25 sites across the USVI also showed that bleaching and the subsequent white plague disease outbreak caused from 10% to 90% loss of coral cover at sites in territorial and federal waters (Smith et al., in prep.). Major coral reef framework building species have been nearly extirpated at some sites. At BIRNM elkhorn coral experienced extensive bleaching and a loss of 53% cover for the species, after substantial regrowth throughout the 1990s (Mayor et al., 2006). The effects of bleaching and diseases on USVI coral reef ecosystems are dealt with in greater detail in the Benthic Habitats data section of this chapter.

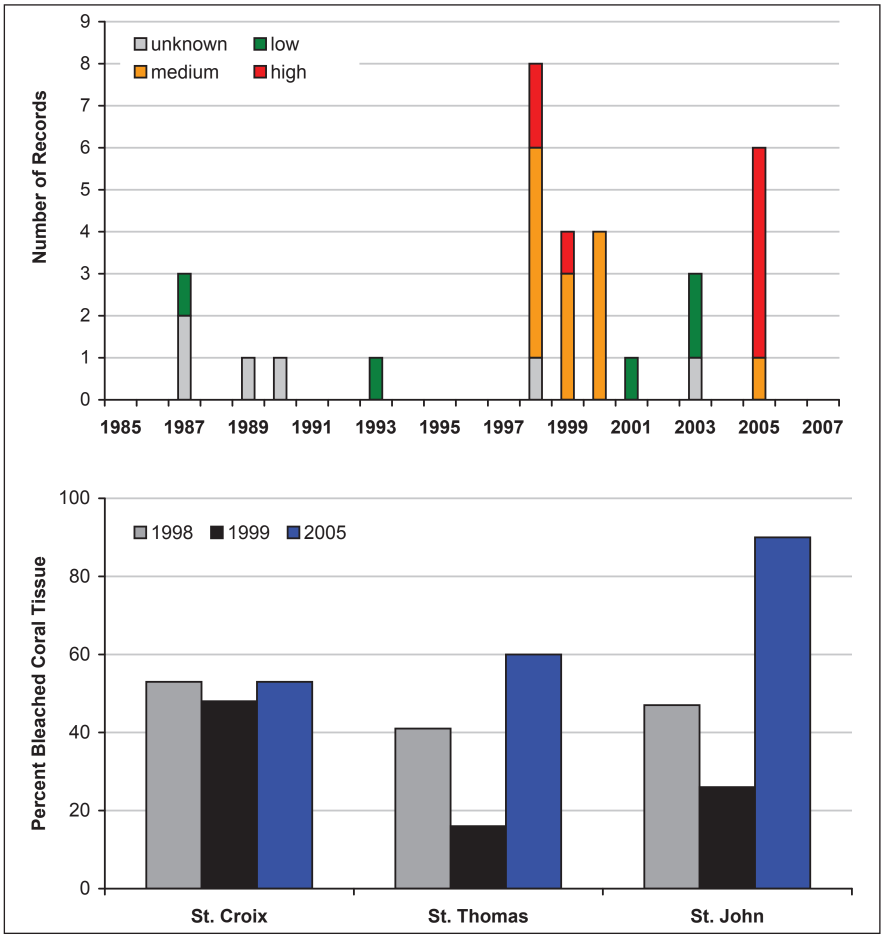

Figure 2.2. Annual trends in coral bleaching in the USVI. Upper panel shows the number of bleaching reports by year and severity. Source: Reefbase 2005, http://www.reefbase.org. Lower panel shows the estimated percent of coral tissues that bleached in 1998-1999 and 2005. Bars represent the mean percent of sampled coral colonies that bleached by island and year. Source: Rogers and Miller, 2001; Nemeth et al., 2003; Nemeth et al., 2005; NOAA, 2005; Miller et al., 2006.

In October 2005, as part of an existing bi-annual coral reef monitoring program for BIRNM and the St. Croix East End Marine Park (EEMP), data on the extent and severity of coral bleaching were collected by NOAA's Center for Coastal Monitoring and Assessment Biogeography Branch (CCMA-BB) and the NPS SFCN. Data from 94 randomly selected 100 m^2 transects over hardbottom habitats revealed that approximately 51% of live coral cover was bleached. Twenty-five of 30 coral species exhibited signs of bleaching, and bleaching was documented at all depths surveyed (1.5-28 m). Results of this project are described more completely in the Benthic Habitats data section of this chapter.

Partly in response to the regional bleaching event of 2005, NOAA's Coral Reef Watch Program sponsored a workshop in St. Croix in January 2006 entitled, *Satellite Remote Sensing Tools for Monitoring Thermal Stress Leading to Coral*

Bleaching. Attendees included federal and local resource managers and scientists from the British Virgin Islands (BVI), Puerto Rico and the USVI. Workshop participants were introduced to remote sensing tools for detection of environmental conditions that can lead to coral stress with the intent of increasing local capacity to respond to future bleaching events. Participants also discussed responses to the 2005 event, findings, needs and potential steps to improve future response efforts.

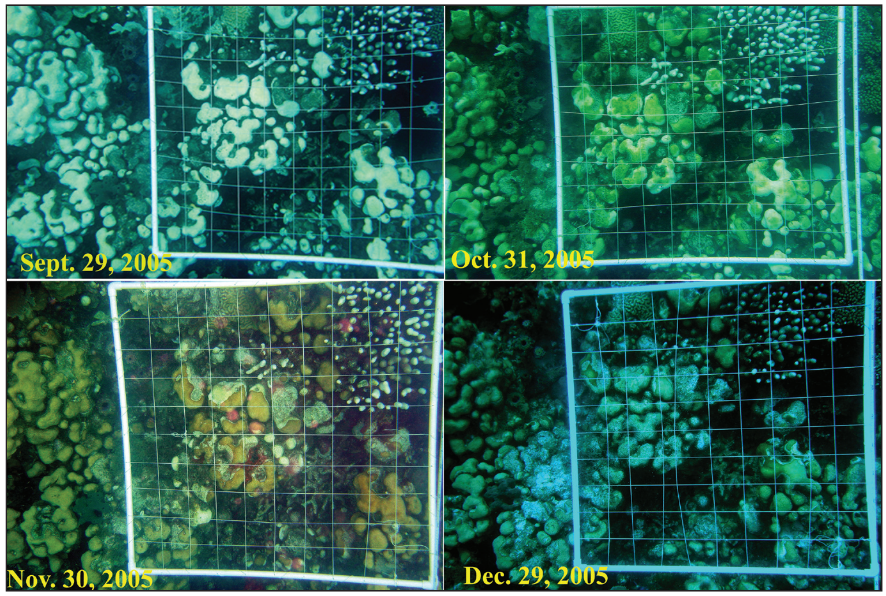

Figure 2.3. Time series of bleaching and disease in Montastraea annularis *and* Porites porites. *Bleached condition on September 2005, followed by partial recovery (October 2005) and disease mortality in November and December 2005. Source: adapted from Miller et al., 2006.*

Diseases

Diseases continue to significantly affect corals in the USVI. After the dramatic 2005 bleaching event, there was a 2,530% increase in disease lesions and 770% increase in denuded skeleton caused by disease over pre-bleaching levels. Mortality was primarily from white plague (NPS, unpub. data) and resulted in the loss of 51.5% live coral cover from more than 30 acres of coral reef (Figure 2.3; Miller et al., 2006). Surveys conducted as part of the TCRMP showed that the disease outbreaks were not confined to coral systems that were most severely bleached, as deep shelf edge sites that suffered little bleaching (5% of coral tissues) had high prevalence of white plague (6%) and suffered mortality similar to shallower, more heavily bleached sites (Figure 2.4). This indicates that high thermal stress can have effects that are decoupled from bleaching severity, and suggests that refuges from severe bleaching may not serve as refugia from mortality associated with high SSTs. More information on the effects of diseases on coral reef ecosystems in the USVI is presented in the Benthic Habitats section of this chapter.

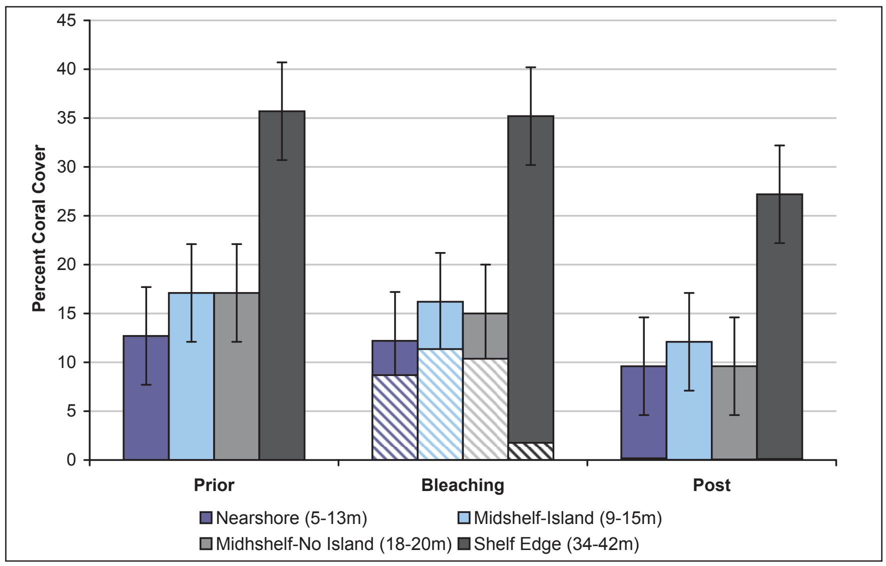

Figure 2.4. Coral cover and percent of coral tissues bleached (diagonal stripe) at 16 sites before the 2005 mass bleaching event, during the event and after the event. Shallow nearshore and midshelf island-associated sites (7-15 m) and deeper midshelf and shelf-edge linear reef sites (15-40 m) showed remarkably different patterns of bleaching, but similar losses of coral cover after a white plague-like disease outbreak. Source: T. Smith, UVI-CMES.

Tropical Storms

The effects of hurricanes on USVI coral reefs have been well documented and reviewed, and tropical storms have been shown to be a major force structuring reef communities in the Caribbean (Rogers et al., 1997; Bythell et al., 2000; Rogers and Beets, 2001; Rogers and Miller, 2001; and Jeffrey et al., 2005). Hurricane Frances, a Category 4 storm that passed about 180 km north of the USVI in 2004, was the most recent hurricane to affect the USVI (Figure 2.5). No major damage to coral reef ecosystems from this storm was reported.

Coastal Development and Runoff

Increasing pressures to develop land, combined with poor planning and regulation of development projects territory-wide, continues to be a major problem for the USVI. Watersheds in the territory have steep slopes and increasing amounts of impervious surfaces, which can create high velocity runoff and erosion. Sedimentation from unpaved roads can be 300-900% higher than that experienced in undisturbed watersheds (Rogers, 2006). Currently the territory utilizes a two-tier system, with different requirements for proposed developments in each tier. However, due to the topography of the islands, impacts from disturbances higher up in a watershed can be felt in coastal areas and may exacerbate impacts originating within the coastal zone. Additionally, lack of a Comprehensive Land and Water Use Plan for the territory makes effective planning for development and regulation of nonpoint sources of pollution extremely difficult. Published analyses of coastal development and associated impacts on the marine environment continue to be scarce in the USVI. An exception is the sediment monitoring program initiated in 2004 by UVI's Center for Marine and Environmental Studies (CMES).

Results from the CMES sediment monitoring program show a clear and significant onshore to offshore gradient (Figure 2.6), which suggests the potential impact of sedimentation on nearshore reefs is higher than on mid-shelf and offshore reefs. A similar onshore-offshore gradient was also found in a number of coral health indices, including bleaching prevalence and percentage of old mortality, indicating that sediment deposition may be a contributing factor in declining coral condition. Additional relationships were detected between sedimentation rates during the rainiest months and disease prevalence and the proportion of old mortality on nearshore reefs. These results suggest that the impact of heavy seasonal sediment loads can be significant on the nearshore environment. More detailed information on the CMES sediment study is included in the water quality section of this chapter.

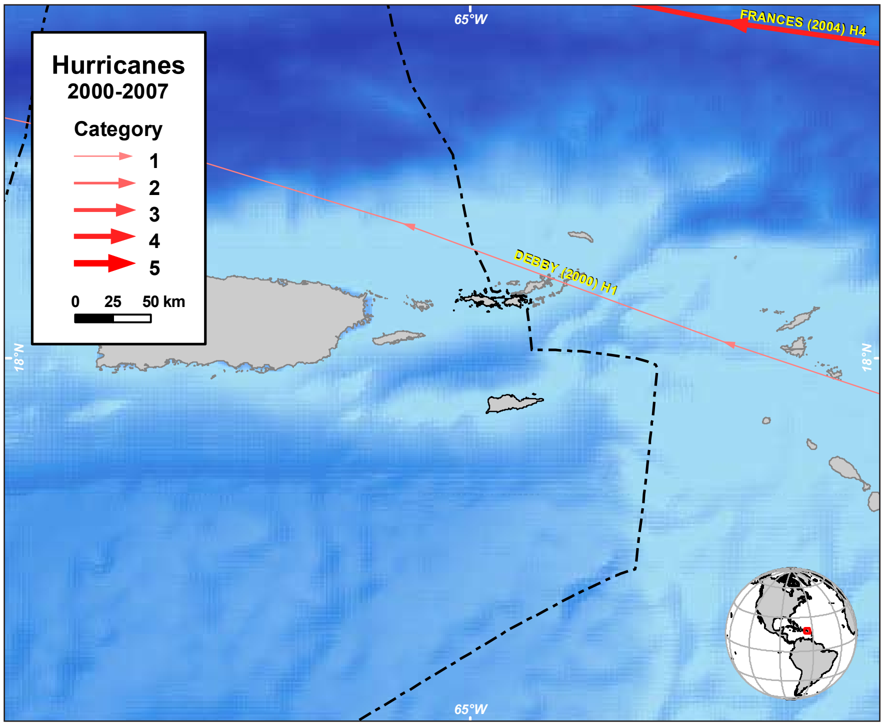

Figure 2.5. Tropical storms affecting the USVI from 2000-2007. Storm name, year and intensity is indicated for each. Map: K. Buja. Source: http://maps.csc.noaa.gov/hurricanes/.

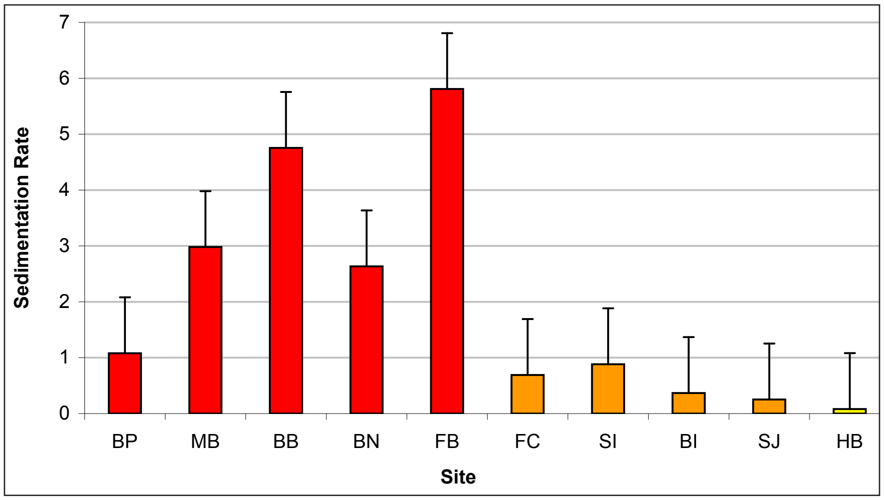

Figure 2.6. Mean sedimentation rates for all sites (grouped from near-shore to offshore). Red bars represent near-shore sites, orange bars mid-shelf sites and the yellow bar represents an offshore site. Source: J. Blondeau, UVI-CMES.

Coastal Pollution

Coastal pollution continues to affect coral reefs and other nearshore ecosystems. Bacterial contamination of coastal waters is a primary problem caused by numerous point and nonpoint source pollution discharges. Such discharges include failures at Publicly Owned Treatment Works which result in sewage bypasses into nearshore waters, failing septic systems and onsite sewage disposal systems, and the improper discharge of vessel waste directly into the water. The DPNR-Division of Environmental Protection (DEP) conducts the Virgin Islands Beach Water Quality Monitoring Program, a comprehensive beach monitoring and public notification program for beaches within the USVI jurisdiction. DEP developed this program to evaluate nearshore water quality represented by grab samples collected from designated beach bathing areas along the shorelines of St. Croix, St. Thomas and St. John. Since the program began in 2003, 43 beaches territory-wide have been sampled on a weekly basis. The information generated by this program has and continues to be used for public notification to minimize human health impacts from pathogens.

Numerous beach advisories were issued in the USVI during the period of 2003-2006; DPNR-DEP does not close beaches. Beach advisories increased in 2004 by 26 days to 101 compared with the number of advisories in 2003. However, the number of beach advisory days in 2003 was much lower than in 1999, when the public was advised to avoid affected beaches for more than 300 days (Figure 2.7).

Tourism and Recreation

Direct and indirect effects of tourism, recreation and associated development continue to affect USVI coral reefs. The history and impacts of tourism in the USVI were previously discussed in Jeffrey et al. (2005). Tourism continues to be a major component of the economy in St. Thomas and St. John but has declined in St. Croix since 2000 (Figure 2.8). Several factors have likely contributed to this decline including fewer airline flights and cessation of regular passenger cruise lines visiting Frederiksted in 2002. Smaller cruise ships continue to use the port in Gallows Bay, and larger cruise lines continue to use the Frederiksted pier for overnight bunkering to refuel.

BIRNM, which is managed by the NPS, was established in 1961 and expanded in 2001 to preserve and protect the unique elkhorn coral barrier reef. BIRNM remains St. Croix's number one tourist destination. NPS has six commercial companies that offer daytrips to the park year-round to snorkel, swim and enjoy the beach. There were over 109,000 commercial visitors and approximately 22,000 private visitors to BIRNM from 2003-2007. Numbers of visitors increased during this reporting period from 20,000 annually in 2003 to over 30,000 in 2006. BIRNM became one of the first fully protected marine areas in the NPS and in the USVI. The park ensures protection for all components of the marine ecosystem with the ultimate goal of promoting ecosystem recovery.

Adjacent to the BIRNM is the East End Marine Park, which is managed by the USVI government. In 2006 a system of 40 day-use moorings were installed within the EEMP to mitigate physical damage to park habitats. Moorings are available for the boating public and concessionaire use. Moorings were sited in heavily used areas where recreational boaters and fishers commonly anchored.

Beginning in 2007, a stateside-based dive operation, Nekton Diving Cruises, began bringing recreational divers to St. Croix. Utilizing a 34-passenger live-aboard dive vessel, the company has committed to improve 20 existing moorings around St. Croix. Nekton's Web site (http://www.nektoncruises.com/Departures/Schedule.aspx?B=Rorqual) shows weekly visits to St. Croix are scheduled until mid January of 2009.

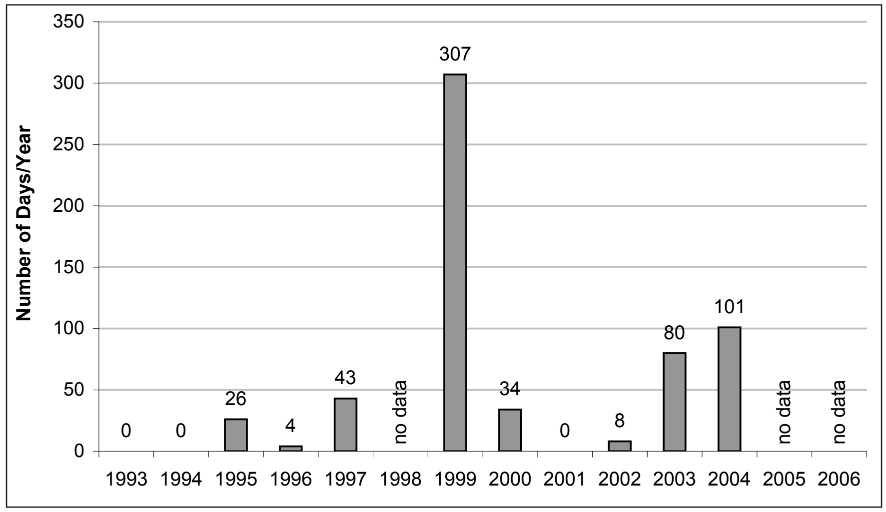

Figure 2.7. Beach days affected by closings days or advisories in the USVI from 1993 to 2006. Source: USVI DEP; Natural Resources Defense Council 2005, http://www2.nrdc.org/water/oceans/ttw/sumvi.pdf.

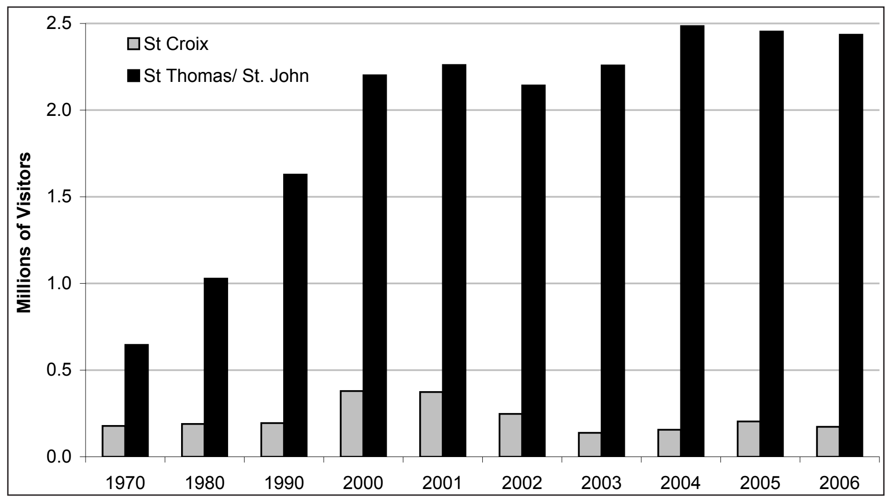

Figure 2.8. Number of visitors to St. Croix and St. Thomas/St. John between 1970 and 2006. Source: USVI Bureau of Economic Research, http://www.usviber.org.

Fishing

Reef fisheries remain a challenge for managers in the territory. Under the current reporting period the Caribbean Fishery Management Council (CFMC) approved the Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to the Fisheries Management Plans for spiny lobster, queen conch, reef fish, coral, and associated invertebrates and plants. As part of the process to amend the Sustainable Fisheries Act, scoping and working group meetings were held to solicit input and recommendations from fishers and the public. The draft amendment was prepared based on the meetings. Due to a lack of data on commercial fisheries for the territory, NOAA recommended extensive fishery closures for waters under CFMC jurisdiction. Although opposed to year-round fishery closures as management steps to protect impacted resources, the local government is considering the adoption of some CMFC preferred alternatives. Adoption of these alternatives would provide for compatible protection of resources in both federal and territorial waters. Alternative management strategies under consideration include: closed seasons for large-bodied grouper and snapper and a ban of specified duration on the capture of Nassau and Goliath grouper (Kojis, 2005).

Jeffrey et al. (2005) provided a comprehensive historical overview of the status of USVI reef fisheries. Since then, DPNR's Division of Fish and Wildlife (DPNR-DFW) has compiled and made available commercial fisheries-dependent and fisheries-independent data. DPNR-DFW coordinates two Cooperative Statistics Programs, the fishery-dependent Commercial Catch Reporting and Trip Interview Programs (TIP; port sampling) in order to monitor the fishery and gain information about its status. Information provided to the Commercial Catch Reporting program by fishers from the period 1975 through 2005 was compiled and analyzed during this report cycle. Catch trends for St. Thomas and St. Croix broken down by gear type are presented in Figure 2.9. DPNR-DFW's TIP collects biostatistical data from a subsample of commercial landings through the voluntary participation of fishers. Sampling under this program since 1980 has shown a continued decrease in size for red hind in the St. Croix fishery, with the average size of red hind caught near the minimum reproductive size for the species (DPNR-DFW, unpub. data). In contrast, data from this program indicate that spawning aggregation (SPAG) closures for the St. Thomas fishery have been effective and that average sizes of these fish caught from St. Thomas are approximately 10 cm larger than those caught in St. Croix (DPNR-DFW, unpub. data). Since these programs employ fishery-dependent data, they provide a description of the fishery but are limited in their ability to characterize fishery resources. Trends observed from these programs may indicate spatial or geographic differences in catch, gear variation and changes in fishing effort due to economic factors.

DPNR-DFW also coordinates the fisheries-independent Southeast Area Monitoring and Assessment Program Caribbean (SEAMAP-C) component to monitor fishery resources. SEAMAP-C is a collaborative effort between NOAA's National Marine Fisheries Service (NMFS), the Department of Natural and Environmental Resources in Puerto Rico and DPNR-DFW. The program's main goal is to "provide an integrated and cooperative program to facilitate collection and dissemination of fishery-independent information for use by government agencies, the fishing industry, researchers and others to enhance knowledge of marine fisheries and their associated ecosystems" (Griffin, 2005). The program uses a standardized sampling methodology across Puerto Rico and USVI to conduct assessments of reef fish, conch, and lobster stock on a three-year rotating schedule. Recent reviews of the SEAMAP-C program suggest that the current survey design is not providing data of the quality necessary to evaluate changes in fishery stocks (Whiteman, 2005; Pagan, 2004; Cummings et al., 2007). An evaluation of the SEAMAP-C sampling design has been proposed and implementation of any suggested changes to the design will be tested through subsequent pilot studies (Cummings et al., 2007). Detailed descriptions of methods and results are included in the Associated Biological Communities section of this chapter and in referenced publications for each program.

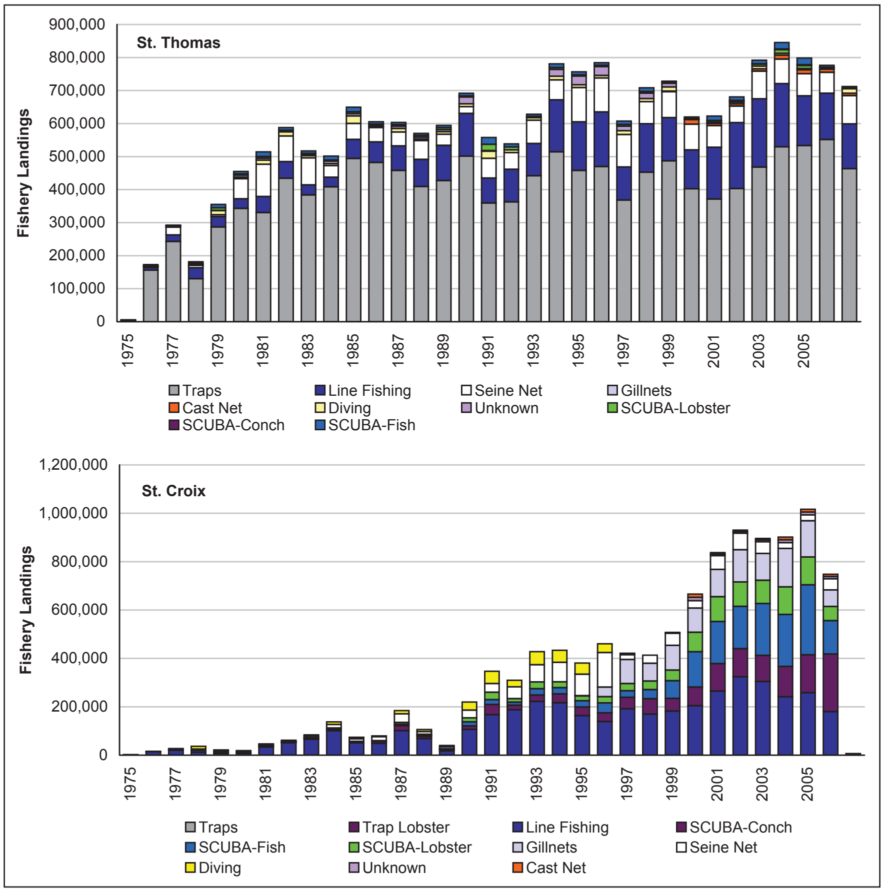

Figure 2.9. Fishery catch trends by gear type in St. Thomas (top) and St. Croix (bottom) as reported to DPNR-DFW's Commercial Catch Reporting Program. Source: D. Olsen, DPNR-DFW.

Trade in Live Coral and Live Reef Species

In 2006, elkhorn (*Acropora palmata*) and staghorn (*A. cervicornis*) corals were listed by NMFS as threatened under the Endangered Species Act (ESA). This listing has the potential to affect coastal development regulation in the USVI, as nearshore coral reefs comprise the primary habitat for these species. Elkhorn and staghorn corals are important framework species, and their branching growth form provides significant habitat for a variety of reef organisms. These corals have, and continue to be, acutely impacted by physical damage (hurricanes, anchoring), bleaching associated with increasing SSTs and coral disease. While these species have made limited, localized recoveries (Mayor et. al., 2006) the general trend is one of continued decline due to the aforementioned factors compounded by additional anthropogenic stressors such as declining coastal water quality due to sedimentation, runoff and point source discharges. The continued loss of these reef-building species has likely altered the functionality of the territory's coral reefs and is especially troubling as the USVI depends on its reefs to support tourism and provide food, recreation and shoreline protection.

Currently, the *Acropora* recovery team is preparing a recovery plan for the species pursuant to section 4(f) of the ESA. The plan will outline strategies to conserve and protect the existing elkhorn and staghorn populations through documentation of species abundance, distribution, habitat requirements, genetic status and disease dynamics, and through outreach and education efforts (http://sero.nmfs.noaa.gov/pr/esa/acropora.htm). More information on the listing and potential regulatory impacts is found in the Current Conservation Management Activities section of this chapter.

Ships, Boats and Groundings

Vessel impacts such as groundings, anchor damage and waste discharges continue to affect coral reef ecosystems in the USVI. One such example from St. John is the April 2002 grounding of a local inter-island ferry, the *Voyager Eagle*. The ferry ran aground on Johnson's reef in the Virgin Islands National Park (VINP; Figure 2.10). Three areas were identified by NPS staff as being injured by the grounding and subsequent removal of the vessel. NOAA's CCMA-BB is collaborat-

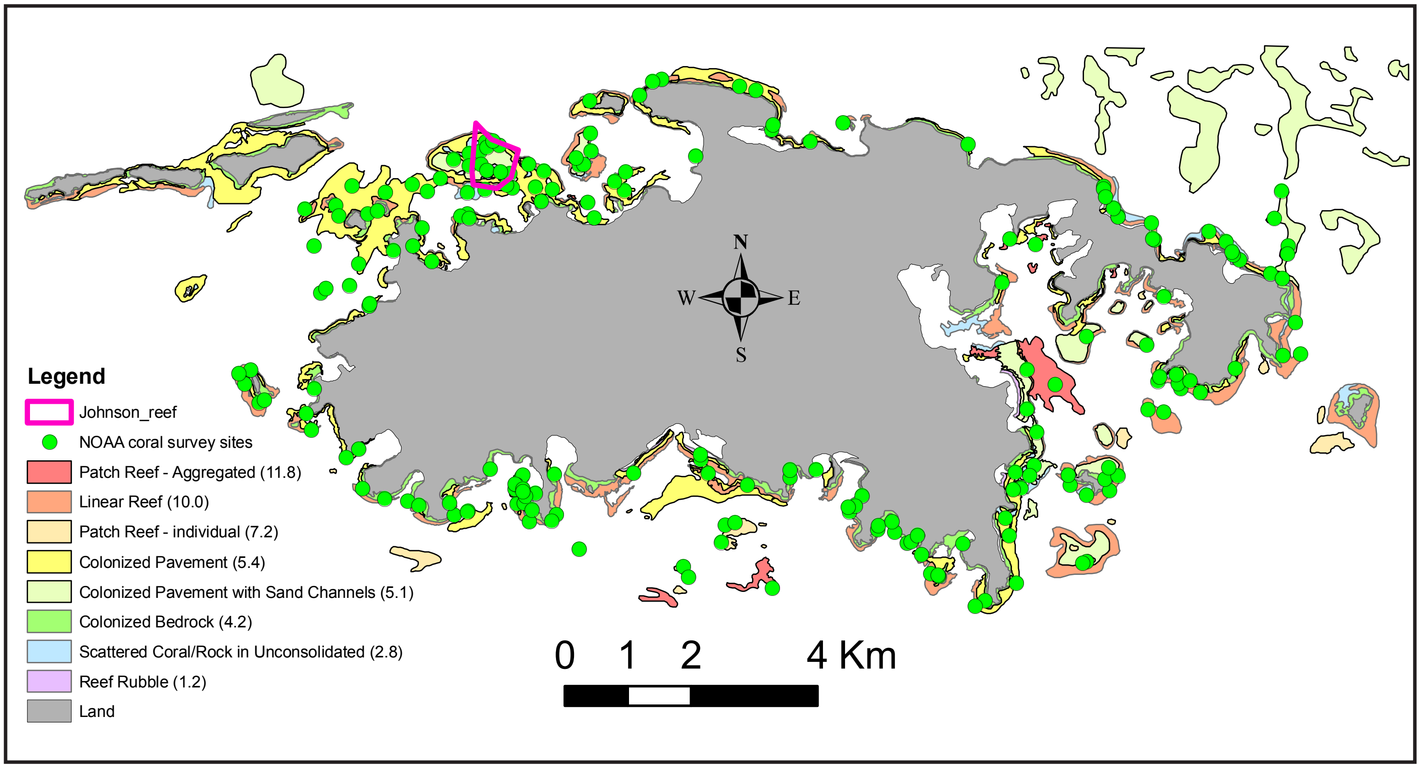

Figure 2.10. Location of the vessel injury area, coral reef types, and NOAA benthic survey locations (green circles) in St. John, USVI. Numbers in parentheses are mean estimates of live coral cover for each reef type. Coral cover was determined from benthic surveys conducted at 183 locations during 2002-2006. Bold text indicates reef types that occur at the grounding site. At each survey location, data were collected from five replicate 1 m² quadrats randomly placed within a 100 m² belt transect. Reef types are from the "Benthic Habitats of Puerto Rico and the U.S. Virgin Islands" (Kendall et al., 2001). Map: C. Jeffrey.

ing with NPS staff to develop estimates of coral cover within the areas damaged by the Voyager Eagle. Quantitative data derived from 1) benthic maps (Kendall et al., 2001) and 2) *in situ* monitoring of benthic composition (http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish.html) are being used to estimate live coral cover in impacted areas. These estimates will be used during litigation and negotiation of compensation for damages caused by the grounding.

In addition to coral damage caused by groundings, vessel anchoring is a problem for USVI reefs. A report by Toller (2006) provides insight on the impacts of decades of damage caused by the anchoring of large vessels on the Frederiksted reef system in St. Croix. This area was used as an anchorage since colonial times. However, in 1994 two anchorages were established to the north and south of the Frederiksted pier despite information that noted the importance of this reef system to local fisheries. Toller (2006) investigated the extent of damage to the reef system to the north of the pier between 2004 and 2005. Extent of the damage was estimated at 21.2 hectares (ha) of reef crest with a maximum cross-shelf width of 256 m (Toller, 2006). Rugosity (a measure of the complexity of the reef surface), coral cover and coral species richness were all significantly reduced (43.5%, >87% and 54%, respectively; Toller, 2006) in the damaged area compared to control sites. Fish community structure, including the average and cumulative number of species, were both lower (20% and 19% respectively; Toller, 2006) than control sites. Results of this study show that anchor damage can dramatically affect the architecture of reef systems and the biological communities they support. This case study highlights the continuing need for planning and regulation of vessel anchoring in the USVI.

Marine Debris

Like most developed areas, marine debris continues to be a problem in the USVI despite educational programs and community cleanups. Currently the only data about marine debris in the USVI is collected during the Ocean Conservancy's annual International Coastal Cleanup (ICC). The USVI has been participating in the ICC for 13 years. Approximately 900 volunteers across the territory participate in land and underwater cleanups associated with this event annually. Additionally, several groups conduct beach cleanups at specific sites around the islands throughout the year.

During the 2006 ICC, 1,083 volunteers removed 19,255 pounds of trash and debris from 53 miles of shoreline. In addition, 18 volunteers participated in underwater cleanups, removing 500 pounds of debris. The types of debris collected in the 2006 ICC were similar to debris types found around the world. The ten most numerous items found in the 2006 ICC all originate from shoreline recreational activities. The most numerous items were glass bottles, cap/lids, cans, plastic bottles and plates/utensils. Items from shoreline recreational and smoking-related activities comprise 92% of all items collected (Figure 2.11). Although some debris washes in from offshore sources, it represents a very small percent of total items collected.

Aquatic Invasive Species

Aquatic invasive species are not recognized as a major threat in this jurisdiction.

Security Training Activities

No security training activities currently occur in this jurisdiction.

Offshore Oil and Gas Exploration

No offshore oil and gas exploration currently occurs in the USVI.

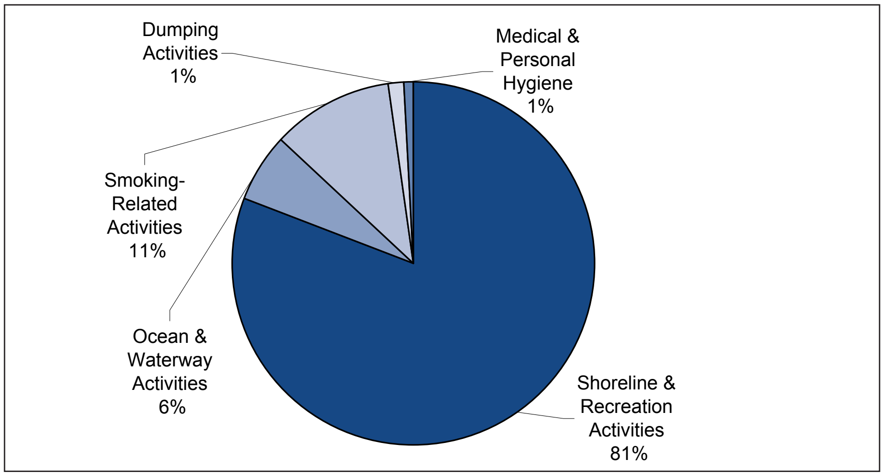

Figure 2.11. Sources of marine debris collected as part of the 2006 ICC in the USVI. Source: M. Taylor, UVI-VIMAS.

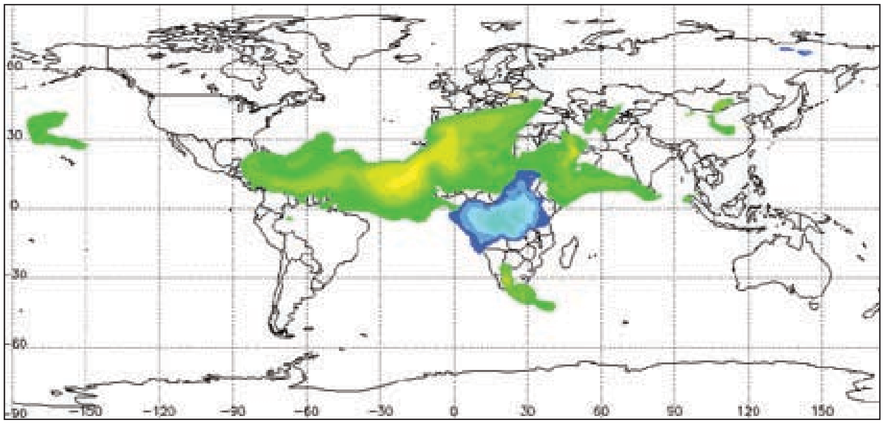

Figure 2.12. Simulated distribution and composition of aerosols on June 23, 2007 showing transport of dust from the Sahel region of Africa across the Atlantic, to the Caribbean. Optical depth in images contoured at 0.2, 0.4, 0.8, 1.6, 3.2, and 6.4. Green and yellow shades indicate dust and blue indicates smoke from biomass burning. Source: Navy Aerosol Analysis and Prediction System (NAAPS) Global Aerosol Model courtesy of Douglas L. Westphal, Naval Research Laboratory.

Other

African Dust

Every year, hundreds of millions of tons of eroded mineral soils (dust) are carried in the atmosphere from the Sahara Desert and Sahel in Africa to the Americas and Caribbean. The quantity of soil transported varies with global climate, tropical SSTs, regional meteorology, surface composition and land use in dust source regions. Saharan dust has been transported across the Atlantic for millions of years, impacting downwind ecosystems through deposition of nutrients to the Amazon Basin, red-clay soils to the limestone islands of the Caribbean, freshwater diatoms and phytoliths to the seafloor off the coast of West Africa, and iron that periodically triggers red-tides in the Gulf of Mexico. At times, a continuous cloud of Saharan dust extends from West Africa to Central and South America and north to the southeastern U.S. (Figure 2.12). Over the past 40 years, the quantity of dust has increased, and the composition of the dust cloud has been altered due to pesticide use, changes in land use, and burning of synthetic materials and biomass (fuel) in the dust source regions and in the areas over which they pass (Garrison et al., 2003 and 2006).

An international team of scientists led by the USGS is examining the contaminants carried with African dust and the role they may play in the degradation of Caribbean coral reefs and other downwind ecosystems (Shinn et al., 2000; Garrison et al., 2003 and 2006). Thus far, African dust has been found to carry viable microorganisms, including pathogens, nutrients such as iron, persistent organic pollutants and heavy metals. During dust conditions in the USVI and Trinidad, African dust contains 2-3 times as many microorganisms per volume as during non-dust conditions. Of those species identified to date, 25% are known plant pathogens and 10% are known opportunistic pathogens of humans (Griffin et al., 2001 and 2003). A coral disease pathogen, the fungus *Aspergillus sydowii,* has been identified in dust (Weir-Brush et al., 2004). Pesticides (such as chlordane, lindane, chlorpyrifos, endosulfans and dacthal), polycyclic aromatic hydrocarbons, and polychlorinated biphenyls have been identified in African dust air masses in the Caribbean (USVI and Trinidad) and in Africa (Garrison et al., 2005). These contaminants are known to be toxic at very low concentrations, to persist in the environment, to bioaccumulate in organisms, and to interfere with reproduction and immune function. Particularly troubling, at the most basic ecosystem level, some of these contaminants are known to shut down phytoplankton photosynthesis (Wurster, 1968).

CORAL REEF ECOSYSTEMS—DATA-GATHERING ACTIVITIES AND RESOURCE CONDITION

This section focuses on resource monitoring activities, data collection and analyses, and summaries of published studies and data sets to provide an assessment of the condition of USVI coral reef ecosystem resources during 2004-2007. Information is presented to describe three functional or structural components of coral reef ecosystems: marine water quality and oceanographic conditions, benthic habitats, and associated biological communities (Table 2.1). A brief summary of ongoing research and monitoring programs, methods, results and discussion are presented for each ecosystem component. Locations of monitoring and research efforts are shown in Figure 2.13.

Table 2.1. Data sets selected to describe the current condition and status of coral reef ecosystems in the USVI for the period 2004-2007. Bold type indicates new monitoring programs. Source: P. Rothenberger.

Ecosystem Component	Data Set	Source Agency	Objectives	Start Date	Frequency	Program Information
Water Quality	Water Temperature Monitoring at BIRNM	NPS	Basic abiotic monitoring	1991	Continuous	
	2004 Integrated Water Quality Monitoring and Assessment Report for the USVI	EPA, DPNR-DEP	"To satisfy 305(b) and 303(d) requirements of the Federal Clean Water Act; to assess the water quality conditions of the Virgin Island's surface and ground water resources"	1998	Every two years	http://www.dpnr.gov.vi/dep/pubs/
	2006 Integrated Water Quality Monitoring and Assessment Report for the USVI	EPA, DPNR-DEP	"To satisfy 305(b) and 303(d) requirements of the Federal Clean Water Act; to assess the water quality conditions of the Virgin Island's surface and ground water resources"	1998	Every two years	http://www.dpnr.gov.vi/dep/pubs/USVI2006IWQAReport.pdf
	National Coastal Condition Report II (2005)	EPA, DPNR-DEP	To describe, summarize, and rate the overall ecological and environmental conditions of U.S. coastal waters; to highlight several exemplary federal, state, tribal and local programs that assess coastal ecological and water quality conditions.	2001	Varies (1-4 yr. cycle)	http://www.epa.gov/owow/oceans/nccr/2005/Chap8_AK_HI_islands.pdf
	VI Beach Water Quality Monitoring Program	DPNR-DEP	Evaluate nearshore water quality; notify public of possible human health impact of pathogens	2004	Weekly	http://dpnr.gov.vi/dep/
	UVI CMES Sediment Monitoring Program	UVI-CMES	Examine relationship between sedimentation rates, distance from shore and coral condition	2004	Monthly (with gaps)	
Benthic Habitats	**DPNR and U.S. EPA Coral Bioassessment/ Biocriteria Monitoring (Fore et al., 2006 a and 2006b; Fisher, 2007)**	**EPA, DPNR-DEP**	**To evaluate a stony coral bioassessment protocol for application to biocriteria development in the USVI**	**2006**	**Twice/year (STX), one mission proposed for STT/STJ**	http://epa.gov/bioindicators/coral/coral_biocriteria.html
	Characterization of benthic habitats in the VINP and BIRNM	CCMA-BB	To spatially characterize and monitor composition of benthic habitats to help quanitfy fish-habitat interactions and support management	2001	Annual (STJ); biannual (STX)	http://www8.nos.noaa.gov/biogeo_public/query_main.aspx
	NOAA Benthic Mapping and Characterization	CCMA-BB	To characterize and map mid- and deep-water habitats in the USVI	2004	Annual	http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/overview.html
	NOAA Coral Bleaching Assessment (Clark et al., in review)	**CCMA-BB, NPS SFCN**	**To assess spatial patterns in the extent and severity of bleaching in and around BIRNM, St. Croix**	**2005**	**One time**	http://coralreefwatch.noaa.gov/caribbean2005/
	NOAA/NMFS USVI *Acropora* Mapping Project	**NOAA NMFS**	**To develop a spatial database on the distriution of *A. palmata* in the U.S. Caribbean**	**2006**	**Ongoing**	
	NPS Assessment of Bleaching Impacts to *A. palmata* at BIRNM (Lundgren and Hillis-Starr, in revision)	**NPS**	**To monitor the status of *A. palmata* in the 3 major BIRNM habitat types**	**2005**	**Originally, 1 month; now 6 month**	**Program will be supplanted by a more comprehensive assessment of *A. palmata* at BIRNM and EEMP**
	Coral Monitoring Program for VINP and VICRNM (Miller et al. 2003 and 2006; Rogers et al., in press).	NPS and USGS	To monitor disease and cover of corals within the Virgin Islands National Park (VINP) and Virgin Islands Coral Reef National Monuments (VICRNM)	1997	Every three months	
	Elkhorn Coral Monitoring Project (Rogers and Muller, In prep.)	NPS and USGS	To map and monitor changes in the abundance and condition of Acropora palmata colonies			
	TNC, UVI-CDC *Acropora palmata* Mapping	**TNC, UVI-CDC**	**To map the spatial distribution of size classes and health status of *A. palmata* colonies at selected sites**	**2006**	**One time**	
	Territorial Coral Reef Monitoring Program (Nemeth et al., 2003; 2004b; 2004c; 2005)	UVI-CMES, DPNR-CZM	To examine long-term trends in coral reef condition including benthic cover and coral health assessments.	2000	Annual and during significant events	

Ecosystem Component	Data Set	Source Agency	Objectives	Start Date	Frequency	Program Information
Associated Biological Communities	NOAA CCMA-BB Monitoring of Temporal Trends in Fish Communities of the USVI	CCMA-BB	To spatially characterize and monitor benthic composition for use in quantifying fish-habitat interactions to support management	2001	STX 2x/ year; STJ annually	http://www8.nos.noaa.gov/biogeo_public/query_main.aspx
	NOAA CCMA-BB Fish Tagging Study (Friedlander and Monaco, 2007)	**CCMA-BB**	**To understand and quantify movement patterns and habitat affinities of USVI reef fishes**	**2006**	**Ongoing**	
	SEAMAP-C fisheries-independent monitoring (Gomez, 2000; Tobias et al., 2002; Tobias, 2005; Whiteman, 2005)	DPNR-DFW	To collect information on densities of queen conch and habitat in shallow back-reef embayments	1998	Variable	http://www.vifishandwildlife.com/Fisheries/FisheriesReports/
	UVI-CMES Monitoring of Spawning Aggregations (Nemeth, 2005; Nemeth et. al., 2004a; 2006a; 2007; Kadison et al., 2007)	UVI-CMES	Assess status of grouper and snapper spawning aggregations and evaluate effects of MPA's on spawning population	1999	Annual	
	TCRMP - Fish Assessments (Nemeth et al., 2004b; 2005; 2006b)	UVI-CMES, DPNR-DFW, DPNR-CZM	To examine long-term trends in reef fish populations	2000	Annual	
	Assessment and Monitoring of Spiny Lobster Populations at BIRNM (Hunt and Cox, 2005)	**NPS and FFWC**	**To determine the status and trends of *P. Argus* inside BIRNM and in adjcent fisheries**	**2004**	**Annual**	

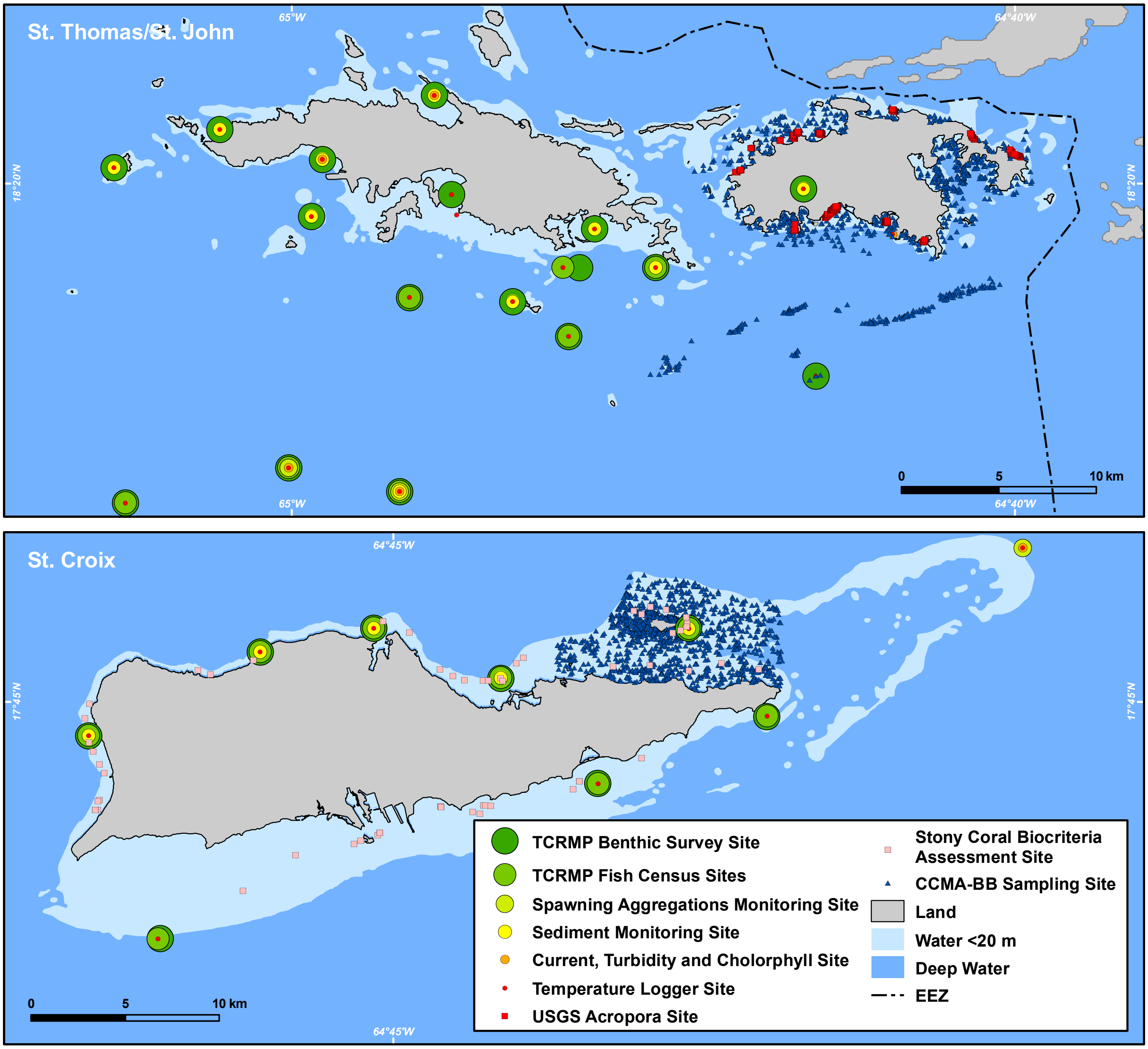

Figure 2.13. Locations of monitoring and research efforts occurring in the USVI between 2004 and 2007. Map: K. Buja.

WATER QUALITY AND OCEANOGRAPHIC CONDITIONS

USVI DPNR-DEP Water Quality Monitoring/EPA Water Quality Assessments

The previous USVI State of the Reef report (Jeffrey et al., 2005) focused on water quality data collected by DPNR-DEP and NPS/USGS prior to the year 2000. DPNR-DEP's Ambient Monitoring Program is presently the primary mechanism for monitoring the territory's coastal water quality. The methods employed and parameters monitored by DPNR-DEP as part of the Ambient Monitoring Program are the same as were detailed by Jeffrey et al. (2005). The program was recently expanded to include deep offshore sites, and now a total of 167 sites (77 around St. Croix, 66 around St. Thomas and 24 around St. John) are sampled on a quarterly basis. DPNR-DEP also implements the VI Beach Water Quality Monitoring Program. Water samples are collected weekly at 43 beaches throughout the territory and processed for *Enterococci*; data from this program is used in conjunction with Ambient Monitoring Program data to issue public advisories on the status of waters at popular beaches. Every two years, the U.S. Environmental Protection Agency (EPA) requires DPNR-DEP to submit reports on the territory's water quality under Section 305(b) of the Clean Water Act. DPNR-DEP is also required, under Section 303(d) of the Clean Water Act, to submit a separate prioritized list of waters that are impaired and implement pollution controls such as the development of Total Maximum Daily Loads (TMDL). Data collected by DPNR-DEP to fulfill reporting requirements are now being integrated into one report, an Integrated Water Quality Monitoring and Assessment Report that is submitted to the EPA. This integrated report describes the condition of territorial waters and whether the waters meet standards pursuant to Section 305(b), identifies impaired waters and those in need of TMDL development pursuant to Section 303(d) and identifies waters being removed from the 303(d) list because they are now in compliance.

Results and Discussion

Results from DPNR-DEP's water quality monitoring programs show that while water quality in the USVI is generally good, it continues to decline. In 2006 DPNR-DEP (2006) included 69 areas are on the 303(d) list of impaired waters up from 50 on the 2004 list (DPNR-DEP, 2004). In conjunction with EPA, DPNR-DEP has created a schedule for the creation of TMDLs for these water bodies. To date, 14 water bodies have established TMDLs, and watershed restoration action strategies continued for eight water bodies in 2007 and 2008.

Surface waters in the USVI continue to be affected by increasing point and nonpoint sources of pollution. Nonpoint sources, such as runoff from construction sites and unpaved roads, failure of best management practices on construction sites, failure of onsite disposal systems, failing septic systems and the direct discharge of waste overboard from vessels cause a majority of the surface water contamination problems in the territory. Primary problems affecting nearshore waters as a result of these discharges are sedimentation and bacterial contamination. Regulation of such activities is difficult and largely voluntary. Sewage bypasses from the municipal sewage system and wastewater effluent from both permitted and illegal discharges continue as well.

Several efforts have been made to remedy these problems or mitigate their effects during this reporting period. DPNR-DEP is currently revising its water quality standards which were last successfully revised in 2004. DPNR-DEP is also developing stormwater regulations to be implemented through a stormwater control program for the territory. The Storm Water Program will enhance DPNR-DEP's ability to regulate and enforce poorly maintained construction and industrial sites. DPNR-DEP has also developed a Clean Marina Program in an effort to mitigate discharges from these facilities. In an effort to address the troubled municipal sewage system, the VI Government created a new agency, the VI Waste Management Authority to oversee the treatment facilities and local landfills. Additionally, treatment plants and pump station equipment was repaired or replaced in St. Croix, St. Thomas and St. John.

UVI–CMES Sediment Monitoring Program

Sedimentation rates on 10 St. Thomas and St. John reefs (five near-shore, four mid-shelf and one offshore) have been determined using passive collectors since December 2004 as part of the coral reef monitoring program conducted by CMES with funding from DPNR-DEP. Sediment traps consist of PVC tubing, 20 x 5 cm internal diameter, that has been driven into non-living portions of reef and placed so the top of the traps sit 0.5 m above the substrate. Collected sediments are rinsed twice with dionoized water to remove salts and dried at 70 ºC. Dried sediments are sieved and weighed to the nearest 0.001 g. Sediments that are < 0.075 mm are considered terrigenous in origin and are used to calculate the sedimentation rate. Rate of sediment accumulation (g/cm^2/day) is determined by dividing the weight of dried sediment by the area of the trap and then by soak time. Full methods are presented in Nemeth et al. (2004).

Results and Discussion

Results showed a clear and significant onshore-offshore sedimentation gradient; nearshore sedimentation rates were six times greater than at mid-shelf reefs, and nearly 50 times greater than at offshore reefs. This clear stress gradient suggests that the potential impact from sedimentation on nearshore reefs is higher than on mid-shelf and offshore reefs. A similar onshore to offshore gradient was also found in a number of coral health indices, including bleaching prevalence and percentage of old mortality, indicating that sediment deposition may be, in part, adversely affecting coral condition. Additionally, very strong (> 90%) and significant correlations were found between sedimentation rates during the rainiest months and disease prevalence, as well as the proportion of old mortality on nearshore coral reefs. These results suggest that the impact of heavy seasonal sediment loads can be significant on the nearshore environment.

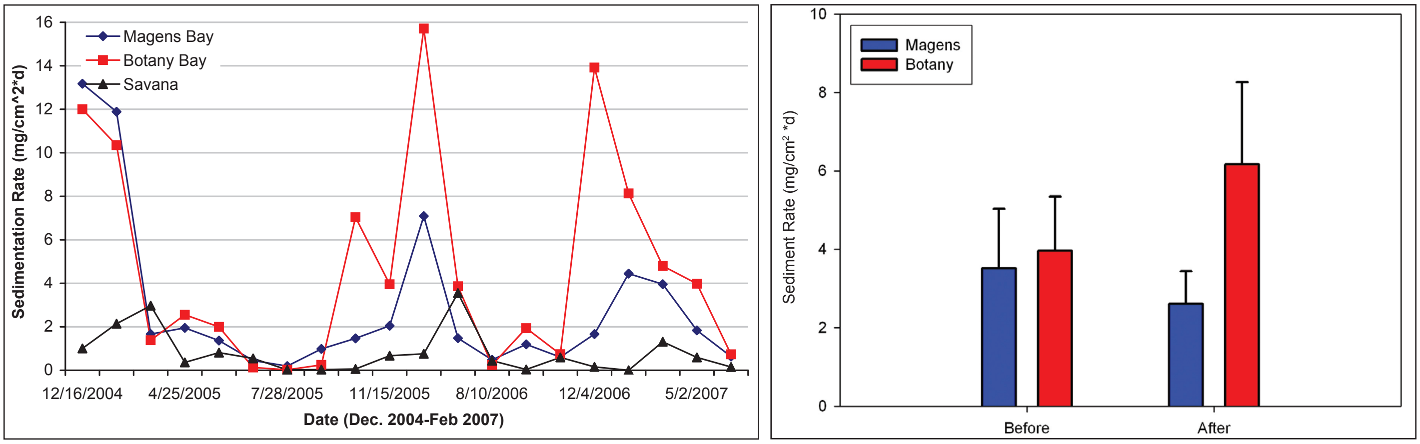

Figure 2.14. Mean sedimentation rate for each sampling period on north side St. Thomas sites (left). Mean sedimentation rate at Magens Bay and Botany Bay (right) before (December 2004-October 2005) and after (November 2005-March 2007) development at Botany Bay. Source: J. Blondeau, UVI-CMES.

Development activities in Botany Bay beginning in October 2005 resulted in a non-significant, yet marked increase in sedimentation rates (Figure 2.14). Interestingly, though, sedimentation rates at Botany Bay were relatively high, as compared to Magens Bay, prior to any development, which is somewhat counterintuitive given that the level of development in the Magens Bay watershed is much higher. This apparent disconnect between runoff potential (e.g., watershed characteristics including slope, soil type and land use) and sedimentation rate underscores the complexity of sediment transport within a watershed and suggests that sediment deposition onto nearshore reefs is driven by other means, likely oceanographic. High resolution, local oceanographic current models developed by UVI and the University of Miami's Rosenstiel School of Marine and Atmospheric Science show that the general westward moving currents for St. Thomas and St. John, tidal and wave energy, as well as the formation of localized eddies are all driving factors in the deposition of terrestrial sediments. Results of this sediment monitoring program suggest that the delivery of terrigenous sediment is a function of watershed characteristics, but the deposition of land-based soils onto reefs is driven by oceanographic mechanisms and, to some degree, is affecting nearshore coral condition.

NPS Water Temperature Monitoring at BIRNM

Water temperature data from BIRNM has been recorded since 1991. Although data gaps exist in many years, partial data exists for every year. Initially, Ryan RTM2000 temperature loggers were placed at the base of the eastern fore reef of Buck Island adjacent to the Underwater Trail at approximately ten meters depth. In 2003, NPS switched to HOBO temperature loggers, and an additional site was established on the back reef approximately midway along the north shore at 2 m depth.

Results and Discussion

The long-term data set from the fore reef of BIRNM displays a clear annual cycle. Temperatures are generally lowest in February and highest in September, and tend to fluctuate between 26-29ºC. There was no clear trend showing that water temperatures have increased since 1991; however, the mass bleaching event in 2005 produced the highest temperatures recorded since 1991. It has been noted that at BIRNM, temperatures regularly exceed the theoretical "bleaching threshold" without causing bleaching. Duration above the bleaching threshold, in addition to temperature intensity, appear to be synergistic factors which combine to influence bleaching (Lundgren and Hillis-Starr, in revision). From data collected over the last four years, temperatures on the back reef appear to fluctuate more (Figure 2.15), getting slightly warmer than the fore reef and heating up more rapidly. However, back reef temperatures also cool down more quickly. Average temperature exceeded the bleaching threshold of 29.3ºC for 85 days on the back reef and for 73 days on the fore reef during the bleaching period. Water temperature peaked at over 2ºC above the long-term average maximum on September 29, 2005 at the back reef location.

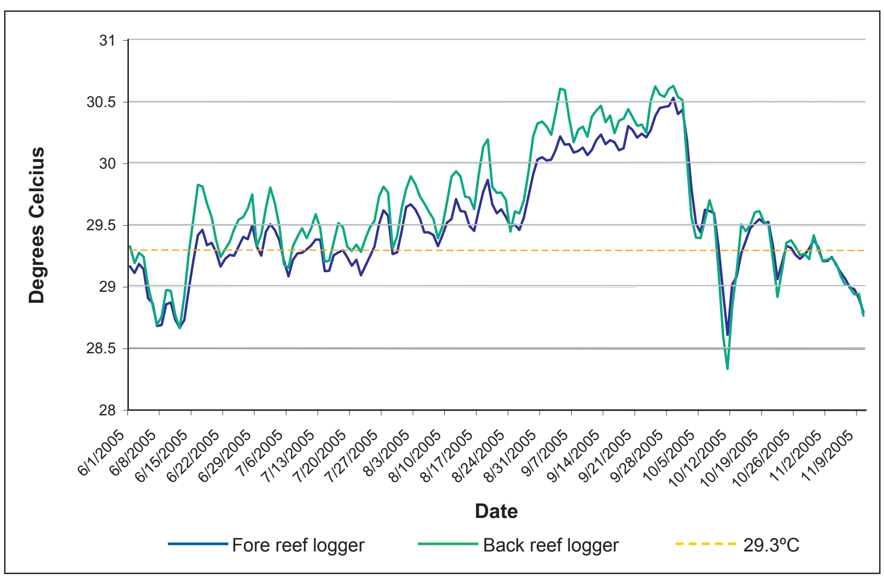

Figure 2.15. Subsurface water temperatures at BIRNM during the 2005 mass bleaching event. Both loggers are located adjacent to Buck Island on the barrier reef. The back reef logger is located at 2.5 m depth on the back reef just north of Buck Island. The fore reef logger is located at 10 meters depth on the easternmost fore reef. Source: adapted from Lundgren and Hillis-Starr (in revision).

BENTHIC HABITATS

Jeffrey et al. (2005) focused on five benthic data sets from various federal and territorial monitoring programs. Four of these five programs have continued and five new coral monitoring projects were launched during this reporting cycle. New projects include those aimed at describing populations of threatened *Acropora* corals, characterizing the scope and effects of the 2005 coral bleaching event and a feasibility study for the development of stony coral biocriteria as a water quality regulatory tool. Data collection methods did not change significantly between reporting periods for the ongoing monitoring programs.

NPS and USGS Coral Disease and Benthic Cover Abundance Monitoring

Long-term monitoring of coral disease, abundance and benthic cover continues to be conducted by the NPS SFCN's Inventory and Monitoring Program around St. John and BIRNM in St. Croix. Methods employed in these monitoring programs have been detailed in Miller et al. (2003), Jeffrey et al. (2005) and Rogers et al. (in press).

Results and Discussion

Information provided in this section has been summarized from Rogers et al. (in press); for more detailed descriptions, please see that publication and Miller et al. (2006). During the 2005 bleaching event more than 90% of coral cover bleached at long-term sites in St. John. Monitoring during and after the event showed that in addition to mortality associated with bleaching, corals also suffered significant losses due to a post-bleaching disease outbreak. While losses of coral cover at the St. John and BIRNM sites occurred from bleaching, the overwhelming mortality documented was attributed to white plague. In 12 months, loss of coral cover at the seven SFCN USVI monitoring sites ranged from 34.1% to 61.8% (NPS, unpub. data; Figure 2.16). *Montastraea annularis* species complex continues to be the dominant coral at these sites, but its abundance relative to other species declined by approximately 7% as a result of this event. Other species such as *Colpophyllia natans* declined in relative abundance, and *Agaricia agaricites* declined in both relative abundance and total cover. Data also showed that disease incidence was more extensive after the bleaching event than prior to the onset of bleaching. Additionally, through side by side comparison of video footage, it was determined that the larger colonies of major framework-building species were more severely bleached. Recovery from the bleaching was variable. *M. annularis* complex showed significant recovery followed by disease impacts, while other species appeared to die as a result of the bleaching event itself. Across the monitoring sites, 6,061 disease lesions were noted on 23 species of coral between September 2005 and July 2006. While several diseases were noted, 99% of the lesions and loss of coral cover was due to white plague. At the long-term (1997-current) coral disease monitoring sites in St. John, a particularly severe outbreak of a coral disease presenting signs consistent with white plague was noted in August of 2005. Significant losses of coral cover have been documented over the term of the study.

Territorial Coral Reef Monitoring Program (TCRMP)—Benthic Cover and Coral Health Assessments

Monitoring of benthic composition and coral health by UVI-CMES as reported in Jeffrey et al., (2005) continued during this reporting cycle. UVI-CMES researchers used digital videography along belt transects to monitor benthic cover at permanent and rapid assessment sites in St. Croix and St. Thomas (Nemeth, 2005). Digital video and diver surveys were used to quantify coral diversity; the percent cover of corals, algae and other organisms; and incidence of coral bleaching and disease at eight permanent sites around the island of St. Croix and 16 permanent sites around the island of St. Thomas and St. John. Detailed video sampling and coral health assessment methods are discussed in Nemeth et al. (2005).

Results and Discussion

Extensive monitoring of coral reef sites outside NPS boundaries has shown a correspondence between nearshore stressors (e.g., sedimentation and other forms of terrestrial runoff) and coral degradation and disease for a gradient in St. Thomas and St. John (Smith et al., in review). Prior to the mass bleaching and mortality event of 2005, the disease and stress indicators, bleaching, and old mortality, were all significantly higher, and coral cover lower, on nearshore coral reefs than at offshore locations (i.e., midshelf cays, deep reefs, and deep shelf edge sites; Figure 2.17). On St. Thomas and St. John nearshore reefs there was also a high correlation (+90%) between sedimentation in the rainy season and prevalence of coral disease and partial mortality. In addition, at nearshore sites in St. Croix, St. Thomas and St. John monitored between 2001 and 2005, there was no significant loss or increase of coral cover, but there was an increase in cover of ephemeral "weedy" coral species and a decrease in ecologically important crustose coralline algae (Figures 2.18 and 2.19). These findings highlight the impairment of nearshore coral reefs relative to reefs buffered from terrestrial stressors, and suggest that current management of run-off in the USVI has been insufficient to stem degradation.

The 2005 mass coral bleaching event had widespread and dramatic effects on the abundance and composition of coral reefs in locations monitored by the TCRMP (Smith et al., unpub. data). The unprecedented warm SSTs in September and October of 2005 caused an average bleaching of 57% of coral cover, and half of all bleached corals had severe bleaching (stark white appearance) over 90% or more of the colony. Stress caused by bleaching resulted in an initial loss of 4% of coral cover during the bleaching event; however, after the warm water subsided in early to mid-2006 an average prevalence of white plague not seen in the previous five years of monitoring (5% versus 0.5%, respectively) precipitated a large loss of coral cover that equaled 40% by 2007 (Figure 2.20). Ecologically important framework-building star corals of the *M. annularis* complex were hardest hit, with some sites losing >70% of coral cover in this genera. Locations that were most affected tended to be shallower than 30 m, previously had high coral cover that could have favored the spread of pathogens, and were subject to other stressors, such as high fishing pressure and/or proximity to industrial effluents. Deeper shelf edge sites that did not bleach extensively, likely due to lower UV penetration and a moderating thermal oceanographic environment, were not immune to the coral disease outbreak that produced large losses in live coral cover (Figure 2.20).

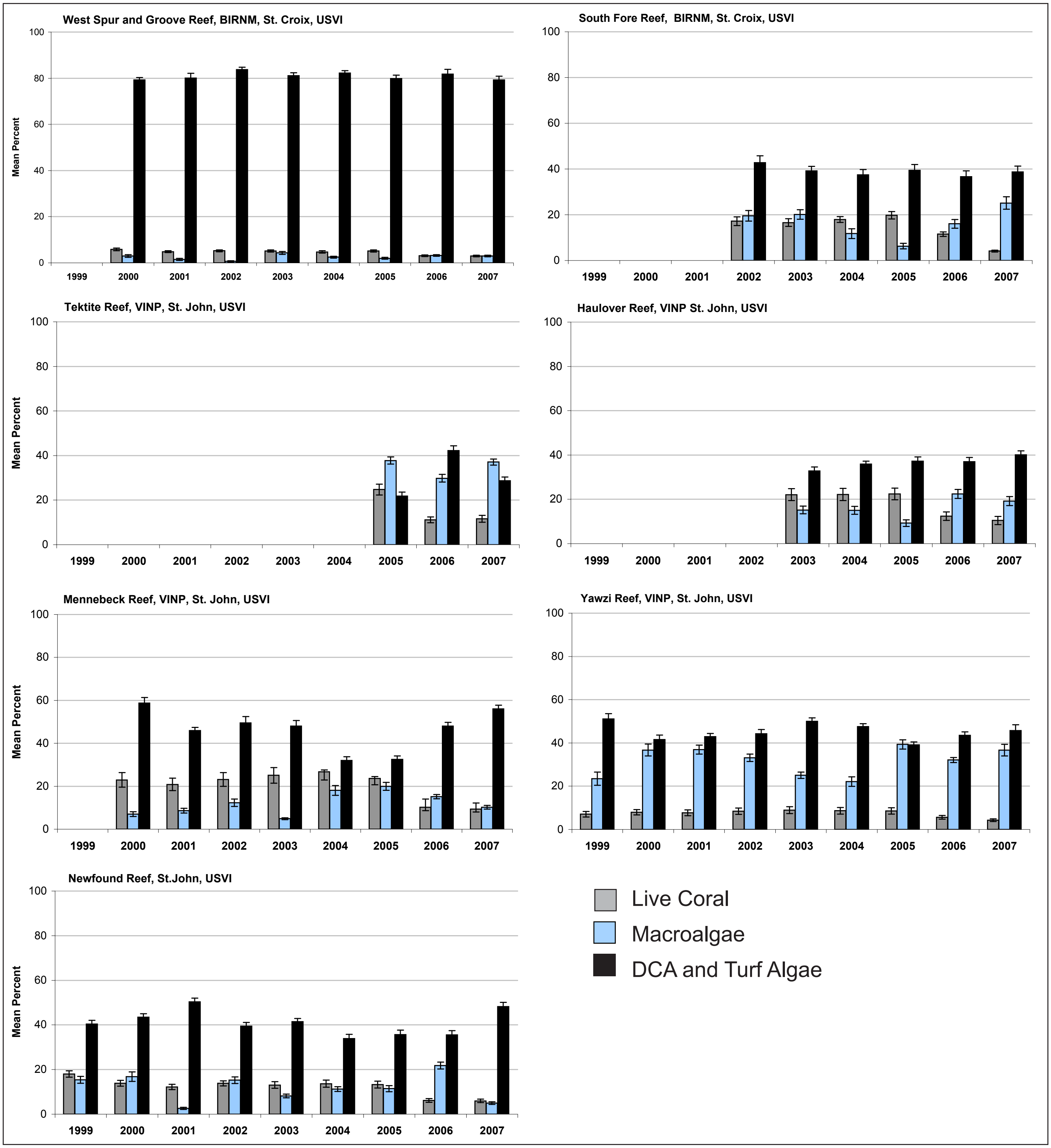

Figure 2.16. Mean percent coral cover (with standard error bars) at seven sites in the USVI. Protocol uses 20 randomly selected video transects per site. Between 2005 and 2006 coral cover declined by half in several locations. Source: NPS unpub. data, compiled by J. Miller, NPS.

*NPS, USGS and UVI-CMES Elkhorn Coral (*Acropora palmata*) Monitoring*

Jeffrey et al. (2005) included preliminary results from this monitoring project. Since then, USGS, NPS and UVI have completed extensive surveys of *A. palmata* around St. John, with one-time assessments at 11 reefs (July 2004–July 2005) and monthly monitoring at reefs in Saltpond and Trunk Bay (July 2005–August 2006), Hawksnest (May 2004 to date) and Haulover (February 2003 to date; Rogers, 2005; Rogers et al., 2005; Rogers et al., 2006; Muller et al., 2007). The geographic coordinates of the perimeter of each monitoring site and the locations of sampled elkhorn colonies are mapped onto geo-referenced aerial photographs. Data are recorded on the depth, three-dimensional size of colonies, type of substrate, percent cover of live and dead coral, presence/absence of specific diseases and lesions, and counts of damselfish territories and coral predators such as snails (*Coralliophila abbreviata* and *C. caribaea)* and fireworms (*Hermodice* spp.).

Results and Discussion

During the 2005 severe bleaching event (Eakin, 2007), elkhorn coral bleached for the first time on record in the USVI. Of 460 *A. palmata* colonies being monitored at four locations in VINP (Hawksnest, Haulover, Saltpond and Trunk Bays), 50% (±9.6%) showed signs of bleaching. Of these, 36% (±7.4%) experienced partial mortality and 15% (±8.5%) suffered complete mortality (McCreedy et al., 2006). Mortality rates of monitored *A. palmata* increased during 2005 at all four sites, but were not always directly related to bleaching. Isolated incidences of disease as well as bleaching contributed to the rise in mortality rates. Unlike deeper reefs dominated by *Montastraea* spp. (Miller et al., 2006), bleaching was not followed by severe outbreaks of disease except at one site, Hawksnest Bay. Here, a combination of disease and bleaching caused more mortality than all other stressors combined. Surviving colonies regained normal color by February 2006.

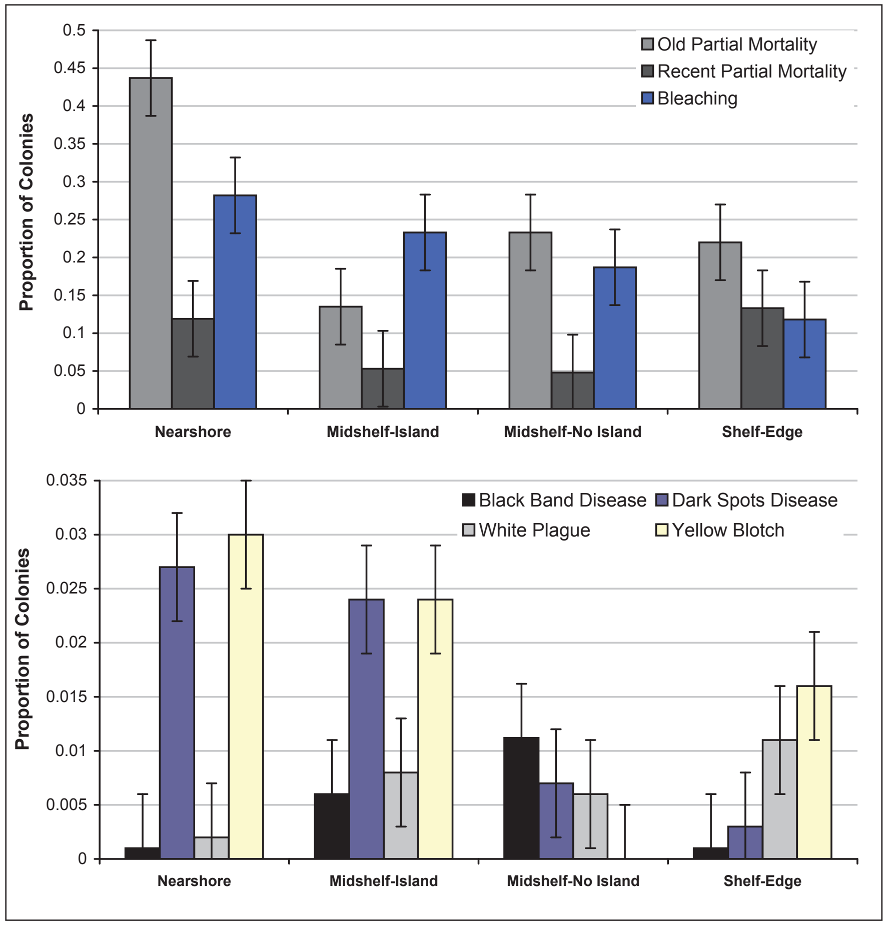

Figure 2.17. The proportion of colonies (prevalence) displaying old and recent partial mortality and bleaching at 16 sites from nearshore, midshelf and shelf-edge sites near St. Thomas and St. John (top) and the proportion of colonies with recognized coral disease (bottom). Both panels show a general increase of stress indicators and some diseases in nearshore environments. Source: T. Smith, UVI-CMES.

From May 2004 through December 2006, disease affected 87% of monitored colonies at Hawksnest (n=60 at the start of the study). Disease signs observed were consistent with white pox. Over 94% of the lesions that were completely surrounded by live tissue showed signs of healing (Muller, 2007). In 2005 (the year of the bleaching event) disease prevalence and the rate of change in prevalence showed a positive linear relationship with water temperature (Muller et al., 2008). In addition, colonies that bleached had greater area of disease-associated mortality than those that showed no sign of thermal stress, indicating disease severity is related to host-susceptibility (Muller et al., 2008; Figure 2.21).

Over a period of 50 months at Haulover (through April 2007), 88% of the elkhorn colonies exhibited disease, including white pox (87%), white band (15%) and unknown disease (9%). Some colonies had more than one disease at a time. Just over half of the colonies were damaged physically, from snorkelers, fishing line and storm waves.

When bleaching was first observed at Haulover in September 2005, 54 colonies of the initial 69 remained. Of the 43% of these that bleached, only one appeared to die directly from bleaching while 11 suffered some mortality. Thirteen colonies regained normal coloration and recovered after bleaching. More colonies died during the bleaching event than during the rest of the study. Seawater temperature in Haulover ranged from

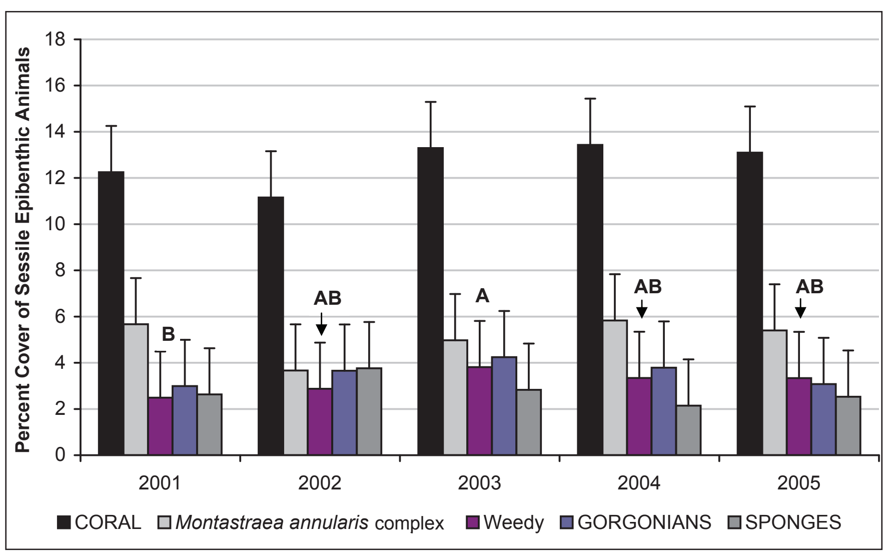

*Figure 2.18. Mean percent cover of sessile epibenthic animals at nine sites sampled annually from 2001 to 2005 on St. Croix, St. Thomas, and St. John. Weedy=a complex of fast recruiting disturbance tolerant coral species (*Agaricia agaricites, Diploria strigosa, Porites astreoides, *and* Siderastrea radians*) that may indicate stressful or disturbed environments. Letters above means indicate significant differences between years. Source: T. Smith, UVI-CMES.*

24.9ºC (February 9, 2005) to 31.4ºC (September 12, 2005). In 2005, the maximum daily temperature exceeded 30ºC on 65 days, including 44 consecutive days. The highest temperatures occurred from August through October 2005. Bleaching was apparent from September 2005 through January 2006, with a peak in September, when over 40% of the colonies were bleached. White band disease, thought to have been responsible for extensive mortality of *A. palmata* in the USVI in the late 1970s and 1980s, was only seen on a few colonies on St. John reefs in the last four years. White pox was far more common.

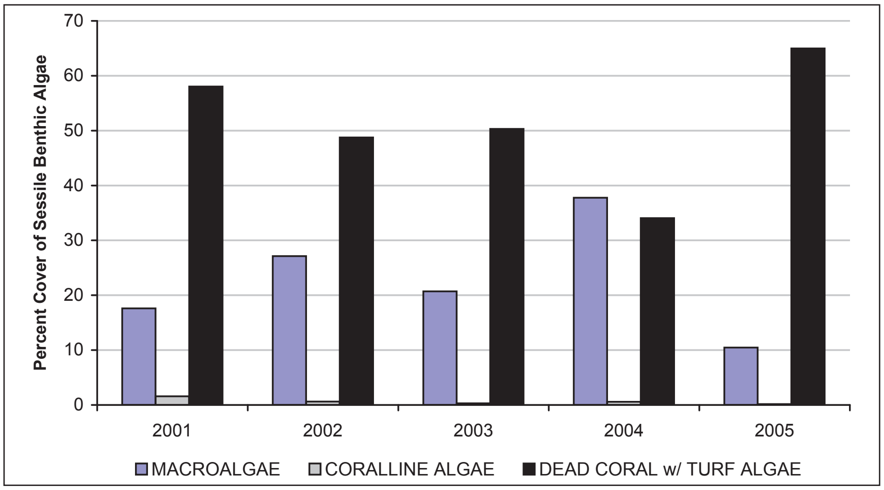

Figure 2.19. Percent cover of sessile benthic algae at 9 sites sampled annually from 2001-2005 on St. Croix, St. Thomas, and St. John. Source: T. Smith, UVI-CMES.

Assessment of Bleaching Impacts to Acropora palmata *at BIRNM*

At BIRNM, *A. palmata* experienced extensive bleaching in 2005. NPS staff quantified the extent of the bleaching and subsequent mortality. In general, *A. palmata* colonies located in the back reef bleached earlier and suffered greater tissue loss than those on the fore reef and reef shelf. Colonies on the fore reef ultimately suffered mortality comparable to the back reef, but the reef shelf experienced half this amount.

Methods

The impact of the bleaching event on *A. palmata* colonies at BIRNM was measured by monitoring 44 colonies at three sites located in back reef, fore reef, and reef shelf habitat types where *A. palmata* is found. Although *A. palmata* is present on shallow haystack features and on the barrier reef surrounding Buck Island, the majority of *A. palmata* habitat at BIRNM is found on the northern reef shelf or north bar, which is deeper habitat (5-10 m) north of Buck Island. Two of the three sites were located on Buck Island's barrier reef, in the back reef near the Underwater Trail and on the south fore reef; the third site was located on the north bar. Colonies were monitored monthly before, during, and after the bleaching event (beginning in March 2005) and therefore provided a complete record of bleaching impacts. Colonies were photographed preferentially from the planar view, but from a consistent oblique angle in shallow water situations.

Results and Discussion

Among the 44 colonies examined, 36 (82%) experienced bleaching. Maximum bleaching for all sites occurred in November 2005. At the back reef site 45.8% of live tissue was bleached, while on the south fore reef 79.8% of live tissue was bleached. At the north bar, outside the barrier reef, 64.1% of the live tissue was bleached. Back reef colonies were impacted before south fore reef and north bar colonies. In August 2005, the back reef site experienced bleaching levels of 25%,

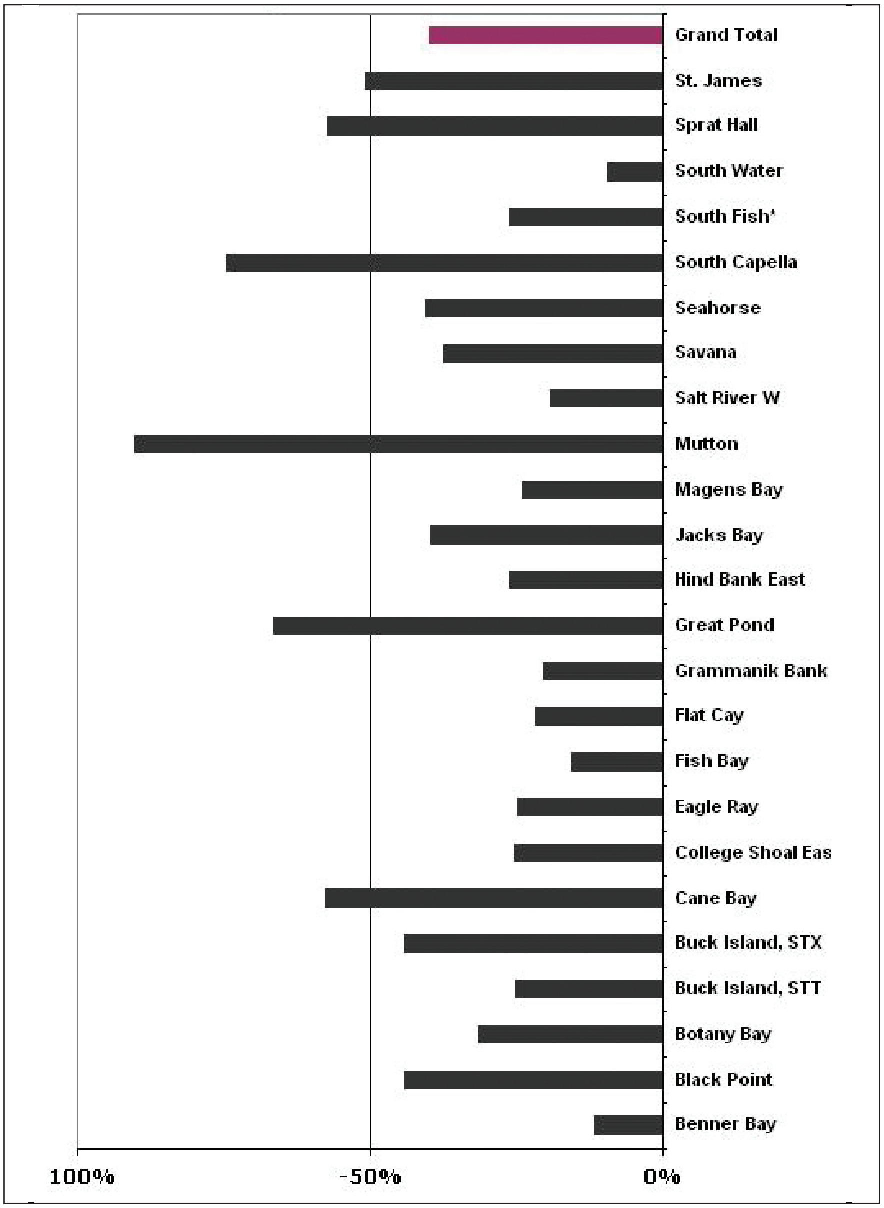

Figure 2.20. The loss of coral cover at 24 territorial coral reef monitoring sites in the USVI between early 2005 (pre-bleaching) and mid to late 2006 (post-bleaching) as the result of the bleaching event and subsequent coral disease outbreak. The largest loss of coral cover were typically seen in high coral cover locations dominated by the important reef-building M. annularis *complex. Source: T. Smith, UVI-CMES.*

whereas the fore reef site experienced only 11% bleaching. Most of the sea water temperature measurements exceeding 30°C were recorded in September, with the highest (30.6°C) on September 29, 2005 on the back reef.

Mortality, like bleaching, was higher in the back reef than at the north bar, and the back reef exhibited greater mortality sooner. The back reef experienced the highest average tissue loss during the event (66.4%), followed by the south fore reef (58.1%) and the north bar (36.4%; Table 2.2). Overall, out of 44 colonies, only two did not experience any mortality during the bleaching event.

Rapid and severe bleaching and mortality associated with the back reef may be linked to restricted water flow, less wave action, and increased light penetration found in these locations (Nakamura and van Woesik, 2001) in addition to slightly higher water temperatures. Mortality on both the fore reef and back reef was at least double that of the reef shelf. Lastly, mortality may have resulted from undetected disease as well as bleaching. Diseased tissue may have been under-represented, as it can be similar in appearance to bleached tissue (particularly white-band and white pox).

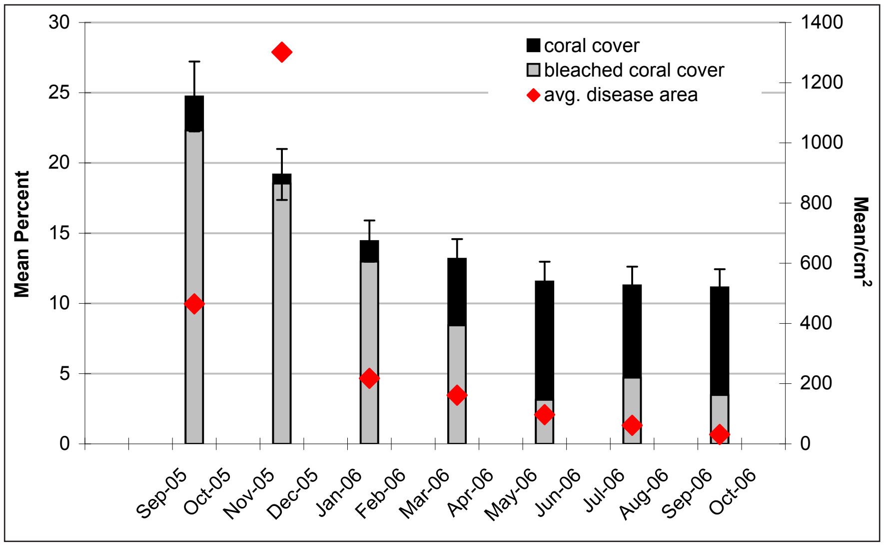

Figure 2.21. Relationship between disease prevalence and bleaching at Hawksnest Bay, St John, USVI in 2005. Source: adapted from Muller et al., 2008.

Table 2.2. Bleaching and mortality assessment of corals at three sites in representative habitats at BIRNM. The north bar (N.Bar) is located on the reef shelf, the south fore reef (SFR) is on shallow fore reef habitat, and the Underwater Trail (UWT) is in the back reef. Source: Lundgren and Hillis-Starr (in revision).

		Assessment AUG 28, 2005	Mortality AUG-NOV 2005	Assessment NOV 1, 2005	Mortality NOV 2005-JAN 2006	Assessment JAN 26, 2006	Cumulative MORTALITY
N. Bar	mean	0.0	9.1	64.1	27.3	2.0	36.4
	median	0.0	0.0	63.0	10.0	0.0	10.0
	ó	–	19.3	36.7	36.7	3.6	41.4
	óM	–	5.8	11.1	11.1	1.1	12.5
	CI	–	12.0	22.7	22.7	2.2	25.7
SFR	mean	11.2	14.3	79.8	50.0	3.2	58.1
	median	0.0	0.0	92.0	57.0	0.0	77.0
	ó	25.0	30.9	34.2	37.2	6.6	39.0
	óM	6.2	7.7	9.1	10.0	1.8	9.8
	CI	12.6	15.6	18.6	20.2	3.7	19.8
UWT	mean	24.1	57.2	45.8	17.4	0.0	66.4
	median	0.0	60.0	40.0	15.0	0.0	85.0
	ó	33.7	39.4	32.0	15.4	–	36.0
	óM	8.2	9.6	10.7	5.1	–	8.7
	CI	17.1	19.9	22.2	10.7	–	17.7

*The Nature Conservancy, UVI–Conservation Data Center Elkhorn Coral (**Acropora palmata**) Mapping*

In October 2006, The Nature Conservancy (TNC) and the UVI Conservation Data Center (UVI-CDC) implemented a joint project to map the spatial distribution and status of *A. palmata* populations in priority coastal areas around St. Thomas and St. Croix. This project was designed to compliment USGS, NPS and UVI monitoring of *Acropora* in St. John using slightly modified data collection methods to ensure accuracy when transferring the data sets into a spatial context. Eight survey sites around each island were identified through a process of combining historical range data and previous studies with extensive site reconnaissance. The geographic coordinates and a non-standardized photograph of each sampled *Acropora* colony were taken along with data representing a modified version of the Demographic Monitoring Protocols for Threatened Caribbean Acropora Coral (Williams et al., 2006). Data collected include the size and type of colony, number of associated fragments, percent live coral cover, presence/absence of disease and bleaching, and water depth. Comments on presence/absence of damselfish, snails and fish bites were also recorded for all colonies. Data were entered at each site to allow population data to be taken quickly and downloaded to a comprehensive database.

Results and Discussion

Using the spatial component of this study in combination with watershed information, studies conducted by UVI-CDC will allow population data to be linked to watershed characteristics and land use, following trends for water quality, sedimentation and nutrient risk assessment and their possible link to deteriorating coral reef conditions. Final products will display the survey results alongside critical land use factors. This work will not establish causation for *Acropora* losses or identify individual factors, but it will help managers understand how land use patterns and development activity, point and non-point sources, and watershed characteristics affect the condition of adjacent marine communities.

NOAA CCMA-BB Assessment of Benthic Composition

The goals and objectives of CCMA-BB's Caribbean Coral Reef Ecosystem Monitoring Project are four fold: 1) to spatially characterize and monitor the distribution, abundance and size of both reef fishes and macroinvertebrates (conch, lobster, *Diadema*); 2) to relate this information to *in situ* data collected on associated benthic composition parameters; 3) to use this information to establish the knowledge base necessary for enacting management decisions in a spatial setting; and 4) to establish the efficacy of those management decisions. All of the data collected by CCMA-BB and local partners are available at http://www8.nos.noaa.gov/biogeo_public/query_main.aspx.

On the island of St. John, monitoring efforts are focused on the waters within and around the VINP and the Virgin Islands Coral Reef National Monument (VICRNM), including the mid-shelf reef. Field missions are based on a collaboration between NOAA, the University of Hawaii, the NPS and USGS. Field missions occur annually and include monitoring of approximately 170 stratified random sampling sites located inside and outside park and monument boundaries, as well as at an offshore deep reef area in waters approximately 30.5 m (100 feet) deep. Information collected thus far has been extensively utilized by participating partner organizations as well as by the USVI DPNR, UVI, OC and others.

On St. Croix, CCMA-BB conducts semi-annual monitoring surveys at approximately 120 stratified random sampling locations within and around the waters of BIRNM and the EEMP. Data has been collected in collaboration with local and regional NPS staff, USVI DPNR, NOAA's Coral Reef Watch Program, the National Aeronautical and Space Administration (NASA) and USGS and has been used by the University of Miami, NOVA Southeastern University, TNC, OC and others.

Methods

The CCMA-BB field methodology consists of two complementary components. The first is a 25 m long belt transect used to quantify fish species size and abundance. Fish data are correlated to fine-scale habitat information to identify spatial patterns in community structure or identify essential fish habitats. The second component involves taking detailed habitat measurements along the same belt transect. These measurements are correlated to the fish data to quantify fish-habitat relationships on a small spatial scale. Survey sites are selected using a stratified random sampling design that incorporates the strata derived from CCMA-BB's nearshore benthic habitat map (Kendall et al., 2001). At each site, fish, macro-invertebrates, water quality and habitat information are quantified following standardized protocols. Detailed methodology for both the fish and benthic habitat surveys are located on line at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html. Between 2001 and 2006, benthic surveys were conducted at 768 reef and hardbottom sites around BIRNM and along the northeastern shore of St. Croix, including within the EEMP. During the same period, 233 surveys were conducted around the island of St. John.

Results and Discussion

Data from the NOAA surveys indicate that reef and hardbottom areas in St. Croix are generally dominated by algae (Figure 2.22). In St. Croix, reefs were comprised of 36.7 ± 1.1% turf algae, 11.4 ± 0.5% macro algae, and 1.8 ± 0.2% crustose coralline algae. In St. Croix, the macroalgae with the highest observed cover were *Dictyota* spp., *Halimeda* spp. and *Sargassum* spp. Reefs in St. Croix also had 4.3 ± 0.5% cyanobacteria and filamentous algae that were morphologically indistinguishable from each other. Live scleractinian coral was low and averaged 5.6 ± 0.5%. Reefs in St. John were comprised of 28.5 ± 1.6% turf, 15.3 ± 1.0% macroalgae and 3.3 ± 0.5% crustose coralline algae (Figure 2.22). In St. John, the most common macroalgae genera observed were *Dictyota* spp., *Halimeda* spp and *Lobophora variegata*. Cyanobacteria and filamentous algae had average cover of 1.5 ± 0.4% on reefs in St. John. Live scleractinian coral cover was low and averaged 5.6 ± 0.5 % in both St. Croix and St. John (Figure 2.22). Gorgonians had higher crown cover in St. John when compared to reef and hardbottom areas in St. Croix ($p<0.0001$). Milleporid (fire) corals and sponges also had higher cover in St. John than in St. Croix ($p<0.0002$).

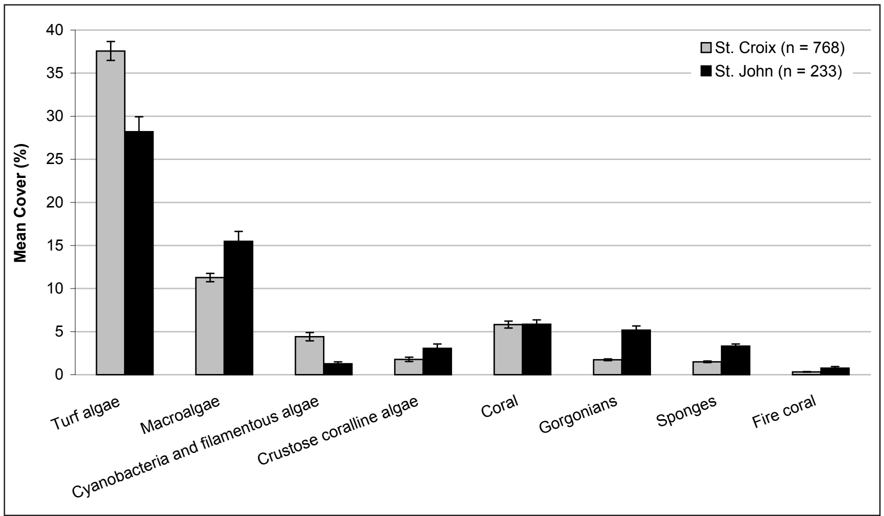

Figure 2.22. Mean percent cover of benthic organisms on reefs and other hardbottom areas in St. John and St. Croix. Source CCMA-BB.

Patterns in the cover of benthic organisms were consistent across reef types identified by Kendall et al. (2001), with two algal categories (turf/crustose algae and macroalgae) dominating all six reef types in St. Croix (Figure 2.23). Cyanobacteria and filamentous algae had the highest cover and were most variable on reef rubble and scattered coral and rock sites. The mean percent cover of live scleractinian coral was significantly higher on patch reefs (12.1 ± 1.3%, $p<0.05$) and lowest on reef rubble (2.0 ± 0.8%) and scattered coral and rock sites (3.4 ± 0.7%, Figure 2.23). Gorgonians had the lowest cover on reef rubble sites. The percent cover of sponges and fire corals were similar among the habitat types surveyed.

Patterns in the cover of benthic organisms were also consistent across reef types in St. John, where turf algae and macroalgae were the dominant cover at the sites surveyed (Figure 2.23). Turf algal cover was most variable on reef rubble sites, likely due to variability in the presence of hard structure at rubble sites. In St. John, live coral was significantly higher on linear and patch reef habitats (p<0.05), which had 9.2 ±1.1% and 9.6 ±2.2% of live coral cover, and lower on reef rubble (2.0 ±1.7%) and scattered coral and rock (3.7 ±1.3%).

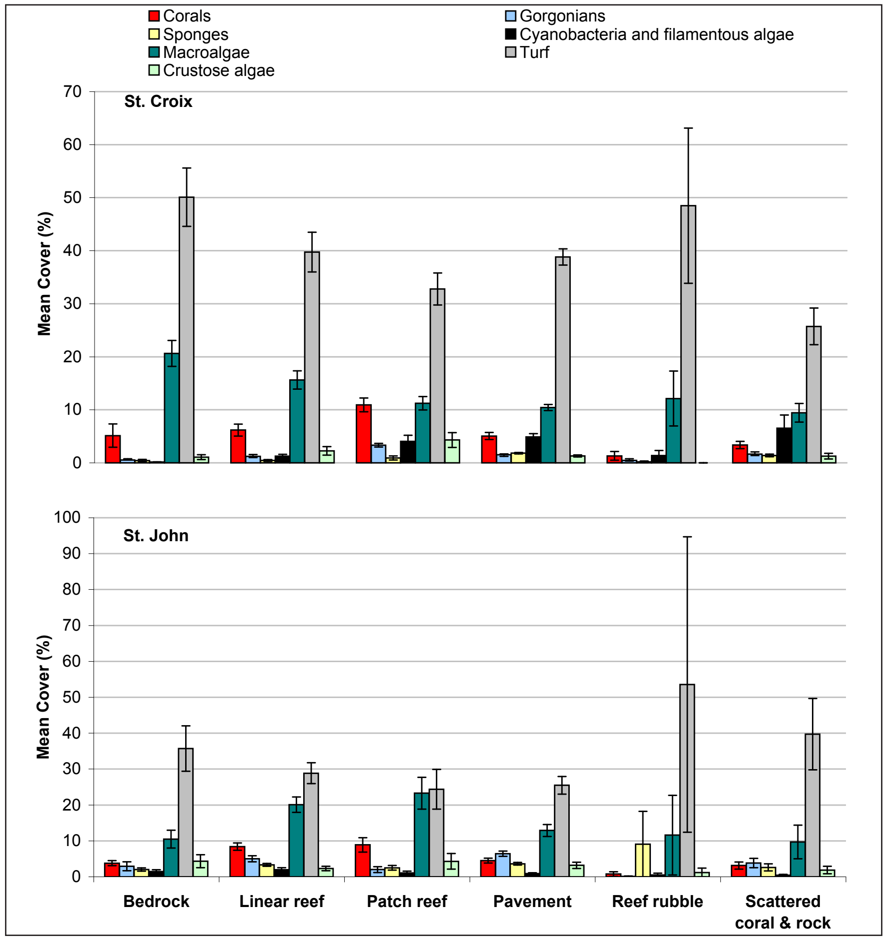

Figure 2.23. Mean ±SE percent cover of benthic organisms found in different reef habitats in St. John and St. Croix. Source: CCMA-BB.

Live scleractinian coral cover in St. Croix and St. John was comprised mainly of 23 coral genera, but only nine of those had mean cover greater than 0.01% in St. Croix, and 14 had a mean cover greater than 0.01% in St. John (Figure 2.24). The three most abundant corals, *Montastraea* spp., *Porites* spp., and *Diploria* spp., had a mean cover of 1 ±0.09% in St. Croix and 2.4 ±0.34% in St. John. Mean *Porites* cover in St. Croix was 0.9 ±0.06% and 1.1 ±0.15% in St. John. Mean cover of *Diploria* spp. was 1.2 ±0.29% in St. Croix and 0.1 ±0.04% in St. John. Some significant differences in coral composition on reefs and hardbottom areas were observed between St. Croix and St. John. *Montastraea* spp., *Siderastrea* spp., and *Agaricia* spp. had higher average cover in St. John than in St. Croix (p<0.0001). However, *Diploria* spp. and *Acropora* spp. had higher cover in St. Croix than in St. John, (p<0.04). The cover of other coral genera was similar between St. Croix and St. John.

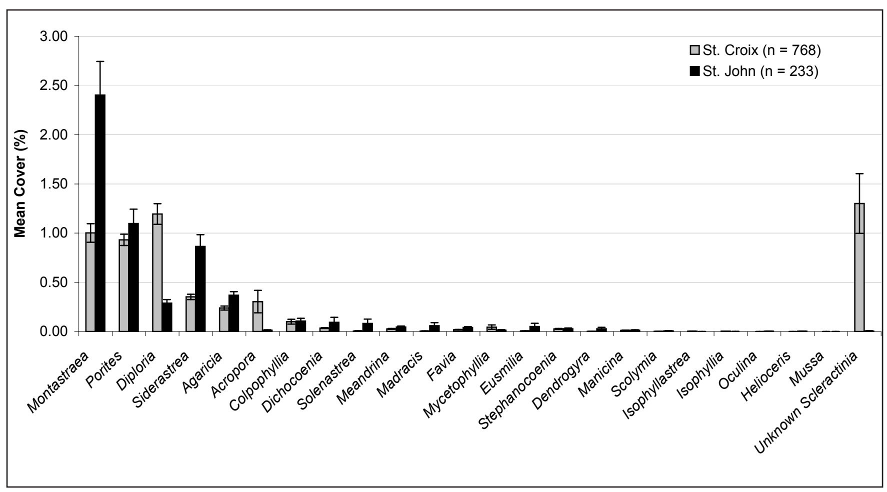

Figure 2.24. Mean ±SE estimates of percent live cover of coral genera on randomly selected reef sites between 0-28 m in St. John and St. Croix. Source: CCMA-BB.

Figure 2.25 shows temporal trends in weighted mean benthic cover in St. Croix and St. John between 2001 and 2006. In St. Croix, the highest weighted mean cover of live coral (27.5 ± 1.8%) was observed during February of 2001. Subsequently, weighted mean estimates of live coral cover ranged from as high as 8.0 ± 1.7% in August 2001 to as low as 2.9 ± 0.8% during October 2006. Although this trend is consistent with the hypothesis of a general temporal decline in coral cover in the USVI, the high percent cover observed in 2001 may have been due to an over sampling of lagoonal and reef crest sites around Buck Island in 2001. Sampling effort in subsequent years was at the same level as in 2001, but was spread over a greater area because of the expansion of the BIRNM, which may have resulted in greater numbers of samples being drawn from hardbottom habitats with lower coral cover. Observed temporal trends in weighted mean cover of other benthic organisms were unremarkable, although cover of algae (macroalgae, turf and crustose coralline algae) showed some oscillation around a global mean value (Figure 2.25).

In St. John, weighted mean live coral cover was highest in 2001 (8.4 ±1.8%) and steadily decreased to its lowest value in July 2006 (4.5 ±0.9%). There was also a slight, concomitant increase in mean weighted cover of macroalgae and turf algae between 2003 and 2006, as well as a consistent increase in the weighted-mean cover of crustose coralline algae between 2001 and 2006. Although consistent with the prevailing hypothesis of a temporal decline in coral cover and simultaneous increase in algal cover in the USVI, the observed trends (i.e., differences in coral and algal cover among years) were not significant (p>0.05). Observed cover of gorgonians was highest at 9.2 ±1.1% in 2003 and lowest (3.5 ±1.0%) in

2006, but there was no consistent or significant trend over time. Fire coral and sponges had low cover during all years.

DPNR and EPA Coral Bioassessment/ Biocriteria Monitoring Program

A collaborative project between USVI DPNR and the EPA was initiated in 2006 to evaluate a stony coral bioassessment protocol for application of biocriteria development in the USVI. The project tested a bio-assessment protocol designed to determine anthropogenic effects on reef-building corals and laid the groundwork for implementing coral reef biocriteria to complement current water quality monitoring efforts of DPNR. Biocriteria, which identify thresholds of biological condition necessary for sustainable reefs, can be applied as water quality standards under authority of the Clean Water Act (CWA). This project was designed to determine which bioassessment indicators were responsive to anthropogenic over natural conditions. Regulatory activity under the CWA must be implemented only in response to human disturbance. Stony coral biocriteria will support regulatory standards and provide clear benchmarks for decision making and public information. Additionally, they inform and support management objectives such as permitting and establishment of MPAs.

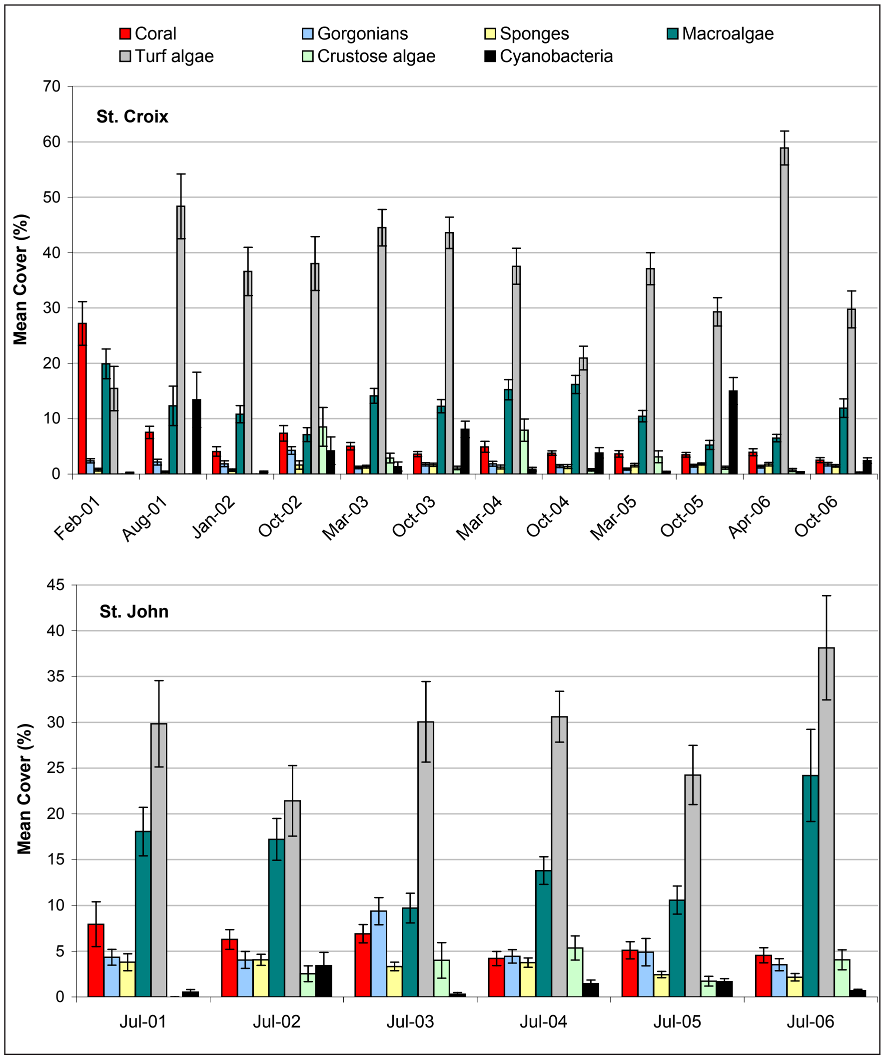

Figure 2.25. Mean (±SE) percent cover of benthic organisms by survey period for St. Croix (top) and by year for St. John (bottom). Source: CCMA-BB.

In 2006, EPA and DPNR led a field mission to test EPA's Stony Coral Rapid Bioassessment Protocol (RBP; Fisher, 2007). The RBP incorporates three underwater observations (colony identification, size and percent live tissue) into multiple indicators of stony coral condition. The indicators vary slightly from conventional condition measurements in order to evaluate value and sustainability, which are essential characteristics of regulatory assessments. Coral size was calculated from measurements of colony height, diameter and width. Three-dimensional colony surface area was estimated using conversion factors validated by three-dimensional photographic colony reconstruction (Courtney et al., 2007). Sixty-one sites within seven coastal management zones were surveyed around St. Croix along three suspected human disturbance gradients. Indicators were analyzed for change along the gradients using Pearson correlation analysis. Centers of human disturbance included Frederiksted pier, Christiansted Harbor and the south coast industrial channel. Candidate metrics evaluated for use as biocriteria included abundance and composition, physical stature, biological condition and community structure.

Results and Discussion

Transect area and indicator sensitivity were sufficient to delineate significant differences among stations. The protocol was found acceptable for use in a long-term monitoring program at USVI (Fore et al., 2006a). Evidence of a strong disturbance gradient was captured by several indicators at the industrial channel on the south coast of St. Croix (Figure 2.26). The chosen indicators are worthy of further consideration for CWA regulatory monitoring programs. The next steps in this project are application of the RBP at St. Croix using a probability-based sampling design and transfer of the program to DPNR for continued implementation.

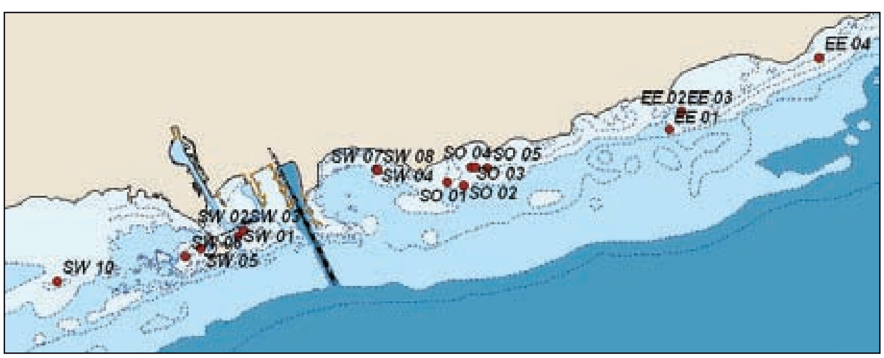

Figure 2.26. The surface area of coral colonies distributed to the east and west of industrial docks in St. Croix was among those indicators showing a consistent response to human disturbance. Total surface area represents the sum of 3-D colony surface area for each colony in the transect. Positive distance from the main industrial dock represents east and negative distance west. Source: EPA.

NOAA Benthic Mapping and Characterization

NOAA's benthic habitat maps of the USVI encompass 490 km^2 of nearshore habitat (Kendall et al., 2001; Figure 2.27). More recently, CCMA-BB has collaborated with other NOAA program offices (NMFS, Office of Coast Survey, Office of Marine and Aviation Operations, Center for Operational Oceanographic Products and Services), the CFMC, NPS, DPNR-Division of Coastal Zone Management (DPNR-CZM) and DPNR-DFW, to characterize and map mid and deep water habitats in the USVI. From 2004 to 2006, scientists conducted annual missions to the USVI on board the NOAA ship R/V *Nancy Foster* to explore and characterize priority habitats from 10 to 1,000 m using high-resolution bathymetry, backscatter and complementary video data. The primary objective of the seafloor mapping project was to integrate abiotic data collected from acoustic sonar systems with biotic information obtained from underwater imagery systems (Remotely and Autonomously Operated Vehicles and drop/drift camera systems) and SCUBA dives to create accurate benthic habitat maps of deeper reef habitats. This project has been designed to meet the identified need for detailed bathymetric models of the USVI seafloor, as well as for continued benthic habitat characterizations and ecological inventories beyond the depth limits of optical remote sensing technologies (about 30 m). Integration of acoustical mapping technologies with traditional optical sensing methods enables the creation of a near-seamless map from the shoreline to 1,000 m water depth.

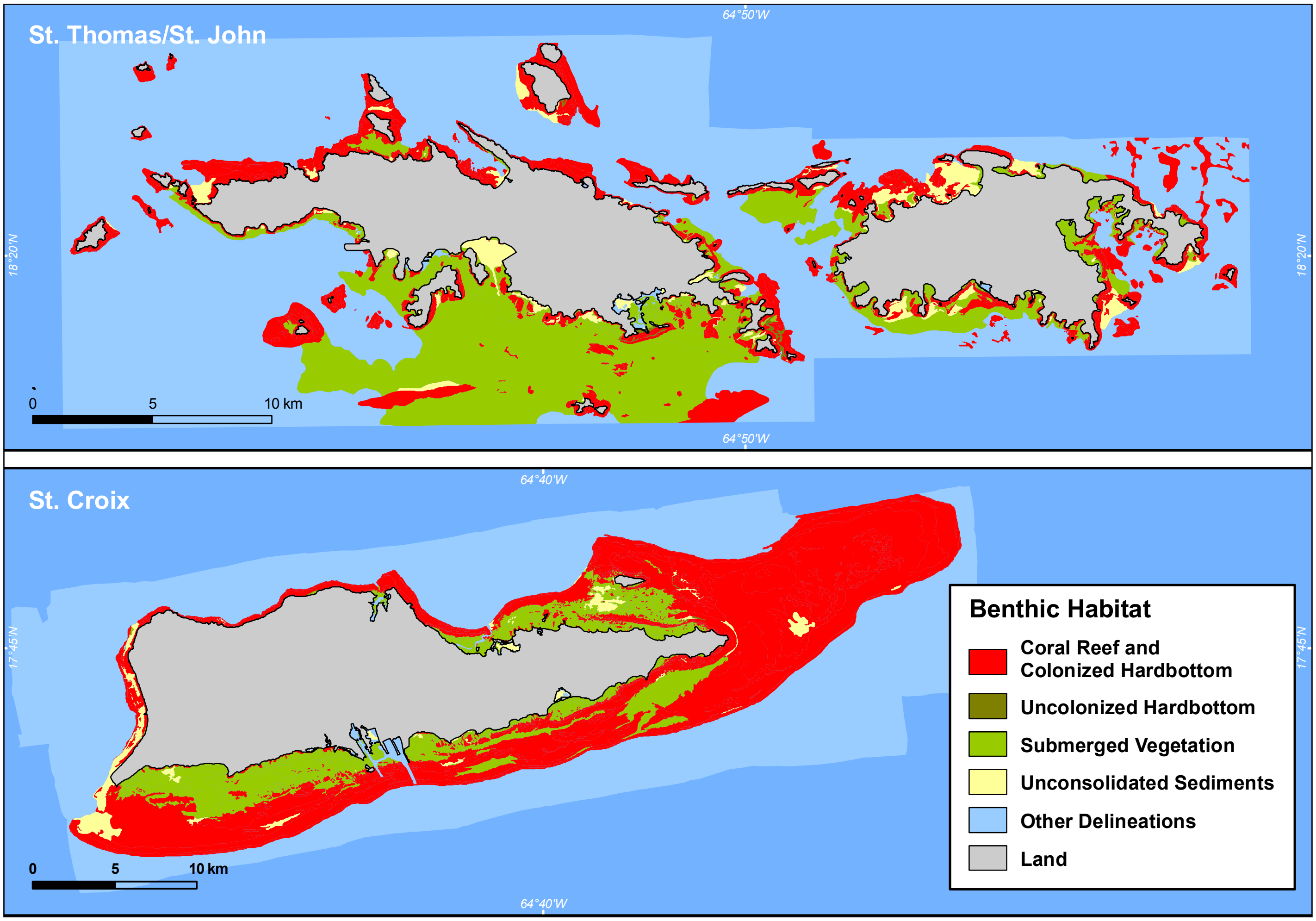

Figure 2.27. Nearshore benthic habitat maps were developed by CCMA-BB based on visual interpretation of aerial photography and hyperspectral imagery. For more information, see: http://biogeo.nos.noaa.gov.

Methods

Areas surveyed to date in the USVI include BIRNM and the Salt River Bay National Historical Park and Ecological Preserve in St. Croix, the VICRNM in St. John, and the Grammanik Bank shelf break south of St. Thomas. Kongsberg EM1002, Reson 8124 and Reson 8101 multibeam echo-sounders were used to collect the bathymetry and backscatter imagery. A remotely operated vehicle (ROV) and drop camera captured underwater video and still images of the seafloor. To date, 292 km^2 of multibeam data (area ensonified), 2,659 ship track lines, and 110 km of ROV transects have been collected in the USVI (Table 2.3). These data sets have supported natural resource management in the USVI, and have helped NOAA continue to meet its commitment to map coral reef ecosystems.

Table 2.3. Survey effort for NOAA CCMA-BB mid and deepwater seafloor mapping around the USVI. Source: C. Jeffrey, NOAA CCMA-BB.

METRICS	2004	2005	2006	TOTAL
Area Ensonified (km^2)	101	110	81	292
Ship Track Lines (km)	1,282	1,138	239	2,659
ROV Track Lines (km)	30	70	10	110

Results and Discussion

Several web-accessible products have been generated from the seafloor characterization of the USVI (http://ccma.nos.noaa.gov/products/biogeography/usvi_nps/overview.html). A Benthic Habitat Viewer database comprising over 9,000 underwater seafloor images, along with information on each image's location, biological inventory, benthic habitat characterization, geomorphological structure, and seafloor terrain characteristics (i.e., bathymetry, slope, and rugosity) is available online at http://www8.nos.noaa.gov/bhv/bhvMapBrowser.aspx. Multibeam bathymetric data are available in a variety of formats including ASCII XYZ text files, ESRI Grids, and georeferenced TIFF images. Mosaics of multi-beam backscatter (geometrically and radiometrically corrected) are also available online as geotiffs and are ready for use in a Geographic Information System (GIS).

NOAA Coral Bleaching Assessment

Data on the extent and severity of coral bleaching were collected during October 2005 by NOAA's CCMA-BB and the NPS SFCN as part of a bi-annual program to monitor coral reef ecosystems around BIRNM and EEMP. The regional coral bleaching event in 2005 was linked to anomalously warm SSTs centered on the northern Antilles near the USVI and Puerto Rico (NOAA Coral Reef Watch; http://coralreefwatch.noaa.gov/caribbean2005/). Data were analyzed to describe the extent, severity, and spatial patterns of coral bleaching before, during and after the event; correlate bleaching with environmental factors (i.e., *in situ* temperature and depth); describe taxonomic differences in bleaching severity; and discuss potential effects of coral bleaching and changes in the cover of live coral and algae on coral reefs and hardbottom areas between 2003 and 2006.

Methods

Underwater visual surveys were conducted biannually within a 48.7 km^2 area of the BIRNM and the EEMP. The area is comprised of a complex mosaic of habitat types, including coral reefs and other hard substrate, seagrasses, and soft sediments with varying depth and rugosity. Data on live unbleached and bleached coral were collected only on hard substrates within the study domain. Data on benthic composition were recorded along randomly selected 25 × 4 m belt transects (100 m^2). Survey sites were selected using a stratified random sampling design incorporating two strata (hard and soft benthic habitat types) derived from NOAA's nearshore benthic habitat maps (Kendall et al., 2001). Detailed information on field methodology is available online at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish.html.

Data on live coral cover, bleached coral, turf algae, water depth (m) and other benthic biota were collected during 617 benthic surveys completed between March 2003 and October 2006. Coral species were identified to the lowest possible taxon. During each survey, the percent areal cover occupied by bleached and unbleached coral colonies was estimated to the nearest 1 cm^2 or 0.1% in a two-dimensional plane perpendicular to the observer's line of vision within a 1 m^2 quadrat divided into 100 smaller (10 x 10 cm) squares. The quadrat was placed at five random locations alongside the transect, resulting in a sample within every 5 m interval along each transect. Colonies were considered entirely bleached if they contained white, blotchy/mottled or pale tissue. Diseased/dead coral was coral skeleton without living tissue but with corallites that were still visible and not colonized by other encrusting organisms. Normal coral colonies were those that were not bleached, diseased, or dead. Coral skeleton and other hard substrates with a mix of short, mat-like macroalgae less than 1 cm in height was categorized as turf algae (Steneck, 1988). Means and standard errors of percent cover of live (bleached and unbleached combined) coral, bleached coral and turf algae were calculated for each site. Sites were used as independent sample units and were considered replicates within survey missions and years. Multiple quadrat measurements (percent cover and depth) within each transect were averaged and average site values were then used to calculate means and standard errors of measured variables by survey mission and by year. Linear regression was used to examine the proportion of bleached coral cover and transect depth, and comparisons of bleached coral and algae cover between monitoring periods were conducted via non-parametric analysis of variance (ANOVA) statistical tests (Sokal and Rohlf, 1995). Spatial patterns of bleached corals within and among sampling missions were mapped using a GIS. Spatial autocorrelation and bleaching "hotspots" were determined with ESRI ArcGIS. Time series plots of the proportion of live coral that was normal or bleached were done from April 2005 through October 2006 to examine temporal trends in coral bleaching. Time series plots of mean percent cover of live coral and turf algae were done from April 2003 through October 2006 to identify temporal patterns and any effects of the 2005 bleaching event on the overall amounts of live coral and turf algae in the study area. Finally, taxonomic differences in living corals' susceptibility to bleaching were also examined.

Results and Discussion

Data from 94 randomly selected 100 m^2 transects over hardbottom habitats revealed that approximately 51% of live coral cover was bleached. Twenty-five of 30 coral species exhibited signs of bleaching, and species-specific bleaching patterns were variable throughout the study area. Although a weak but significant negative relationship (r^2=0.10, p=0.0220) with depth was observed, bleaching was evident at all depths (1.5-28 m). Bleaching was spatially autocorrelated (p=0.001) indicating that corals located in the seaward portion of the study area were most affected. Improved coral condition was observed upon subsequent monitoring missions during December 2005, March and October 2006 (Figure 2.28). Bleached coral incidence declined significantly and comprised 28%, 15% and 3% respectively, of total coral cover observed among transects. No spatial or depth correlations were observed in post-bleaching monitoring. Mortality estimates as a response to the bleaching event were not quantified; however, total coral cover for *Agaricia* spp. and *Porites porites* were significantly lower in October 2006 one year after the bleaching event. Mean live coral cover decreased by 23% in the BIRNM between 2003 and 2006 (Figure 2.29). Turf algae cover has been variable but has increased since the bleaching event.

Documentation of prior bleaching events has been limited to specific reefs with little information regarding broader spatial patterns within a coral reef ecosystem. These data documented the intensity, extent, and spatial variability of coral beaching across a large study area (47 km^2), and show the need to understand the effects of coral bleaching on demographic processes in a complex coral ecosystem. Furthermore, these data provide evidence that bleaching can have differential effects on components of coral reef ecosystems and that coral community structure is changing. The ecological implications of these changes are uncertain and should be the focus of future research. Understanding reef degradation and climate-induced stressors at various spatial and temporal scales, as well as recovery processes should be a priority for scientifically-based conservation and management.

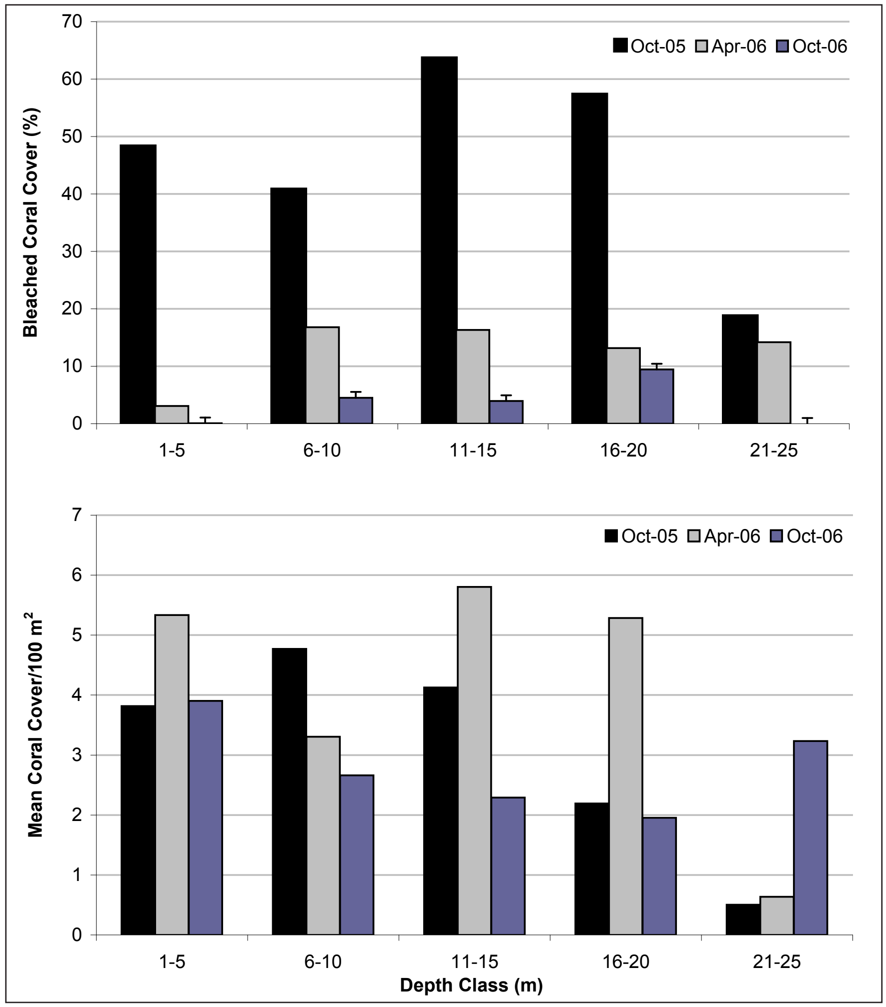

Figure 2.28. Percentage of bleached coral (top) and mean live coral cover (bottom) at monitoring sites in St. Croix in October 2005, April 2006, and October 2006. Source: Clark et. al., in review.

NOAA Fisheries (NMFS) USVI Acropora Mapping Project

In May 2006, staghorn coral (*A. cervicornis*) and elkhorn coral (*A. palmata*) were formally listed as threatened under the Endangered Species Act (ESA), which marks the first time a coral species has been listed under the ESA since its inception in 1973. According to the act, a species is considered endangered if it is in danger of extinction throughout all or a significant portion of its range. A species is considered threatened if it is likely to become an endangered species within the foreseeable future.

NMFS has begun gathering data on the extant spatial distribution of acroporid corals throughout the Caribbean and Atlantic to aid in management and regulatory activities related to ESA listing. The goal is to designate critical habitat areas based on best available information about species distribution and habitat parameters throughout U.S. territories. Existing data sets on *Acropora* distribution are being compiled to develop a geodatabase for use in delineating critical *Acropora* habitat. Example maps can be found in the National Level Activities chapter.

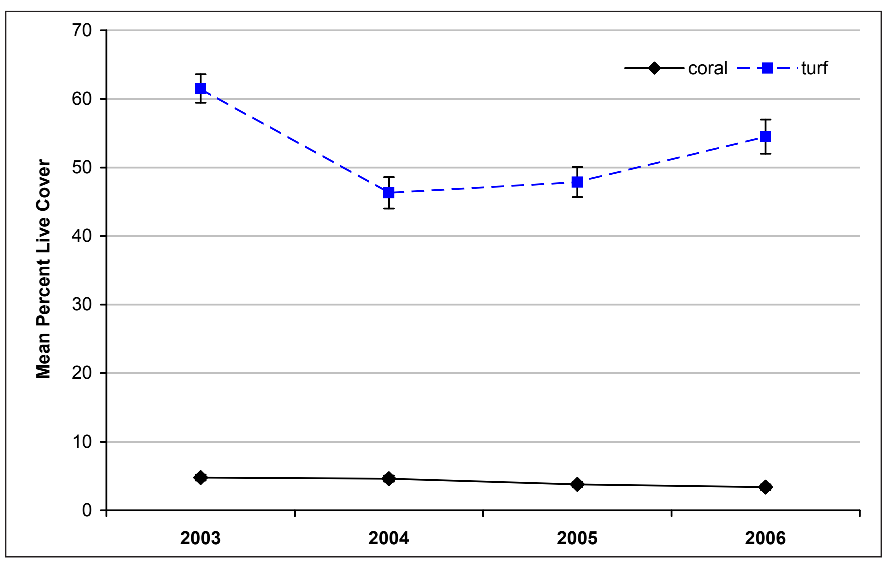

Figure 2.29. Mean and standard error for live coral and turf algae cover within BIRNM study area, 2003-2006. Source: Clark et al., in review.

Results and Discussion

GIS databases have been compiled for the islands of St. Croix and St. John, based on data submitted by the NPS, the USGS and NOAA's CCMA-BB. To date, this project has not obtained data on acroporid species distribution for St. Thomas. In St. Croix, NPS staff has identified 2,492 *A. palmata* colonies greater than 1 m in size at 455 of 617 sites within BIRNM (Mayor et. al., 2006). CCMA-BB documented the presence of *A. palmata* at 32 of 815 hardbottom sites within the BIRNM and at 11 of 430 sites within the northern EEMP. In St. John, USGS staff surveyed 1,643 sites within 11 bays in the VINP and found 3,314 *A. palmata* colonies at 1,494 of the sites visited. Of the 65 sites without colonies, 51 contained *A. palmata* fragments with living tissue. USGS also conducted surveys at 149 sites in two bays outside of the VINP (Dittliff Point and Newfound Bay) and found 313 colonies of *A. palmata*.

A. cervicornis has not received as much research attention as *A. palmata*, and much less data has been provided about the distribution and incidence of this species in the USVI. CCMA-BB staff documented the presence of *A. cervicornis* at 12 of 815 hard bottom sites within the BIRNM and at two of 430 sites within the EEMP, but they did not observe any colonies at 39 additional other sites visited in northeast St. Croix. In St. John, NOAA staff conducted surveys at 490 sites. *A. cervicornis* was observed at four of 258 sites in the VINP but was not seen at 39 sites within the VICRNM. *A. cervicornis* was also documented at one of 195 sites surveyed outside of the VINP and the VICRNM.

Summary of Overall Condition, Status and Trajectory of USVI Benthic Communities

Prior to the 2005-2006 bleaching and disease events, reef resilience was observed at three of six study sites monitored by NPS SFCN (two in VINP, one in BIRNM); the data showed that statistically significant increases in coral cover had occurred in the recent past (Miller et al., 2005). Long-term coral reef monitoring throughout the territory revealed the devastating consequences of elevated SST and its effects on coral reefs. Losses of over half the live coral cover on reefs multiple-centuries old show their vulnerability to the unprecedented intensity of natural and anthropogenic stressors found in the territory. The full effect of these losses may not be known for years but have the potential to influence fisheries, shoreline protection and tourism within the territory.

ASSOCIATED BIOLOGICAL COMMUNITIES

The previous USVI report (Jeffrey et al., 2005) focused on data sets from four monitoring and assessment programs to characterize community structure, biomass, trophic structure, and the size frequency distribution of fish assemblages in the USVI. Two of these four programs continue reef fish monitoring, and one new fish tracking study and a lobster population assessment were initiated during this reporting cycle (Table 2.1). Data from a UVI-CMES SPAG monitoring program (sites initiated both prior to and during this reporting period) have been included as well. Data from DPNR-DFW's fishery-dependent Commercial Catch Reporting and TIP (port sampling) Programs were not available for inclusion in this report, and as a result are not discussed in detail in this section, but a brief description of these programs and observed trends are discussed in the Fishing threat section of this chapter. SEAMAP-C data from DPNR-DFW's fishery-independent monitoring program are available for reef fish as well as for conch in St. Croix back reef embayments. Data collection methods did not change significantly between reporting periods for ongoing monitoring programs (Nemeth et. al., 2004; NOAA, http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.html).

NOAA CCMA-BB Monitoring of Temporal Trends in Fish Communities of the USVI

The background, goals, objectives and methods for CCMA-BB's Caribbean Coral Reef Ecosystem Monitoring (CREM) project are provided in the Benthic Habitats section. All of the data collected by CCMA-BB and local partners are available at http://www8.nos.noaa.gov/biogeo_public/query_main.aspx.

Results and Discussion

Between 2001 and 2006, a total of 1,275 and 849 locations were sampled in St. Croix and St. John respectively. Data from surveys in St. Croix suggest that reef fish assemblages were variable and showed seasonal patterns in time. In St. Croix, the mean density and biomass of reef fishes typically were lower in spring surveys (February–March) than in late summer or fall surveys (August–November) for all years (Figure 2.30). During spring months, there was a general increase in fish density between 2001 and 2006, but that increase may not be significant. Mean (±SE) biomass also appeared to increase during spring months from 2,663 ± 293 g/100 m² in 2001 to its highest at 7,325 ± 1,689 g/100 m² in 2004. Mean density and biomass of fishes were more variable during fall months. Mean (±SE) fall densities were highest during October of 2002 (314 ± 52 fishes/100 m²) and almost three times that of August 2001 (74 ± 7 fishes /100 m²). In fall of 2004, mean (±SE) fish density decreased below 2001 levels, but showed a subsequent but steady increase throughout 2006. Mean fall biomass was also highest during 2002 and variable in subsequent years (Figure 2.30).

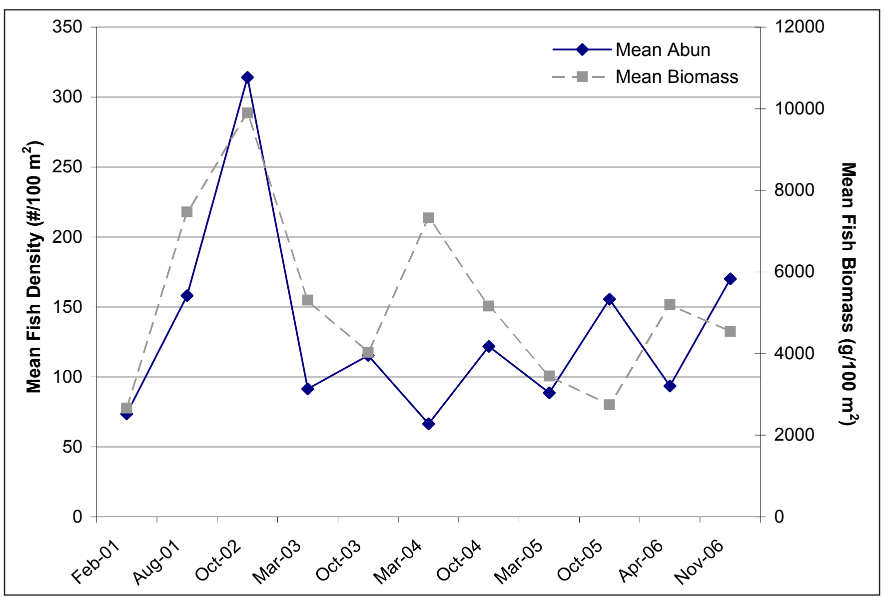

Figure 2.30. Mean (± SE) fish assemblage abundance and biomass in St. Croix, USVI. Source: NOAA CCMA-BB.

In St. John, surveys were conducted during summer months, therefore observations of seasonal patterns were not possible. Reef fish densities showed very little variation among years and ranged from a low of 150 ± 18 fish per 100 m² in 2004 to 172 ± 21 fish per 100 m² in 2006 (Figure 2.31). Mean biomass was more variable among years and was highest at

6,148 g/100 m² in 2004 and lowest in 2006 (3,034 ± 379 g/100 m²).

Reef fish assemblages were also temporally variable in trophic (Table 2.4) and taxonomic structure. In St. Croix, herbivores comprised more of the biomass than piscivores for all survey periods except during August 2001 (Figure 2.32). In St. John, herbivores also consistently comprised more of the biomass than piscivores for all years except 2003 (Figure 2.32). Fluctuations in relative biomass of herbivores and piscivores most likely relate to the occurrence of large schooling jacks or snappers during surveys.

The density of commercially important groupers (Table 2.5; species from the genera *Cephalopholis*, *Epinephelus*, and *Mycteroperca)* remain at low levels and were variable among years with no consistent trend. Most were observed either on or near reef and hardbottom areas. In St. Croix, the highest densities of grouper were observed in March 2003 (3 ± 1 grouper per 100 m²) and the lowest were seen in 2001 (approximately one fish per 100 m²). *C. fulvus* was the most common grouper species seen for all years and were often larger than the known size of sexual maturity. Fewer *E. gutattus* were observed, and only one juvenile Nassau grouper (*E. striatus)* was encountered during April 2006. Less than 3% of snappers and groupers observed on transects between 2001 and 2007 were ≥35 cm (CCMA-BB, unpub. data).

In St. John the density of commercially important groupers was lower than that observed in St. Croix and was about one fish per 100 m² for all years. *C. fulvus* was the most common grouper species observed and only one *E. striatus* juvenile was observed between 2003 and 2006.

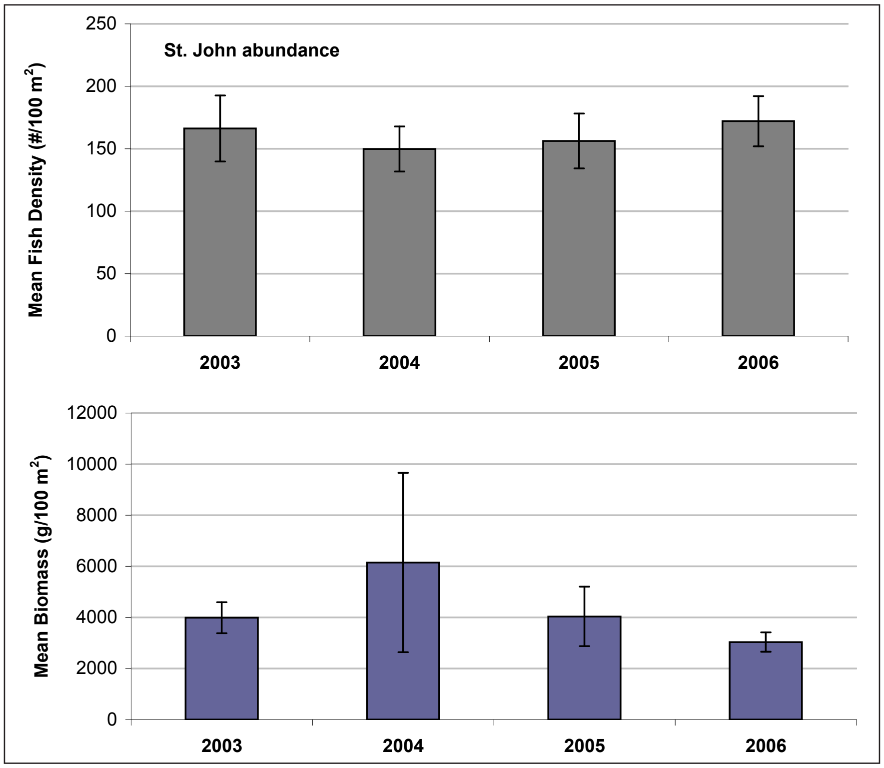

Figure 2.31. Mean (± SE) fish assemblage abundance and biomass in St. John, USVI. Source: NOAA CCMA-BB.

Table 2.4. Trophic guilds used to determine trophic biomass ration of fishes in the USVI. Source: Randall, 1967.

TROPHIC GUILD	FOOD TYPE	EXAMPLE TAXA
Herbivores	Marine plants	Damselfish, parrotfish, surgeonfish
Piscivores, mobile invertivores/piscivores	Other fish, crabs	Red hind, other groupers, snappers
Mobile invertivores, sessile invertivores, zooplanktivores, generalized carnivores	Crustaceans, corals, zooplankton, etc.	Spanish hogfish, wrasses, gobies, filefish, butterflyfish, blennies, cardinal fishes, angelfish, squirrel fishes, goatfish scadblennies

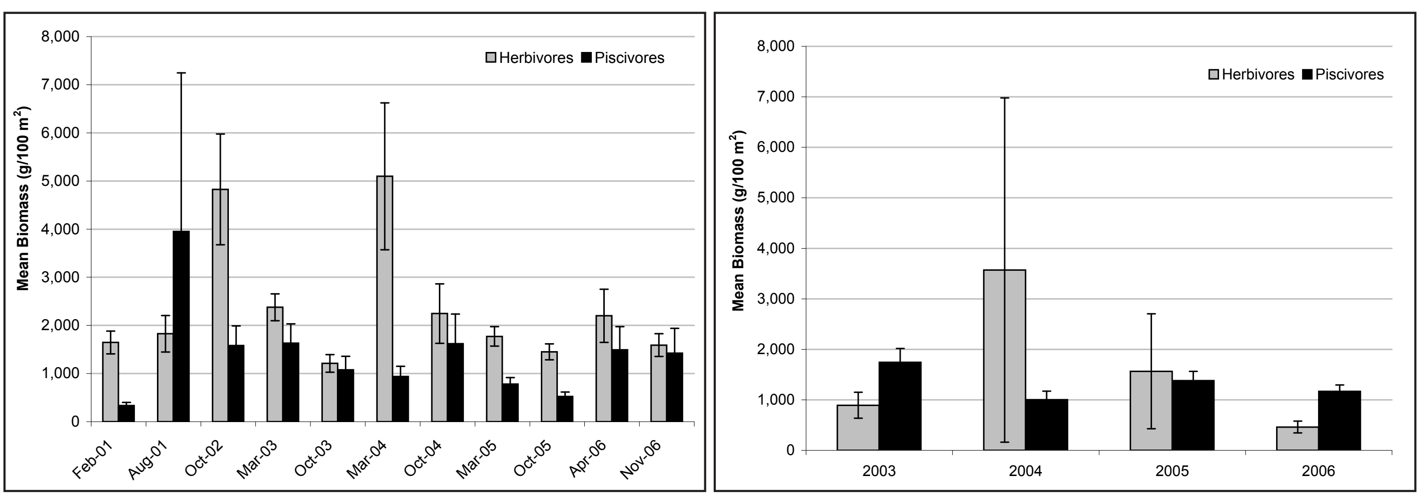

Figure 2.32. Estimates of mean (± SE) biomass of herbivores and piscivores from all surveys in St. Croix (left) and St. John (right). Source: NOAA CCMA-BB.

UVI-CMES Monitoring of St. Thomas Coral Reef Fishes

Fish surveys were conducted off St. Thomas by UVI-CMES as part of the TCRMP between 2003 and 2006. The surveys were conducted in parallel with fish monitoring on St. Croix between 2003 and 2005, and results were published annually in reports to DPNR-CZM (Nemeth et al., 2004b; Nemeth et al., 2005; Nemeth et al., 2006b). In 2003 fish surveys were conducted on six sites south of St. Thomas (Figure 2.13) within three strata (nearshore, mid-shelf and shelf-edge). In 2004, nearshore sites were dropped from the survey and in 2005 and 2006 one additional mid-shelf site and one shelf-edge site were added (Figure 2.13). Detailed survey methodology can be found in Nemeth et al., 2004b.

Results and discussion

Comparison of pooled data between years indicated no pronounced changes in fish assemblage structure on reef sites from 2003 to 2006 in St. Thomas. Total fish abundance was not significantly different over time (p=0.080) nor was average species richness (p=0.538). A comparison of repeated sites shows fairly high variability in fish abundance between and within sites (Figure 2.33a), but lower variability in species richness and diversity (Figures 2.33b and 2.33c).

Fish abundance by family was also variable over time, apparently due to natural variation, seasonality and variable recruitment (Nemeth et al., 2006b). In particular, acanthurid and scarid numerical abundance varied over time on midshelf reefs, and lutjanid and serranid abundance varied on shelf-edge sites that hosted SPAGs. The most common fishes on all sites were the blue chromis (*Chromis cyanea*) and bicolor damselfish (*Stegastes partitus*). Herbaceous pomacentrids (*Stegastes planifrons* and *S. diencaeus*) were numerically abundant at nearshore and mid-shelf sites but were nearly absent on the shelf-edge. Scarids, represented primarily by the princess, striped and redband parrotfish (*Scarus iserti*, *S. taeniopterus* and *Sparisoma aurofrenatum*) were also much more abundant nearshore than offshore, with most individuals under 20 cm. The creole wrasse (*Clepicus parrae*), a planktivore, was very common on offshore sites but was rare at all but one mid-shelf site (Nemeth et al., 2006b).

Commercially important groupers and snappers ranged from common to rare on St. Thomas reef sites from 2003 to 2006. The large bodied serranids, represented by the red hind (*E. guttatus*), Nassau grouper (*E. striatus*), yellowfin grouper (*Mycteroperca*

Table 2.5. Species of commercially important snappers (Lutjanidae) and groupers (Serranidae) for which estimates of mean biomass density (g/m²) were calculated for VINP, St. John and the BIRNM, St. Croix. Source: Appeldoorn et al., 1992.

FAMILY	SPECIES	COMMON NAME
Lutjanidae (snapper)	*Lutjanus analis*	mutton snapper
	Lutjanus apodus	schoolmaster
	Lutjanus griseus	gray snapper
	Lutjanus jocu	dog snapper
	Lutjanus mahogoni	mahogany snapper
	Lutjanus synagris	lane snapper
	Ocyurus chrysurus	yellowtail snapper
Serranidae (grouper)	*Cephalopholis cruentatus*	graysby
	Cephalopholis fulvus	coney
	Epinephelus guttatus	red hind
	Epinephelus morio	red grouper
	Mycteroperca tigris	tiger grouper

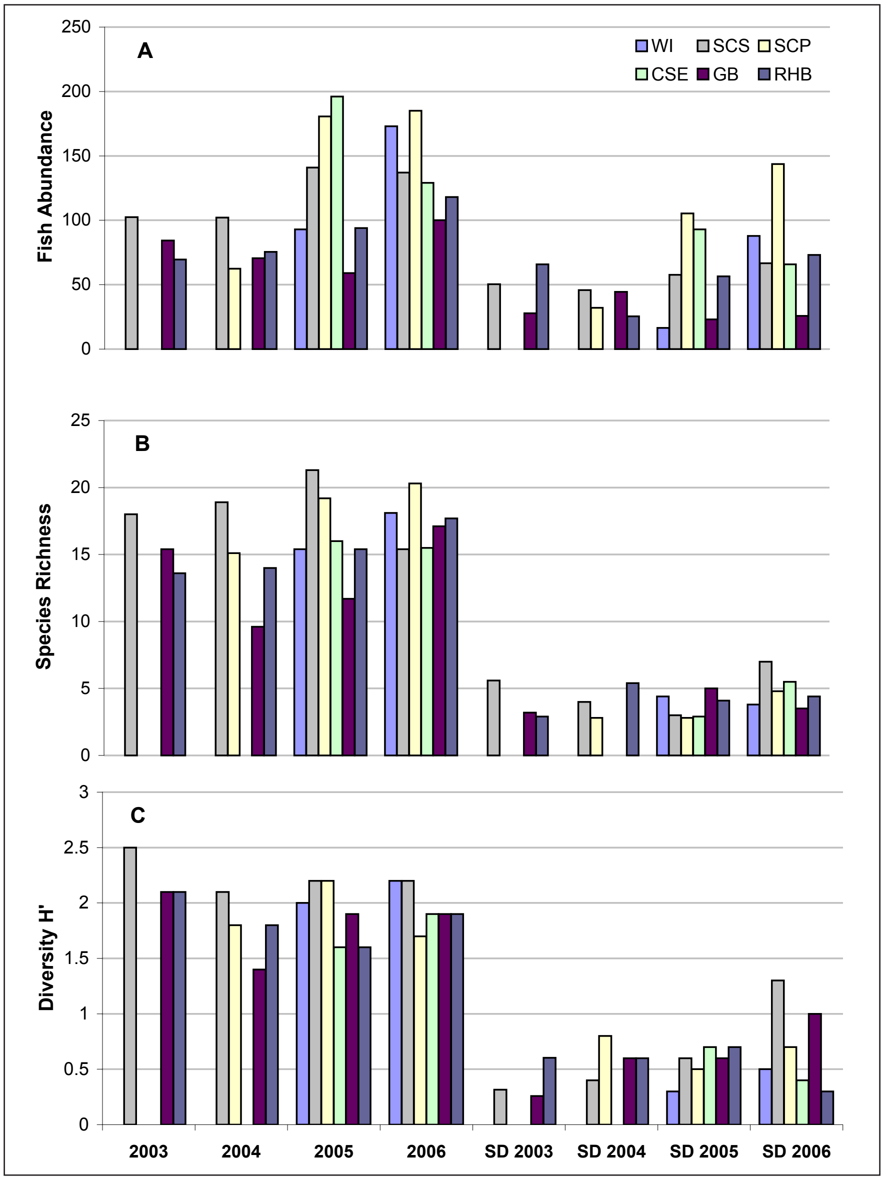

Figure 2.33. Reef fish assemblage structure across six St. Thomas sites from 2003-2006. a) Average abundance, b) Average species richness, and c) Average Shannon diversity (H'). Sites are as follows: WI=Water Island, SCS=Seahorse Cottage Shoal, SCP=South Capella, CSE=College Shoal East, GB=Grammanik Bank, RHB=Red Hind Bank. Source: E. Kadison, UVI-CMES.

venenosa), yellowmouth grouper (*M. interstitialis*) and tiger grouper (*M. tigris*) were all observed at offshore sites, but red hind and Nassau were absent at mid-shelf and inshore sites. Lutjanids were observed at all sites but were also much more abundant on offshore sites and were represented primarily by schoolmaster (*Lutjanus apodus*), cubera (*L. cyanopterus*) and yellowtail snapper (*Ocyurus chrysurus*). Results for 13 selected serranid and lutjanid species of commercial importance are shown in Table 2.6. Changes in the abundance of these fishes over the sampling years appeared to be primarily due to seasonality. The occurrence of large groupers and snappers on the shelf off St. Thomas, however, is in contrast to fish surveys made off St. Croix, where these species are rarely documented (Toller, 2002; Jeffrey et al., 2005). Their presence in St. Thomas is likely due to the two fishery reserves that protect grouper and snapper SPAGs and over 45 km^2 of the south shelf edge from fishing.

Table 2.6. Mean density and biomass of commercially important snappers (Lutjanidae) and groupers (Serranidae). Results from St. Thomas visual surveys 2003-2006. Source: E. Kadison, UVI-CMES.

		2003				2004				2005				2006			
Scientific Name	**Common Name**	Total No.	Density[1]	Biomass Total (g)	Biomass Density[2] (g/m^2)	Total No.	Density[1]	Biomass Total (g)	Biomass Density[2] (g/m^2)	Total No.	Density[1]	Biomass Total (g)	Biomass Density[2] (g/m^2)	Total No.	Density[1]	Biomass Total (g)	Biomass Density[2] (g/m^2)
Lutjanidae																	
Lutjanus analis	mutton snapper	3	0.038	2,015.0	4.198	-	-	-	-	2	0.033	486.4	1.351	4	0.067	4,447.6	12.354
Lutjanus apodus	school-master	10	0.125	7,824.9	16.302	72	2.000	19,648.5	81.869	209	3.483	53,138.7	147.608	128	2.133	79,049.3	219.581
Lutjanus griseus	gray snapper	3	0.038	233.1	0.486	4	0.111	2,058.5	8.577	29	0.483	5,545.7	15.405	15	0.250	3,855.1	10.709
Lutjanus jocu	dog snapper	3	0.038	1,840.8	3.835	-	-	-	-	3	0.050	2,336.3	6.490	4	0.067	10,468.2	29.078
Lutjanus mahogani	mahogany snapper	1	0.013	286.0	0.596	2	0.056	147.8	0.616	13	0.217	3,081.7	8.560	2	0.033	777.1	2.159
Lutjanus cyanopterus	cubera snapper	4	0.050	7,177.0	14.952	3	0.083	5,382.7	22.428	45	0.750	80,740.8	224.280	180	3.000	322,963.3	897.120
Ocyurus chrysurus	yellowtail snapper	86	1.075	13,925.3	29.011	6	0.167	873.3	3.639	11	0.183	1,489.8	4.138	22	0.367	11,240.9	31.225
Serranidae																	
Epinephelus guttatus	red hind	17	0.213	12,384.0	25.800	2	0.056	919.2	3.830	15	0.250	3,811.7	10.588	23	0.383	11,974.1	33.261
Epinephelus striatus	Nassau grouper	3	0.038	4,137.6	8.620	-	-	-	-	2	0.033	1,192.1	3.311	1	0.017	1,379.2	3.831
Mycteroperca tigris	tiger grouper	6	0.075	5,545.7	11.554	1	0.028	1,242.2	5.176	22	0.367	11,624.6	32.291	3	0.050	3,726.6	10.352
Mycteroperca venenosa	yellowfin grouper	1	0.013	2,488.0	5.183	1	0.028	703.2	2.930	2	0.033	3,066.3	8.518	-	-	-	-
Mycteroperca interstitialis	yellow-mouth grouper	-	-	-	-	-	-	-	-	1	0.017	606.3	1.684	1	0.017	1,242.2	3.451

Notes: Total No.=Sum of all individuals observed in transects at sites surveyed. Density[1]= mean numeric density (number of individuals observed per replicate sample). Data from all sites pooled. Total Biomass=Species -specific median weight per size class multiplied by the number of individuals observed in each size class, summed. Density[2]= Mean biomass density (weight per m^2). Calculated as total weight of all individuals divided by total survey area (number of transects x 60 m^2 per transect).

Recent studies have shown that extensive coral bleaching leading to the reduction of live coral cover can cause dramatic changes in fish community structure and a reduction in fish diversity (Jones and Syms, 1998; Graham et al., 2006; Feary et al., 2007a). With the exception of a few species that are lost rapidly due to their specialized use of live coral for diet or shelter, most community shifts do not occur at detectable levels until several years after the event (Graham et al., 2007). Although not well understood, lag effects on fish community structure are believed to be a function of lost recruitment cues for larval reef fishes (Feary et al., 2007b) and loss of fish habitat as dead coral skeletons are worn away, reducing reef complexity (Graham, 2007). Continued fish monitoring over the next several years in the USVI will be important to determine if additional changes occur as a result of the coral bleaching event of 2005.

USVI DPNR-DFW Monitoring of St. Croix Coral Reef Fishes

The abundance, size and species composition of fish populations were monitored annually at eight coral reef sites around St. Croix between 2002 and 2005 as part of the TCRMP. The DPNR-DFW coordinated reef fish monitoring on St. Croix in parallel with a compatible reef fish monitoring study by UVI-CMES on St. Thomas. Monitoring was funded through an award from NOAA to DPNR-CZM as part of the National Coral Reef Ecosystem Monitoring Program. Fish census methodology was reported in Jeffrey et al.(2005) and Nemeth et al.(2004b and 2005). The St. Croix component of the reef fish monitoring program was terminated in 2006 due to staff limitations and personnel turnover within DFW.

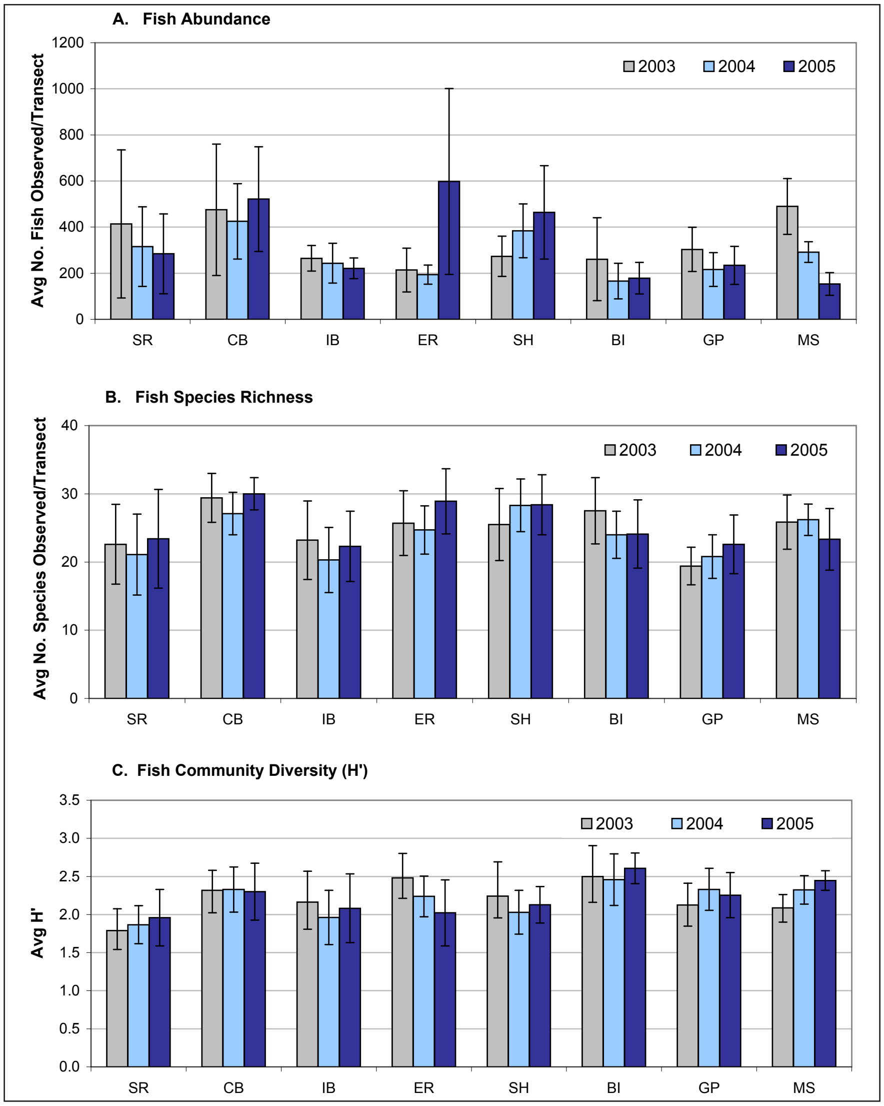

Figure 2.34. Reef fish assemblage structure across eight St. Croix reef sites. Data are from belt transect surveys conducted in 2003, 2004 and 2005. A. Average abundance. B. Average species richness. C. Average Shannon diversity (H'). Reef sites are as follows: SR=Salt River, CB=Cane Bay, IB=Isaacs Bay, ER=Eagle Ray, SH=Sprat Hole, BI=Buck Island, GP=Great Pond, MS=Mutton Snapper spawning aggregation site. Source: W. Toller, ASI.

Results and Discussion

Three years of fish survey data from eight St. Croix reef sites were analyzed for metrics of reef fish assemblage structure. Comparisons of aggregated data (all sites pooled) among years indicate that there were no pronounced changes in reef fish assemblage structure during the monitoring period. Significant differences were not detected for average fish abundance over time (p=0.086)], or for average fish species richness over time (p=0.16). This finding reflects the high variability in fish abundance among sites within any given year. Variability in abundance was generally reduced when individual sites were compared among years (Figure 2.34a). Similar site-to-site patterns of variability were observed for fish richness and diversity (Figures 2.34b and 2.34c).

The trophic composition of St. Croix reef fish assemblages was analyzed after pooling sites for each year. In all years, omnivores dominated the reef fish assemblage in terms of biomass. Omnivores also dominated assemblages in terms of numeric abundance (82-85% of all fish observed), primarily due to highly abundant planktivorous or omnivorous wrasses (Labridae) and damselfishes (Pomacentridae). Herbivore biomass represented approximately 30% of entire assemblage. Piscivores contributed least to assemblage biomass (10-14%) and were least abundant numerically (2.7-3.1% of all fish observed). Among the years observed, there was no clear indication of a change in trophic composition through time.

As documented previously (Jeffrey et al., 2005), commercially important snappers and groupers remained comparatively uncommon in St. Croix visual surveys during the recent survey period. Results for 12 selected lutjanid and serranid species of commercial importance are shown in Table 2.7. Mean numeric density and mean biomass density was dominated by small-bodied species. The highest densities were observed for coney (*C. fulvus*), graysby (*C. cruentata*), schoolmaster (*L. apodus*) and mahogany snapper (*L. mahogoni*). No large-bodied serranids of the genus *Mycteroperca* were observed in belt transects in any of the three years. Mutton snapper (*L. analis)* were rarely encountered (Table 2.7).

The quantity of herbivorous reef fishes harvested in the St. Croix commercial fishery has increased during the past decade (W. Tobias, pers. comm.), making scarids a commercially important species group. Three species dominate St. Croix landings of scarids: stoplight parrotfish (*Sparisoma viride*), redtail parrotfish (*S. chrysopterum*) and redfin parrotfish (*S. rubripinne*; Tobias, 2004; Toller and Tobias, 2005; Trumble et al., 2006). A size frequency distribution for scarids observed during 2003-2005 is shown in Figure 2.35. Comparison among years did not indicate a trend towards decreasing mean size during the study period. However, few parrotfish >30 cm, which are targets of the commercial fishery, were observed during the monitoring period. The observed low frequency with which parrotfish attain large body size may be indicative of increased fishing mortality rates.

Table 2.7. Mean density and biomass of commercially important snappers (Lutjanidae) and groupers (Serranidae). Results from St. Croix visual surveys (DPNR-DFW). Source: W. Toller.

Species	Common Name	2003				2004				2005			
		Total No.	Density[1]	Biomass Total (g)	Density[2] (g/m²)	Total #	Density[1]	Biomass Total (g)	Density[1]	Total #	Density[1]	Biomass Total (g)	Density[2] (g/m²)
Lutjanidae													
Lutjanus analis	Mutton snapper	1	0.013	1,540.5	0.333	0	-	-	-	1	0.014	1,540.5	0.352
Lutjanus apodus	School-master	27	0.351	7,407.7	1.603	24	0.316	4,899.4	1.074	13	0.178	6,225.8	1.421
Lutjanus griseus	Gray snapper	0	-	-	-	0	-	-	-	0	-	-	-
Lutjjanus jocu	Dog snapper	0	-	-	-	0	-	-	-	0	-	-	-
Lutjanus mahogoni	Mahogany snapper	40	0.519	3,661.6	0.793	25	0.329	1,695.7	0.372	21	0.288	1,760.8	0.402
Lutjanus synagris	Lane snapper	0	-	-	-	0	-	-	-	0	-	-	-
Ocyurus chrysurus	Yellowtail snapper	30	0.390	4,589.1	0.993	4	0.053	1,211.4	0.266	47	0.644	9,504.1	2.170
Serranidae													
Cephalopholis cruentata	Graysby	105	1.364	7,342.1	1.589	91	1.197	6,329.9	1.388	94	1.288	5,935.2	1.355
Cephalopholis fulvus	Coney	188	2.442	13,039.7	2.822	122	1.605	8,090.5	1.774	141	1.932	7,552.9	1.724
Epinephelus guttatus	Red hind	16	0.208	3,057.6	0.662	2	0.026	1,419.4	0.311	12	0.164	2,259.7	0.516
Epinephelus morio	Red grouper	0	-	-	-	0	-	-	-	0	-	-	-
Mycteroperca tigris	Tiger grouper	0	-	-	-	0	-	-	-	0	-	-	-

Notes: Total No. = Sum of all individual observed in all transects among the 8 sites surveyed; Total No. = Sum of all individual observed in all transects among the 8 sites surveyed; Total Biomass = Species-specific median weight per size class multiplied by the number of individuals observed in each size class, summed for all size classes; Density² = Mean biomass density (weight per m²). Calculated as total weight (grams) of all individuals divided by total survey area (number of transects x 60 m² per transect).

SEAMAP-C Reef Fish Assessments

A new analysis has been conducted of data collected during surveys of reef fishes using traditional fishing gear during 1992-2002 (Whiteman, 2005). Earlier analyses found that 60% of the original data were missing from the program database, thereby limiting the accuracy of any conclusions drawn from the data set (Pagan et al., 2004). Details of sampling methodology are provided in Gomez (2000); Tobias et al. (2002); and Whiteman (2005). Briefly, sample areas were defined northeast of St. Croix and south of St. John. Sampling consisted of deploying a series of fish traps as well as baited hand lines. Total or fork length, weight, sex and developmental stage of gonads were recorded for all fish.

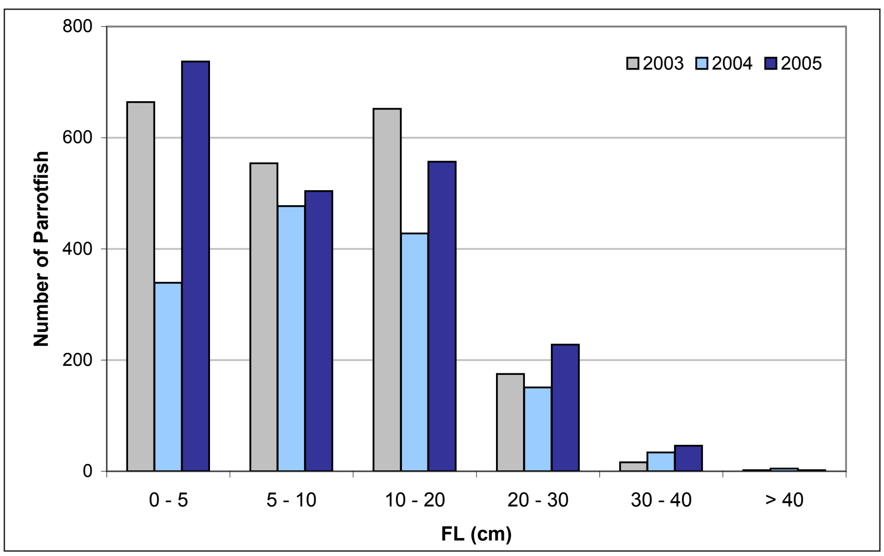

Figure 2.35. Size-frequency distribution of parrotfishes (all Scarids pooled) observed in St. Croix monitoring reef fish surveys, 2003-2005. Source: W. Toller, ASI.

It is important to note that while this data provides a baseline for local fishery resources, confounding variables such as differences in sampling locations between sampling years, catch variation due to gear type and differences in gear deployment between implementation of the study and actual fishing practice, reduce the ability of managers to attribute observed changes to actual shifts in fishery populations. Several recent reviews of the program suggest that the current survey design is not providing data of the quality necessary to evaluate changes in fishery stocks (Whiteman, 2005; Pagan et al., 2004; Cummings et al., 2007). As a result, an evaluation of the SEAMAP-C sampling design has been proposed; suggested changes will be tested via future pilot studies (Cummings et al., 2007).

Results and Discussion

Results provided here have been summarized from Whiteman (2005). For St. Croix the catch in both 1993–1994 and 2002 was dominated by coney (*C. fulvus*) and sand tilefish (*Malacanthus plumieri*), which represented 56% and 71% of the total catch biomass, respectively. Remainder of the catch differed for sampling years, with only 15 species common between years. Fish were classified as catch or bycatch depending on species and total or fork length. No significant change was noted in total trapped biomass classified as catch or bycatch between sampling years; however, in 1993–1994 bycatch was dominated by queen triggerfish (*Balistes vetula*) while in 2002 it was dominated by butterflyfish (*Chaetodon spp.*). Hook and line bycatch was dominated by *M. plumieri* in both sampling years. In St. John the catch in 1992–1993 and 1994–1995 was dominated by red hind (*E. guttatus*) and *B. vetula*, totaling 43–50% of total catch biomass. These two species also dominated the marketable total trapped biomass for the same years. However, by 1999–2000 *C. fulvus* comprised a greater proportion of total trapped biomass, while *E. guttatus* declined in total biomass from 29% to 16% in 1994–1995 and 1999–2000, respectively. *E. guttatus* and *B. vetula* also declined in capture frequency between 1992–1995 and 1999–2000. Total trapped biomass classified as bycatch increased from 5–6% to 12% for the same sample years and was dominated by butterflyfish (*Chaetodon* spp.; 1992–1993 and 1999–2000) and schoolmasters (*L. apodus*; 1994–1995). Hook and line biomass classified as bycatch has declined between 1992 and 2000, from 43% to 5%. This decline is attributable to a decrease in the total biomass of ocean triggerfish in the catch. These changes in catch composition appear to indicate changes within the target fish populations. On both islands the catch was dominated by small serranid species and throughout the sampling period there was no data to indicate change in the populations of larger species such as Nassau grouper. Further investigations into composition of catch classified as bycatch are warranted in order to determine the causes of the changes over time and ultimately the impacts of fishing on fishery resources (Whiteman, 2005).

NOAA CCMA-BB Fish Tagging Study

A fish-tagging study was initiated by CCMA-BB in 2006 to track and monitor the movement and residency time of fishes within and across habitats in St. John, USVI. Resources within the VICRNM are poorly documented, its degree of connectivity to VINP is unknown, and over-exploitation has in part contributed to large changes in local reef fish assemblages. The VICRNM was established to provide full protection from resource exploitation; VINP has allowed resource harvest by artisanal fishers since 1956. In order to better understand habitat utilization patterns and movement of fishes among fished and unfished managed areas, an array of hydro-acoustic receivers was deployed and a variety of reef fish species were acoustically tagged. Objectives of this project are: 1) to track fish movements in the VINP and the VICRNM, and 2) to determine the degree of connectivity between the managed areas. Information on this project can be found at http://ccma.nos.noaa.gov/ecosystems/coralreef/acoustic_tracking.html.

Methods

In July 2006, an array of nine hydroacoustic receivers with a detection range of about 350 m were deployed in Lameshur Bay. Sites were selected to allow overlap between nearby receivers in reefs and seagrass beds inshore and offshore of the reefs to allow detection of movement among habitats and between the VINP and the VICRNM. Simultaneously, 55 fishes were captured, tagged with VEMCO V9-2-L-R64K internal transmitters and released after 24 hours near the capture location. In April 2007, data on movement patterns of tagged fish were downloaded, an additional 21 receivers were deployed along 20 km of St. John's southern shoreline and 78 fishes were tagged (Figure 2.36).

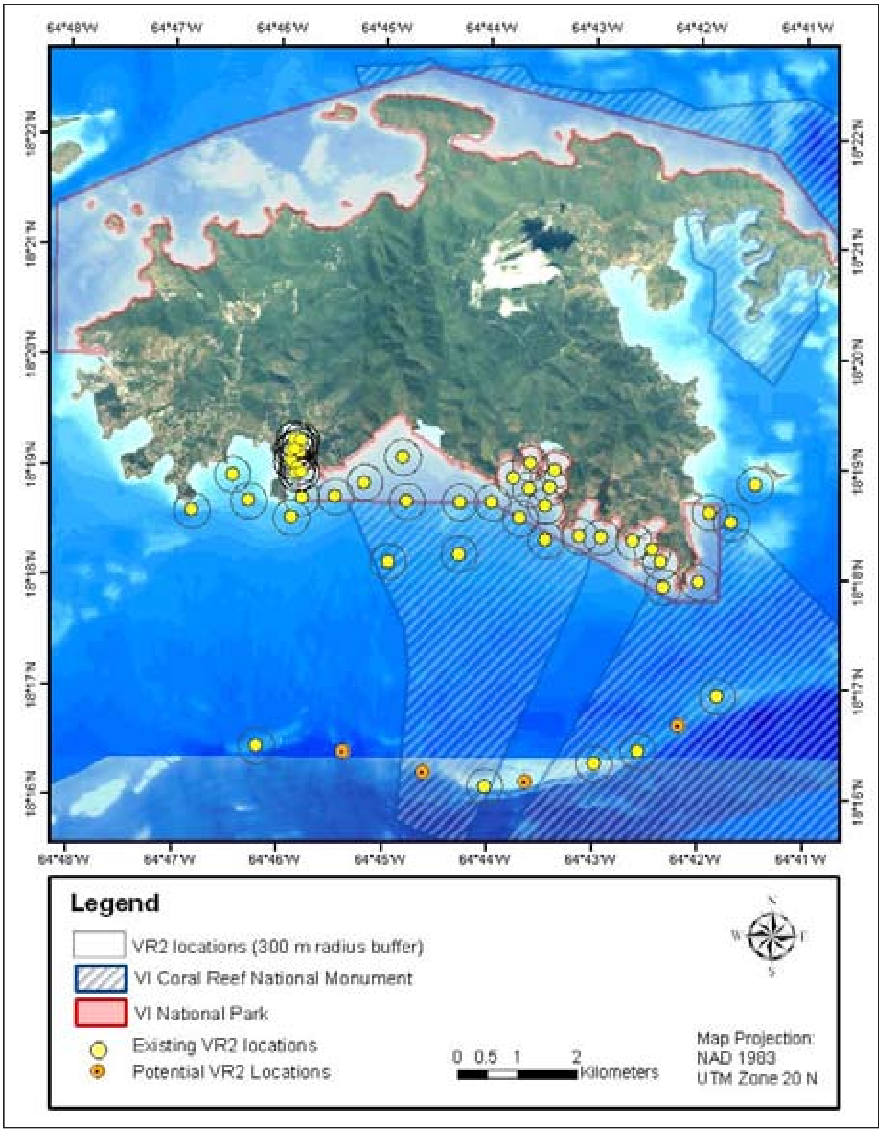

Figure 2.36. Location of current and planned hydroacoustic receiver (VR2) array design to examine movement patterns of fishes inside and outside VINP, VICRNM and outside areas in St. John, USVI (n=40). Receivers have a 350 m radius detection buffer indicated by circles. Yellow spheres represent VR2s deployed by NMFS SEFSC for a conch movement study. Source: C. Jeffrey, NOAA CCMA-BB.

Results and Discussion
A total of 123 fishes, representing 18 species and 10 families, were acoustically tagged in 2006 and 2007. Preliminary analysis of data from 55 fishes tagged in July 2006 indicates that lane snappers (*L. synargris*) and bluestriped grunts (*Haemulon sciurus*) showed diel movement from reef habitats during daytime hours to offshore seagrass beds at night. The timing of movement was highly predictable and coincided with sunrise and sunset over the course of the year. The data from 2006 also show that fish associated with reefs without adjacent seagrass beds made more extensive movements than fishes associated with reefs with adjacent seagrass habitats.

During July 2007, all 30 receivers were downloaded to recover the telemetry data for the 123 tagged fish. These data are currently being analyzed to determine broad-scale movement patterns and habitat use. Deployment of additional receivers (Figure 2.36) and continued analysis of telemetry information from fishes tagged in 2006 in Lameshur Bay is planned. Results of the study will allow resource managers to understand the movement of fish into and out of management units to identify resources that may require greater (or lesser) management focus and provide data necessary for the development of ecosystem management strategies for VIIS, VICRNM, and the Territory.

SEAMAP-C Assessment of Conch Densities in Back reef Embayments on St. Croix
DPNR-DFW collected data on queen conch (*Strombus gigas*) densities, abundance and habitat preference in six shallow (1-7 m) back reef embayments on St. Croix. Surveys were conducted in three northeast bays from 1998 to 1999 and in three southeast bays from 2000 to 2001. Details of sampling methodology are provided in Mateo and Tobias (2001 and 2004) and Tobias (2005). Briefly, ten random two meter by 50 m belt transects were surveyed in each embayment. All conch encountered were counted and measured (total shell length). Data on habitat type was also recorded and percent habitat cover for each transect was estimated (Mateo and Tobias, 2001 and 2004).

Results and Discussion
Results provided here have been summarized from Tobias (2005). This was the first study of conch densities and distribution in St. Croix's shallow back reef embayments. Conch density (44 conch/ha over all six bays) from this study is higher than had been previously reported for St. Croix populations on the insular shelf platform (Wood and Olsen, 1983; Friedlander et al., 1994; Friedlander, 1997). A more recent study by Gordon (2002) documented significantly higher conch densities of 99.7 conch/ha for the insular shelf platform; this density is higher than found by any past studies or this study. The discrepancies may be attributable to several factors including patchiness of the resource and differences in survey methodology. Data from the current study suggest that conch densities in these bays are not sufficient to maintain inshore populations, based on research by Stoner and Ray (1996) who reported that densities of <53 adult conch/ha can adversely affect reproduction. Mean conch size observed across all bays was 17.1 cm, and 87% of surveyed conch were under the legal size limit (22.8 cm). Of the five habitat types identified in the bays (seagrass, algal plain, patch reef, sand and rubble), a total of 98% of recorded conch (79% of those <22.8 cm and 63% of those ≥22.8 cm) were found in seagrass, algal plain or sand (or combination of these habitats). This data suggest the importance of these back reef embayments as nursery areas for St. Croix conch populations. It is likely that conch in these habitats are heavily impacted by recreational take as evidenced by extensive shell middens on adjacent shorelines. Upon implementation of park rules and regulations, baseline information from this study can be used to evaluate park effectiveness in protecting and facilitating the recovery of these conch populations.

Assessment and Monitoring of Spiny Lobster Populations at BIRNM, St. Croix, USVI
Florida Fish and Wildlife Conservation Commission (FWC) was contracted by the NPS to document lobster resources in BIRNM and to determine the effectiveness of the reserve for Caribbean spiny lobsters (*Panulirus argus*). The sampling protocol was designed to test the hypothesis that lobsters in the reserve will be larger and more abundant than those found in the surrounding fishery. Outside the reserve, lobsters are harvested year-round, typically by divers. The minimum legal harvest size is 3.5" (89mm) carapace length (CL).

Methods
Preliminary lobster surveys were conducted in BIRMN in April 2004. In June 2004, lobsters were surveyed both in the reserve and in the surrounding fishery (limited to adjacent waters comprising the northern portion of the EEMP). Yearly surveys have been conducted in both the reserve and surrounding fishery during April since that time. Sixty-minute timed surveys are used to estimate the relative abundance of lobsters. Surveys are conducted by teams of two divers who count and attempt to catch all lobsters encountered within the survey time frame. Capture time is not included in order to standardize search time. For a complete description of methods see Cox and Hunt (2005). Sampling is stratified by habitat type in the BIRNM reserve and surrounding fished area. Habitats include: Deep Reef (spur-and-groove reef on the shelf slope); Western Ledges (high relief ledges inside the northwest border of BIRNM; Linear Reef (slope of the fringing reef from 15-40' depth); Back Reef; Patch Reefs (isolated patch reefs surrounded by sand halos and seagrass); and Nearshore Patch Reefs (rubble/hardbottom patches in Teague Bay outside BIRNM).

Results and Discussion
Despite implementation of no-take rules in the expanded reserve in 2003, active fish traps were found in the reserve in both April and June of 2004. The new reserve boundaries were marked and enforced beginning in 2005. Since that time, fish traps have not been recorded within the reserve. Two additional species, *P. guttatus* and *P. laevicauda*, have been documented in the BIRNM reserve. An additional species, *Justitia longimanus* was found in the adjacent fishery. Recruit-

ment of Caribbean spiny lobsters in BIRNM appears to be limited not by larval influx but by appropriate settlement habitat. Post-larval settlement on artificial collectors placed in the lagoon surrounding Buck Island was similar to or greater than settlement on collectors in the Florida Keys for the period April 2004–April 2005 (Figure 2.37). Thus far, the only high-quality larval lobster settlement habitat observed has been on algal-covered patch reefs located outside of the reserve in Teague Bay on the northeastern shore of St. Croix.

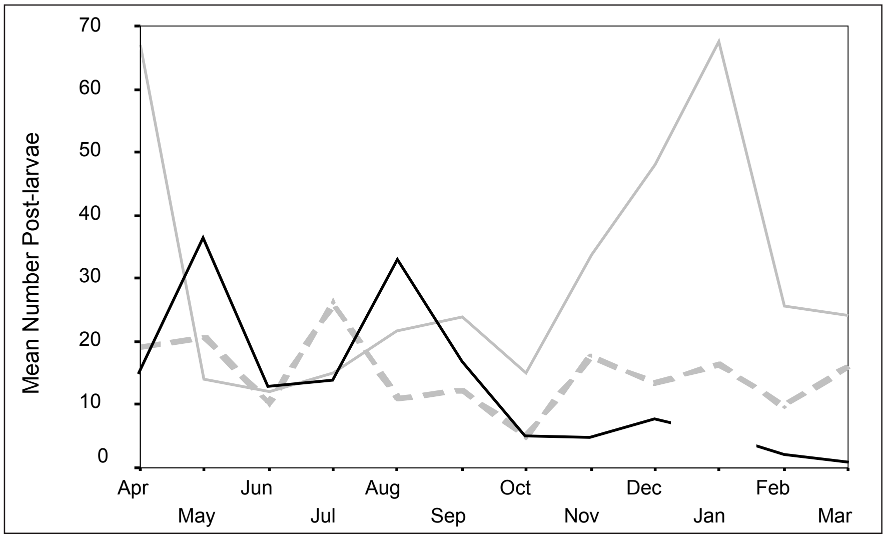

Figure 2.37. Post-larval lobster settlement on collectors at BIRNM (black) compared with collectors in the Florida Keys (gray), April 2004-March 2005.

There are significantly more legal-sized (CL ≥89 mm) spiny lobsters inside the BIRNM reserve than in the surrounding fishery. Additionally, an increase in the abundance of legal-sized lobsters has been documented inside the reserve since the installation of boundary buoys in 2005 (Figure 2.38). There was no significant difference in the mean size of legal-sized lobsters in the reserve or the fishery in our first three sampling periods (Figure 2.38). In 2006, however, just one year after boundary markers were installed, legal-size lobsters in BIRNM were significantly larger than those in the fishery. As in the Florida Keys Western Sambo Ecological Reserve, the largest lobsters in the reserve are found on patch reefs (Cox and Hunt, 2005). The documented increase in size and abundance of lobsters in the reserve relative to lobsters in the surrounding fishery is evidence that BIRNM may become an effective reserve for spiny lobsters. FWC and NPS will continue to monitor spiny lobsters in and around BIRNM to assess reserve efficacy over the long term. It is essential to continue effective protection for park resources through signage, law enforcement patrols and education.

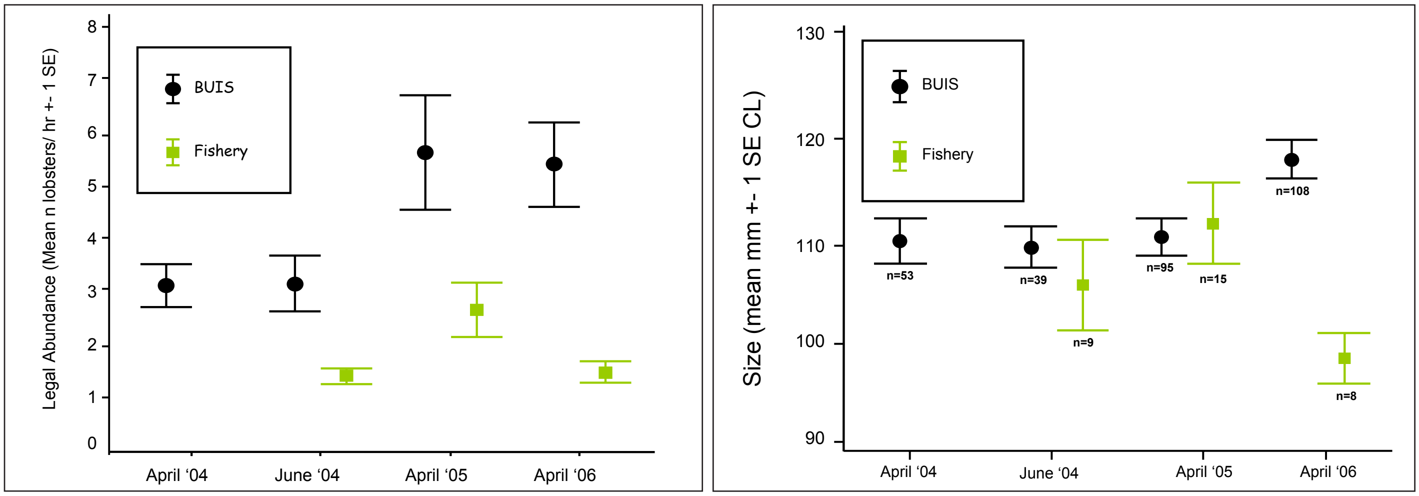

Figure 2.38. Abundance (left) and size (right) of legal-sized spiny lobsters (CL ≥89 mm) in BIRNM (black) and the surrounding fishery (green), April 2004-2006. C.Cox, unpub. data.

UVI-CMES Monitoring of Spawning Aggregations

In the late 1970s and early 1980s, unregulated fishing on grouper spawning aggregation (SPAG) sites throughout the USVI led to the extirpation of Nassau grouper (*E. striatus*) and brought the red hind (*E. guttatus*) population to the verge of collapse (Olsen and LaPlace 1978; Beets and Friedlander, 1992). Based on recommendations from the CFMC in 1990 an important red hind SPAG, the Red Hind Bank, 12 km south of St. Thomas was closed during the spawning season from December through February each year. In 1995, another red hind SPAG on Lang Bank, 16 km east of St. Croix, and a mutton snapper (*L. analis*) SPAG south of St. Croix were also closed during the respective spawning seasons. Determined to be critical habitat for reef fishes, and in particular red hind reproduction, an area encompassing 41 km^2 including the Red Hind Bank was closed to fishing year-round beginning in 1999, establishing the Red Hind Bank Marine Conservation District (MCD) as the first no-take federal fishery reserve in the USVI. Another small deep reef south of St. Thomas, the Grammanik Bank (Figure 2.39) also traditionally hosted SPAGs of yellowfin (*Mycteroperca venenosa*) and Nassau grouper (*E. striatus*). During 2000 and 2001, an estimated 20,000 pounds of yellowfin grouper was harvested by fishers from the Grammanik Bank, prompting the CFMC to call an emergency closure of the bank from March through May 2004, the grouper spawning season. In 2005 a 0.75 km^2 area surrounding the bank was closed permanently to trap fishing, and closed to all fishing except for highly migratory species from February 1 through April 30 each year.

A comprehensive SPAG monitoring effort was initiated by the UVI-CMES in the MCD in 1999 (Nemeth, 2005) and on the Grammanik Bank in 2003 (Nemeth et al., 2004a; Kadison et al., 2007). Red hind monitoring was extended to Lang Bank, St. Croix for two years in 2004 and 2005 (Nemeth et al., 2006a; Nemeth et al., 2007).

Methods

The methodology used by CMES to determine SPAG site boundaries and spawning population characteristics are outlined in Nemeth (2005). SCUBA surveys and fish traps are used to determine fish densities, size distributions and aggregation temporal dynamics. Ultrasound imaging (Whiteman et al., 2003) is used to determine the gender of fish. A tag/recapture program using external dart or t-tags has been conducted since 2002 to help determine fish migration patterns across the insular shelves (Nemeth, 2005). An additional migration study focused on movement patterns of fish in and out of the protected aggregation areas was initiated in 2007. Hydro-acoustic tags were surgically implanted in red hind, Nassau grouper and yellowfin grouper during the spawning season and receivers were placed along the insular shelf edge and around fishery closure area boundaries. Data currently being collected will help determine if the MCD and Grammanik Bank closures are adequate in size and location to protect the spawning fish while on the aggregation sites.

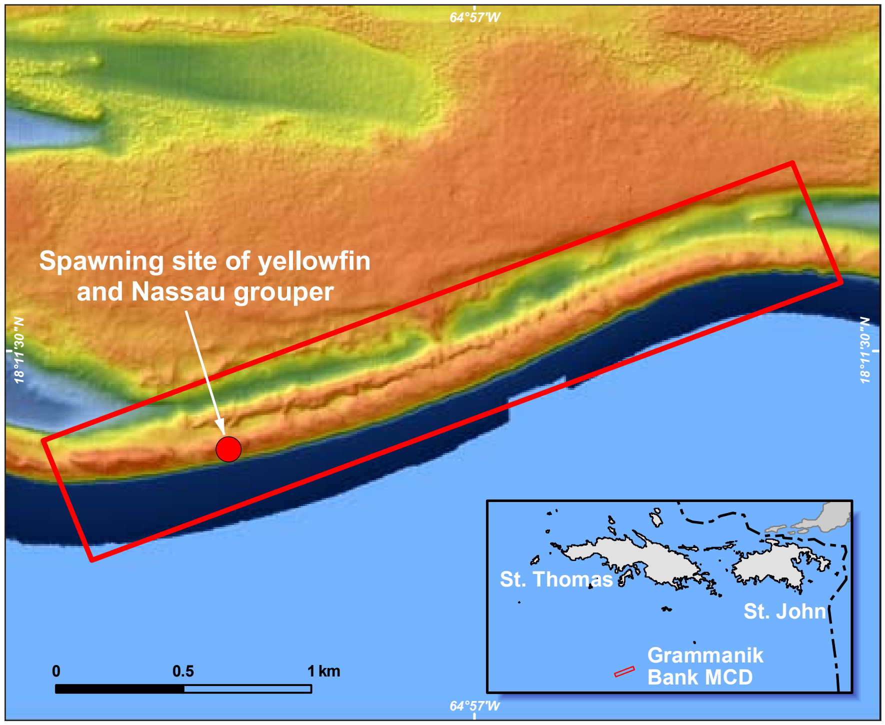

Figure 2.39. Yellowfin and Nassau grouper form spawning aggregations at sites on Grammanik Bank. Source: E. Kadison, UVI-CMES; Map: K. Buja.

Results and Discussion

Hind Bank MCD and Lang Bank

A total of over 3,000 red hind have been collected and tagged on the MCD since 1999 and approximately 1,000 fish have been tagged on Lang Bank. The MCD red hind aggregation is the first reported recovery of a SPAG (Nemeth, 2005), with an estimated spawning population of over 84,000 fish and improved regional fisheries (St. Thomas/St. John) associated with the establishment of the year-round closure. Although Lang Bank was also closed to fishing during the spawning season (December through February) the SPAG has not fared as well since seasonal protection beginning in 1995. Red hind from the St. Thomas MCD aggregation were significantly larger (38.0 versus 32.5 cm TL) and nearly nine times more abundant in a comparative study (Nemeth et al., 2006a). This may be due to inappropriate placement of closure boundaries, seasonal versus year round protection or lack of enforcement on Lang Bank. Port sample surveys of red hind length also show that red hind are significantly larger in St. Thomas. Movement patterns, temporal and spatial changes in sex ratios and annual and lunar predictability appear similar between aggregations in the MCD and Lang Bank (Nemeth et al., 2007). Red hind SPAGs occur after the winter solstice (December 20) and before February 20, showing a distinctive peak from 20-40 days after the winter solstice. Spawning typically occurs in declining seawater temperature, between the range of 26-27.5 °C (Nemeth et al., 2007). Males arrive earlier to the spawning site than females, swimming from west to east at both sites, and appear to stay longer before returning to their home territories. Other species have been observed aggregating in the MCD including tiger grouper (*M. tigris*), mutton snapper (*L. analis*) and schoolmaster snapper (*L. apodus*). On Lang Bank, large numbers of queen triggerfish (*B. vetula*) were observed around the full moons in January and February 2005.

Grammanik Bank

Since monitoring began in 2004, over 450 Nassau and 500 yellowfin grouper have been collected and tagged on the Grammanik Bank during the months of February, March and April (Table 2.8). Fish begin aggregating a few days before the full moon across the 1.5 km bank and spawn seven to 10 days after the full moon (Nemeth, unpub. data). Size is not significantly different between sexes in Nassau grouper and ranges from 42.7 to 84.6 cm TL with a mean of 61.9 cm TL. Male yellowfin grouper are signifi-

Table 2.8. Number of Nassau grouper and yellowfin grouper collected from 2004 to 2007 by year.

	NASSAU GROUPER		YELLOWFIN GROUPER	
Year	n	Sex ratio M:F	n	Sex ratio M:F
2004	63	0.43:1.00	28	1.15:1.00
2005	116	0.68:1.00	42	1.80:1.00
2006	185	0.85:1.00	244	1.46:1.00
2007	87	0.62:1.00	186	1.56:1.00
Total	**470**	**0.69:1.00**	**501**	**1.53:1.00**

cantly larger than females, with mean sizes of 77.9 cm TL and 70.0 cm TL respectively, suggesting a protogynous hermaphroditic life history. Sex ratios of Nassau grouper and yellowfin grouper on SPAGs have shown consistent trends on a yearly basis from 2004 to 2007 (Table 2.8) averaging 0.69:1 (M:F) for Nassau grouper and 1.53:1 for yellowfin grouper. Aggregations of yellowfin mixed with Nassau grouper have been observed over the southwest corner of the Grammanik Bank between four and seven days after the full moon. These aggregations ranged in size of from 20 to 1,000 individuals. Yellowfin spawning was observed six to nine days after the full moon in March and April 2007. Although groups of Nassau grouper have been observed within the yellowfin grouper aggregation demonstrating pre-spawning behavior and coloration, they have not been observed spawning. Based on visual surveys the estimated spawning population size of yellowfin grouper and Nassau grouper on the Grammanik Bank is 1,000 and 200 fish respectively. Several other species have been observed on the bank either spawning or in very large aggregations. Approximately 200 tiger grouper (*M. tigris*) were observed spawning on the bank in February 2004, with harems made up of one male spawning with one to four females (Kadison, unpub. data). Cubera snapper (*L. cyanopterus*) have been observed on the bank annually from May through August since 2003 in aggregations of up to 600 fish, and dog snapper (*L. jocu*) have been observed in aggregations of close to 1000 fish in February and March, exhibiting pre-spawning behavior and releasing clouds of sperm (Kadison et al., 2007). In March 2007 an aggregation of over 100 mutton snapper was seen over the sand channel adjacent to the Grammanik Bank. In addition to these reef fishes, schools of hundreds to thousands of horse-eye jacks (*Caranx latus*) and cero mackerel (*Scomberomorus regalis*) are regularly observed during March and April over the bank, further highlighting the importance of the reef as a multi-species aggregation area.

CURRENT CONSERVATION MANAGEMENT ACTIVITIES

The previous USVI State of the Reefs report (2005) provided an overview of the federal and territorial agencies with jurisdictional control of submerged lands in the USVI. These agencies continue to conduct research and monitoring activities into local coral reef ecosystems. Additionally, many non-governmental agencies are contributing to efforts to increase the effective management of these important marine resources.

Marine Protected Areas

While Marine Protected Areas (MPAs) in the USVI were included in the last report (Jeffrey et al., 2005), the USVI's system of Areas of Particular Concern (APC) were not discussed. In 1978, 18 APCs were identified and designated (Figure 2.40), and in 1994 they were established by law (Bill No. 20-0252). Most APCs have a significant marine component; analytical studies have been completed for all APCs and several have draft management plans. To date, none of the analytical studies or management plans have been adopted by the Territorial government, which manages the APC system. As a result, the APC designation cannot be used as a regulatory or planning tool. However, three of the APCs have active resource use management activities occurring within them; not including the St. Croix EEMP, which comprises portions of four APCs (see below). Sandy Point is a National Wildlife Refuge managed by the U.S. Fish and Wildlife Service, a portion of the Southgate Pond APC is owned and managed by the St. Croix Environmental Association (SEA), and the beach portion of the Magens Bay APC is managed by the Magens Bay Authority.

A new MPA was established in 2005 to protect a deep reef south of St. Thomas that serves as a spawning ground for several important commercial fish species. The Grammanik Bank Seasonally Closed Area is managed by NOAA through the CFMC. The area is closed to all fishing from February 1st to April 30th annually. During the rest of the year the use of fish traps, pots, bottom long lines, gill and trammel nets are banned within the closure area.

St. Croix East End Marine Park

As discussed in the 2005 chapter, the St. Croix East End Marine Park (EEMP) was established in 2003 when the Governor of the Virgin Islands signed Act 6572 into law. The EEMP represents the culmination of 40 years of vision (incorporates portions of four APCs) and several years of collaboration to establish a marine park for St. Croix. The park is managed through DPNR-CZM and to date has been supported entirely through federal funds. The EEMP is designed to be a multi-use park that spans approximately 60 mi^2 divided among four management zones: open fishing area, recreation area, turtle wildlife area and no-take area (Figure 2.40). The EEMP has been a mechanism for the USVI to implement Local Action Strategy initiatives and is a first step toward a territorial marine park system. Since the 2005 edition of this report, draft rules and regulations and a sustainable funding strategy were completed and a system of 55 day-use moorings was installed. Park rules and regulations were drafted by DPNR-CZM with extensive input from the EEMP Advisory Committee, stakeholders and the general public. The draft rules and regulations were approved by the CZM Commission in April of 2006 and are currently awaiting final approval by the VI Government. Several additional programs have been initiated including, but not limited to, the development of an education and outreach program, installation of boundary and zoning markers, installation of signage, completion of a vessel use survey and development of a watershed and coastal wetlands protection plan. Complete information on park programs is presented on the park's Web site (http://www.stxeastendmarinepark.org).

In December 2006, DPNR-CZM and CCMA-BB collaborated on a week-long, on-site training mission to develop a biological monitoring program for the park. CCMA-BB staff assisted in the identification of appropriate program goals and objectives and the development of a sampling regime to meet them. CCMA-BB staff also provided field training in the use of the NOAA monitoring protocols. Implementation of the new regime is planned to coincide with and complement the future scheduled missions of CCMA-BB to assess the adjacent waters of the BIRNM.

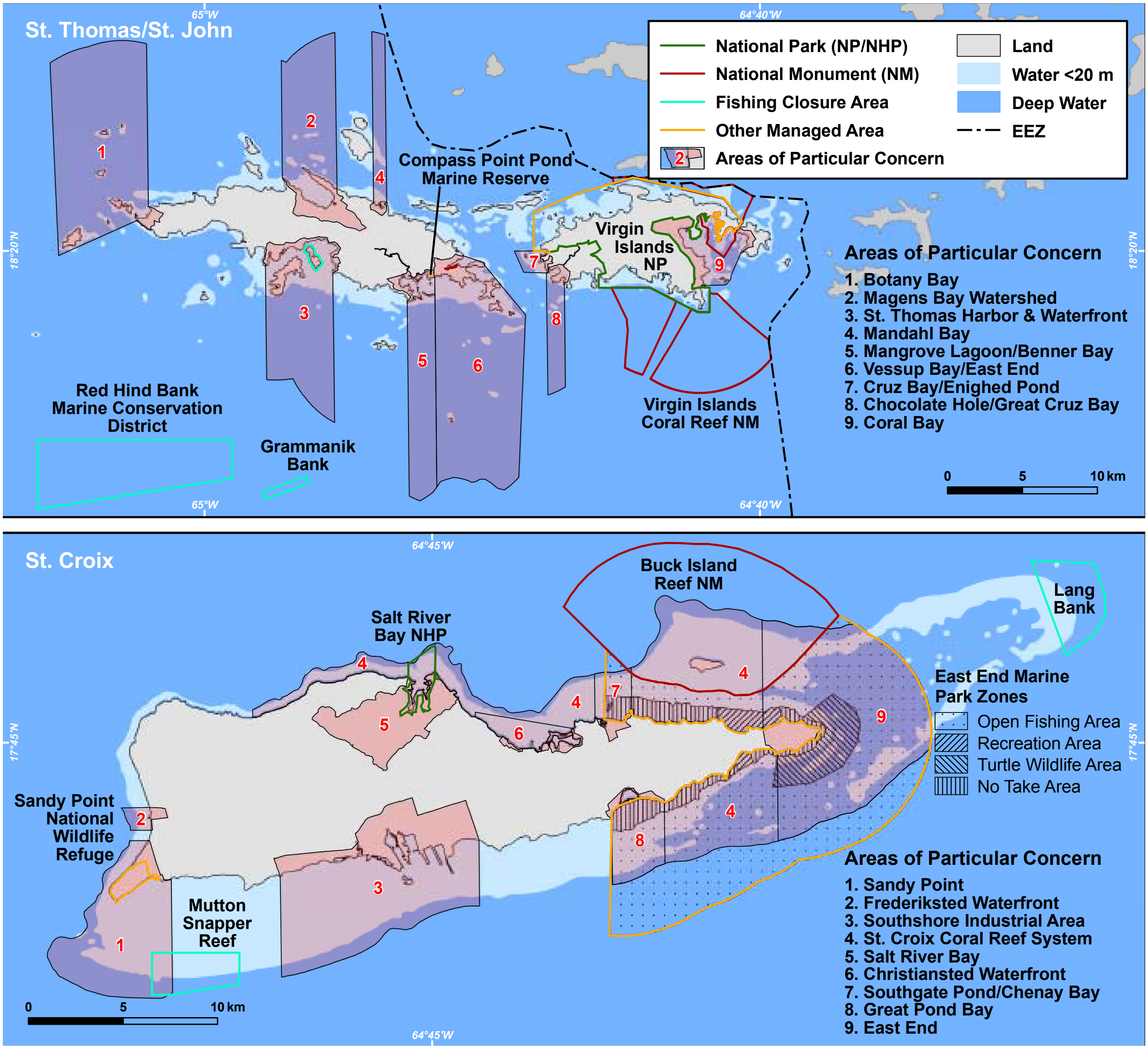

Figure 2.40. Map of the USVI showing managed areas mentioned in this chapter. Map: K. Buja.

Territorial MPA System Initiative

In addition to creating the EEMP, Act 6572 authorized the establishment of a territorial system of marine protected areas. Two non-governmental organizations, OC and TNC, have partnered with DPNR-CZM to further the development of the territorial MPA initiative. The USVI offices of OC and TNC are implementing two complementary territorial marine protected area system projects. Both projects rely on and encourage community participation.

OC's project titled, "Assessment of the Marine Protected Areas of the U.S. Virgin Islands as Part of a Functionally Integrated Network" entails assessing the ecological, legislative and socioeconomic status of territorial MPAs. A thorough assessment of the socioeconomic value and potential of the MPAs as individual units will allow managers to gain an understanding of how park units will function when integrated into a territorial network. Assessments will be conducted through review of available data, maps, statistical reports, regulations, and primary sources derived from focus groups, semi-structured interviews, structured surveys and observations. Planning for surveys and data collection will be done in consultation with fishing community representatives and other stakeholders and experts.

The TNC project, "Bridging Gaps for a Territorial Marine Park System in the U.S. Virgin Islands," will incorporate the results of the assessments completed by OC into decision-making tools using MARXAN software. Priority conservation targets will be assessed and threats to the targets evaluated and ranked. Results will be used to inform the design of a territorial MPA network based on conservation goals and existing threats, while incorporating concepts of ecological and social resilience. The design options will help identify management priorities in existing MPAs and areas that could be added to the network. Detailed ecological profiles of MPAs and socioeconomic considerations combined with a threat based analysis will help elucidate the functional role that each MPA plays, or could play, within a territorial park system.

Resource Management Trainings/Workshops

Since the last report, there has been a serious effort to increase management effectiveness, leverage resources, increase inter-agency collaboration, share data products and build local resource management capacity. Several workshops and trainings have been held to achieve these goals by providing instruction in various management tools, identifying gaps in resource monitoring and introducing new tools for data management and sharing. These efforts are summarized below.

Caribbean Workshop on MPA Effectiveness and Adaptive Management

This workshop, held by NOAA, TNC and OC in May 2005 on St. Croix, strengthened efforts to develop and improve management plans in selected Caribbean MPAs. The workshop was designed to build interest, momentum, and capacity for Caribbean-based marine managers and conservation practitioners to adaptively manage MPAs in the region. The workshop introduced and made use of the IUCN guidebook, *How is your MPA doing?* (Pomeroy et al., 2004) as a way to introduce managers to the rationale for evaluating MPA management effectiveness and a process for selecting indicators, completing an evaluation, and using results for adaptive management. Through hands-on use of this tool, managers were encouraged to strengthen existing MPA management plans and develop new plans that logically and inherently encourage adaptive management by identifying clear and appropriate goals, objectives, and management strategies. Participants included MPA managers and leaders from the USVI, Puerto Rico, the BVI, Grenada, The Bahamas and Bonaire. Each jurisdiction worked as a group throughout the workshop and focused on priority MPA sites for which they defined and strengthened MPA goals and objectives, developed management actions to achieve these objectives, and selected appropriate effectiveness indicators to be measured at each site and incorporated into ongoing monitoring efforts.

Workshop on Satellite Remote Sensing Tools for Monitoring Thermal Stress Leading to Coral Bleaching

This workshop, sponsored by NOAA's Coral Reef Watch Program, was held in January 2006 on St. Croix partly in response to the mass coral bleaching event of 2005. A major goal of the workshop included building local management capacity through the introduction of various remote sensing tools to detect environmental conditions that lead to coral stress. Participants included federal and local resource managers and scientists from the BVI, Puerto Rico and the USVI. In addition to in-depth discussion of Coral Reef Watch satellite bleaching products, participants made presentations on the various responses to the 2005 bleaching event. Dialogue included methods of response, findings, gaps, needs, monitoring approaches and ways to improve collaboration. Participants also discussed how responses could be improved in the event of a future bleaching event.

Vital Signs Indicator Development Workshops

The NPS SFCN is one of 32 NPS Inventory and Monitoring Program networks, whose responsibility it is to acquire the information and expertise needed by park managers to maintain the integrity of the ecosystems within their park units. In order to achieve this goal the SFCN held a series of Vital Signs Indicator Development Workshops early in 2006. Vital Signs are physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park (SFCN Vital Signs Fact Sheet). These workshops were attended by 70 scientists, agency staff, NPS staff and non-NPS natural resource managers. The process resulted in a list of 62 indicators ranked for importance to each park unit within the SFCN. The development of monitoring plans for selected vital signs indicators is ongoing.

Conservation Planning Training

Over 25 DPNR, USDA, UVI and local nonprofit staff members participated in an Area-Wide Conservation Planning Training workshop held May 23-25, 2006 at the UVI St. Croix Campus. The training was conducted by USDA Natural Resources Conservation Service (NRCS) trainers and hosted by the Virgin Islands Resource Conservation & Development Council, Inc. (VI RC&D), in cooperation with DPNR-CZM and the SEA. The training was sponsored in support of the USVI Land-Based Sources of Pollution Local Action Strategy and was designed to help build USVI technical capacity in order to improve the watershed planning process. The training featured a hands-on approach to watershed planning through the use of a local case study at Southgate Pond. Participants learned about the importance of the planning process and identifying a good cross-section of stakeholders; collecting and analyzing data and information for the area; and developing Inventory and Implementation Action Plans and an Evaluation and Monitoring Plan.

Workshop on Managing Watersheds and Stormwater Runoff in the USVI

In August 2006, DPNR-CZM hosted a three day Watershed Planning Workshop to improve territorial stormwater management, watershed planning and coral reef protection. With the assistance of NOAA, experts from the Center for Watershed Protection (CWP) designed the workshop using territory-specific regulatory and programmatic parameters. Workshop participants included DPNR technical staff from DEP, Energy, Historic Preservation, Building Permits, DFW, Comprehensive and Coastal Zone Planning, and CZM. Content and activities were structured to increase agency-wide watershed-based planning and resource management capacity. Outcomes from the workshop included a report of findings and recommendations for strengthening existing program effectiveness and catalyzing DPNR's watershed management efforts, as well as a watershed management plan and demonstration project for Coral Bay, St. John. This collaborative watershed management project between DPNR, CWP, EPA, USDA-NRCS and the Coral Bay Community Council has provided a mechanism for leveraging of funds and technical capacity to improve stormwater management techniques in upland watersheds thereby protecting offshore coral reefs.

U.S. Caribbean Comprehensive Coral Reef Ecosystem Monitoring Project (C-CCREMP) Workshop

C-CCREMP is a project funded by NOAA's Coral Reef Conservation Program (CRCP) that is exploring the expansion and integration of current coral reef ecosystem monitoring activities into a comprehensive long-term regional assessment and monitoring program involving federal agencies, academia, local resource marine management agencies, and other partners in the U.S. Caribbean. In September of 2006, CCMA-BB and Southeast Fisheries Science Center held workshops in La Parguera, PR and St. Thomas, USVI to strengthen collaboration among local scientists and managers and to investigate the feasibility of conducting periodic comprehensive monitoring activities in the U.S. Caribbean islands using consistent characterization and assessment methods. The workshops were intended to introduce the project to partners and solicit input from the scientific and management community. To further support regional collaboration, NOAA placed a staff member in the USVI in 2007 to improve coordination projects and support other CRCP coral reef ecosystem monitoring activities.

16th U.S. Coral Reef Task Force Meeting (USCRTF)

The 16th Meeting of the USCRTF was held in St. Thomas in October 2006. Issues facing U.S. Caribbean reefs were a priority at the business meeting and many of the associated workshops. The Status of USVI Coral Reef Ecosystems workshop aimed to provide basic information on the health of USVI reefs to local policy and decision makers, as well as their federal counterparts. The workshop's objective was to engage in a solution-oriented discussion about USVI's coral reefs and consisted of a series of presentations by local managers and scientists, followed by panel discussions. Workshop outcomes were reported to CRTF members during the business meeting session on Caribbean Coral Reefs and included: development of a coral strategy for the USVI; training and assistance in conducting effectiveness assessments to achieve adaptive management of reefs; and replication of the workshop to targeted audiences (Rothenberger, 2006). Workshop outcomes were supported by the VI Government and resulted in a CRTF resolution (#16.10) to support the USVI Government, through DPNR-CZM, in the review, analysis, development, and implementation of responses to workshop recommendations. Other resolutions of particular importance to the USVI included those to address coral disease issues and development and implementation of response plans to coral bleaching (http://www.coralreef.org).

Gear Bans

Gill nets are large mesh nets that catch finfish by entangling their gills. The nets catch indiscriminately by entangling anything that cannot fit through the mesh, resulting in the take of unwanted and untargeted species including reef invertebrates, sea turtles and birds. Net fishing can also impact coral habitats directly through interaction of gear with benthic communities. Indirect impacts of net fishing may be of even greater consequence for USVI coral reef ecosystems. By placing nets along daily migration routes, the USVI gill net fishery selectively targets large herbivores such as parrotfish and surgeonfish, which play an important ecological role in coral reef ecosystems. Their removal through overfishing has been linked to shifts from coral to algal-dominated communities.

Net fishing is a fairly new technique in the USVI that began in the 1990s as a result of declining catch rates of traps and other gear types during a prolonged economic recession on St. Croix. Gear loss due to hurricane impacts and gear bans in other jurisdictions (e.g., Florida) also contributed to increasing use of gill nets. After Florida's net ban in 1994, gear suppliers began promoting their equipment in the USVI. Net fishing now accounts for a greater proportion of annual landings on St. Croix than traditional fishing gear (Toller and Tobias, 2005).

A proposed gill net ban originated when a St. Croix gill netter voiced concerns about gill net overfishing. A subsequent 2001 DPNR VI commercial fisher opinion survey identified excessive catch by fishers using gill and trammel nets as a problem requiring regulation. Local dive operators expressed concerns that overfishing and continued use of gill nets could have serious impacts on the St. Croix fishing industry as well as on dive tourism. DPNR data shows that average fish size on St. Croix is consistently smaller than on St. Thomas, where little gill netting takes place. The proposed ban was widely supported and recommended by both the St. Croix Fishery Advisory Committee and DFW in a paper presented at the 58th Annual Meeting of the Gulf and Caribbean Institute (Toller and Tobias, 2005). DFW sought and received a $70,000 grant to compensate fishers displaced by the ban. In July 2006, gill-net fishing was banned in the USVI when Governor Charles Turnbull signed into law a revision of Title 12, Chapter 9A, Section 321-1 of the VI Code. However, to date the ban has not been enforced, and DFW funds to compensate affected fishers were never distributed.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

Coral reef ecosystems in the USVI continue to be threatened by a number of natural and anthropogenic stressors. There are multiple causes for declining coral reef health in the USVI. Arguments can be made that coral reef health is declining due to ineffective natural resource management, inadequate land use planning, exploitation of resources, or natural events (hurricanes or increasing SSTs). The continued decline of territorial coral reef health is exacerbated by a lack of critical data and institutional limitations to address the anthropogenic stressors known to adversely affect these ecosystems. The challenge for coastal communities, and the USVI in particular, will be to recognize the economic, cultural, and scientific value of coral reefs, and to create and implement a community-based vision for their conservation.

Recent assessments of territorial coastal water quality indicate that while it continues to be generally good, there have been declines since the last report (Jeffrey et al., 2005). This decline is in part attributable to nonpoint source pollution from development-induced erosion, sedimentation and poorly maintained septic systems. Point sources of pollution such as inadequate wastewater and solid waste treatment and disposal also contribute to the territory's declining water quality. While all of these sources contribute to the deterioration of coral reef health, it is unknown if and how corals affected by pollution are more vulnerable to additional stressors such as increasing SSTs or disease.

Unfortunately, despite indications of the potential resiliency of territorial reefs at some locations, coral reefs in the USVI were severely impacted by the 2005 bleaching event and subsequent disease outbreaks. Prior to this major bleaching/disease event, three of six study sites monitored by NPS SFCN (two in VINP, one in BIRNM) showed statistically significant increases in coral cover (Miller et al., 2005). These gains were short-lived; subsequent surveys revealed the devastating consequences of elevated seawater temperature and their effects on coral reefs. Ultimately, the loss of over half of the remaining live coral cover on reefs highlight their vulnerability to the unprecedented amount of natural and anthropogenic stressors found in the territory. The effect of these losses and potential impacts on the wider ecosystem, including populations of ecologically and commercially important fish and invertebrates, as well as the ecosystem services they provide may not be known for years or decades.

The considerable response to the bleaching event provided significant insight into the scope and impacts of the event. However, the bleaching event also made it clear that the USVI coral monitoring community was largely unprepared to respond to such a large-scale and temporally restricted event. The response strained agency resources, and it's unclear whether such a response could have been repeated if the USVI experienced a similar event in 2006. It has also become clear that the information needed to mitigate such events is incomplete. It is unknown how the effects of the bleaching event and subsequent disease-related mortality will impact USVI reefs in the future. Questions remain as to whether surviving corals are more resilient to these types of occurrences, or if surviving the 2005 event has weakened them so that they will not be able to withstand the next. Long-term impacts on coral reproduction are unknown. More research is needed into the process of bleaching and disease, particularly into synergistic effects of these processes. Additionally, baseline information on coral diseases and their impacts on USVI coral reefs is lacking. This information is critical to effectively manage and respond to these types of events. Without it, the ability of managers to address compounding factors within their control, thereby potentially mitigating the impacts of such events, is impaired.

Obtaining information on reef fisheries remains a challenge for resource managers in the USVI. Data on fishing effort and catch from the commercial fishery are scarce because of inconsistent and incomplete reporting by fishers (SEDAR 14, 2007). Likewise, very few data are available on recreational harvest of reef fishes, although recreational fishing is considered an important source of fishing mortality in the territory. A recent review of fisheries data from the USVI by NOAA concluded that available data collected from fishery dependent and independent surveys were inadequate for determining the status of queen conch, mutton snapper and yellowfin grouper fisheries. Nevertheless, existing data indicate that catch composition continues to be dominated by herbivorous fishes (e.g., small parrotfishes) rather than the large snappers and groupers that dominated commercial reef fish catch forty years ago (Jeffrey et al., 2005). Additionally, incompatibility between some federal and territorial fishery regulations and inter-island differences in permitted gear types (e.g., trap mesh size) complicates reef fish management by making enforcement of existing regulations more difficult. Data from fishery-independent surveys in shallow, nearshore environments are more available but may not reflect the status of fished populations in deeper offshore waters. Data from such studies indicate that federal and territorial marine protected areas and seasonal closures may be increasing the abundance, size, and spawning activity of some targeted species (e.g., queen conch, red hind and Nassau grouper).

Stressors affecting USVI reefs are cumulative in nature. Rising SSTs, sedimentation, pollutants, storms, fishing and disease all act in concert to compromise coral condition and resiliency. In order to begin proactive, effective management of our reefs, it is imperative to focus regulatory and management efforts on stressors that can be locally controlled (i.e., mitigating sedimentation through better land use planning and practice, mitigating pollutants through reduction of sewage bypasses, etc). In order to accomplish this, maintaining and restoring coral reef ecosystem health must become a priority for the USVI community.

Gaps, Problems and Recommendations

The last report (Jeffrey et. al., 2005) identified several areas where action could be taken to help conserve coral reefs. These included increased collaboration between agencies working on coral reef issues in the USVI, improving enforcement of existing regulations, expanding management capacity and increasing awareness of coral reef ecosystems among residents and visitors alike. Progress has been made in many of these areas, but additional efforts are warranted.

Several activities occurred within this reporting period to address these issues. Many workshops were held between federal, territorial and NGOs with the goals of identifying gaps in knowledge and effort, and strategizing to find ways to address them. Other workshops provided managers with tools to assess effectiveness of current management measures. However, much remains to be done. It is widely acknowledged that all agencies working for the conservation and management of coastal and marine areas in the USVI are limited by resources (staff, funding, technical capacity, etc.). In addition to increased collaboration and communication between agencies based in the territory, there is a need for their federal and international counterparts to do the same.

Lack of management and enforcement capacity continues to be a significant challenge for the USVI (Wusinich-Mendez and Curtis, 2007). Until coral reef ecosystem health is embraced as a community priority and reflected in policy and regulatory decisions, effective protection and management of these vital ecosystems will remain marginal. Enforcement agencies are chronically understaffed and territorial resource management offices experience significant staff turnover, particularly during administration changes. These staffing issues have in the past presented significant challenges to effective coral reef management, including: loss of institutional memory, a compromised thread of continuity, and abandonment of management processes which can stall program progress. Data on the direct and intrinsic economic value of USVI coral reef ecosystems would provide validation for the protection of these areas. Translation of this economic data into a format that can be distributed to policy makers and members of the public will increase the likelihood that coral reef health becomes a priority issue for the community. Formalized agency directives to increase collaborative efforts among resource management agencies would provide additional support for coral reef programs by leveraging of resources, minimizing duplicitous efforts, identifying gaps and minimizing competition for funds.

There continues to be a disconnect between scientists, resource managers and policy makers. Translation of scientific data on coral reef ecosystems into meaningful action such as revised management and planning policies (adaptive management), revised regulations and increased resources for initiatives remains a significant issue. A preliminary analysis of the percentage of conservation effort among agencies involved in coral reef issues in the USVI bears this out, and is presented in Figure 2.41 (Curtis, 2006). This analysis showed that while a large amount of effort (approximately 45%) is being expended on resource monitoring and public awareness activities, very little of that effort is translated into management activities like enforcement (3%), marine protected area establishment (6%) or habitat restoration (3%). New approaches and venues are needed to make coral reef science relevant and readily available to non-traditional audiences including policy makers, realtors, hoteliers, contractors and others.

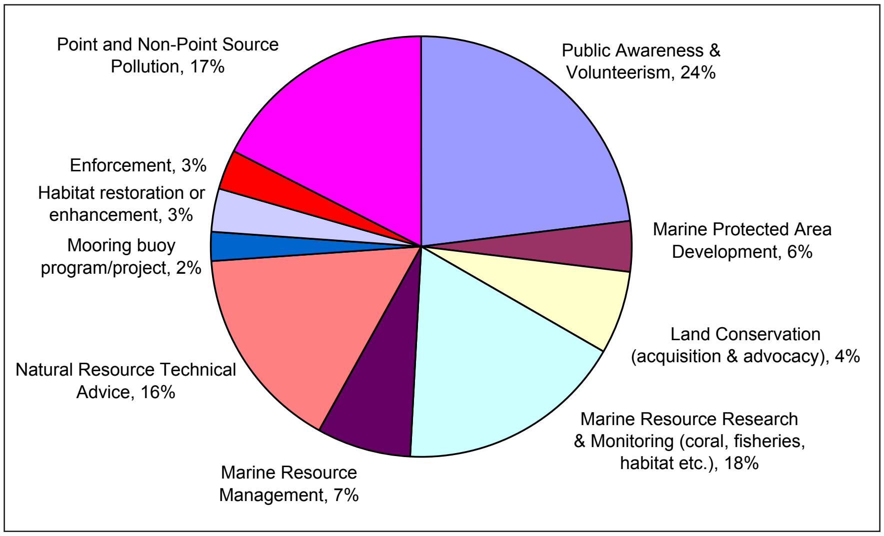

Figure 2.41. Distribution of the percentage of conservation effort among 31 agencies or collaborating groups that contribute to coral reef conservation in the USVI. Percentages for each type of activity represent the number of agencies and/or collaborating groups engaged in that activity out of all agencies or collaborating groups working in coastal or marine resource issues in the USVI. Source: Curtis, 2006.

The USVI has many of the necessary components for an effective regulatory framework to help restore coral reef ecosystem health, such as established MPAs, existing land use and resource management regulations, long-term data sets, and ongoing monitoring efforts. Initiatives such as zoning and implementation of other coastal and resource management regulations should be used in combination to develop a comprehensive strategy for the protection of coral reefs in the USVI. However, it is important to remember that successful implementation of protective policies is reliant upon perceived community value, technical capacity and political will.

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