The United States Virgin Islands

TERRITORIAL CORAL REEF MONITORING PROGRAM

ANNUAL REPORT

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A collaboration between:

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MISSION STATEMENT

Mission

OUR VISION

To provide critical information on the status and threats to all Virgin Islands coral reef ecosystems in order to increase management effectiveness and improve basic and applied coral reef research

OBJECTIVES

- **Monitor the status and trajectories of coral reefs across a majority of habitats and threats, including land-based sources of pollution & thermal stress**
- **Link changes in coral reef health with specific stressors, indicating specific management interventions most effective for preserving reefs**
- **Integrate assessments of understudied mesophotic coral reef ecosystems and threatened species in the USVI**
- **Provide data, outputs, and advice to stakeholders and create a nexus of information for reef research**

EXECUTIVE SUMMARY

Executive Summary

Coral reefs in the Caribbean are facing a dramatic decline and are at a crossroads. Management decisions made today will affect the goods and services that reefs provide for decades to come. The government of the United States Virgin Islands (USVI), in coordination with the NOAA Coral Reef Conservation Program and the University of the Virgin Islands, implemented the **Territorial Coral Reef Monitoring Program** (TCRMP). The TCRMP has established baseline conditions and temporal trends of coral reefs and fish populations and has identified threats that will influence the future reef health and development.

A major focus of the TCRMP is to provide information that can lead to more effective management strategies that balance the immediate needs of the Virgin Island's population with preservation and sustainability of coral reefs and the renewable goods and services they provide.

The intent of this report is to distill monitoring data into actionable information that can guide management decisions and inform the public and policy-makers on areas that need further effort. This executive summary presents information on threats to USVI reefs that require management intervention/action as well as positive signs that can inform our understanding of sustainability.

CORAL REEFS OF THE VIRGIN ISLANDS: MANGEMENT ACTIONS NEEDED

The TCRMP data has identified threats to USVI coral reef ecosystems that need increased management attention if reef corals are to persist in a condition that is equal to or better than current conditions.

Coral Reef Bleaching. High thermal stress caused by climate change is currently the greatest threat to USVI coral reef ecosystems. The 2005 coral bleaching event caused the largest loss of coral in the documented history of the USVI, with a 50% decline in coral cover in shallow waters less than 25m/85' deep. This event surpassed all known modern impacts from physical damage (storms and anchoring), ecosystem changes (fishing and disease), and pollution (terrestrial sediments and toxins). These events are predicted to increase with a warming planet, troubling news for the USVI

While local management actions cannot remove impacts to reefs from global warming, reefs that are otherwise less stressed by land-based sources of pollution, fishing, and/or physical damage are known to recover more quickly from bleaching. Hence, local management actions that promote seascape-wide coral reef health offer the best strategy for sustainable reefs. We can also identify areas that are naturally more resistant to thermal stress and offer these areas further protection, since they offer insurance against the worst possible future outcomes for USVI reefs.

Figure 1. Partially bleached and recovering colony of *Siderastrea siderea* at Flat Cay, St. Thomas (Nov. 12, 2005).

Overfishing. There are clear indications that reefs of the USVI are suffering the effects of overexploitation of reef resources, although there are also positive signs. The entire district of St. Croix has an extremely low abundance of commercially important grouper species, including the threatened Nassau grouper. In St. John and St. Thomas, many common species have completely or nearly disappeared from nearshore waters in the last 30 years. For example, a study conducted by Rogers et al. (1982) on the southwest coast of St. Thomas during the airport runway expansion (1979-1981) found a variety of species that are no longer encountered or are rare, including the black, Nassau, tiger, and yellowfin groupers, as well as the federally protected parrotfish species blue, midnight, and rainbow. A study by Randall (1963) also found high relative abundances of groupers and threatened parrotfish on the south coast of St. John. Rebuilding these fish stock will require comprehensive life-history information for target species, a willingness to find strategies to rebuild stocks, and partnerships between commercial and recreational fishers, community stakeholders and managers.

Land-Based Source of Pollution. The steep hillsides of the USVI are natural conduits for run-off during heavy rain events and in many instances there is little interception of materials before they reach the sea and impact coral reefs. When tropical soils are naturally disturbed or through the actions of man, they can erode and release fine-grained silt and clay particles. In the USVI, these fine-grained particles are quickly transported to coral reefs where they can block sunlight, directly smother corals, or increase the growth organisms that compete with corals for space. There is evidence from the TCRMP that terrestrial sediments are having large negative impacts on nearshore coral reefs by increasing mortality of ecologically important corals.

CORAL REEFS OF THE VIRGIN ISLANDS: POSITIVE SIGNS

Despite the incredible declines in reef health witnessed since the inception of the TCRMP in 2001, there are many positive signs for the USVI that should be highlighted. These successes offer lessons that can be applied to troubled reefs and may indicate refuge areas where we might "double-down" on current management strategies.

Reef Refuges. The USVI is blessed, perhaps uniquely for the Caribbean, with extensive areas of deep bank and slope reefs that may be buffered from the direct impacts of climate change and local pressures. The mesophotic (pronounced: me-zo-photik; meaning; "middle-light") reefs of the USVI are the best developed in the Caribbean from what is currently known. Mesophotic Coral Ecosystem (MCE) bank reefs with high populations of star corals (*Orbicella* spp.), which have recently been proposed for listing as endangered on the United States Endangered Species List (NOAA 2012), form extensive tracts on the south shelf of St. John and St. Thomas, from the British Virgin Islands to Vieques, Puerto Rico. Well-formed, but patchier mesophotic boulder coral reefs also form on the Lang Bank, St. Croix and the northern Puerto Rican Shelf. During the 2005 bleaching event, where shallow water reefs lost 50% of coral cover, MCE studied by the TCRMP hardly bleached and lost a more modest 20% coral cover. Thus, there is hope that these reefs will serve as refuges for corals during a time of increasing ocean temperatures.

In federal waters some of these areas are wholly or partly protected from fishing of ecologically important species that help maintain reef health. These include the Red Hind Marine Conservation District (est. 1999), the Grammanik Bank Seasonally Closed Area (est. 2005), and the Lang Bank Red Hind Seasonally Closed Area (est. 1993). However, extensively developed mesophotic reef in unprotected territorial waters also exist near the island of French Cap and Sail Rock, St. Thomas District. It is important that these areas are identified, their threats assessed, and they are incorporated into the territorial and federal management planning process.

Rebounding Fisheries Species. There are positive signs of recovery for certain fish species in some areas. At the Grammanik Bank grouper spawning aggregation site there have been increasing numbers of Nassau grouper present for annual spawning (Kadison et al. 2010, Jackson et al. 2014) and a red hind aggregation in the Red Hind Marine Conservation District (MCD) has dramatically rebounded (Nemeth 2005). Red hind caught in the fishery on the south side of St. Thomas are more numerous and larger (D. Olsen, pers. comm.). It is also the impression of the authors that stocks of grouper and snapper are increasing in the MCD, although TCRMP measurements are confounded to some degree by the rotating array of aggregating fishes. Other territorial and federal closed areas in St. Croix, St. John, and St. Thomas are more recently established and may not show effects for several years. In 2011 the TCRMP recorded the first ever sightings of two Nassau grouper in St. Croix, a positive sign. No Nassau grouper were observed in 2012 unfortunately. For species that are completely protected from fishing (Nassau grouper and blue, midnight, and rainbow parrotfish), educational campaigns for recreational and commercial fisherman are critical, as awareness of regulations appears to be lacking (Authors, unpub. obs.).

Land-based source of pollution. While development of steep island slopes has continued despite current regulations intended to prevent sediments from entering nearshore waters, research has identified key targets for restoration and some effective habitat restoration best-management practices. Results from TCRMP research suggest that there are certain levels of silt-laden terrestrial run-off that are damaging to corals, providing a target for reductions of sediment in the marine environment. Unpaved road segments have been implicated as the worst culprits in the production of sediment-laden run-off (Ramos-Scharrón and MacDonald 2007b) and this provides a clear target for where management can be most effectively applied. Restoration of watersheds has shown that implementation of best-management practices and control structures can be effective in reducing sedimentation. For example, the American Recovery and Reinvestment Act project “USVI Coastal Habitat Restoration Through Watershed Stabilization” showed promising results (Virgin Islands Resource Conservation and Development Council; P.I. M. Taylor).

This report presents results of the 12th year of monitoring on reefs surrounding St. Croix, St. John, and St. Thomas (years 2001-2012). Monitoring sites were distributed across the insular platform in depths from 5 to 63 m (16 – 220’) in an effort to capture the diversity of reef types present in the Virgin Islands. Long-term data is presented from 33 sites. While not exhaustive, the TCRMP is generally representative of the geographic areas and variety of reef types in the USVI. Digital video and diver surveys were used to quantify benthic cover and coral health at 14 permanent sites surrounding the island of St. Croix and 19 permanent sites on the Puerto Rican Shelf surrounding the island of St. John and St. Thomas. In addition, at 32 of these sites sea urchin density and fish community structure were evaluated. This report presents data from a major expansion of coral reef monitoring sites.

Research Highlights

SPECIES-SPECIFIC RESPONSES TO BLEACHING

Bleaching Resistant Species in the Caribbean and Implications for Coral Reef Management

TCRMP research has uncovered new information on the response of Caribbean corals to thermal stress events that has high relevance for management and was recently published in the journal *Ecosphere* (Smith et al. 2013). Shallow reefs of the USVI were affected by thermal stress in 2005 and 2010 when temperatures exceeded a stress point for many corals known as the bleaching threshold. The longer corals spend above the bleaching threshold and the greater the temperature surpasses the bleaching threshold the more likely corals are to bleach (Fig. 1), or lose the pigmented microalgae that live in their cells and give corals the lion's share of their nutrition. Weakened corals are susceptible to disease and direct mortality. In 2005 the temperatures were very high for very long and the majority of shallow water corals bleached, with a loss of 50-60% of the coverage of reef corals in the USVI (Miller et al. 2009). In 2010 the temperatures were on their way to surpass the heat stress in 2005, but temperatures were cooled by the upwelling of deep water stimulated by the passage of Hurricane Earl (August 30th). Heat stress was less than half that experienced in 2010, with limited bleaching, disease and mortality, often confined to specific areas (Brandt et al. 2013).

Figure 2. Bleaching of *Orbicella faveolata* and *O. annularis* at Flat Cay, St. Thomas (Nov. 12, 2005).

These corals were affected by disease during recovery in 2006 and lost tissue. Most corals suffered partial mortality that removed over 50% of the living tissue, but left parts of the colony alive and capable of recovery.

RESEARCH HIGHLIGHTS

The TCRMP was able to use its resources to provide one of the most comprehensive data sets of coral reef response to thermal stress and bleaching in the Caribbean. One central question to ask of the data was were the responses of very different coral species similar over the extreme and mild thermal events? We used data from 18 of our shallow water (<25m/83' depth) monitoring sites to look at the response of nine coral species for which we had hundreds to thousands of observations. The response was divided in to bleaching (the proportion of corals that bleached and the extent of bleaching on the colonies surface), disease (the proportion of corals that showed white disease signs), and mortality (the proportion of colonies that had partial or total mortality and the change in the reef coverage of the species).

We found that there were three distinct groupings of species that we labeled "types". Type I had high bleaching and initial mortality, no subsequent white disease, and severe losses of cover (exhibited by *Agaricia agaricites* and branching *Porites* species); Type II had moderate bleaching and initial mortality, high subsequent white disease prevalence, and severe losses of cover (exhibited by *Colpophyllia natans*, and *Orbicella* spp.); Type III had moderate to low bleaching and paling, low to no subsequent white disease, and low to no loss of cover (exhibited by *Diploria strigosa*, *Montastraea cavernosa*, *Porites astreoides*, and *Siderastrea siderea*).

The biggest surprise was that a group of species (Type III) was almost entirely resistant to bleaching induced mortality. These species may become progressively more dominant on coral reefs of the Caribbean with increasing frequency and severity of coral bleaching events. In contrast, the Type II species, including main reef building species in the Caribbean, *Orbicella* spp., was only moderately affected by bleaching across our sites, but was highly susceptible to disease after the bleaching event. However, for thermally sensitive Type I and II species partial mortality was much more common than whole colony mortality and the surviving tissues may aid in recovery.

SPECIES-SPECIFIC RESPONSES TO BLEACHING

RECOMMENDATIONS

The findings of our research have very important implications for localized management with regards to thermal stress that includes which coral species do not need a lot of active management and which corals should be managed and where management might be most effective.

Strategy #1. Do not expend a lot of effort to protect Type III species, as they will likely weather future thermal stress events quite well. These species also tend to be ones that are quite resistant to other localized stressors, such as sedimentation. Type III species will persist through at least the first half of the 21st century and will likely become more dominant in reef systems. However, they may not increase in abundance sufficiently to replace the species lost to thermal stress. Hence, even with persistence, ecological roles played by reefs, such as the provision of nursery and adult habitat for fishes will likely degrade.

Strategy #2. Stress local management actions that promote the regrowth of surviving coral tissues. These include the usual actions, such as limiting land-based sources of pollution and sediments and reducing fishing that affects populations of herbivorous fishes and urchins that consume seaweeds that compete with coral for space. As an example, the highly thermally sensitive *Agaricia agaricites* is recovering after 2005 from tissue fragments in reefs with low land based sources of pollution and low seaweed abundance (e.g., Flat Cay), but not at reefs that are clearly still being impacted by local stressors (e.g., Fish Bay).

Strategy #3. Large *Orbicella* spp., some many hundreds of years old, were mostly, but not completely, killed in 2005 (Fig. 2). These corals are akin to the giant sequoia trees of central California that are long-lived and virtually irreplaceable. The fact that the centuries old genotypes are hanging on in USVI reefs is cause for hope and action. Every effort should be made to protect these recovering ancients, including education and active restoration. As for the latter, restoration of *Orbicella* spp. has not yet been attempted in the USVI to our knowledge. However, the fact that un-eroded large skeletons still remain intact provides an opportunity for replantation of fragments that could re-sheet old skeletons, short-circuiting the recovery process and protecting essential habitat. This area is very ripe for research into effective restoration strategies.

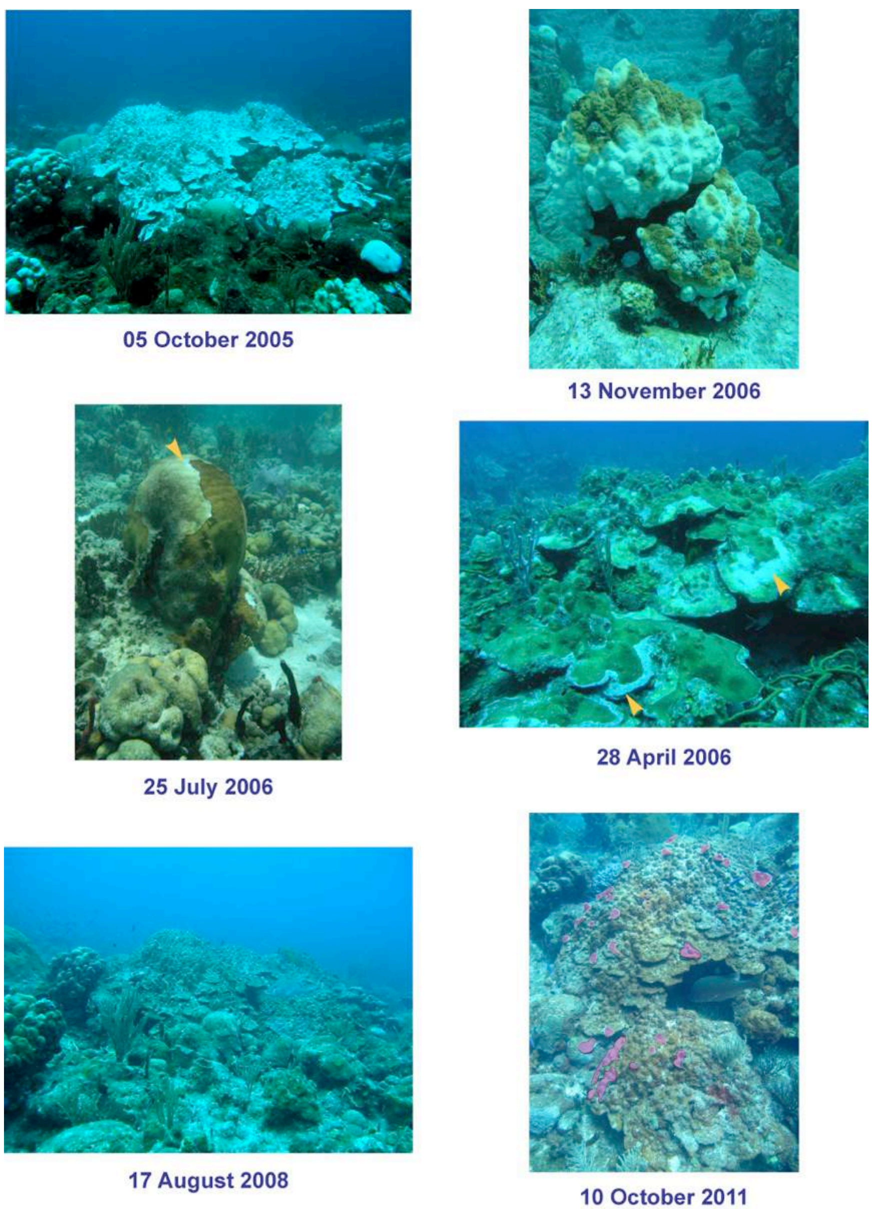

Figure 3. The multi-faceted response of *Orbicella* spp. to the 2005 bleaching event.

Corals were moderately to severely bleaching in 2005 and then were affected by white disease in 2006. As an example of the potential for active management, a colony at Savana Is., St. Thomas that is hundreds of years old was heavily bleached in 2005 (top left). This colony was not entirely killed (bottom left) and by 2011 small tissue areas (pink coloring in bottom right) were recovering over the skeleton. The process is very slow and might be aided by restoration that targets these ancient corals still extant in USVI reefs. Images taken from Smith et al. 2013.

INTRODUCTION

Introduction

The U.S. Virgin Islands consists of three large islands, St. Thomas, St. John and St. Croix, and numerous smaller islands surrounded by a diverse, tropical marine environment that includes coral reefs, seagrass beds, and mangrove forests (Fig. 4). The islands of St. Thomas and St John lie on the Puerto Rican Shelf, an extensive shallow water platform that connects them to Puerto Rico to the west and the British Virgin Islands to the east. Sixty-five kilometers to the south of St. Thomas and St. John and separated by the Anegada Passage and the Virgin Islands Trough (over 3,000 m deep), St. Croix lies on an isolated platform. This forms an effective barrier to the migration of coral reef fishes and invertebrates. The coral reefs of the Virgin Islands represent a wide range of characteristic coral reef habitats of the Caribbean, including patch reefs, fringing reefs, barrier reefs, shelf reefs, and extensive bank and slope mesophotic coral reef ecosystems.

Tourism drives the economy of the Virgin Islands, famous for white sand beaches that give way to clean, clear marine waters. The Virgin Islands are ideal for sailing because of the persistent trade winds and the numerous bays that provide protected anchorages. The diverse marine life of the coral reefs and other habitats attracts thousands of skin and scuba divers each year. Sportfishing on charter boats and private vessels also makes an important contribution to the economy.

In addition to their tourist appeal, the coral reefs and other habitats in the Virgin Islands are essential to the lives of hundreds of thousands of species including economically important queen conch, whelk, spiny lobster, snapper and grouper. Over three hundred full-time or part-time commercial fishermen fish in territorial and federal waters surrounding all three islands (Tobias 1997). Recreational and artisanal fishing is a frequent activity and is likely to have a significant impact on nearshore fish populations, but there exists very limited data on species composition and spatial distribution of annual catches (Authors, personal observation). In tough economic times and after natural disasters, fishing is an important means of supplemental income or extra protein for many people.

Over the last few decades, major hurricanes, coral disease outbreaks and mass coral reef bleaching have caused extensive coral mortality to the coral reefs surrounding the Virgin Islands (Gladfelter 1982, Edmunds and Witman 1991, Rogers et al. 1991, Rothenberger et al. 2008, Woody et al. 2008, Miller et al. 2009). Recovery from these natural disturbances is hindered by a multitude of human impacts that affect coral reefs, such as overfishing of ecologically important species, physical damage to reef structure, and pollution (Hatcher 1984, Pastorok and Bilyard 1985, Rogers and Garrison 2001, Mumby 2006, Mumby et al. 2006, Mumby and Harborne 2010). Moreover, rapid development of steep island slopes has dramatically increased soil erosion and sedimentation into nearshore waters (Brooks et al. 2007, Gray et al. 2008, Smith et al. 2008), particularly below unpaved road surfaces (Anderson and Macdonald 1998, Ramos-Scharrón and MacDonald 2007a). Chronic sedimentation affects the abundance and diversity of corals and other reef organisms, increases coral stress and susceptibility to diseases and bleaching, and reduces the ability of corals and other reef organisms to recover and regenerate after natural disturbances such as hurricanes (Acevedo and Morelock 1988, Rogers 1990, Nemeth and Sladeck Nowlis 2001, Fabricius 2005). The first sightings of the invasive Indo-Pacific lionfish (*Pterois volitans*) occurred in the US Virgin Islands in 2009. This predator has the ability to dramatically alter coral reef fish community structure (Cote and Maljkovic 2010) and these alterations may have additional, indirect impacts on benthic communities (Albins and Hixon 2011).

High thermal stress and coral bleaching events affected the northeastern Caribbean in 2005 and 2010, but these events had contrasting signatures in the United States Virgin Islands. The year 2005 was the most severe high sea surface temperature (SST) event on record for the northeastern Caribbean (Eakin et al. 2010). In the Virgin Islands a peak of

10.25 Degree Heating Weeks (DHW) was registered from satellite SST records (NOAA 2012) and a period of approximately 59 days above the local bleaching threshold of 29.5°C (Aug. 20 – Oct. 18); a level of thermal stress accumulation associated with severe coral bleaching and some mortality. The warm season of 2010 started as warm or warmer than 2005, with the bleaching threshold surpassed for 21 days between August 12 and September 2. In a clear example of ameliorative storm cooling (Manzello et al. 2007), the passing of the storm center of Hurricane Earl on August 30th, approximately 100 km to the northeast of the St. Thomas-St. John, caused a rapid decline in SST's below the bleaching threshold to 29.3°C, and then from October 5 - 8, the passage of Hurricane Otto caused windy and cloudy weather that further reduced SST below 29.1°C. Total DHW accumulated in 2010 began to decrease after the beginning of October, when it had reached 5.1 DHW, a level associated with some bleaching and limited mortality.

Most research around the Virgin Islands has focused on fringing reefs (5 – 30 m depth) located along the shoreline of the three main islands, St. Thomas, St. John, and St. Croix. In contrast, very little information exists for offshore and deeper reef systems, which can be quite extensive. Surrounding St. Thomas and St. John, these other reef systems include mid-shelf reefs (5 – 30 m depth) located 2 to 10 km from the shore of the main islands and mesophotic reefs (>30 m depth) located from 0.5 to 15 km offshore along the edge of the insular platform (Armstrong et al. 2002, Herzlieb et al. 2005, Armstrong et al. 2006, Armstrong 2007, Menza et al. 2007, Menza et al. 2008, Nemeth et al. 2008, Smith et al. 2010a). Distance from shore may be a factor in the historical degeneration of coral reef systems in the Virgin Islands (Herzlieb et al. 2005, Calnan et al. 2008, Smith et al. 2008). A systematic approach to investigating these cross-shelf coral reef systems allows us to evaluate the variable impacts and synergistic effects of natural impacts and human-induced stress that influence the decline or recovery of Caribbean coral reef systems. The first two years of this project (2001 and 2002) concentrated on the fringing reefs surrounding St. Croix. In 2003, monitoring continued at St. Croix reefs and began at reef systems distributed across the insular platform surrounding St. Thomas. In 2004, 2005 and 2006 monitoring continued at reefs surrounding both islands, with additional reefs surrounding St. Thomas added in 2004, 2005, and 2011. Mesophotic coral reef monitoring sites were added to St. Croix during the 2008 and 2009 monitoring, as well as an additional monitoring site in the St. Croix East End Marine Park. In 2011, the TCRMP also expanded to include sites established under separate funding that will be continued in the core TCRMP monitoring activities funded by USVI DPNR and NOAA CRCP.

OBJECTIVES FOR MONITORING CORAL REEFS

Effective management is necessary to maintain the resources in the territorial and federal waters of the Virgin Islands in an ecologically and economically sustainable manner. Monitoring programs are essential for successful management because they provide managers with fundamental information with which to make and reinforce decisions. Standards for resource protection can be measured by comparison to baseline data established by monitoring. Monitoring also provides the means to assess the status and trends of ecological resources, allowing managers to determine the effectiveness of current management and to develop effective management plans for the future. The Territorial Coral Reef Monitoring Program monitors the condition of coral reefs throughout the U.S. Virgin Islands and provides key information to better manage these ecosystems. This report presents monitoring results from 2001-2012 in St. Croix and from 2003-2012 in St. Thomas. For both islands, temporal changes from year to year in the conditions of the reef communities were assessed.

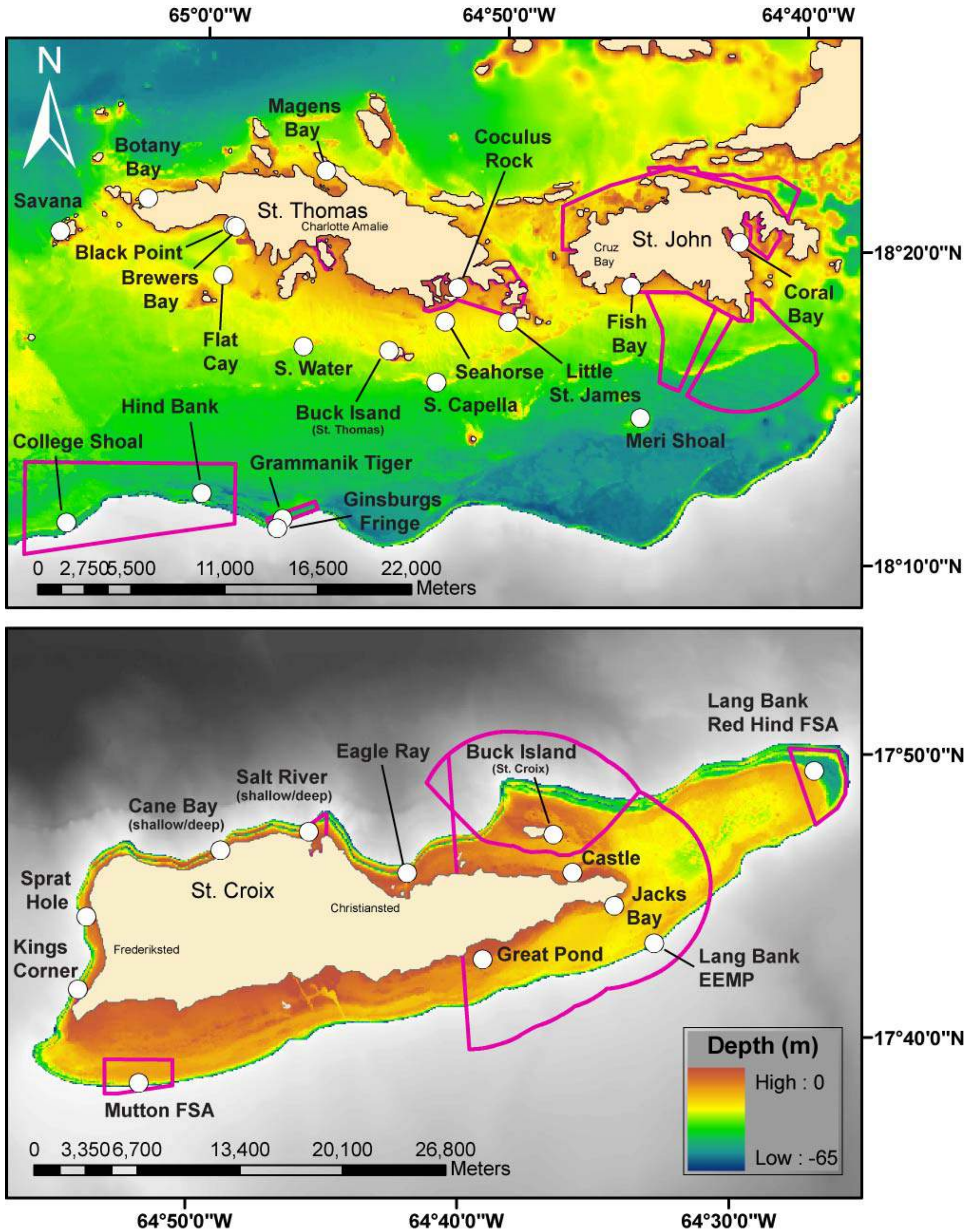

Figure 4. Locations of Territorial Coral Reef Monitoring Sites in the US Virgin Islands, 2008-2010.Boundaries indicate federal and territorial marine protected areas.