The United States Virgin Islands

TERRITORIAL CORAL REEF MONITORING PROGRAM

2018

A collaboration between:

The Center for Marine and Environmental Studies, University of the Virgin Islands

The Division of Coastal Zone Management, USVI Department of Planning and Natural Resources

The Coral Reef Conservation Program, National Oceanic and Atmospheric Administration

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Brandt ME, Brandtneris VB, Byrne I, Ewen K, Gutting A, Heidmann S, Hollister K, Jerris K, Jobsis P, Potts C, Prosterman S, Taylor M, Tonge R, Townsend J, and the 2018 NSF RAPID Sponge Cruise

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Cite As: Smith TB, Ennis R, Kadison E, Nemeth RS, Henderson L (2018) The United States Virgin Islands Territorial Coral Reef Monitoring Program. 2018 Annual Report. University of the Virgin Islands, United States Virgin Islands 289pp

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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

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 about 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 (Smith et al. 2013b; Smith et al. 2016a). 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 (Kadison et al. 2017). 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 stocks 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. Positive signs of an increasing recruiting and spawning population of Nassau groupers in the northern USVI suggests that management actions, including no-take restrictions and protection of spawning aggregation sites, can have tangible, positive effects (Kadison et al. 2010)

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 altered through human activity, 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 of 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 (Henderson et al. in press).

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 local pressures (Smith et al. 2019a,b). 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 listed as threatened on the United States Endangered Species List (NOAA 2014), 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. The lower MCE consists mostly of lettuce corals (primarily *Agaricia undata*) and form a semi-continuous ring on steep slopes and walls at depths between 50-70m. These reef are isolated from some local impacts, but may be susceptible to global climate change (see below).

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.). In 2015 there was a recruitment pulse of juvenile Nassau grouper to shallow nearshore environments of St. Thomas and St. John in 2015. In Brewers Bay, St. Thomas over 70 juvenile Nassau grouper were recorded (R. Nemeth, unpub. data), increasing evidence that the reproductive population is contributing to the recovery of the species. 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. Although uncommon, Nassau grouper have been recorded at various TCRMP sites around St. Croix since 2011, a positive sign. 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 (Henderson et al. 2019). 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 19th year of monitoring on reefs surrounding St. Croix, St. John, and St. Thomas (years 2001-2019). 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 34 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 15 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.

All data is now available at the TCRMP website and updated annually after quality control:

https://sites.google.com/site/usvitcrmp/home

The Impact of Hurricane Irma and Hurricane Maria on Coral Habitats of the US Virgin Islands

The United States Virgin Islands (USVI) was impacted by two category 5 storms in September 2017 (Fig. 2). Hurricane Irma (Sep. 6) passed 32 km N. of St. Thomas and brushed St. John, with sustained wind speeds of 150 kt (278 km h-1). Wave heights at Oceanographic Buoy 41058 northwest of St. Thomas reached 12 m before sensor failure. Hurricane Maria (Sep. 20) passed 20 km SE of St. Croix, with sustained wind speeds of 140 kt (259 km hr-1). Wave heights at Oceanographic Buoy 41052 south of St. John reached wave heights of 7.9 m. Personal losses and infrastructure damage to the USVI was severe. This included heavy damage to the marine research infrastructure at the University of the Virgin Islands, where the TCRMP is coordinated (Fig. 3). Hurricane damage also extended below the water and affected reef-forming corals at TCRMP sites (Fig. 3). Other research on the coast of St. John found that previous degradation of coral reefs led to a minimal response to the storms, although there was an increase in fleshy macroalgae (Edmunds 2019). Across TCRMP sites assessed in early 2018, coral damage was measured as corals fragmented or loose on the substrate. The prevalence of this type of coral damage increased significantly following the storms (Fig. 4). There was high variability in damage across sites that likely reflected different surface wave conditions and site depths, which influence the seafloor orbital velocities experienced at a site.

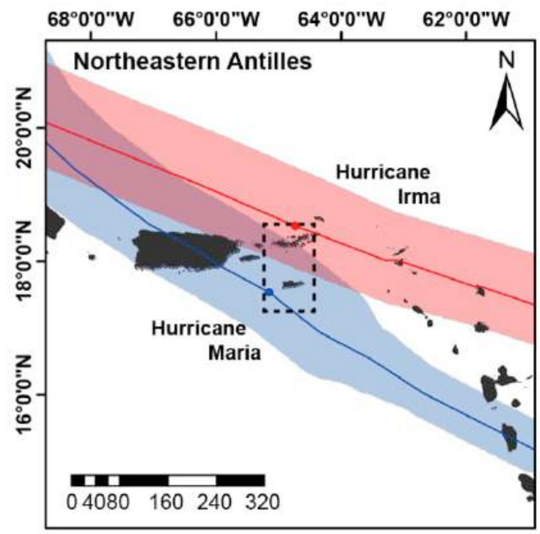

Figure 2. Hurricane strength wind swaths and storm centers for Sep. 2017 (Data from NOAA NHC, 2019).

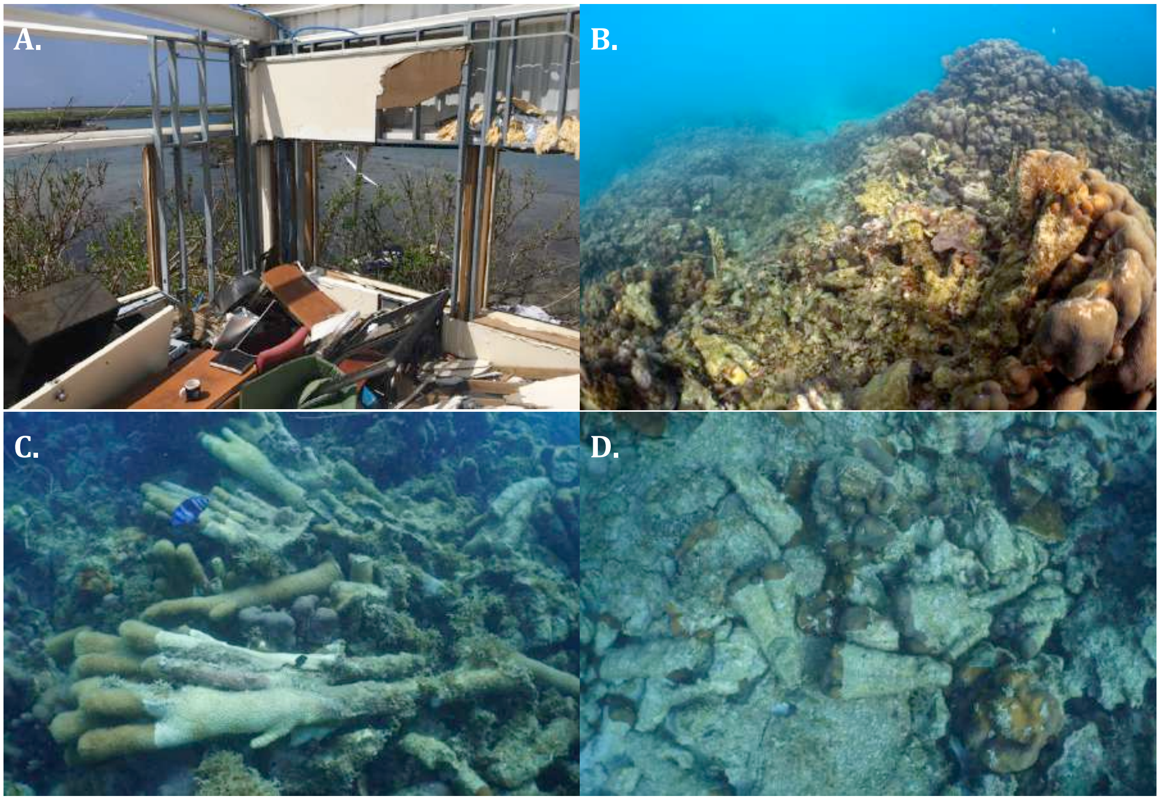

Figure 3. The damaged research infrastructure and coral reefs of the US Virgin Islands following Hurricanes Irma and Maria in September 2017.

(A) The office of TCRMP research coordinator Tyler Smith at the UVI MacLean Marine Science Center, St. Thomas following the storms (Oct. 3, 2017; credit: T. Smith). (B) – (D) Examples of coral reef damage in Brewers Bay, St. Thomas. (B) A destroyed section of *Orbicella annularis* fringing reef (Nov. 28, 2017). (C) A broken colony of *Dendrogyra cylindrus*. (D) A fragmented colony of *O. annularis* (Dec. 13, 2017; credits: R Ennis).

Using the Simulation of Wave Nearshore Model (Booij et al. 1999) operationalized for the US Caribbean (Canals et al. 2012), surface wave conditions over Hurricanes Irma and Maria were calculated (Fig. 5). Bathymetry (depth) and the surface wave conditions were used to calculate seafloor orbital velocities using linear wave theory (as in Smith et al. 2016b; Fig 5). Seafloor velocities reached as high as 6 m s^{-1} in some locations.

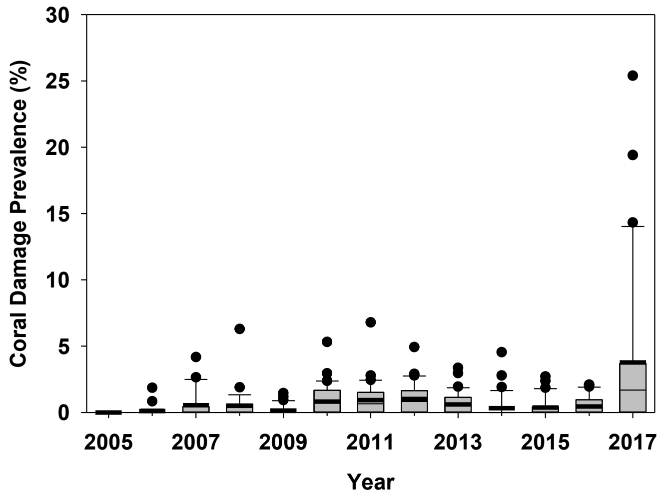

Figure 4. The prevalence of coral damage at individual TCRMP sites.

Elements are 90[th] percentile (whiskers), 75[th] percentile (box top/bottom), mean (thick black line), median (thin black line), outliers (points). The prevalence of damage was significantly different between years ($p < 0.0001$) and 2017 had a higher prevalence than all other years.

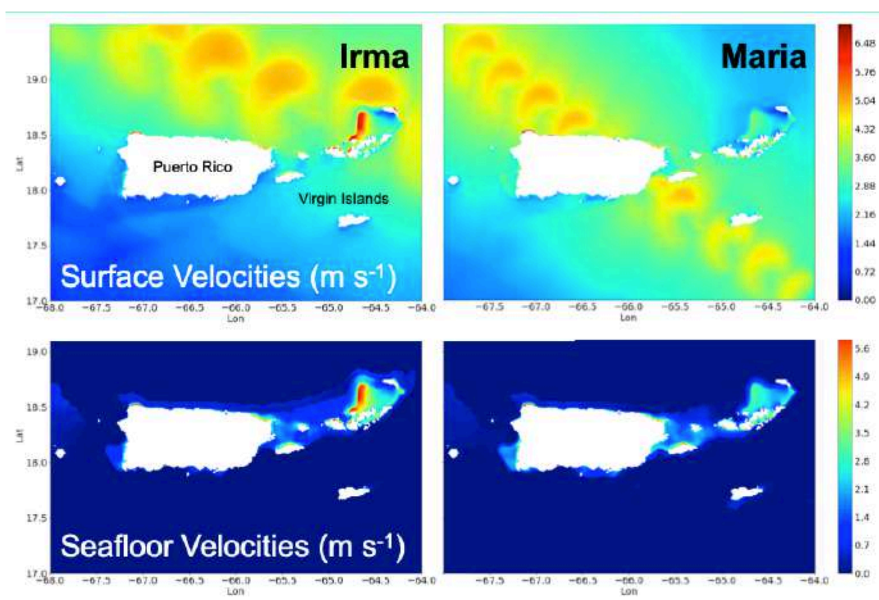

Figure 5. Modeled surface (top) and seafloor (bottom) orbital velocities over Hurricane Irma (left) and Hurricane Maria (right).

In situ assessments of coral damage at TCRMP sites were compared with modeled benthic orbital velocities and an approximate threshold of 2 m s^{-1} was identified as a velocity above which coral damage started to increase. The threshold value was used to extrapolate the area of affected coral habitat affected across the USVI (Fig. 6, 7).

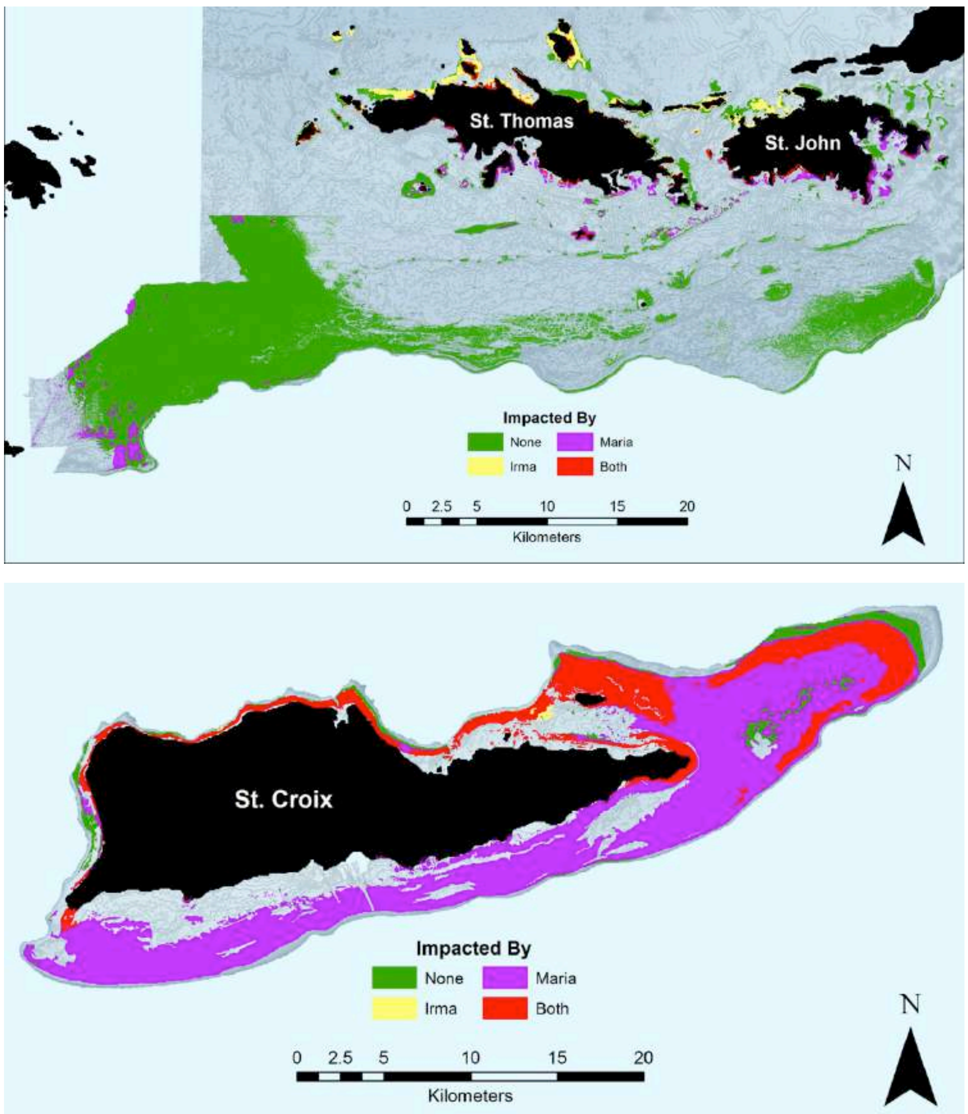

Figure 6. Coral reef habitats potentially damaged by storms (>2 m s^{-1} seafloor velocity).

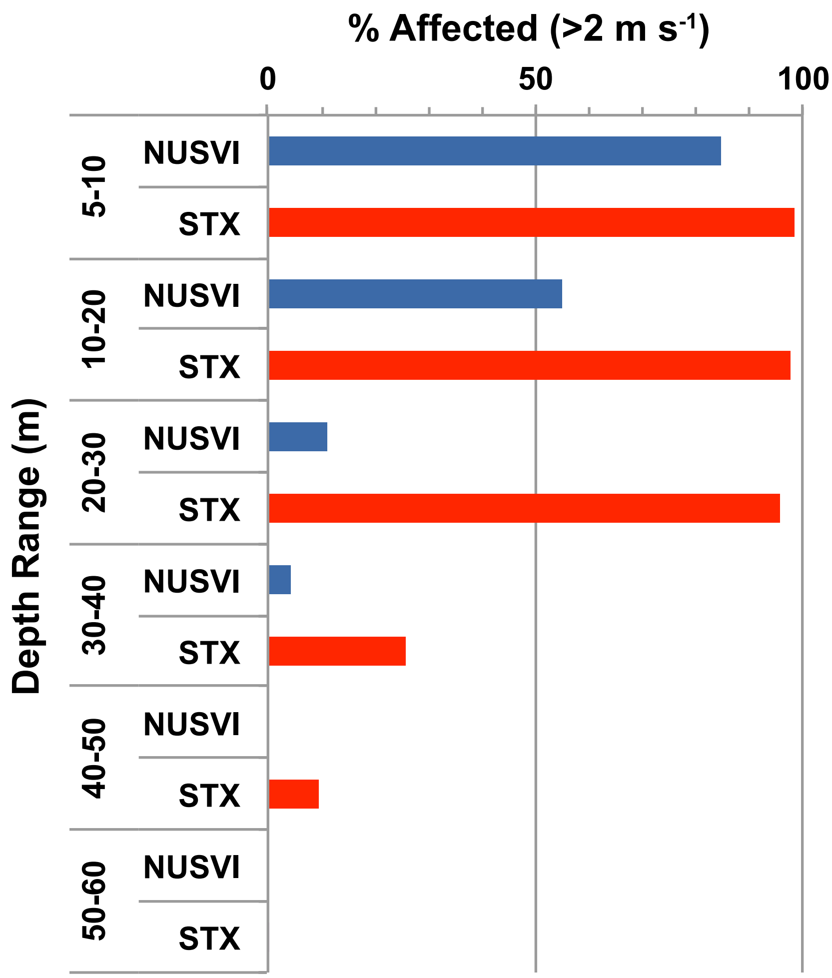

Figure 7. Proportions of coral reef habitat potentially damaged by storms (seafloor velocity > 2 m s^{-1}) by depth category and island group (NUSVI = northern USVI – St. John and St. Thomas; STX = St. Croix).

The proportion of potentially impacted coral reef habitats varied between the northern USVI and St. Croix. In the northern USVI there was a high proportion of damage to reefs

(85%) in shallow water (5 – 10 meters depth), but this declined rapidly with depth, with about 10% damage below 20 m. In St. Croix there was high predicted damage (> 90%) to corals in depths shallower than 30 m.

Modeled seafloor velocities can be a good predictor of coral damage and can be used to extrapolate damage to the scale of the seascape. Spatial distribution of damage can help to guide restoration activities, evaluate the economic costs of storms to coral reef natural resources, and inform ecological studies of the health and distribution of corals. Future activities will use higher resolution, higher frequency wave model runs and more refined estimates of coral damage by coral species to refine the spatial predications. This analysis is one of the first to extrapolate storm damage across a seascape and was largely made possible by the synoptic research conducted by the TCRMP.

Update: Invasion of the Indo-Pacific Red Lionfish

The invasive Indo-Pacific lionfish (Fig. 8) has rapidly spread over more than 4,000,000 km^2 of marine habitat across the Western Atlantic, Caribbean and Gulf of Mexico since 2009 (REEF 2012). Invasive lionfish occupy a range of habitat types and depths, where they consume an array of native fishes and crustaceans at very high rates, including those species that are important as food for commercial fish species, or as foragers of algae that compete with and limit coral growth (Schofield 2009; Green et al. 2011). The first reported sighting in USVI waters was in 2009 on the west end of St. Croix under the Frederiksted pier. Several more lionfish were seen over the next few weeks off St. Croix and in early 2010 the first fish was reported in St. Thomas. By early 2011 lionfish were seen commonly, and although a concerted effort was made to eradicate the fish, the population continued to increase. Today, the species remains quite prevalent throughout the territory however their populations seem to have stabilized, with fewer fish being seen by divers and fishermen than in the earlier years of the invasion (2011-2013).

Figure 8. Indo-Pacific red lionfish (*Pterois volitans*) on Seahorse Cottage Shoal, 2017; depth 22m.

There continues to be an effort to control the lionfish through fishing. A small market for the species as a food fish exists on all three islands. Ciguatoxin that causes Ciguatera Fish Poisoning is present in in about 12% of fishes from toxic areas, such as the south coast of St. Thomas and St. John (Robertson et al. 2013); however, poisonings from the fish have not been reported in the Caribbean, suggesting the threat to human health is not large. Many fishermen report catching lionfish regularly and throwing them back into the sea. They do not consider the market value to be worth the work in processing the relatively small fish, however they do kill the fish before discarding them.

Lionfish were first observed in the TCRMP data on roving dives at two sites in 2010, Lang Bank and Kings Corner, both located off St. Croix (Fig. 9). By 2011, seven TCRMP sites across the territory (out of 32) held lionfish, including four sites in the northern USVI. Both numbers of lionfish and the number of sites they were observed on increased over the years from 2012 through 2015; only slightly in St. Croix but dramatically in the northern USVI. At their peak in the dataset (2015) 112 lionfish were counted on transects at ten sites off the northern USVI, and 15 at seven sites off St. Croix (Fig. 3). In the latest year of sampling (2018) lionfish encounters were lower on northern USVI sites than in 2015, but slightly higher than 2016 and 2017, suggesting a population equilibrium had been reached. The number of lionfish observed on transects in the northern USVI was 74 over 11 sites. In St. Croix the number of lionfish observed on all transects increased by 50% from February 2018 to November 2018. This was due to the addition of another mesophotic site, Buck Island STX Deep, to the monitoring program. Five lionfish were observed on transects at this new site. Seven lionfish were observed on three additional sites in St. Croix in November 2018. This number is close to that seen in February 2018, and lower than any year since 2012.

Mesophotic sites off both the northern USVIs and St. Croix continue to have the highest abundances of lionfish. The Hind Bank East FSA and Grammanik Tiger FSA especially hold large numbers. The mesophotic sites may also have reached the carrying capacity of lionfish, with numbers observed on transects in 2018 equal or slightly lower than reported in 2017/2018. The exception is the Grammanik Tiger FSA, which had double the number reported in 2017. The Grammanik Bank had a notable decrease in lionfish in 2015, 2016, and 2017, and the number seen in 2018, although higher than the previous three years, was lower than that reported in 2012-2014.

Lionfish across the territory ranged in estimated size from 6cm to 40cm TL, but the majority of fish were between 11 and 20cm TL (52% in 2018). Another 37% were 21-30cm TL and 7% were 30-40cm TL. No fish were observed less than 5cm TL. Half of the lionfish greater than 30cm TL were seen on mesophotic sites and 50% were seen on inshore reefs. Lionfish in the 21-30cm TL size range were primarily from mesophotic reefs (88%). Unlike other years there were no lionfish observed less than 6cm TL across all sites and no fish greater than 29cm TL on St. Croix sites.

The preferential habitat for lionfish in the western Atlantic has not been reported empirically; however, based on dives conducted across the USVI shelves by the authors as well as reports from fishermen it appears that the species utilizes a variety of habitats and any available structure within the area. They may be somewhat limited from turbulent or high current environments by their large fins. Movement studies are now being conducted by CMES using hydroacoustic technology at both Grammanik Bank and in the Buck Island National Monument. Lionfish tagged underwater with hydroacoustic tags are being tracked over time through an array of receivers deployed across the shelf. This work should help us understand movement related behavior and habitat/resource use by this invasive fish.

It is unknown if the relatively high densities of lionfish on mesophotic reefs at TCRMP sites represent a preference for deepwater habitats, or a reduced fishing pressure. The Grammanik Bank, Hind Bank and Buck Island STX Deep are marine reserves where bottom fishing is prohibited. Predation by large piscivores could partially control the recruitment or growth of lionfish at the Grammanik Bank, a snapper and grouper fish spawning aggregation, but the data is equivocal. There is ongoing research being conducted by the CMES to help determine if the reduced fishing pressure of the mesophotic reserves is affecting lionfish populations and overall fish community structure. The study is comparing lionfish densities and size frequencies at random points within the MCD and the Virgin Islands Coral Reef National Monument as well as outside the reserves in similar habitats.

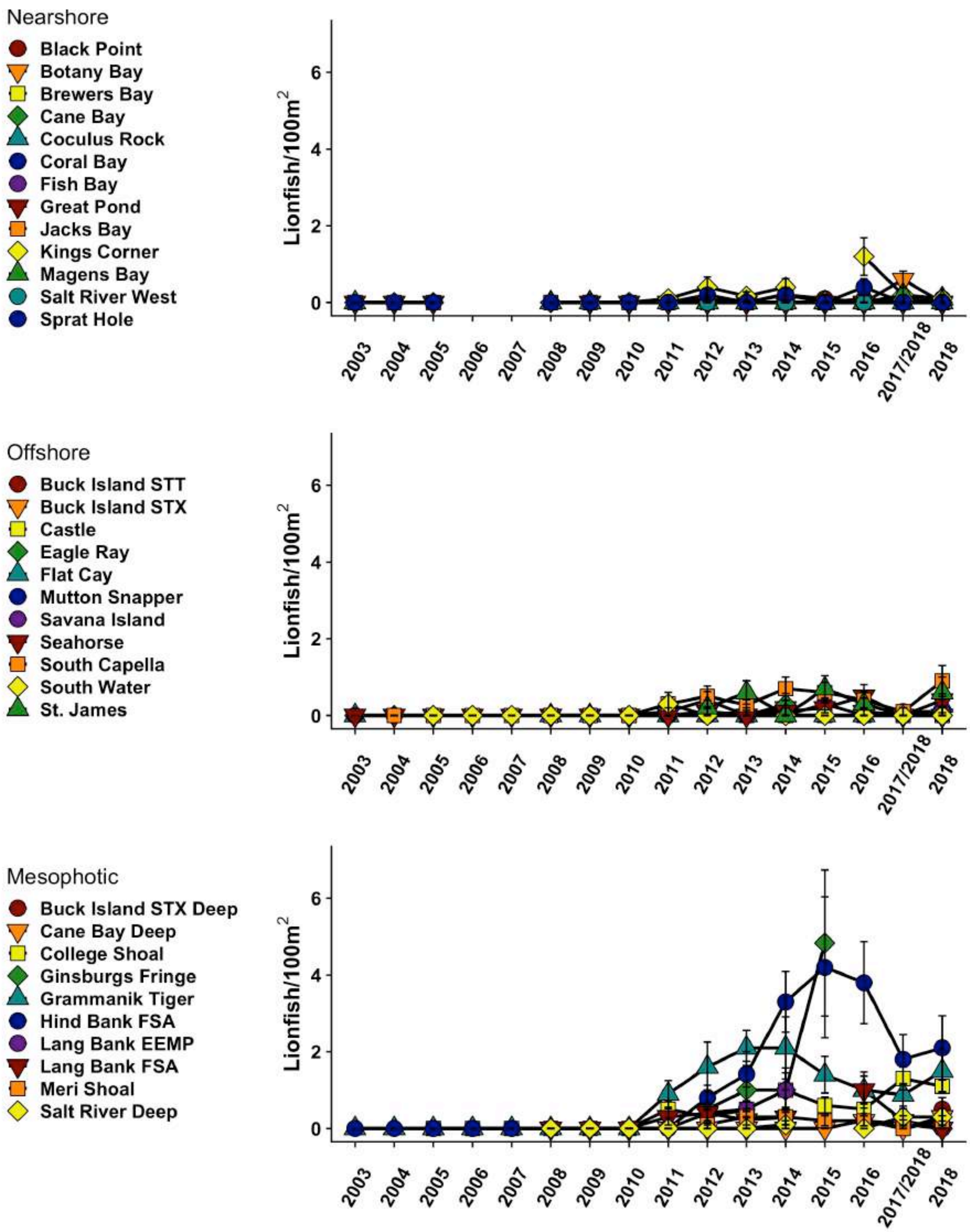

Figure 9. The abundance (±SEM) of red lionfish on TCRMP transects from 2003 to 2018.

Improved Signs for the Threatened Nassau Grouper

The once prolific Nassau grouper (*Epinephelus striatus*) is today commercially extinct over much of its range. Historically this species has been dominant both culturally and economically in Caribbean fisheries. Although protected in federal waters of the United States since the 1990's, the Nassau is still considered to be one of the most threatened groupers worldwide, is listed as endangered on the IUCN Red List, and is a candidate for the US Endangered Species Act. The USVI Nassau grouper fishery collapsed in the 1980's, shortly after, and likely a consequence of, a large Nassau grouper spawning aggregation site located south of St. Thomas being extirpated by overfishing.

In 2005 the Caribbean Fisheries Management Council closed the Grammanik Bank south of St. Thomas seasonally to fishing, based on evidence that it was a yellowfin grouper spawning aggregation site. This closure inadvertently protected a small aggregation of Nassau grouper that may have relocated from the extirpated historic Nassau aggregation located a few kilometers to the west. The territorial government of the USVI banned the capture and sale of Nassau grouper year-round beginning in 2006, thereby spreading protection from federal into territorial waters. In addition, the prohibition of fileting fish at sea was enacted, and a three month (February 1 through April 30) seasonal closure on five species of groupers (*E. striatus, E. morio, E. flavolimbatus, Mycteroperca venenosa,* and *M. tigris*) was established.

There is evidence that these management measures may be positively affecting both Nassau and yellowfin grouper populations in the US Virgin Islands. Over the past three years there have been reports by divers that both species, but especially Nassau grouper, are commonly seen on reefs around St. Thomas and St. John. Fishermen are also reporting regular occurrences of Nassau grouper in their fish traps and have requested that the Division of Fish and Wildlife equip them with needles to bleed the expanded air bladders of fish that are hauled up from deep water so that they can be safely released. In

TCRMP survey data from 2015-2018, substantially more Nassau grouper were observed than in earlier years, and they were observed on more sites, including nearshore sites (Fig. 10, 11). Additionally, juvenille young-of-the-year Nassau were commonly seen in nearshore areas of St. Thomas and St. John in 2006, 2014, 2015, and 2016 (R. Nemeth, unpub data).

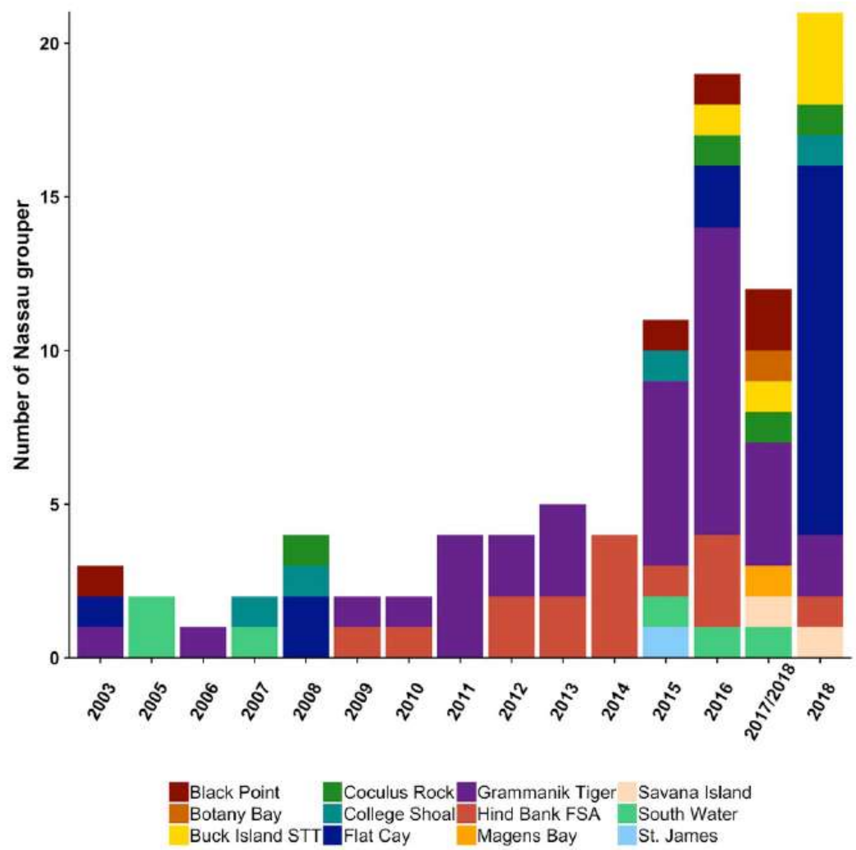

Figure 10. Nassau grouper observed across all 19 northern TCRMP sites on belt transects conducted annually from 2003-2018. Note that individual fish may have been counted multiple times across observers at some locations in 2018.

The small Nassau grouper aggregation found on the Grammanik Bank appears to be growing in size since its discovery in 2003. The bank, located approximately 4 km east of the historic Nassau grouper spawning site, is a multi-species aggregation area hosting spawning of several species of fish including yellowfin grouper, tiger grouper, dog snapper (*Lutjanus jocu*), cubera snapper (*Lutjanus cyanopterus*), and Bermuda chub (*Kyphosis incisor*). Nassau grouper also aggregate on the site and presumably spawn there shortly after dark in the months of January through April. The bank is closed seasonally to fishing from February 1 to April 30 and is closed to bottom tending gear year-round, thus providing some protection for the aggregating Nassau grouper.

The Nassau grouper aggregation site at the Grammanik Bank is of disputed age; some local fishermen claim that the bank is not a historical location for Nassau spawning, whereas others suggest that a small number of Nassau have always spawned in that location (anon). No fish have been observed to aggregate in the historic Nassau grouper aggregation after over a decade of observation (R. Nemeth, unpub. obs.) and one hypothesis is that the Nassau grouper now utilizing the Grammanik Bank are a small sub-population of the original spawning group from the historic bank.

Figure 11. (top) Nassau grouper on Flat Cay, St. Thomas in November 2018. (bottom) Nassau grouper aggregating on the Grammanik Bank.

The Nassau grouper have increased in number on the Grammanik Bank during the week after the full moon of January through April since 2002 (Fig. 12). In January, February, March, and April of 2018, between 200 and 360 fish were observed on single dives on the western end of the bank. Numbers in January, February and March were again close to 400. This represents an over 200% increase from the number of fish observed during the early and mid-2000's. In 2019 nearly 300 fish were seen in single dives. Bad weather did not allow for daily surveys however in late afternoon dives fish were seen in spawning coloration (dark and bicolor) and spawning behaviors such as chasing, leading and nuzzling were observed. Spawning rushes and actual gamete release continue to evade the researchers; however, it appears that spawning at some level is occurring, probably after dark. Nassau grouper movement is being studied by researchers at CMES using hydroacoustic telemetry. Fish tagged with VEMCO transmitters are tracked as they utilize the spawning area on the bank, as well as when and how they move and migrate in and out of the closed area.

The early and tentative recovery of the Nassau grouper in the northern USVI is positive but is far from complete. While fisheries closures have helped, targeted conservation actions may also be important for locking in and building on these gains for this threatened fish. Nassau grouper caught incidentally from deeper water (>20m deep) usually need to have their swim bladders deflated to allow them to submerge and survive when released. Thus, avoiding incidental capture even with release is important. In the northern USVI, a more complete fishing closure of the Grammanik Bank that encompasses the full seasonal cycle of Nassau grouper spawning activities (December to May) would ensure minimal incidental capture. Additionally, creating a migratory corridor between the nearby Hind Bank Marine Conservation District, a no-take closure that appears to support a relative high adult population on Nassau, would also limit fisheries impacts. In St. Croix, where a struggling small population of Nassau grouper are present, closing an area at the tip of the Lang Bank where there is a small aggregation of about 10 individuals (authors' observation) would help to ensure that they are not taken incidentally or poached. Throughout the USVI, more education on Nassau grouper and their protected status would be very helpful. The early life cycle of Nassau grouper typically involves settling in shallow, nearshore structures surrounded by seagrass. Even as populations increase, these juveniles are highly vulnerable to recreation line fishing and spearfishing before they migrate to offshore locations. Education and citizen science opportunities to get the community behind the recovery of Nassau would greatly enhance the protections already in place by encouraging compliance. Nowhere else in US waters is the chance to protect and recover the Nassau as strong as in the USVI and the territory could lead a huge conservation success story for ailing fish populations.

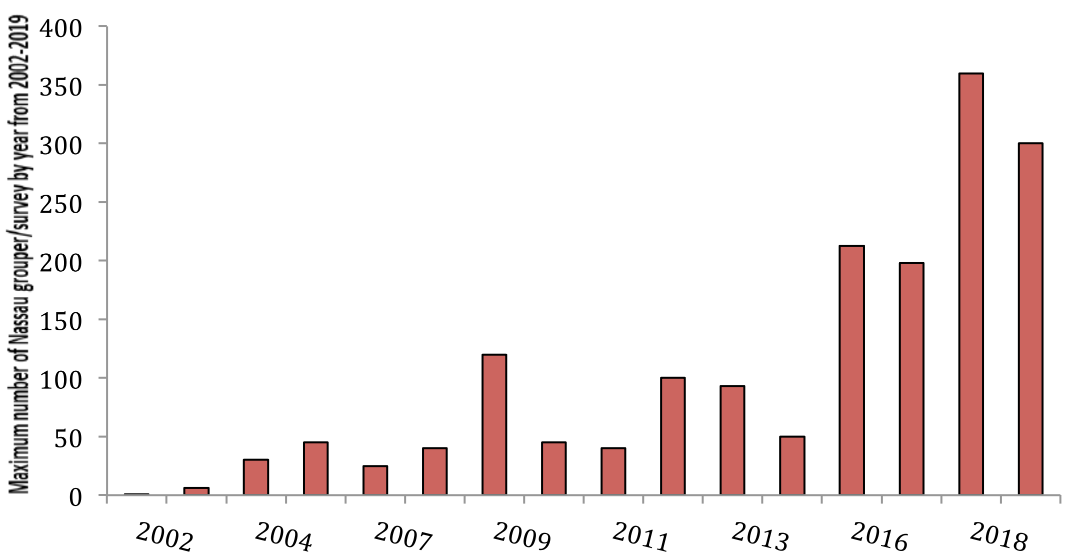

Figure 12. Maximum number of Nassau grouper observed on a single point count during the spawning season (January- April) on the Grammanik Bank from 2002 through 2019.

RESEARCH HIGHLIGHTS

Emergence of the Invasive Red Algae *Ramicrusta* spp.

Many nearshore coral reefs throughout the Caribbean region have been experiencing increases in macroalgae cover. This increase in macroalgae has been linked with negative impacts to living stony corals through abrasion, shading, and chemical release. While the majority of macroalgae cover at TCRMP locations is dominated by *Dictyota* spp. and *Lobophora* spp., several have experienced relatively rapid increases in an encrusting red algae *Ramicrusta* spp (hereafter *Ramicrusta*). The genus *Ramicrusta* is present in multiple locations in the Pacific Ocean (Dixon and Saunders 2013), but was not reported in the Caribbean until 2009 at Discovery Bay, Jamaica (Pueschel and Saunders 2009). The genus has since been documented in Bonaire (Eckrich and Engel 2013) and Puerto Rico (Ballantine David et al. 2016). At present, three *Ramicrusta* species have been identified: *Ramicrusta textilis* (Pueschel and Saunders 2009) in Jamaica and Puerto Rico, *Ramicrusta bonairensis* (Ballantine, Ruiz, Lozada-Troche & Norris 2016) in Bonaire, and *Ramicrusta monensis* (Ballantine, Ruiz, Lozada-Troche & Norris 2016) in Puerto Rico. The TCRMP believes this genus has now become established in the USVI but exact ID is pending judgment of specialists. Until then this summary assumes the species is/are of the genus *Ramicrusta.* There is very little known about the biology of *Ramicrusta* and the environmental factors that determine its presence.

Ramicrusta ranges in color from red to brown and primarily forms thin crusts, though frondose edges may be present (Fig. 7). *Ramicrusta* appears to be a strong competitor relative to most other benthic organisms, rapidly colonizing and expanding on open substrate. It has been observed overgrowing live coral tissue, sponges, gorgonians, zoanthids, and other kinds of macroalgae. Interactions with live coral colonies appear to be indiscriminate, and often cause bleaching and partial, if not complete, colony mortality. Successful recruitment of coral larvae or other benthic organisms has not been recorded on *Ramicrusta* substrate with the exceptions of occasional short fronds of

Dictyota spp. (Ennis, pers. obs. 8 Dec 2016). This combination of factors has the potential to be particularly devastating to reef ecosystems that are already under stress from other environmental conditions.

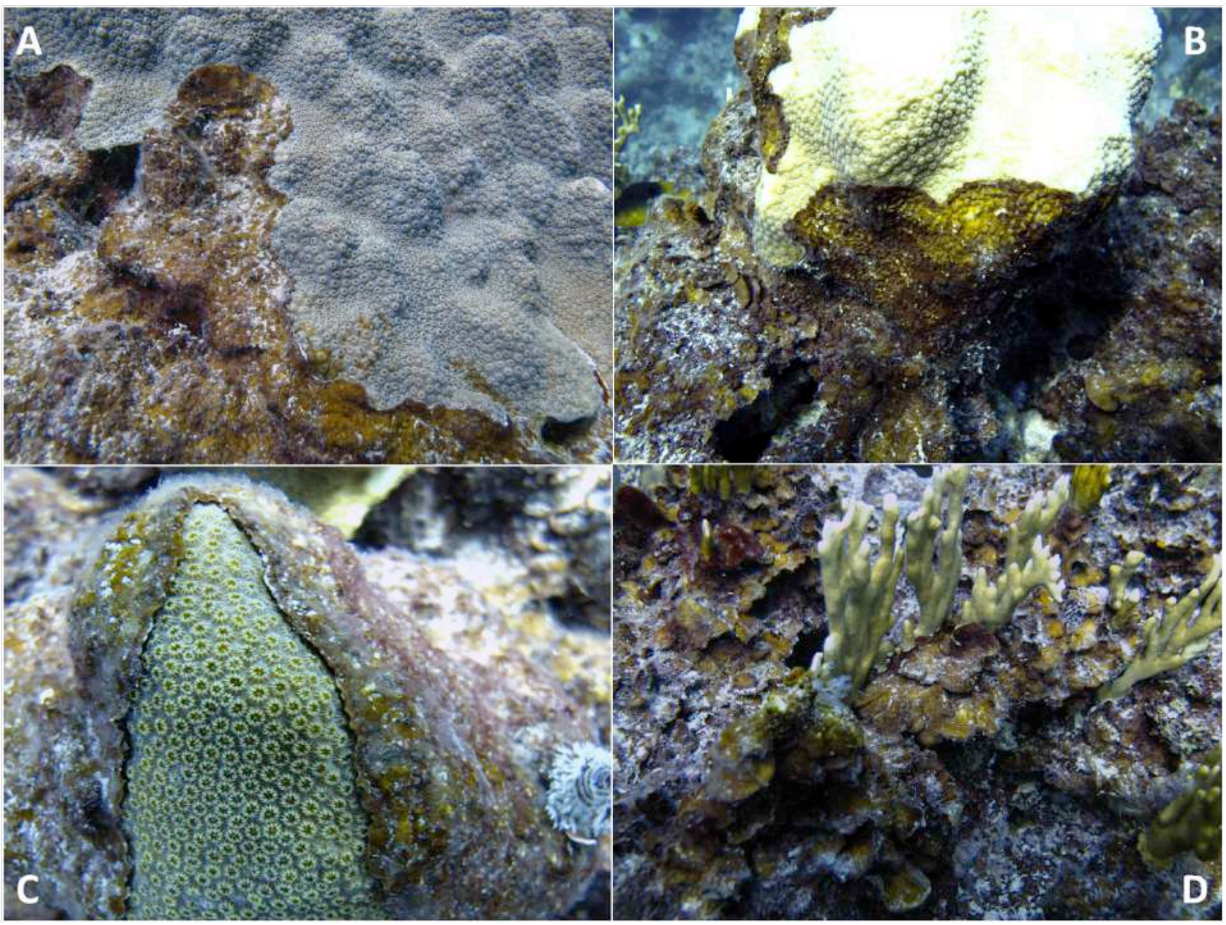

Figure 13. Representative photos of *Ramicrusta* spp. overgrowing *Orbicella faveolata* (A), *Orbicella annularis* (B), *Orbicella annularis* (C), and *Millepora alcicornis* (D) at the TCRMP location Savana.

A preliminary investigation into *Ramicrusta* presence, abundance, and impacts in the TCRMP benthic cover dataset has revealed its presence at nearly 60% of TCRMP locations in 2016, but abundance seems to be variable (Fig. 14). While the majority of locations had less than 25% presence of Ramicrusta in TCRMP non-overlapping video images, College Shoal East and Savana had prevalence of *Ramicrusta* in benthic cover clips of 87.3% and 98.25%, respectively.

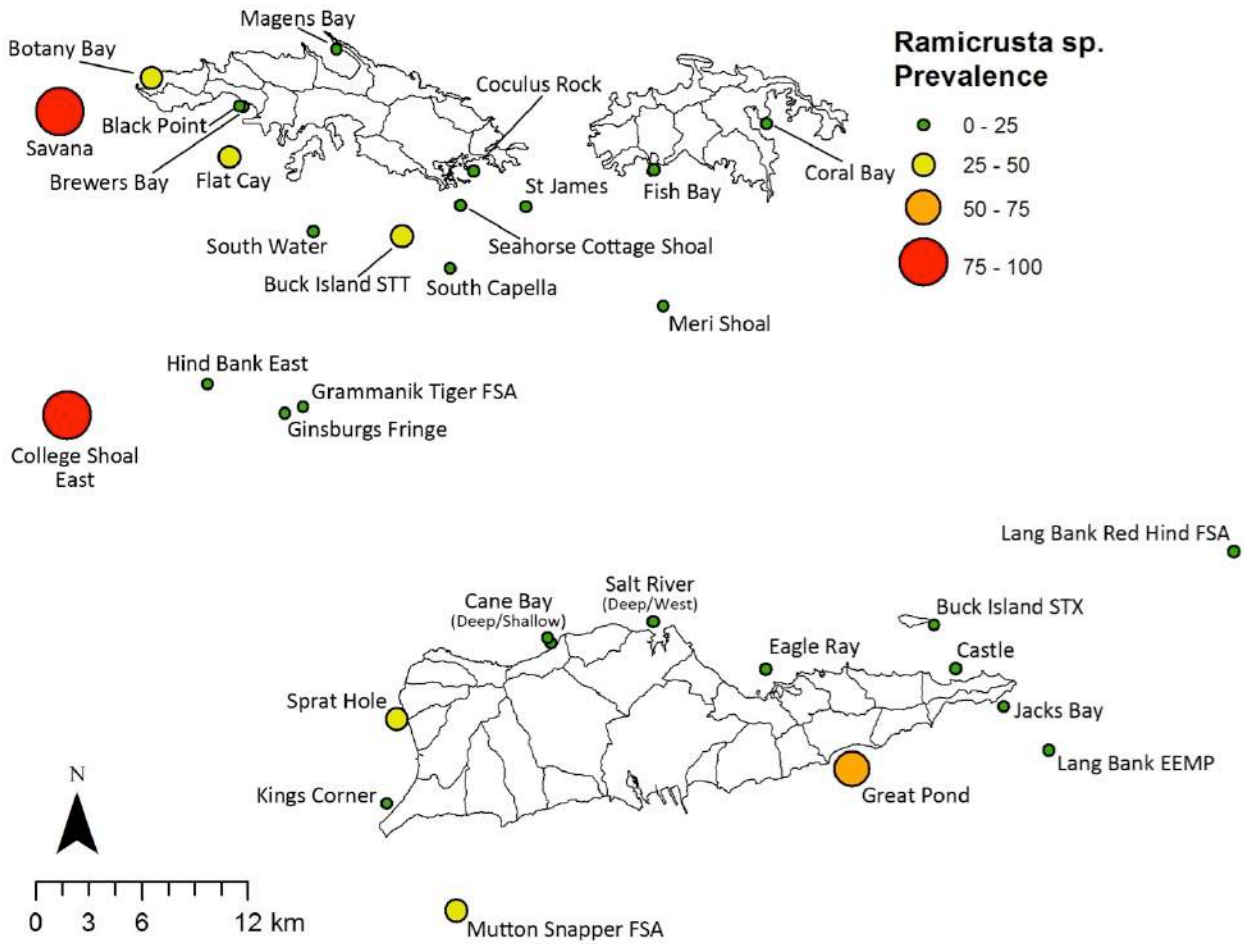

Figure 14. Abundance of *Ramicrusta* sp. presence in non-overlapping video clips at TCRMP locations in 2016.

Further analysis of benthic cover at Savana, which is an offshore site with little apparent human impacts, has shown that *Ramicrusta* has been present at low cover since the location's first sampling in 2003 (Fig. 15). *Ramicrusta* cover at Savana was less than 10% until the 2005 bleaching event, after which cover increased nearly five-fold by 2008 and is currently about 60% of the total benthic cover (Fig. 15). The increase in *Ramicrusta* cover after the 2005 bleaching suggests a tipping point was reached when coral cover declined from 20% to 10%. *Ramicrusta* initially took over this space by 2006, but has since increased linearly and by 2016 occupied 60% of the substrate, depressing all other benthic categories. Corals are in high contact with the algae and are being overgrown on the margins. Ramicrusta is likely driving the decline in coral cover since 2010.

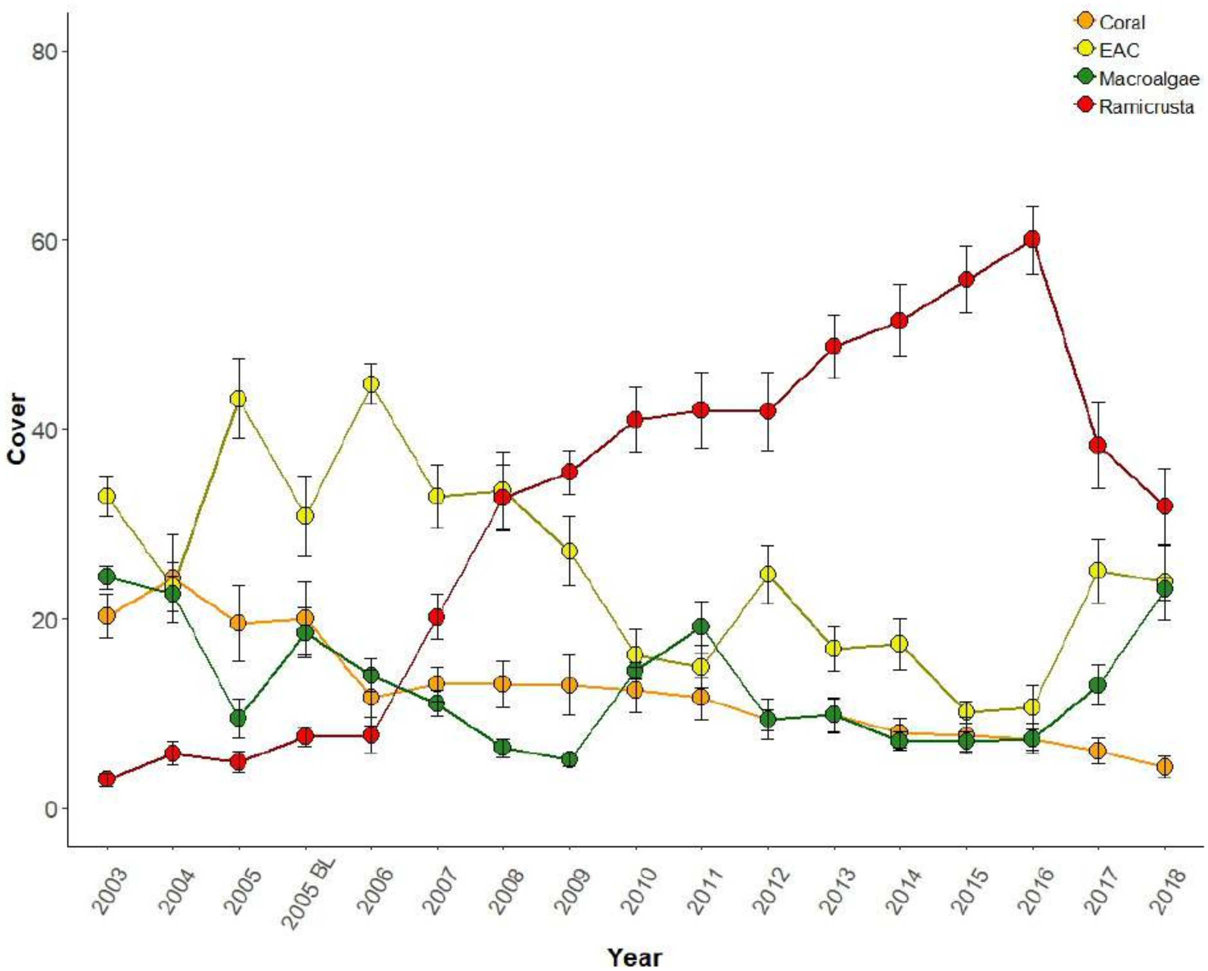

Figure 15. Benthic cover (±SEM) of *Ramicrusta* sp., coral, epilithic algae community, and fleshy macroalgae at Savana from 2003-2018.

Although the change in *Ramicrusta* benthic cover at Savana is an extreme case relative to all other TCRMP locations, it demonstrates the need for continued monitoring of changes in the cover of this algae. This is especially relevant given the potential devastation of overgrowth and the general lack of information regarding the life history of the genus in the Caribbean. Further examination of the long-term TCRMP dataset could provide valuable insight into the factors driving or controlling *Ramicrusta* sp. abundance. Future work by TCRMP and UVI will attempt to experimentally determine the mechanisms of impacts on corals and factors controlling the growth of *Ramicrusta*, such as productivity and impacts of herbivores. It is not clear if *Ramicrusta* was introduced to the Atlantic Ocean or has always been present in low abundance. However, it is clear that *Ramicrusta* is rapidly increasing in abundance at the expense of stony corals.