Coral Reef Monitoring
in St. Croix and St. Thomas,
United States Virgin Islands

Year Three Final Report
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Executive Summary

Coral reefs in the Caribbean are facing a dramatic decline. To effectively manage and maintain these important ecosystems, the government of the Virgin Islands, in coordination with federal agencies and the University of the Virgin Islands, has implemented a long-term coral reef monitoring and assessment program. This program will help establish a baseline condition of coral reefs and fish populations for determining the effectiveness of various management initiatives on the sustainability of these important resources. This program will also allow natural resource managers to gauge the impacts of natural disturbances and human activities on coastal habitats and their rates of recovery. This report presents results from the third year of monitoring in St. Croix, with comparisons to data obtained in years one and two, and the first year of monitoring in St. Thomas. St. Thomas monitoring and assessment employed a stratified design based upon the position of reefs along the insular platform (near-shore, mid-shelf, and shelf-edge) to facilitate a systematic evaluation of the effects of natural and human-induced stresses, as well as factors influencing the decline or recovery of Caribbean coral reef systems.

Digital video and diver surveys were used to quantify coral diversity and the percent cover of corals, algae and other organisms, incidence of coral bleaching and disease, sea urchin density, and fish community structure at eight permanent sites surrounding the island of St. Croix and six permanent sites surrounding the island of St. Thomas. Sedimentation rates, current speed and direction, and temperature were assessed at two St. Thomas sites using sediment traps and data recorders. In addition, digital video and diver surveys were performed at six St. Thomas *Acropora* reefs to quantify percent cover, size distribution, tissue mortality, predation, disease, and recruitment for all *Acropora* species at these reefs. Assessment of these reefs provides a baseline to measure the recovery of *Acropora* corals, which were once abundant, but have been decimated by disease and storm damage.

In St. Croix, turf algae covering dead coral was the predominant benthic cover at most sites. Percent cover of living coral and other benthic organisms changed little over the three years of monitoring. However, the relative abundance of stress tolerant coral species increased at several sites, indicating a decrease in reef quality. Coral disease and bleaching were variable between sites and years. Sea urchin densities were low and showed little change between years. In 2003, fish diversity ranged from 47 to 61 species, while fish abundance averaged 200 to 500 fish per census. The majority of observed fish were small ($\leq$5 cm). Commercially important large groupers, snappers, and angelfishes were uncommon to absent at all sites. Due to differing sampling methods between years, annual comparisons of fish communities in St. Croix were not possible. Methodology is now standardized.

In St. Thomas, turf algae covering dead coral was the predominant substrate type at three sites, macroalgae was predominant at two sites, and living coral had the highest percent cover at one site. Near-shore reefs tended to have lower percent cover living coral and higher percent cover dead coral covered with turf algae than mid-shelf and shelf-edge reefs. Near-shore sites also tended to have higher relative abundances of stress tolerant corals than the other reef systems. Coral disease and bleaching varied between sites. Sea urchins were observed only at the two near-shore sites. Current patterns, temperature, and sedimentation differed between the mid-shelf and shelf-edge sites. At the St. Thomas *Acropora* reefs, all measured parameters varied between species and sites. No significant differences were found between near-shore and mid-shelf *Acropora* reefs. St. Thomas fish diversity ranged from 36 to 54 species, while fish abundance averaged 70 to 120 fish per census. The majority of observed fish were small (5 – 10 cm). Commercially important large groupers, snappers, angelfishes, and triggerfishes were observed at low densities, but were more frequently observed at the mid-shelf and shelf-edge sites. Butterflyfish densities indicated higher levels of reef health for mid-shelf and shelf-edge reef systems.

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. The islands of St. Thomas and St John are joined by an extensive shallow water platform that connects them to Puerto Rico and the British Virgin Islands. Twenty-five kilometers to the south of St. Thomas and St. John, St. Croix lies on a separate platform. St. Croix is separated from St. Thomas and St. John by the Virgin Islands Trough (over 7,300 m deep).

Tourism drives the Virgin Islands economy. The marine environment with its clean, clear water and fringing sandy beaches is our major tourist attraction. The waters of 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 in the coral reefs and other habitats attracts thousands of skin and scuba divers each year. Sport fishing also makes an important contribution to the economy, especially on St. Thomas.

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 the economically important queen conch, whelk, snapper and grouper. Over three hundred full-time or part-time commercial fishermen fish in territorial and federal waters on all three islands. In tough economic times, fishing is an important means of supplemental income for many people.

Over the past 20 years, eight major hurricanes, numerous outbreaks of disease and sporadic bleaching events have caused extensive coral mortality to the coral reefs surrounding the Virgin Islands (Gladfelter, 1982: Edmunds and Witman, 1991; Rogers *et al*., 1991; Causey *et al*., 2000). Recovery from these natural disturbances is hindered by a multitude of human impacts that affect coral reefs such as overfishing, ship groundings, anchor damage, and non-point source pollution (Roberts, 1993; Sebens, 1994; Rogers and Garrison, 2001). Moreover, rapid development of inland and coastal areas has dramatically increased soil erosion and sedimentation onto many of these coral reefs (Rogers, 1990; MacDonald *et al*., 1997; Anderson and MacDonald, 1998). Chronic sedimentation may affect the abundance and diversity of corals and other reef organisms, increase coral stress and susceptibility to diseases and bleaching, and reduce the ability of corals and other reef organisms to recover and regenerate after natural disturbances such as hurricanes (Acevedo and Morelock, 1988; Rogers, 1990; Rice and Hunter, 1992). The cumulative effects of these human impacts reduce coral abundance and larval recruitment and may make corals more susceptible to disease and bleaching (Nemeth and Sladek Nowlis, 2001).

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 other reef systems, which can be quite extensive. Surrounding St. Thomas and St. John, these other reef systems include the shallow water *Acropora palmata* reefs (<5 m depth), mid-shelf reefs (5 – 30 m depth) located 2 to 10 km from the shore of the main islands, and deep reefs (>30 m depth) located 10 to 15 km offshore along the edge of the insular platform. A more systematic approach to investigating these cross-shelf coral reef systems will allow us to evaluate the variable impacts and synergistic effects of natural impacts and human-induced stress as well as factors influencing 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 (Nemeth *et al*., 2002; Nemeth *et al*., 2003). In 2003, monitoring continued at St. Croix reefs and began at reef systems distributed across the insular platform surrounding St. Thomas.

The St. Thomas cross-shelf reef systems, with the exception of the shallow *Acropora* reefs, are very similar in composition (i.e. dominated by the genus *Montastraea*) but differ in a number of important ways. Because of the close proximity of near-shore fringing reefs to human populations and their relatively shallow depths, these reefs are susceptible to both harmful human activities (overfishing, sedimentation, nutrient enrichment, and physical damage) and the effects of natural disturbances (storm wave damage, high sea surface temperatures, high irradiance). The mid-shelf coral reefs, either fringing reefs associated with offshore cays or non-emergent linear reefs on the insular platform, are less susceptible to human induced stresses as described above, but are exposed to similar levels of natural impacts. Thus, the mid-shelf reefs provide an ideal control for measuring the effects of anthropogenic stresses on near-shore reefs due to their comparable depth but greater distance from land-based sediments and pollutants. The deep reefs located along the edge of the insular platform are largely free from human induced stresses (excluding fishing and anchoring) and natural impacts due to their greater distance from human populations and their greater depth, respectively. Since the shelf-edge deep reefs are quite extensive, but largely unknown, studying these systems will greatly contribute to our understanding of the coral reef resources in the Virgin Islands.

Acropora reefs occur in shallow waters adjacent to areas of high human population density and on uninhabited off-shore cays in the Virgin Islands. *Acropora palmata* once dominated the shallow water areas in the Virgin Islands and the Caribbean prior to the devastating effects of white band disease (Gladfelter, 1982) and severe hurricanes (Woodley *et al*., 1981; Rogers *et al*., 1982; Edmunds and Whitman, 1991; Hubbard *et al*., 1991; Rogers *et al*., 1991; Bythell *et al*. 1993). However, recent observations indicate that this species may be showing signs of recovery (C. Rogers personal communication; R. Nemeth, S. Herzlieb personal observation). Monitoring stands of this major reef building species close to and far from centers of human activity will allow us to determine the factors facilitating or hindering its recovery.

Objectives for Monitoring Coral Reefs

In order to maintain the marine resources of the Virgin Islands in an ecologically and economically sustainable manner, the territorial and federal waters of the Virgin Islands must be effectively managed. By providing managers with fundamental information with which to make and enforce decisions, monitoring programs are essential for successful management. Monitoring establishes baseline data against which standards for resource protection can be measured. Also, monitoring provides the means to assess the status and trends of ecological resources, allowing managers to determine the effectiveness of current management plans and to develop effective management for the future. The intent of this project is to monitor the condition of coral reefs throughout the U.S. Virgin Islands to better manage these ecosystems. This will be accomplished by continuing to monitor previously established reef sites surrounding St. Croix and to begin monitoring reefs surrounding St. Thomas, comparing biotic and abiotic parameters among the near-shore, mid-shelf, and shelf-edge *Montastraea* reefs and biotic parameters among the near-shore and mid-shelf *Acropora* reefs.

Section I: St. Croix

Methods

Benthic Assessments:

In April 2001 (year one), the University of the Virgin Islands established permanent video transects at eight long-term sites for annual monitoring (Nemeth *et al*. 2002). In 2002 (year two), two more long-term sites were added (Nemeth *et al*. 2003). To make more efficient use of time and resources in 2003 (year three), monitoring was discontinued at two of the long-term sites established in year one (Lang Bank and Salt River East Wall), bringing the total number of long term monitoring sites in St. Croix to eight, two of which (Great Pond and Jacks Bay) are within the East End Marine Park Boundary (Figure 1, Table 1). Monitoring of Lang Bank was discontinued due do the low percent coral cover found in years one and two and the logistic difficulty involved with reaching the site. Monitoring at Salt River East Wall was discontinued due to the close geographic proximity to Salt River West Wall and the similar benthic composition between the two sites (Nemeth *et al.*, 2003).

Table 1. St. Croix site location information and number of benthic transects at each site.

Site	Date Sampled			GPS Coordinates	Depth (ft.)	No. of Transects		
	Yr. 1	Yr. 2	Yr. 3			Yr. 1	Yr. 2	Yr. 3
Buck Island	8/10/01	1/14/02	3/29, 5/2, 5/4, & 5/21/03	N 17° 47.122, W 64° 36.550	35	3	3	6
Cane Bay	4/25/01	5/29/02	4/21/03	N 17° 46.433, W 64° 48.810	30	6	6	6
Great Pond	-	3/24/03	7/31/03	N 17° 42.668, W 64° 39.148	14	-	6	6
Jacks/Isaac Bay	8/02/01	6/11/02	09/05/03	N 17° 44.588, W 64° 34.309	35	6	6	6
Lang Bank	8/01/01	5/29/02	-	N 17° 44.443, W 64° 32.209	50	6	5	-
Long Reef/Eagle Ray	7/26/01	5/30/02	3/28/03	N 17° 45.688, W 64° 41.929	30	6	6	6
Mutton Snapper	-	1/17/03	5/19/03	N 17° 38.217, W 64° 51.683	75	-	5	6
Salt River East Wall	10/12/01	5/23/02	-	N 17° 47.221, W 64° 45.445	40	6	6	-
Salt River West Wall	8/23/01 10/12/01	5/22/02	4/08/03	N 17° 47.116, W 64° 45.564	20	6	6	6
Sprat Hole	9/25/01	6/14/02	4/13/03	N 17° 44.038, W 64° 53.722	40	6	5	6

At all sites except Buck Island and Mutton Snapper, all video, coral disease and bleaching, and sea urchin density data were collected along six 10 m permanent transects established in previous years. In years one and two, only three transects were sampled at Buck Island. In year three, three more transects were established here by driving stakes 10 m apart into non-living areas of the reef near the three existing transects. When sampling the permanent sites, transect lines were stretched between the stakes, then removed after sampling. For Mutton Snapper, transects were marked in year two and year three by haphazardly laying 10 m transect lines on areas judged to be representative of the reef. Since permanent transects were not established at this site, data from year three and year two do not represent the exact same area of reef, but do correspond to the same general area. Video, disease, bleaching, and urchin samplings for all sites except Buck Island were performed on the same day. At Buck Island, video samplings for transects 1 – 3 and transects 4 – 6 were performed on 3/29/03 and 5/04/03, respectively. Urchin/disease/bleaching transects were performed for transects 1 – 3 and transects 4 – 6 on 5/21/03 and 5/2/03, respectively.

To video sample, one diver swam along each transect videotaping the benthic cover using a Sony TRV-950 digital camcorder in a Light and Motion Stingray II underwater housing. The diver swam at a uniform speed, pointing the camera down and keeping the lens approximately 0.4 m above the substrate at all times. A guide wand attached to the camera housing was used to help the diver maintain the camera a constant distance above the reef. After taping, approximately 20 - 30 non-overlapping images per transect were captured and saved as JPEG files on a computer using a Sony video capture card. Captured images represented an area of reef approximately 0.31 m^2 (0.64 m x 0.48 m). Microsoft Excel and Adobe Photoshop were used to superimpose ten randomly located dots on each captured image. The substrate type located under each of the dots was then identified to the most descriptive level possible and entered into a database. For each transect, the percent cover of coral, dead coral with turf algae, macroalgae, sponges, gorgonians, and sand/sediment were calculated by dividing the number of random dots falling on that substrate type by the total number of dots for that transect. Mean values for percent cover were calculated for each site and coral diversity was measured by using the Shannon-Weaver diversity index.
Paired *t*-tests were performed to determine if there were significant differences in the percent cover of these benthic categories at each site between years one, two and three. Since three transects were added at Buck Island in year three (transects 4 – 6), significant differences at Buck Island between years were tested using data from all sampled transects in year three as well as means determined from transects 1 – 3, which were sampled in all years. This was done to ensure that any differences found between years at Buck Island reflected temporal changes in benthic composition at the site and were not the result of increasing the number of sampled transects.

At all sites all coral colonies $\geq$0.1 m in diameter or height that were located directly under the transect lines were measured for maximum width and height and assessed for signs of disease or bleaching. Assessments of each coral colony were done by estimating the percent surface area (planar view) appearing bleached and diseased for each colony. For each site, the mean percent of coral colonies with disease was calculated by dividing the number of colonies with disease by the total number of colonies assessed on each transect, then determining the mean value among all six transects. The mean percent of bleached colonies for each site was calculated in the same fashion. Paired *t*-tests were used to determine if there were significant differences in the percent of diseased and bleached colonies between years two and three. Since bleaching and disease data were collected by a different method in year one, comparisons to year one were not possible.

Divers also counted the number of *Diadema antillarum* sea urchins within 1 m on either side of each transect at all long-term sites. The mean number of sea urchins per 10 m^2 was calculated for each site and paired *t*-tests were performed to determine if there were differences in the mean density of sea urchins at each site between years one, two, and three.

Fish Census:

For all years in St. Croix, fish surveys were performed at the same sites as the benthic assessments (Figure 1). In 2003, methods for surveying fish communities on St. Croix were modified from the previous year. In 2002, fish surveys were conducted using the stationary point-count method (Bohnsack and Bannerot 1986). In 2003, belt transects were used instead of point counts (except where noted) in order to maximize data compatibility with concurrent studies in the USVI and elsewhere. This methodological change affects time-series comparisons of St. Croix data sets but not those of St. Thomas, where surveys were being conducted for the first time in 2003.

Belt transects 30 x 2 m (60 m^2) followed the method of Brock (1954). In brief, each diver affixed a transect tape to the seafloor at haphazardly chosen positions that were sufficiently separated from other transects (>5 m) and slowly swam a straight distance parallel to the reef profile. All fish observed within this swath or passing in front of (but not behind) the diver were identified to species. Fish size (fork length) was estimated to the nearest cm, and number of individuals was recorded into the following size categories: ≤5 cm; 5-10 cm; 10-20 cm; 20-30 cm; 30-40 cm, and >40 cm. On St. Croix, diminutive/cryptic fish species (gobies, blennies, apogonids) were excluded from fish counts. At each site, ten replicate belt transects were conducted with the exception of Mutton Snapper site (7 transects). An attempt was made to standardize the duration of each belt transect to 20 minutes on St. Croix.

In 2003 roving diver surveys (RDS) were used in conjunction with belt transects. In this method, divers swam a haphazard circuit in the immediate vicinity of the survey site while listing all observed fish species into abundance categories as follows: 1 fish; 2-10 fish, 10-100 fish; 101-1000 fish; and >1000 fish. Observations were recorded onto pre-printed forms (species lists). On St. Croix, one RDS was conducted at each site for 30 minutes.

Survey information and observations were recorded onto underwater data forms. In the laboratory, data were entered into Microsoft Excel spreadsheets and analyzed for descriptive statistics of reef fish community structure (average density, species richness, Shannon - Weaver Diversity (H'), etc). Jaccard's coefficient of similarity, based upon species presence or absence, was calculated for all intra-island site comparisons. A summary of fish census effort for St. Croix is presented in Table 2.

Table 2. Summary of fish census effort, St. Croix.

Survey Method	Site	Survey Date	Total No. of Replicates	Total Survey Time (min)	Avg. Time per Transect (min)
Belt Transect	Buck Island	9/16/03	10	198	19.8
	Cane Bay	8/28/03	10	331	33.1
	Great Pond	9/19/03	10	190	19.0
	Jacks Bay	9/5/03	10	214	21.4
	Long Reef	9/8/03	10	221	22.1
	Mutton Snapper	9/23/03	7	137	19.6
	Sprat Hole	9/10/03	10	195	19.5
	Salt River	8/26/03	10	251	25.1
Roving Diver	Buck Island	5/4/03	1	30	na
	Cane Bay	5/29/03	1	30	na
	Great Pond	c.5/22/03	1	30	na
	Jacks Bay	9/5/03	1	30	na
	Long Reef	06/03	1	30	na
	Mutton Snapper	5/21/03	1	30	na
	Sprat Hole	9/10/03	3	90	30.0
	Salt River	c.5/22/03	1	30	na
Point	Sprat Hole	9/10/03	6	232	38.7

Results and Recommendations

Benthic Assessments:

For year three, the percent cover of living coral at the St. Croix sites ranged from a low of 6.6% at Long Reef/Eagle Ray to a high of 35.9% at Mutton Snapper. The percent cover of living coral remained fairly constant at each site from year one to year three, with no significant differences between years at any site (Figure 2A). For year three, turf algae covering dead coral was the most dominant substrate type at all eight sites except for Jacks Bay and Mutton Snapper, where macroalgae was the most abundant substrate type. Dead coral with turf algae ranged from a low of 21.7% at the Mutton Snapper site to a high of 81.2% at Salt River. At most sites, dead coral covered with turf algae varied between years, with significant differences at Buck Island for years one and two, Great Pond and Long Reef/Eagle Ray for years two and three, and Sprat Hole for years one and two and two and three (Figure 2B). In year three, macroalgae ranged from a low of 0.45% at Great Pond to a high of 47.0% at Jacks Bay. Macroalgae varied between years with significant differences at Buck Island between years one, two, and three, and Long Reef and Sprat Hole for years one and two and two and three (Figure 2C). Since macroalgae can overgrow dead coral with turf algae and macroalgal cover can vary seasonally, comparisons of algal cover between years are difficult, as all sites with significant differences were sampled at different times of year. We recommend future samplings be performed consistently in late spring/early summer each year, when macroalgal cover is highest (R. Nemeth, unpublished data). Sponges and gorgonians each comprised less than 10% of the benthic cover at all sites, with sponge cover varying significantly at Buck Island between year three and years one and two (Figure 2D, E). Sand/sediment was the only non-living substrate type found at the sites, ranging from 0% at Great Pond to 6.2% at Buck Island. No significant differences were found for percent cover of sand/sediment between years (Figure 2F). For all benthic categories, temporal comparisons at Buck Island utilizing means from transects 1 – 6, as well as transects 1 – 3 in year three produced similar results, indicating that differences (or lack of) between year three and previous years were the result of temporal changes at the site and not from the addition of transects.

The coral reefs of St. Croix were generally dominated by coral species in the genus *Montastraea*. For analysis purposes, corals within the *Montastraea annularis* complex (*M. annularis*, *M. faveolata*, and *M. franksii*) were grouped into a single MACX category (Figure 3, Figure 4A-H). In 2003, *Montastraea* corals were the most abundant corals at five of the eight sites. *Millepora alcicornis* was most abundant at Great Pond and Jacks Bay and *Porites astreoides* was most abundant at Long Reef. At all sites, species composition tended to differ between years (Figure 4A-H). Buck Island, Cane Bay, and Salt River tended to show decreases in the percent composition for corals in the *M. annularis* complex with increases in the percent composition for *P. astreoides* and *Siderastrea siderea.* As was the case with the percent cover, the addition of three transects at Buck Island had no effect on patterns of species composition. Cane Bay showed increases in *Diploria strigosa* and *D. labyrinthiformis* as well. Similarly, Sprat Hole showed a decrease from year one to three for the *M. annularis* complex with an increase in the percent composition by *P. astreoides*. These trends warrant special attention, as *P. astreoides* and *S. siderea* are especially stress tolerant corals (Acevedo *et al*., 1989; Torres and Morelock, 2002). Increases in the relative abundance of these stress tolerant species and decreases in the relative abundance of less tolerant corals such as those within the *M. annularis* complex may indicate an overall decrease of reef quality. At Jacks Bay, *P. astreoides* and *S. siderea* as well as the *M. annularis* complex tended to increase from year one to year three and the relative abundance of *M. cavernosa* and *P. porites* tended to decrease. Long Reef showed an increase of the *M. annularis* complex, *P. astreoides*, and *D. labyrinthiformis*, with decreases of *M. cavernosa*, *S. siderea*, and *Agaricia agaricites*. Great Pond showed dramatic differences in relative abundance of *M. cavernosa*, *P. astreoides*, *Millepora alcicornis*, and *Millepora complanata* between 2002 and 2003. These differences may be a reflection of the sites shallow depth (~ 3.5 m) and low percent coral cover. On shallow reefs, strong surge can move the transect line marking the video transects, resulting in variation in the exact coral colonies videotaped with each sampling. In cases of low percent total coral cover, small variations in the percent cover of each species captured in the video transects can result in large differences the relative abundance of each species. The Mutton Snapper site showed an increase in the relative abundance of corals in the *M. annularis* complex and decreases for *M. cavernosa*, *P. astreoides*, and *S. siderea*. A decrease in the relative abundance of stress tolerant species and an increase in the relative abundance of less stress tolerant species may reflect an improvement of reef quality at this site, which is the deepest of the sampled St. Croix sites (75 ft. depth).

For 2003, the Shannon – Weaver Diversity Index (H') for coral ranged from a high of 2.28 at Long Reef to a low of 0.52 at Mutton Snapper. Coral diversity increased at most sites from year one to year three, with the exceptions being Great Pond (decreasing slightly) and Mutton Snapper (Figure 5). This is consistent with the increase of stress tolerant species at most sites. The decrease of coral diversity at Mutton Snapper can be attributed to the decrease in the relative abundance of stress tolerant species and the increase of the relative abundance of the *M. annularis* complex.

In 2003, Salt River showed the highest incidence of both diseased and bleached coral colonies, with diseased corals comprising 7.6% of the sampled colonies and bleached corals comprising 14.0% of the colonies. Mutton Snapper and Sprat Hole were the only other sites with disease, with 5.5% and 0.9%, respectively. Jacks Bay and Great Pond were the only sites without bleaching in 2003. Sprat Hole had significantly less disease in 2003 than 2002 ($P<0.01$, Figure 6). In 2003, *M. franksii* was the most common coral with disease, while *S. siderea* was the most common with bleaching (Figure 7). Divers observed white plague, dark spots disease, and yellow blotch disease. In some instances, corals appeared diseased, but could not be categorized as a specific disease. These were classified as 'unknown' and included in counts of total disease. Since bleaching and disease vary seasonally in the Virgin Islands (S. Herzlieb, unpublished data), and the sites were sampled at different times of year in 2002 and 2003, comparisons between years are difficult. We recommend that future samplings for disease and bleaching be performed at the same time of year.

No *Diadema antillarum* sea urchins were present at most sites in 2003, the exceptions being Cane Bay (1.3 urchins/10 m^2), Great Pond (6.5 urchins/10 m^2), and Jacks Bay (0.2 urchins/10 m^2). No significant differences in urchin density were found between years.

Fish Census:

On St. Croix, a total of 25,473 fish representing 101 species were observed in 77 belt transects at eight survey sites. Abundance was highly variable within and among sites (Figure 8A). The highest densities were observed at CB, MS, and SR. Species richness was also variable (Figure 8B), but generally high with between 19 species (at GP) and 30 species (at CB) observed per transect. The greatest number of fish species was observed at CB (61 species) and the fewest at GP (47 species). Reef fish diversity (Shannon - Weaver H') was less variable within and among sites (Figure 8C).

A comparison of belt transect data to Roving Diver Survey (RDS) data indicated that the level of RDS replication on St. Croix (one per site) was insufficient to adequately characterize the fish communities. Community richness as determined by RDS was, on average, only 74% of estimates derived from belt transects (10 replicates per site). For comparison, in St. Thomas where RDS was replicated 3 times per site, richness from RDS was on average 165% of belt transect estimates. Therefore, in the following discussion, data from belt transects are emphasized. We recommend increasing the number of RDS replicates to three or more in future St. Croix surveys to adequately characterize fish communities.

Reef fish communities were compared among sites based upon taxonomic composition (species presence or absence) using Jacaard's index of similarity (Figure 9). Fish communities at CB, SR and SH shared relatively high similarity (0.65 to 0.67) and LR was similar to JB (0.67). The fish community at GP was least similar to all other sites (0.38 to 0.51).

The majority of fish observed in 2003 were small, with most fish (12,909 fish or 50.7%) falling into the smallest size category ($\leq$5 cm). An additional 7,012 fish (27.5%) fell into the next smallest size category ($\leq$10 cm long). Intermediate size fish (10-20 cm and 20-30 cm) were less abundant, comprising 17.3% and 4.1% of observations, respectively. Indeed, relatively few large fish (30-40 cm) were observed (67 fish or 0.3%) and fewer very large fish (>40 cm) were observed (40 fish or 0.2%).

Reef fish communities among sites were compared based upon ten families (Figure 10A-J). Planktivorous labrids and pomacentrids predominated at all sites, with five species accounting for 63% of all fish observed in belt transects: bluehead wrasse, *Thalassoma bifasciatum* (19.5%); blue chromis, *Chromis cyanea* (18.2%); bicolor damselfish, *Stegastes partitus* (10.4%); creole wrasse, *Clepticus parrae* (8.1%); and brown chromis, *Chromis multilineata* (7.0%). Parrotfishes (Scaridae) and surgeonfishes (Acanthuridae), which represent the most prominent group of herbivores, were the next most abundant families. Scarids reached their highest densities at BI whereas acanthurids were most abundant at JB and GP. Among acanthurids, the ocean surgeon (*Acanthurus bahianus*) was very common, the blue tang (*A. coeruleus*) was common, and the doctorfish (*A. chururgus*) least common. Among scarids, the redband (*Sparisoma aurofrenatum*), stoplight (*Sp. viride*), striped (*Scarus croicensis*), and princess (*Sc. taeniopterus*) parrotfishes were very common. The herbivorous pomacentrid, yellowtail damselfish (*Microspathodon chrysurus*), was exceptionally abundant at GP, where it was observed at densities over 10-fold greater than all other sites.

The remaining families (Figure 10E-J) were observed at much lower densities at most sites. Small serranids, such as hamletfish (*Hypoplectrus* sp.) and harlequin bass (*Serranus tigrinus*) were relatively common, as were two small groupers, coney (*Cephalopholis fulvus*) and graysby (*C. cruentatus*). Larger groupers were either rare (red hind, *Ephinephelus gattatus*, and rock hind, *E. adcensionis*) or absent. Similarly, lutjanids were only observed at low densities, with mahogany snapper (*Lutjanus mahogani*) and schoolmaster (*L. apodus*) encountered frequently, yellowtail snapper (*Ocyurus chrysurus*) observed infrequently, and mutton snapper (*L. analis*) observed rarely. Haemulids were observed at all reef sites, with the French grunt (*Haemulon flavolineatum*) the most abundant and most common. Butterflyfish were common at most sites, especially the foureye butterflyfish (*Chaetodon capistratus*) and banded butterflyfish (*C. striatus*). Angelfishes were uncommon (SR,CB, JB, LR, SH, MS) or absent (BI, GP) and represented primarily by a single species, the rock beauty (*Holacanthus tricolor*) although one queen angelfish (*H. ciliaris*) was observed at JB, LR and MS. The family Balistidae (triggerfishes) was moderately abundant but represented by a single species, black durgon (*Melichthys niger*) at all but one site (MS) where two queen triggerfish (*Balistes vetula*) were seen.

In order to compare St. Croix fish census results from this year (using belt transects) to the previous year (using stationary point counts), both methods were used at one reef site (SH) on the same day. We used the same methods with the same level of replication and the same observers as described here and previously in 2002. Under these conditions, the point count and belt transect methods gave very similar results for most fish species in terms of rank order of abundance and rank frequency of observation. Results from the methods differed primarily in that belt transects identified a greater number of species (55 vs. 41) and more individuals were observed per replicate (typically 1 - 4 times more). For the latter, scaling of results to total area surveyed (dividing belt transect data by 2.93) did not substantially improve agreement between methods. Many of the discrepancies appear to be species-specific. In some cases, fish movement during the observation period may inflate density estimates by belt transects (e.g. small scarids, acanthurids), while in other cases topographic complexity may obstruct observation and therefore deflate density estimates by point counts (e.g. fairy basslets, various recruits).

In the previous year (Toller 2002) it was noted that many of the larger, long-lived resident reef fish were absent from St. Croix surveys. We combined results from RDS and belt transects in an attempt to quantify the abundance of 12 commercially important, rare, and/or vulnerable species (Table 3). From this list, only red hind (*Epinephelus guttatus*) and mutton snapper (*Lutjanus analis*) were observed. Although the level of replication for roving diver surveys was inadequate, the results nonetheless support direct observations of fish communities at these reef sites, with the exception of the cubera snapper (*L. cyanopterus*), which was occasionally encountered (Toller, personal observation).

Table 3. Abundance of 12 commercially important, rare and/or vulnerable fish species on St. Croix.

			Relative Fish Abundance*											
Site	Method	Total Survey Time (min)	Nassau grouper	yellowfin grouper	yellowmouth grouper	tiger grouper	red hind	cubera snapper	mutton snapper	dog snapper	hogfish	rainbow parrotfish	blue parrotfish	midnight parrotfish
Salt River	belt	251	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	30	-	-	-	-	2	-	-	-	-	-	-	-
Cane Bay	belt	331	-	-	-	-	-	-	1	-	-	-	-	-
	RDS	30	-	-	-	-	-	-	-	-	-	-	-	-
Isaac's Bay	belt	214	-	-	-	-	4	-	-	-	-	-	-	-
	RDS	30	-	-	-	-	2	-	2	-	-	-	-	-
Eagle Ray	belt	221	-	-	-	-	4	-	-	-	-	-	-	-
	RDS	30	-	-	-	-	2	-	-	-	-	-	-	-
Sprat Hole	belt	195	-	-	-	-	2	-	-	-	-	-	-	-
	RDS-1	110	-	-	-	-	0.3(1,0)	-	2	-	-	-	-	-
	RDS-2	30	-	-	-	-	2	-	2	-	-	-	-	-
	point	232	-	-	-	-	-	-	-	-	-	-	-	-
Buck Island	belt	198	-	-	-	-	6	-	-	-	-	-	-	-
	RDS	30	-	-	-	-	1	-	-	-	-	-	-	-
Great Pond	belt	190	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	30	-	-	-	-	-	-	-	-	-	-	-	-
Mutton Snapper	belt	137	-	-	-	-	-	-	-	-	-	-	-	-

* For belt transects, fish abundance is reported as the total number of individuals observed in ten transects. For RDS, abundance is reported as the mean abundance index (maximum and minimum indices in parentheses) for 3 replicate surveys. Abundance indices were as follows: 0 = no fish, 1 = 1 fish, 2 = 2-10 fish, 3 = 11-100 fish.

Section II: St. Thomas

Methods

Benthic Assessments and Abiotic Parameters:

Between August 2002 and September 2003, the University of the Virgin Islands assessed twelve sites in St. Thomas, USVI. Of these sites, six were reefs dominated by corals in the genus *Montastraea* and six were reefs dominated by corals in the genus *Acropora.* The *Montastraea* reefs were categorized into three reef types based upon their location along the insular platform off the coast of St. Thomas: near-shore reefs (5 – 30 m deep) located along the shoreline of St. Thomas, mid-shelf reefs (5 – 30 m deep) located 2 to 10 km offshore of St. Thomas, and shelf-edge reefs (>30 m deep) located 10 to 15 km offshore St. Thomas along the edge of the insular platform. Since there are no shelf-edge *Acropora* reefs, only near-shore and mid-shelf *Acropora* sites were sampled. Two *Montastraea* and three *Acropora* sites were included in each category (Figure 11, Table 4). Since most research and monitoring in the Virgin Islands in general has been concentrated on near-shore fringing reefs along the three main islands of St. Thomas, St. John, and St. Croix, these sites were chosen to fill gaps in the knowledge of other reef systems, as well as to establish an experimental design to test hypotheses involving differences in biotic and abiotic parameters of reefs located at different points along the insular platform off the coast of St. Thomas.

Table 4. St. Thomas site location information.

Site	Date Sampled				GPS Coordinates	Depth (ft.)
	Video	Disease, Bleaching, Urchins	Predation, Disease, Size Distribution	Fish Surveys		
Montastraea reefs:						
Benner Bay[1]	5/20/03	5/20/03	-	8/05/03	N 18° 18.754, W 64° 51.635	15 - 26
Black Point[1]	9/09/03	09/09 & 9/22/03	-	10/02/03	N 18° 20.670, W 64° 59.157	23 - 36
Flat Cay[2]	6/04/03	6/04/03	-	6/4/03	N 18° 19.093, W 64° 59.462	40 - 56
Seahorse Cottage Shoal[2]	6/12/03	6/12/03 6/18/03	-	6/12/03	N 18° 17.680, W 64° 52.050	61 - 80
Grammanik Bank[3]	4/03/03	7/29/03	-	6/17/03	N 18° 11.468, W 64° 57.019	126
Red Hind Bank[3]	1/13/03 1/15/03	8/06/03 8/13/03	-	6/16/03	N 18° 12.130, W 65° 00.095	128 - 131
Acropora reefs:						
Botany Bay[1]	6/25/03	-	7/09/03	-	N 18° 21.507, W 65° 01.998	3 - 12
Caret Bay[1]	9/04/02	-	8/12/03	-	N 18° 22.318, W 64° 59.320	8 - 20
Coculus Point[1]	7/01/03	-	8/05/03	-	N 18° 18.554, W 64° 53.951	3 - 8
Flat Cay[2]	8/01/02	-	7/10/03	-	N 18° 19.028, W 64° 59.328	3 - 25
Hans Lollik[2]	8/07/03	-	8/07/03	-	N 18° 24.278, W 64° 54.182	8 – 20
Inner Brass[2]	9/09/02	-	8/11/03	-	N 18° 22.650, W 64° 57.859	6 - 10

[1] near-shore sites
[2] mid-shelf sites
[3] shelf-edge sites

Montastraea reefs:

Video transects, coral disease and bleaching assessments, and sea urchin counts were all performed using the same methodology as previously described for the St. Croix sites. At all St. Thomas sites except Black Point, Seahorse Cottage Shoal, the Grammanik Bank and the Red Hind Bank, video, disease and bleaching, and urchin samplings were performed on the same day. The greater depths of Seahorse Cottage Shoal and the shelf-edge sites limited the amount of time the divers could safely stay at depth. Therefore, data collection at these sites was performed over the course of several days. For the near-shore sites, permanent transects were established by driving stakes 10 m apart into non-living areas of the reef. The transects were placed in a linear fashion with a randomly generated distance between each transect. For Flat Cay, non-permanent transects were marked by a diver haphazardly picking a starting point, stretching a transect tape for 10 m in a randomly generated compass direction, marking the end of the transect, then swimming a random distance in a random direction to determine the starting point off the next transect and repeating the process. For Seahorse Cottage Shoal and the shelf-edge sites, transects were marked by haphazardly laying transect line on areas judged to be representative of the reef. For the sites sampled over the course of several days, transect lines were laid each day. Thus, on occasions when the disease, bleaching, and urchin surveys were not completed on the same day as the video sampling, these data were not collected at the exact same locations sampled by video, but in the same general area of the reef. After sampling, video, bleaching and disease, and sea urchin data were analyzed using the same methodology as previously described for the St. Croix sites. Significant differences in percent cover of the previously described benthic categories, coral disease and bleaching, and sea urchin density between near-shore, mid-shelf, and shelf-edge sites were determined by *t*-tests. At depths greater than 25 m (i.e. the shelf-edge sites), coral species within the *M. annularis* complex appear very similar, making identification to species difficult, especially from video images. In instances where corals could not be reliably identified to species, they were classified as MACX, unidentified coral within the *M. annularis* complex.

To measure abiotic factors, two sediment traps and one Aanderaa RCM 9 MkII data recorder were installed at the Flat Cay and Red Hind Bank sites, respectively (Table 5). This mid-shelf and shelf-edge site were chosen as abiotic stations to complement oceanographic data that will be collected by the NOAA CREWS station to be placed at the near-shore reef in Brewer's Bay. The data recorders were installed according to the manufacturer's instructions in small sand patches within the reef in the same general area where the benthic transects were assessed. The data recorders were set to record temperature and current speed and direction at hourly intervals. The sediment traps were constructed of PVC tubing 20 cm long and 5 cm internal diameter. At each site, the traps were mounted 10 m apart on stakes driven into non-living areas of the reef with the top of each trap 0.5 m above the substrate. The traps were placed such that one trap was within 2 m of the data recorder at each site.

Table 5. Dates Aanderaa data recorders and sediment traps deployed and retrieved.

	Set 1		**Set 2**		**Set 3**		**Set 4**	
Data recorders:	Deployed	Retrieved	Deployed	Retrieved	Deployed	Retrieved	Deployed	Retrieved
Flat Cay	4/8/03	7/25/03	7/29/03	10/29/03	11/4/03	2/12/04	-	-
Red Hind Bank	4/10/03	8/13/03	8/15/03	10/28/03	10/31/03	2/27/04	-	-
Sediment traps:								
Flat Cay	7/08/03	8/15/03	8/15/03	9/10/03	9/10/03	10/29/03	10/29/03	11/20/03
Red Hind Bank	7/15/03	8/15/03	8/15/03	9/10/03	9/10/03	10/28/03	10/29/03	11/26/03

After retrieval, data from the data recorders were downloaded into a personal computer according to the manufacturer's instructions using software supplied by Aandera instruments. Since there were small amounts of sediment in all the traps (i.e. the total sediment did not completely cover the bottom of the trap), glass fiber filters were used to process the sediment. The glass fiber filters were first rinsed with distilled water while installed in a vacuum pump manifold, then oven dried, placed in a desiccator for 15 minutes, then weighed. After filter preparation, the filters were placed on the vacuum pump manifold and the contents of the sediment trap were poured onto the filter, using distilled water to rinse all sediment from the trap. The vacuum pump was then turned on and the samples were rinsed with distilled water. The sediment and filters where then placed in a drying oven for 1 hr. at 100^{o} C. Finally, the weight of the sediment sample was determined by weighing the dried sediment and glass filter and subtracting the filter weight. In all cases, the rate of sediment accumulation ($g/cm^2/d$) was determined by dividing the weight of the dried sediment by the area of the cross section of the sediment trap, then by the number of days the traps were on the reef (soak time).

Acropora reefs:

Digital video transects and diver surveys were used to assess all *Acropora* sites. Due to the nature of the structure of *Acropora* reefs, video transect methodology differed from that used at the *Montastraea* sites. At each *Acropora* site, five 30 m transect lines were haphazardly laid on areas judged to be representative of the reef. A diver videotaped the benthic cover along each transect in the same fashion used on the *Montastraea* reefs. We determined that video images recorded at a distance of 0.4 m are 0.64 m in width. Therefore, a 30 m video transect defines an area of 19.2 m^2. After taping, video images containing *Acropora* colonies were captured as still images to a personal computer. For each image, an analyst measured the surface area of living *Acropora* colonies using ImagePro image analysis software. The percent cover of live coral for each transect was then determined by dividing the digitally measured areas by 19.2 m^2, and the mean percent cover was calculated for each site. Percent cover was determined for each *Acropora* species: *A. palmata*, *A. cervicornis*, and *A. prolifera*. Significant differences in percent cover of *Acropora* between near-shore and mid-shelf reefs were determined by *t*-tests. During the diver surveys, each diver chose a species to sample (*A. palmata*, *A. cervicornis*, or *A. prolifera*) then swam (snorkel or SCUBA) in a randomly determined direction over the reef. The divers assessed every colony of their chosen species that they came across while swimming along this line until they assessed 25 colonies of their chosen species, or until they reached the end of the reef. In cases where divers failed to see 25 colonies before reaching the end of the reef, the divers swam in another randomly chosen direction until they assessed 25 colonies, or until it became apparent that the diver would be unable to locate any more colonies of the given species. For each colony, divers measured the maximum length, width, and height, estimated percent tissue mortality (planar view - total dead and recent dead), and noted the presence of *Coralliophila* snails (predators of *Acropora* corals) and white band disease. The length, width, and height were then multiplied together to determine a representative volume for each colony and the colonies were categorized into the following size classes (cm^3): <1000; $>1000 \leq 15{,}625$; $>15{,}625 \leq 125{,}000$; $>125{,}000 \leq 1 \times 10^6$; and $>1 \times 10^6$. Divers also counted the number of *Acropora* sexual recruits in each of 10 haphazardly placed 1 m^2 quadrats at each site. Recruits were defined as colonies <10 cm in maximum dimension that appeared to be established from settled larvae, as opposed to fragmentation. Typically, these recruits were too small and amorphic to be reliably identified to species. Significant differences between near-shore and mid-shelf reefs for tissue mortality, number of coral colonies infested with *Coralliophila* snails, incidence of white band disease, and recruitment were determined by *t*-tests. At all sites except Hans Lollik, video samplings and diver surveys took place on separate occasions.

Fish Census:

On St. Thomas, fish surveys were conducted on the six *Montastraea* dominated reefs where video benthic assessments were performed. No fish surveys were conducted on the *Acropora* dominated reefs. Methods used to survey fish communities were similar to those for St. Croix with the following modifications: on each site, ten replicate belt transects were completed with the exception of Seahorse Cottage Shoal, where 7 were completed. No attempt was made to standardize the duration of the belt transects, but transect times averaged 7.5 minutes. Three roving diver survey (RDS) replicates were completed at each site except on the two shelf-edge sites, where 4 replicates per site were completed. Roving diver surveys were 60 minutes in duration or the highest quarter hour of that time possible within time limitations imposed by depth. On the inshore sites (Benner Bay and Black Point), RDS replicates lasted the entire 60 minutes, on mid-shelf sites (Seahorse Cottage Shoal and Flat Cay) they were 45 minutes, and on shelf-edge sites (Grammanik Bank and Red Hind Bank) survey replicates were 15 minutes. All species of fish observed were recorded during both survey types (belt transect and RDS) with the exception of the glass goby (*Coryphopterus personatus*). Survey data were recorded, managed and analyzed using the same software and descriptive statistics as that for St Croix.

Results and Recommendations

Benthic Assessments and Abiotic Parameters:

Montastraea reefs:

For the St. Thomas sites, percent cover of living coral ranged from a low of 8.3% at Benner Bay to a high of 42.0% at the Grammanik Bank. The percent cover of dead coral covered with turf algae ranged from 15.0% at Seahorse Cottage Shoal to 45.6% at Benner Bay. The percent cover of macroalgae ranged from 13.8% at Black Point to 42.7% at Seahorse Cottage Shoal (Figure 12A-C). Sponges and gorgonians each comprised less than 10% of the benthic cover at all sites. No gorgonians were observed on the shelf-edge sites. The percent cover of sand/sediment ranged from 3.0% at the Grammanik Bank to 28.0% at Black Point. For this category, Black Point was predominately sediment covering the entire substrate, while the other sights were predominately sandy areas in between vertical reef structures (Figure 12D-F). Near-shore reefs tended to have lower percent cover of living coral and higher percent cover of dead coral covered with turf algae than mid-shelf and shelf-edge reefs, but there were no significant differences in percent cover of any benthic category between near-shore, mid-shelf, and shelf-edge sites. Given the small sample size of $n = 2$ for each reef type and the high variation between reefs within each category, comparisons between reef types are difficult. We recommend sampling a greater number of reefs of each type to make comparisons more statistically robust. We also recommend further stratifying site selection for the mid-shelf reef systems, distinguishing between shallower mid-shelf reefs associated with small islands or cays and the deeper mid-shelf reefs that are not. In this study, we found the reefs at the two mid-shelf sites to differ dramatically.

Seahorse Cottage Shoal had significantly higher percent cover of living coral and significantly lower percent cover of dead coral covered with turf algae and percent cover sponges than Flat Cay (*t*-tests, $P = 0.003$, $P = 0.006$, and $P = 0.002$, respectively). It is difficult to attribute these differences to a specific cause. The reef at Flat Cay is associated with a small island, while Seahorse Cottage Shoal is not and Seahorse Cottage Shoal is at a greater depth than Flat Cay (Table 4). Also, Flat Cay is frequently visited by recreational divers, while Seahorse Cottage Shoal is not. Finally, current direction data collected at Flat Cay indicate that despite this reef's location on the insular platform, this site may still be considerably impacted by terrigenous stresses from St. Thomas (see subsequent paragraph regarding abiotic parameters). Sampling a greater number of mid-shelf reefs both associated and unassociated with cays will help to elucidate the effects of natural and anthropogenic stresses on these as well as near-shore reef systems.

The coral reefs of St. Thomas were generally dominated by coral species in the genus *Montastraea*. Near-shore sites tended to have lower percent composition of corals within the *M. annularis* complex and higher percent composition of the stress tolerant corals *P. astreoides* and *S. siderea* than mid-shelf and shelf-edge sites (Figure 13). Corals within the *M. annularis* complex were the most abundant corals at all sites except Benner Bay, where *M. cavernosa* was most abundant (Figure 14A-F).

The Shannon – Weaver Diversity Index (H') for coral ranged from a high of 2.26 at Flat Cay to a low of 1.20 at the Grammanik Bank. In general, the deeper sites (SC, GB, RH) had lower diversity than the shallow sites (Figure 15). This supports the recommendation of stratifying the mid-shelf sites into shallower sites associated with cays and deeper mid-shelf reefs not associated with cays or islands.

Benner Bay showed the highest incidence of both diseased and bleached coral colonies, with diseased corals comprising 17.4% of the sampled colonies and bleached corals comprising 47.8% of the sampled colonies. The Red Hind Bank showed the lowest incidence of diseased corals (1.4%) and Flat Cay showed the lowest incidence of bleached corals (0%). Near-shore sites tended to have a higher incidence of bleaching than mid-shelf and shelf-edge sites, but there were no significant differences in incidence of disease or bleaching between near-shore, mid-shelf, and shelf-edge sites (Figure 16). Once again, the small sample size of $n = 2$ for each reef type and the high variation within each category made comparisons between reef types difficult. *M. cavernosa* and *S. siderea* were the most common corals with disease, while *S. siderea* was the most common coral with bleaching (Figure 17). Divers observed black band disease, dark spots disease, yellow blotch disease and white plague. In some instances, corals appeared diseased, but could not be categorized as a specific disease. These were classified as 'unknown' and included in counts of total disease.

D. antillarum sea urchins were observed only at the two near-shore sites, with 0.5 urchins/10 m^2 at Benner Bay and 0.3 urchins/10 m^2 at Black Point. No significant differences in sea urchin density were found between near-shore, mid-shelf, and shelf-edge sites.

Abiotic Parameters:

At Flat Cay, current direction headed just west of south throughout the course of the deployment of the data recorder (Figure 18). Given the position of Flat Cay southwest of heavily developed and industrial areas of St. Thomas (Charlotte Amalie, Krum Bay, Lindbergh Bay, and the Cyril E. King Airport) and differences in percent coral and algal cover between Flat Cay and Seahorse Cottage Shoal, Flat Cay may still be considerably impacted by terrigenous stresses despite the reef's mid-shelf location. This supports the recommendation of further data collection at mid-shelf reefs to elucidate the relative effects of terrigenous stresses. Current at the Red Hind Bank headed predominantly both north and south with higher current speeds occurring from late summer to early winter (Figure 19). Daily mean temperature at Flat Cay tended to be higher than the Red Hind Bank, with the highest temperatures in September and October at both sites (Figure 20, Figure 21). Sedimentation rates were higher at Flat Cay than the Red Hind Bank for all periods of deployment except Set 4 (Table 6).

Table 6. Sedimentation rates ($g/cm^2/day \times 10^{-4}$) at Flat Cay and the Red Hind Bank.

Flat Cay	**Set 1** (Jul. – Aug.)	**Set 2** (Aug. – Sep.)	**Set 3** (Sep. – Oct.)	**Set 4** (Oct. – Nov.)
Trap 1	7.55	6.76	6.35	1.07
Trap 2	5.94	5.88	2.88	3.45
Mean $\pm$ SD	6.74 $\pm$ 1.14	6.32 $\pm$ 0.62	4.62 $\pm$ 2.46	2.26 $\pm$ 1.69
Red Hind Bank				
Trap 1	0.30	4.06	1.42	4.06
Trap 2	2.83	7.82	0.86	1.36
Mean $\pm$ SD	1.56 $\pm$ 1.79	5.94 $\pm$ 2.66	1.14 $\pm$ 0.40	2.71 $\pm$ 1.90

Acropora reefs:

Average percent cover of all *Acropora* species combined (*A. cervicornis*, *A. palmata*, and *A. prolifera*) for the sampled St. Thomas sites ranged from a low of 5.8% at Caret Bay to a high of 13.0% at Hans Lollik. Percent cover of *Acropora* was not significantly different between near-shore and mid-shelf sites (Figure 22). Percent cover of *A. cervicornis* ranged from a low of 0.3% at Hans Lollik to a high of 6.1% at Botany Bay. Percent cover of *A. palmata* ranged from a low of 1.6% at Botany Bay to a high of 12.6% at Hans Lollik. Percent cover of *A. prolifera* ranged from 0% at Botany Bay, Caret Bay, and Inner Brass Island to 6.4% at Coculus Point. No significant differences were found between near-shore and mid-shelf reefs for percent cover of any *Acropora* species (Figure 23). For *A. cervicornis*, colonies with an estimated volume between 15,626 cm^3 and 125,000 cm^3 were the most common size class at all sites. Caret Bay had the greatest number of colonies with an estimated volume <1000 cm^3 and Flat Cay was the only site that had colonies with an estimated volume >1×10^6 cm^3 (Figure 24). For *A. palmata*, colonies with an estimated volume between 125,000 cm^3 and 1×10^6 cm^3 were the most common size class at all sites, except for Coculus Point, where colonies with an estimated volume between 1,000 cm^3 and 15,626 cm^3 were the most common size class and Inner Brass Island, where colonies with an estimated volume between 15,626 cm^3 and 125,000 cm^3 were the most common size class. Inner Brass Island was the only site with colonies with an estimated volume <1000 cm^3 and Coculus Point and Inner Brass Island were the only sites without colonies with an estimated volume >1×10^6 cm^3 (Figure 25). *A. prolifera* was the least abundant of the *Acropora* species at all sites. No colonies were observed at Caret Bay, and only five colonies were observed at Inner Brass Island. Divers were able to find and assess 25 colonies at all other sites, but this required more time and effort than for the other *Acropora* species. Colonies with an estimated volume between 15,626 cm^3 and 125,000 cm^3 were the most common size class at most sites with *A. prolifera*, the exceptions being Hans Lollik, where colonies with an estimated volume between 1,000 cm^3 and 15,626 cm^3 were the most common and Inner Brass Island, where colonies <1,000 cm^3 and between 1,000 cm^3 and 15,626 cm^3 were the most common size classes. No *A. prolifera* colonies with an estimated volume >1 x 10^6 cm^3 were observed at any of the sites (Figure 26).

Inner Brass Island had the lowest *A. cervicornis* tissue mortality of all the sites, with a mean of 8.4% surface area of each colony comprised of dead coral skeleton. Hans Lollik had the highest *A. cervicornis* tissue mortality, with a mean of 30.4% of the surface area of each colony comprised of dead coral skeleton (Figure 27). *A. palmata* tissue mortality ranged from a low of 11.0% at Inner Brass Island to a high of 37.0% at Caret Bay (Figure 28). *A. prolifera* tissue mortality ranged from a low of 8.4% at Inner Brass Island to a high of 19.2% at Hans Lollik (Figure 29). No significant differences were found for both total and recent tissue mortality for any *Acropora* species between near-shore and mid-shelf sites. *Coralliophila* snail infestation was most common on *A. palmata* at Caret Bay, where snails were observed on 72.0% of the sampled colonies. Snail infestation was lowest on *A. cervicornis* and *A. palmata* at Botany Bay, where no snails were observed on assessed corals (Figure 30). No significant differences in snail infestation were found for any *Acropora* species or all species combined between near-shore and mid-shelf sites. Incidence of white band disease was highest on *A. palmata* at Caret Bay, where 28.0% of the assessed colonies were infected. No white band disease was observed on any *Acropora* species at Botany Bay and no white band disease was observed on *A. cervicornis* and *A. prolifera* at Coculus Point and *A. cervicornis* and *A. palmata* at Flat Cay (Figure 31). No significant differences in the percent of colonies infected with white band disease were found for any *Acropora* species or all species combined between near-shore and mid-shelf sites.

Recruitment density ranged from 0.1 recruits/m^2 at Caret Bay to 1.3 recruits/m^2 at Coculus Point (Table 7). No significant differences in density of *Acropora* recruits were found between near-shore and mid-shelf sites.

Table 7. *Acropora* recruits at St. Thomas sites (n = 10 quadrats for each site).

Site	No. of Recruits/m^2 $\pm$ SD
Botany Bay	0.5 $\pm$ 0.71
Caret Bay	0.1 $\pm$ 0.32
Coculus Point	0.9 $\pm$ 1.29
Flat Cay	0.1 $\pm$ 0.32
Hans Lollik	0.6 $\pm$ 0.52
Inner Brass	0.4 $\pm$ 0.70

Fish Census:

A summary of fish survey effort is presented in Table 8 for St. Thomas. Because no attempt was made to standardize or record belt transect duration, effort by survey type can only be estimated. We recommend that belt transect duration be recorded and standardized when possible in future St. Thomas samplings. Due to the time constraints imposed by the depths of the mid-shelf and shelf-edge sites in St. Thomas, RDS duration cannot be standardized for all sites, but only for sites of similar depths. Therefore, the resulting species richness values can only be compared between sites within the same depth ranges.

Table 8. Summary of fish census effort on St. Thomas.

Survey Method	Site	Survey Date	Total No. of Replicates	Total Survey Time (min)	Ave. Time per Replicate (min)
Belt Transect	Benner Bay	8/5/03	10	NR	~ 7.5
	Black Point	10/2/03	10	NR	~ 7.5
	Seahorse Cottage Shoal	6/12/03	7	NR	~ 7.5
	Flat Cay	6/4/03	10	NR	~ 7.5
	Grammanik Bank	6/17/03	10	NR	~ 7.5
	Red Hind Bank	6/16/03	10	NR	~ 7.5
Roving Diver	Benner Bay	8/5/03	3	180	60
	Black Point	9/11/03	3	180	60
	Seahorse Cottage Shoal	6/18/03	3	135	45
	Flat Cay	6/4/03	3	135	45
	Grammanik Bank	6/18/3	4	60	15
	Red Hind Bank	6/16/03	4	60	15

A total of 5,117 fish representing 87 species and 22 families were observed in 67 belt transects. Fish abundance was variable within and between sites (Figure 32A). The highest densities of fish were observed at FC and SC, both mid-shelf reef sites. Species richness was variable within and between sites, but was again highest on the mid-shelf reefs (Figure 32B). The site with the greatest number of fish species observed on belt transects was FC (54 species) and the site with the fewest was BP (36 species). Community diversity was less variable between sites, but was slightly lower on the shelf-edge sites, GB and RH (Figure 32C).

On roving diver surveys a total of 125 species representing 35 families were observed. Table 9 presents a summary of the total number of species observed and species richness values for each site, using both belt transects and RDS. Species richness values were higher on RDS than belt transects at all sites. Values for RDS were not comparable across reef sites due to differences in the duration of the surveys.

Table 9. Comparison of Species Richness across sites off St. Thomas, using belt transect data and roving diver survey (RDS) data.

Site	Belt Transects			RDS		
	Total Survey Time (min)	Total No. Species	Ave. Species Richness (St. Dev.)	Total Survey Time (min)	Total No. Species	Ave. Species Richness (St. Dev.)
BB	~75	38	16.3 (1.9)	180	83	59.7 (2.9)
BP	~75	36	15.6 (3.3)	180	64	47.3 (4.0)
SC	~75	49	18.0 (5.6)	135	72	57.7 (2.1)
FC	~75	54	22.7 (3.2)	135	84	60.7 (1.5)
GB	~75	43	15.4 (3.2)	45	58	36.8 (2.5)
RH	~75	42	13.6 (2.9)	45	68	39.5 (6.4)

Reef fish communities were compared among sites based on taxonomic composition (species presence or absence) using Jaccard's index of similarity. This was done separately for belt transects and RDS (Figure 33). Jaccard's indices computed with data from belt transects indicated that fish communities at BP, SC and FC shared relatively high similarity (0.47 to 0.56) and GB was similar to RH (0.50). The fish community at the two shelf-edge sites, GB and RH, were most dissimilar to the two near-shore sites, BB and BP (0.31 to 0.40). Similarity indices for roving dives were highest between the near-shore and mid-shelf sites (0.51 to 0.64), and between shelf-edge sites (0.58). The most dissimilar site was GB, which produced relatively low similarity indices (0.35 to 0.44) when compared to all sites except RH.

The majority of fish observed in 2003 were small or intermediate in size, with most (2,748 fish or 54.1%) falling into the second smallest size category (5-10 cm). Fish in the next larger size category (10-20 cm) made up an additional 22.8% (1159 fish) of the individuals seen. Very small fish (<5 cm) were recorded in less abundance (716 fish or 14.1%) and individuals in the largest size categories (20-30 cm, 30-40 cm and >40 cm) were less abundant still, comprising 5.2%, 3.1% and 0.7% of the observations respectively.

Reef fish communities among sites were compared based upon ten families (Figure 34). Planktivorous pomacentrids predominated at all sites except BB and RH, which were dominated by invertebrate-feeding labrids and planktivorous labrids respectively. Labrids were fairly evenly distributed on BB between yellowhead wrasse (*Halichoeres garnoti*), clown wrasse (*H. maculipinna*) and slippery dicks (*H. bivittatus*). On RH, labrids were almost exclusively represented by the creole wrasse (*Clepicus parrae*). The highest densities of pomacentrids were observed on FC, where blue chromis (*Chromis cyanea*) and brown chromis (*Chromis multilineata*) represented 78% of that family observed. Parrotfishes (Scaridae), which represent the most prominent group of herbivores, had the highest densities at BP, SC and FC. They were most commonly represented by the princess parrotfish (*Scarus taeniopterus*) and striped parrotfish (*Sc. iserti*). Stoplight parrotfish (*Sparisoma viride*) and redband parrotfish (*Sp. aurofrenatum*) were also relatively common on the near-shore sites, BB and BP. The more rare scarid species observed on some sites were the redtail parrotfish (*Sp. chrysopterum*), the yellowtail parrotfish (*Sp. rupripinne*) and the queen parrotfish (*Sc. vetula*). Acanthurids (tangs) were observed most frequently at BB. Among acanthurids, blue tangs (*Acanthurus coeruleus*) and the ocean surgeons (*A. bahianus*) were the most common. Acanthurid and scarid relative densities were reciprocal on sites BB, BP and SC

(Figure 34C and 34D). This pattern is found in fish surveys off St. Croix as well, both in the present study, and in 2002 (Toller).

The remaining families (Figure 34E-J) were observed at much lower densities at most sites. Figure 34E represents the commercially important serranids, the groupers. These were uncommon at all sites but were most frequently encountered on the shelf-edge sites, GB and RH. Graysby (*Cephalopholis cruentatus*), the smallest and most common grouper, were observed on all sites. Red hind (*Epinephelus guttatus*) and Nassau grouper (*E. striatus*) were uncommon to rare, but were observed on nearshore (BP) mid-shelf (FC) and shelf-edge sites (GB, HB). Yellowfin (*Mycteroperca venenosa*) and tiger groupers (*M. tigris*) in contrast, were only observed on the offshore sites, GB and RH. Lutjanids (snappers) were also observed at low densities. Only the yellowtail snapper (*Ocyurus chrysurus*) was encountered relatively frequently and on all sites. Schoolmaster snapper (*Lutjanus apodus*) were observed infrequently on mid-shelf (SC) and shelf-edge reefs (GB, HB). Mutton snapper (*L. analis*), cubera snapper (*L. cyanopterus*), gray snapper (*L. griseus*), dog snapper (*L. jocu*), mahogany snapper (*L. mahogoni*) and lane snapper (*L. synagris*) were observed rarely. The greatest number and variety of snappers was seen at SC, with six species observed. Fish surveys at Seahorse Cottage Shoal took place two days prior to the full moon in June. During the full moon in May, large numbers of Lane and Gray snappers were observed during a concurrent UVI study. Collected snappers possessed hydrated oocytes, indicating imminent spawning and confirming Seahorse Cottage Shoal as a snapper spawning aggregation site. Continued monitoring at this site is essential, especially as Seahorse Cottage Shoal is under no fisheries protection. We recommend future samplings at Seahorse Cottage Shoal be performed near the full moon in May during snapper spawning aggregations. Relatively high snapper densities at BP represented only one species, the yellowtail snapper (*O. chrysurus*). Haemulids (grunts) were again most common and most diverse at the mid-shelf site, SC, followed by one of the shelf-edge sites, RH. The French grunt (*Haemulon flavolineatum*) was the most abundant of the family and occurred at all six reef sites. Chaetodontids (butterflyfish) were common on the mid-shelf reef sites (SC, FC) and the shelf-edge sites (GB, RH). Foureye butterflyfish (*Chaetodon capistratus*) were by far the most common of the chaetodontids and occurred on all reef sites. Banded butterflyfish (*C. striatus*) were less common, but were observed on five of six sites. Longsnout butterflyfish were observed only on the shelf-edge sites (GB, RH). Chaetodontid densities have been suggested to indicate levels of reef health (Crosby and Reese, 1996). In our study, on both belt transects and RDS, chaetodontid observations were highest on mid-shelf and shelf-edge reef sites. The increased distance from shore and decreased effects of land based runoff and pollution may be reflected in densities of these fish. The commercially exploited angelfishes were very uncommon but were present on all sites. They were most common and most diverse on HB (5 species) and FC (4 species). The rock beauty (*Holacanthus tricolor*) occurred on all sites and was the only representative of the family on BB and GB. The family Balistidae (triggerfishes) was rare to absent on all sites except GB. Balistids were represented by a single species, the black durgon (*Melichthys niger*) at GB, by queen triggerfish (*Balistes vetula*) at FC and SC, and by one orangespotted filefish (*Catherines pullus*) at BP.

As with the St. Croix fish data, results from RDS and belt transects were combined in an attempt to quantify the relative abundance of 12 commercially important, rare and/or vulnerable species on the St. Thomas reef sites (Table 10). Of those species, the red hind (*E. guttatus*) was seen on all sites, and the three largest groupers, the Nassau (*E. striatus*), yellowfin (*M. venenosa*) and tiger (*M. tigris*) were observed on both shelf-edge reefs (GB and HB). The most rare snappers, dog (*L. jocu*) and cubera (*L. cyanopterus*) were observed on the shelf-edge sites as well, and the mutton snapper (*L. analis*) was seen on one near-shore site (BB), one mid-shelf site (SC) and one shelf-edge site (RH). Hogfish (*Lachnolaimus maximus*) were observed on only one site (SC) and the rainbow parrotfish (*Scarus guacamacia*) on another (BB).

Table 10. Abundance of 12 commercially important, rare and/or vulnerable fish species on St. Thomas.

Site	Method	Total Survey Time (min)	Relative Fish Abundance*											
			Nassau grouper	yellowfin grouper	yellowmouth grouper	tiger grouper	red hind	cubera snapper	mutton snapper	dog snapper	hogfish	rainbow parrotfish	blue parrotfish	midnight parrotfish
Benner Bay	belt*	75**	-	-	-	-	-	-	-	-	-	-	-	-
	RDS***	60	-	-	-	-	1.7(2,1)	-	0.7(2,0)	-	-	1.3(2,0)	-	-
Black Point	belt	75	1	-	-	-	4	-	-	-	-	-	-	-
	RDS	60	2.0(2,2)	-	-	-	0.7(1,0)	-	-	-	-	-	-	-
Seahorse Cottage	belt	53	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	45	-	-	-	-	0.7(1,0)	-	2.7(3,2)	-	1.0(2,1)	-	-	-
Flat Cay	belt	75	1	-	-	-	2	-	-	-	-	-	-	-
	RDS	45	0.3(1,0)	-	-	-	0.7(1,0)	-	-	-	-	-	-	-
Grammanik Bank	belt	75	1	-	-	3	5	4	-	-	-	-	-	-
	RDS	15	0.5(2,0)	1.0(2,0)	-	0.5(2,0)	1.0(2,0)	3.0(3,3)	-	-	-	-	-	-
Red Hind Bank	belt	75	-	1	-	3	5	-	3	-	-	-	-	-
	RDS	15	0.5(2,0)	0.8(3,0)	-	0.5(2,0)	1.0(2,0)	-	0.8(2,0)	0.8(2,0)	-	-	-	-

* belt transect occurence reported as total number of fish observed over 10 repetitive surveys (except SC with 7 repetitive surveys).
**Belt transect survey time was estimated to average 7.5 minutes/survey
***RDS occurances reported as mean Abundance Index (AI) over 3 or 4 repetitive surveys with maximum and minimum AI in parentheses.
AI: 0=no fish, 1=1fish, 2=2-10 fish, 3=11-100 fish, 4=101-1000 fish

Summary and Discussion

St. Croix

On St. Croix, turf algae covering dead coral was the dominant substrate at most sampled sites, comprising greater than 50% of the substrata at six of the eight sites. The percent cover of other benthic organisms ranged from 6.6% to 35.9% for living hard coral, 0.45% to 47.0% for macroalgae, 0.22% to 3.63% for sponges, and 0% to 5.62% for gorgonians. Coral species composition was similar between most sites, with twelve coral species representing 98% of the coral community. Coral diversity (H') varied between 0.52 and 2.28 between sites. Coral condition varied between sites with incidence of coral disease and bleaching ranging from 0% to 7.6% and 0% to 14.0%, respectively. *Diadema* sea urchins were uncommon and observed on transects at only three of the eight sites.

Annual comparisons showed little change in percent cover of live coral. However, species composition tended to differ between years at all sites. Half of the sampled sites showed increases in the relative abundance of stress tolerant coral species and decreases in the relative abundance of less stress tolerant species, indicating a possible decrease in overall reef quality at these sites. One site (Mutton Snapper) showed a decrease in stress tolerant species and an increase in less stress tolerant species, indicating a possible increase in reef quality at this site. Coral diversity increased at most sites from year one to year three. Percent cover of sponges, gorgonians and sand remained fairly constant between years, with only one site (Buck Island) showing significant changes in percent sponge cover in year three. Due to variations in sampling time, annual comparisons of percent cover turf algae, macroalgae, and disease and bleaching are difficult due to seasonal fluctuations in macroalgal cover and levels of coral disease and bleaching. Percent cover dead coral covered with turf algae showed significant changes in 2003 at three sites (Great Pond, Long Reef, and Sprat Hole) and percent cover of macroalgae also showed significant changes in 2003 at three sites (Buck Island, Long Reef, and Sprat Hole). Sprat Hole showed a significantly lower incidence of disease in year three than in year two. No significant annual differences in bleaching were found. Based upon recommendations from year two, efforts were made to sample all St. Croix sites within the same time period in late spring and early summer. This goal was partially met in year three. Five of the sites were sampled in April and May, while the remaining three sites were sampled in March, July, and September, respectively. Future monitoring efforts will attempt to refine sampling effort further and sample all sites in late May and early June, making temporal comparisons for percent cover turf and macroalgae and disease and bleaching assessments more robust. No significant annual differences in sea urchin density were found.

Fish abundance averaged from approximately 200 to 500 fish per census. The number of fish species observed at the St. Croix sites ranged from 47 to 61 species. The St. Croix fish fauna was numerically dominated by planktivorous wrasses and damselfishes. Parrotfishes and surgeonfishes were the next most abundant families. The commercially important large groupers, snappers, and angelfishes were uncommon to absent at all sites. Triggerfishes were moderately abundant, but dominated by a singe species, the black durgon. The commercially important queen triggerfish was absent at most sites, with only two queen triggerfish observed at Mutton Snapper. The majority of fish observed in year three were small, with most fish $\leq$5 cm. Relatively few large fish (30 – 40 cm) and very few larger fish ($\geq$40 cm) were observed.

Due to differing methods utilized for fish censuses between years (point counts and belt transects), annual comparisons of fish surveys are difficult. Also, previous surveys utilizing point counts and belt transects determined that accurate assessments of commercially important fish species, such as groupers and snappers, are difficult because these fish are typically rare at monitoring sites. In year three, Roving Diver Surveys (RDS) were performed to attempt to more accurately characterize fish communities, but it was determined that the level of RDS replication was insufficient. To better facilitate annual comparisons and characterize St. Croix fish communities, future monitoring efforts will consistently utilize belt transects and increased replication of RDS at all sites.

While no attempt was made to stratify the St. Croix sites based upon depth or distance from shore, the deepest of the sites, Mutton Snapper had the highest fish abundance of all the St. Croix sampled sites. In addition, Mutton Snapper had the highest percent living coral cover and the lowest percent cover of dead coral with turf algae. This site was also the only site that showed decreases in the relative abundance of stress tolerant coral species and an increase in the relative abundance of less stress tolerant corals (i.e. corals within the *Montastraea annularis* complex). While continued monitoring of the established St. Croix sites is vital (especially Jacks Bay and Great Pond, which are within the East End Marine Park) stratification of St. Croix sites based upon such factors as distance from shore and fishing pressure would facilitate the attribution of causal factors to observed changes in reef communities.

St. Thomas

On St. Thomas *Montastraea* reefs, turf algae covering dead coral was the predominant substrate type at three of the six sites, ranging from a percent cover of 15.0% to 45.6% across all sites. Macroalgae was the predominant substrate at two of the sites, ranging from 13.8% to 42.7% across all sites, and living coral was the predominant substrate at one site ranging from 8.3% to 42.0% across all sites. The percent cover of sponges ranged from 2.8% to 9.9% and the percent cover of gorgonians ranged from 0% to 4.0%. There were no significant differences in percent cover for any benthic category between near-shore, mid-shelf, and shelf-edge reefs, but near-shore reefs tended to have lower percent cover of living coral and higher percent cover of dead coral covered with turf algae than both mid-shelf and shelf-edge reefs. The coral reefs of St. Thomas were generally dominated by coral species in the genus *Montastraea*. Near-shore sites tended to have higher percent composition of stress tolerant corals and lower percent composition of less stress tolerant species than the mid-shelf and shelf-edge sites. Coral diversity (H') ranged between 1.20 and 2.26, with deeper sites tending to have lower diversity than shallow sites. Coral condition varied between sites, with incidence of coral disease and bleaching ranging from 1.39% to 17.36% and 0% to 47.78%, respectively. *Diadema* sea urchins were uncommon and observed only at the two near-shore sites. No significant differences in incidence of disease or bleaching and sea urchin density were found between reef systems.

Abiotic factors at the St. Thomas *Montastraea* reefs tended to differ between the sampled mid-shelf site (Flat Cay) and the shelf-edge site (the Red Hind Bank). Current headed predominantly just west of south at Flat Cay and predominantly both north and south at the Red Hind Bank. Current direction at Flat Cay indicated that this reef may be significantly affected by terrigenous stresses, despite the reef's mid-shelf location. Daily mean temperature at Flat Cay tended to be higher than the Red Hind Bank. Higher current speeds occurred from late summer to early winter at both sites and the highest temperatures occurred in September and October at both sites. Sedimentation rates were higher at Flat Cay than the Red Hind Bank for the majority of the study. Abiotic data collected in this study can be used to complement data from the NOAA CREWS station, to be placed at the near-shore reef in Brewer's Bay, St. Thomas.

At the St. Thomas *Acropora* reefs, percent cover of all *Acropora* species combined ranged from 5.8% to 13.0%. Percent cover of *A. cervicornis* ranged from 0.3% to 6.1%, percent cover of *A. palmata* ranged from 1.6% to 12.6%, and percent cover of *A. prolifera* ranged from 0% to 6.4%. Size distribution of colonies of all *Acropora* species varied within and between sites. Tissue mortality ranged from 8.4% to 30.4% of the surface area of each colony comprised of dead coral skeleton for *A. cervicornis*, 11.0% to 37.0% for *A. palmata*, and 8.4% to 19.2% for *A. prolifera* across all sites. *Coralliophila* snail infestation varied within and between *Acropora* species and sites. For *A. cervicornis*, occurrence of white band disease ranged from 0% at Botany Bay, Coculus Point, and Flat Cay to 28.0% at Caret Bay and Inner Brass Island. White band disease on *A. palmata* ranged from 0% at Botany Bay and Flat Cay to 28% at Caret Bay. White band disease on *A. prolifera* ranged from 0% at Coculus Point to 20% at Inner Brass Island. Recruitment density ranged from 0.1 recruits/m^2 to 1.3 recruits/m^2. No significant differences for percent cover, tissue mortality, snail infestation, white band disease, and recruitment density were found between near-shore and mid-shelf *Acropora* reefs.

Fish surveys concentrated on *Montastraea* reefs. No censuses were performed at *Acropora* reefs. Fish abundance averaged from approximately 70 to 120 fish per census. The number of fish species observed at the St. Thomas sites ranged from 36 to 54 species. The St. Thomas fish fauna was numerically dominated by planktivorous damselfishes at all sites except Benner Bay and the Red Hind Bank, which were dominated by wrasses. Parrotfishes and surgeonfishes were also abundant on the sampled St. Thomas reefs. The commercially important large groupers, snappers, angelfishes, and triggerfishes were observed at much lower densities at all sites, but were most frequently encountered on the mid-shelf and shelf-edge sites. Butterflyfish densities were higher at mid-shelf and shelf-edge reefs than at near-shore reefs, indicating higher levels of reef health for mid-shelf and shelf-edge reef systems. The majority of fish observed in 2003 were small or intermediate in size, with most falling into the 5 – 10 cm size category. Relatively few large fish were observed, but were most common at the mid-shelf and shelf-edge sites. Three of the St. Thomas sites monitored in this study have been determined as spawning aggregation areas for grouper (Red Hind Bank, Grammanik Bank) and snapper (Seahorse Cottage Shoal, Grammanik Bank). The Red Hind Bank is within a marine protected area (Red Hind Bank Marine Conservation District), while Seahorse Cottage Shoal and the Grammanik Bank are currently unprotected. Continued monitoring at these sites is vital to detect changes in these ecologically important areas.

Since only two *Montastraea* reefs of each type were sampled in this study, comparisons between near-shore, mid-shelf, and shelf-edge reefs are difficult. We recommend that future monitoring efforts incorporate more replicates of each reef system as resources become available. Also, characteristics of the two sampled mid-shelf reefs (Flat Cay and Seahorse Cottage Shoal) varied significantly, supporting the recommendation that mid-shelf reefs be stratified into two types: shallow mid-shelf reefs associated with cays, and deep mid-shelf reefs not associated with cays. Since other monitoring efforts performed by the University of the Virgin Islands are concentrating on shallow mid-shelf reefs associated with cays, we recommend that future monitoring efforts for this study concentrate on deep mid-shelf reefs not associated with cays. This will allow concurrent monitoring efforts to complement each other to provide a greater understanding of Virgin Islands reef systems.

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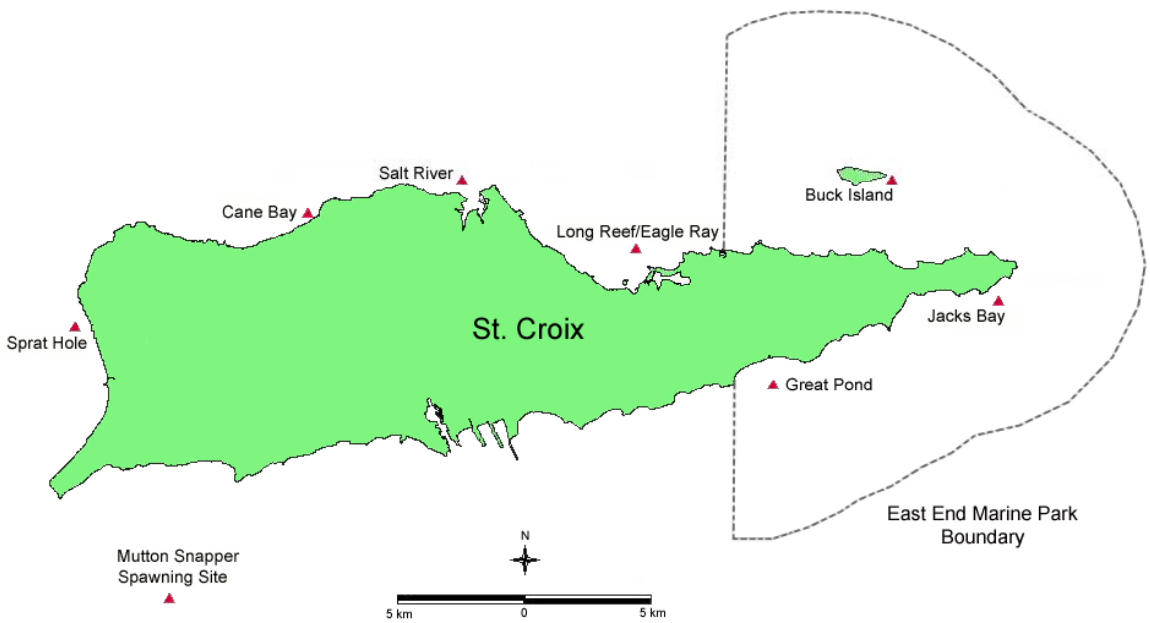


Fig. 1 Locations of monitoring sites in St. Croix, USVI. Great Pond and Jacks Bay are located within the East End Marine Park. Buck Island is located within the Buck Island Reef National Monument.

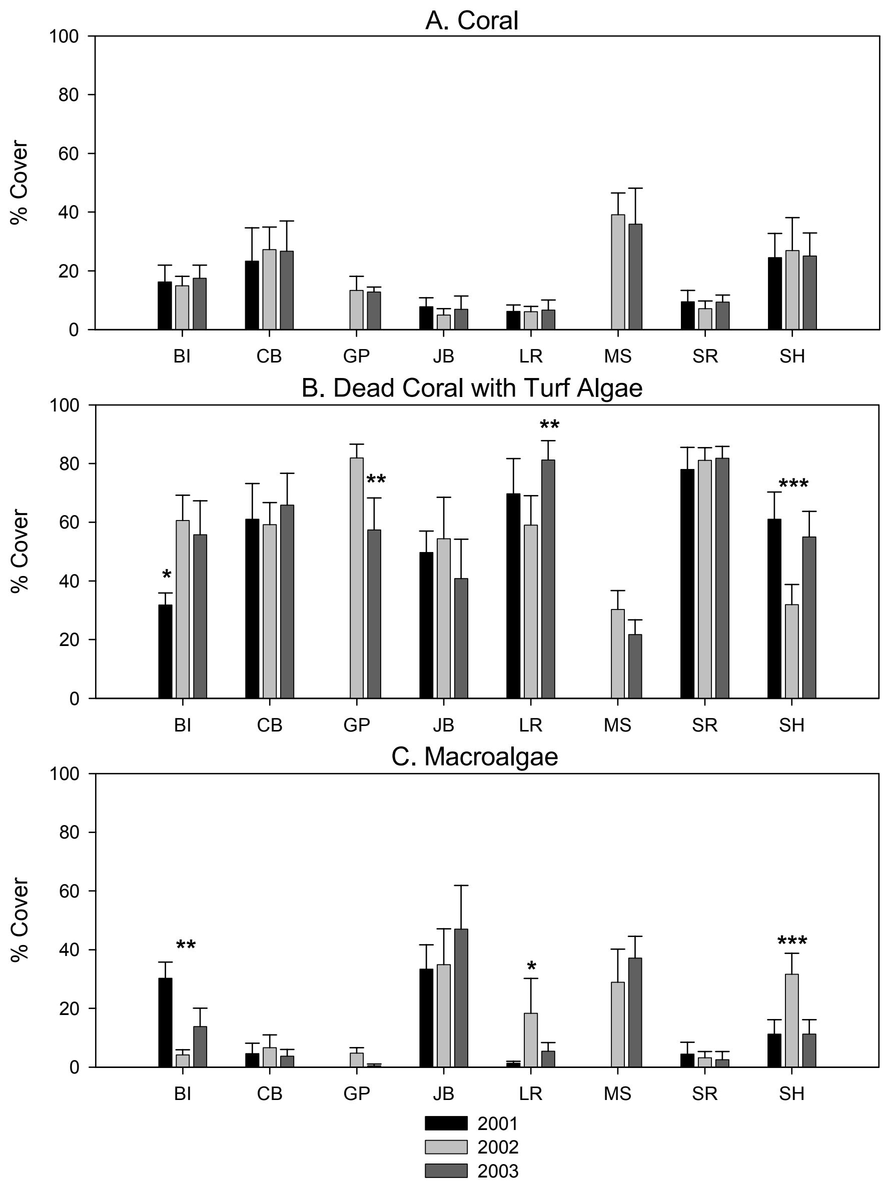


Fig. 2A, B, C Mean percent cover of A. Scleractinian corals, B. Dead coral with turf algae, and C. Macroalgae for the year one, year two, and year three sampling periods at eight monitored sites:
BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray;
MS Mutton Snapper; SR Salt River; SH Sprat Hole.
GP and MS sampling began in 2002. n = 6 transects for all sites, except for n = 3 transects for BI in 2001 and 2002 and n = 5 transects for MS and SH in 2002.
Error bars represent standard deviation. Asterisks denote significant differences:
* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

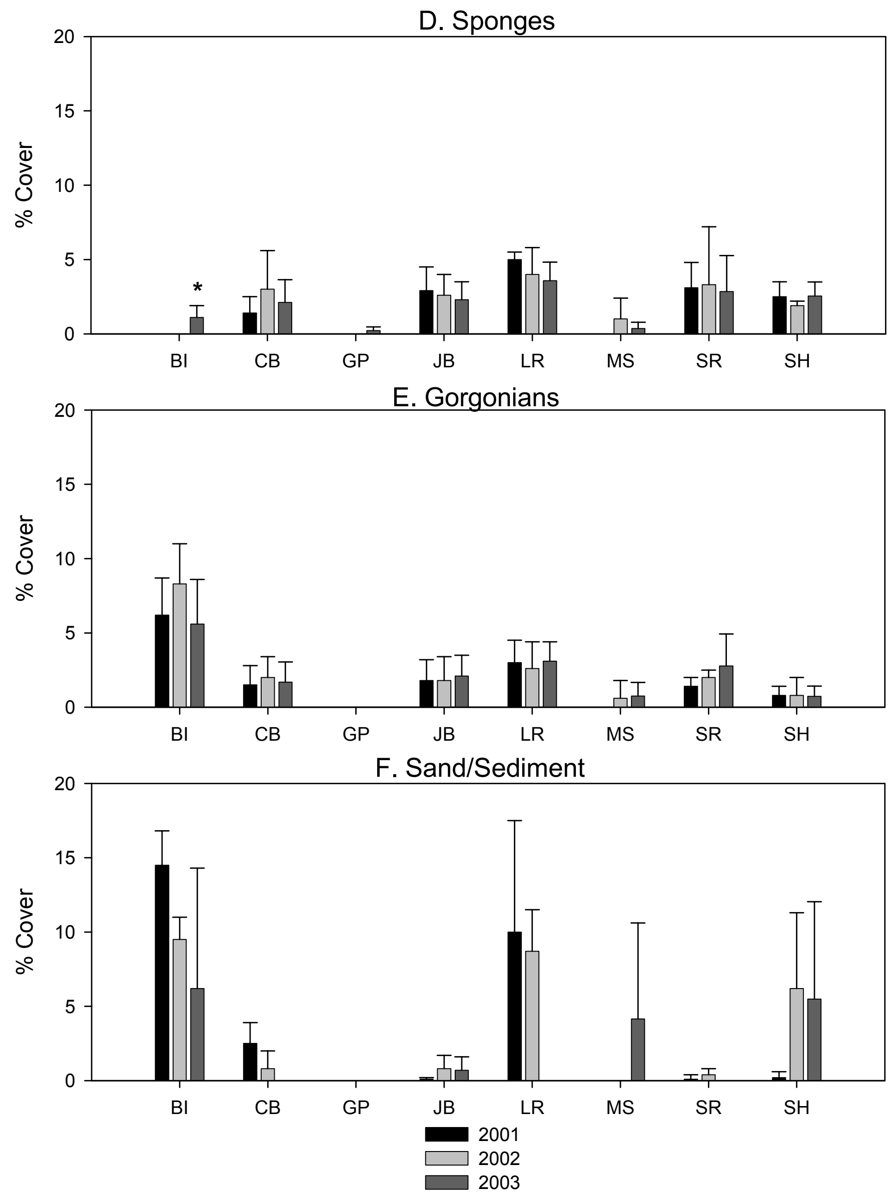


Fig. 2D, E, F Mean percent cover of D. Sponges, E. Gorgonians, and F. Sand/Sediment for the year one, year two, and year three sampling periods at eight monitored sites: BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray; MS Mutton Snapper; SRW Salt River; SH Sprat Hole. GP and MS sampling began in 2002. n = 6 transects for all sites, except for n = 3 transects for BI in 2001 and 2002 and n = 5 transects for MS and SH in 2002. Error bars represent standard deviation. Asterisk denotes significant difference: * = P < 0.05

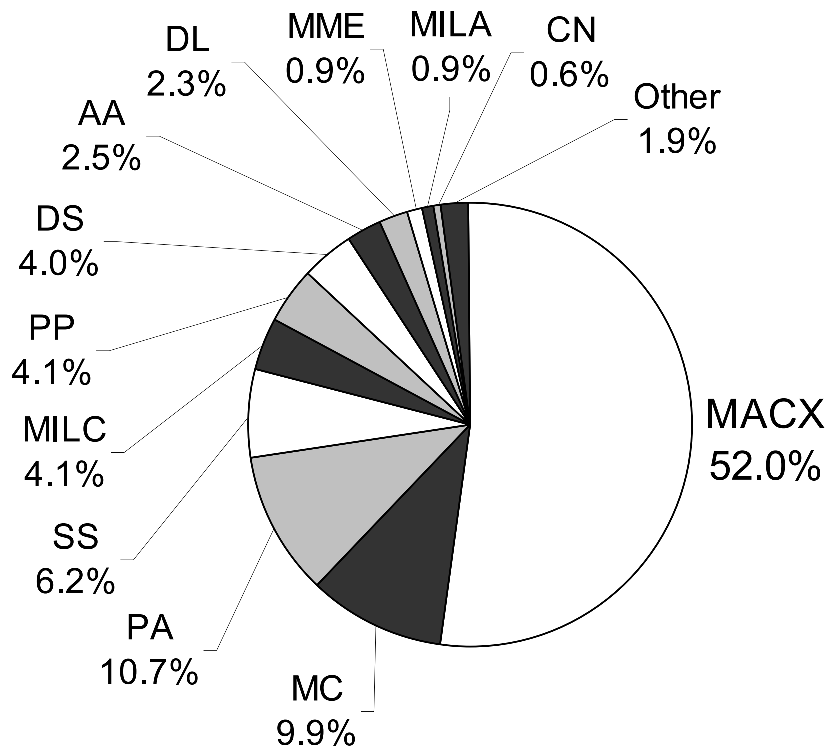


Fig. 3 Percentage coral species composition at all sampled sites in St. Croix, USVI. MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastea siderea*; MILC *Millepora complanata*; PP *Porites porites*; DS *Diploria strigosa*; AA *Agaricia agaricites*; DL *Diploria labyrinthiformes*; MME *Meandrina meandrites*; MILA *Millepora Alcicornis*; CN *Colpophyllia natans.* Other denotes percent of all other coral species combined and includes: *Acropora palmata, Agaricia fragilis, Agaricia lamarcki*, *Eusmilia fastigiata, Madracis mirabilis*, *Mycetophyllia ferox, Mycetophyllia lamarckiana*, and *Stephanocoenia michelinii*.

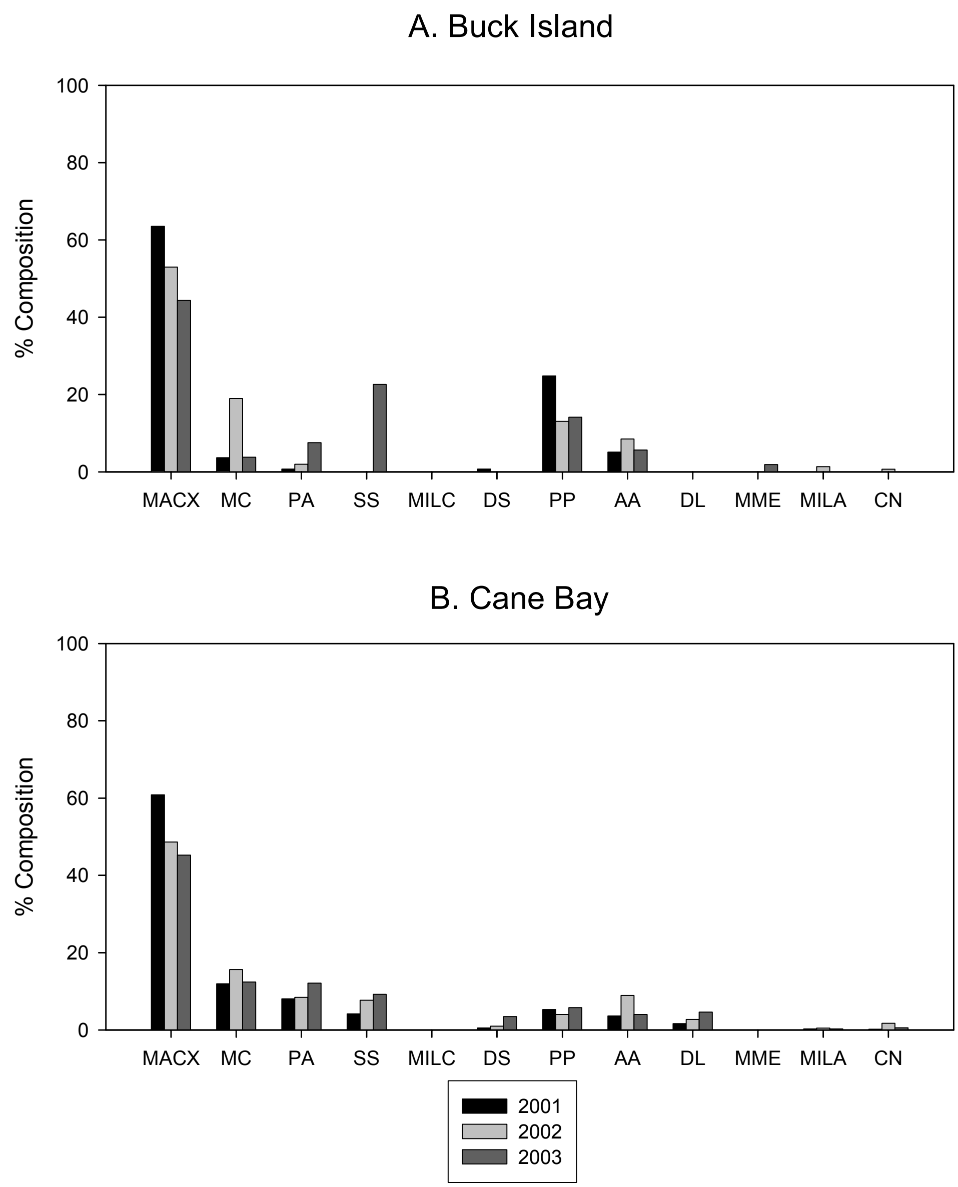
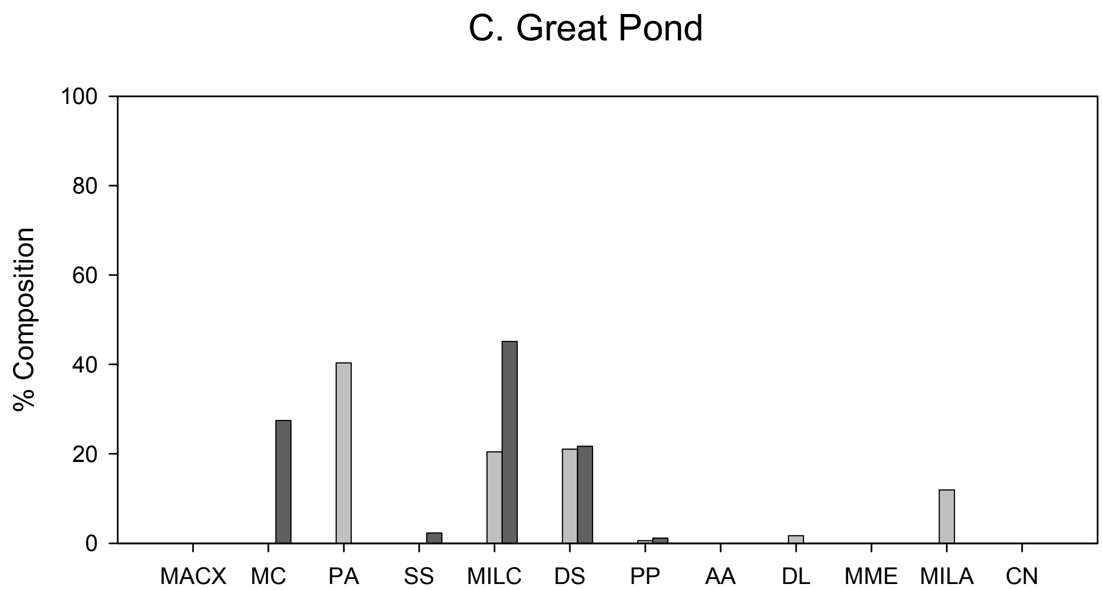


Fig. 4A, B Percent of species composition of living coral cover of the most common coral species at A. Buck Island and B. Cane Bay for years 2001, 2002, and 2003.
Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of dots on all living coral at each site.
MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora complanata*; DS *Diploria strigosa*; PP *P. porites*; AA *Agaricia agaricites*; DL *D. labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophylia natans*.
n = 6 transects for all samplings, except n = 3 transects for Buck Island in 2001 and 2002.



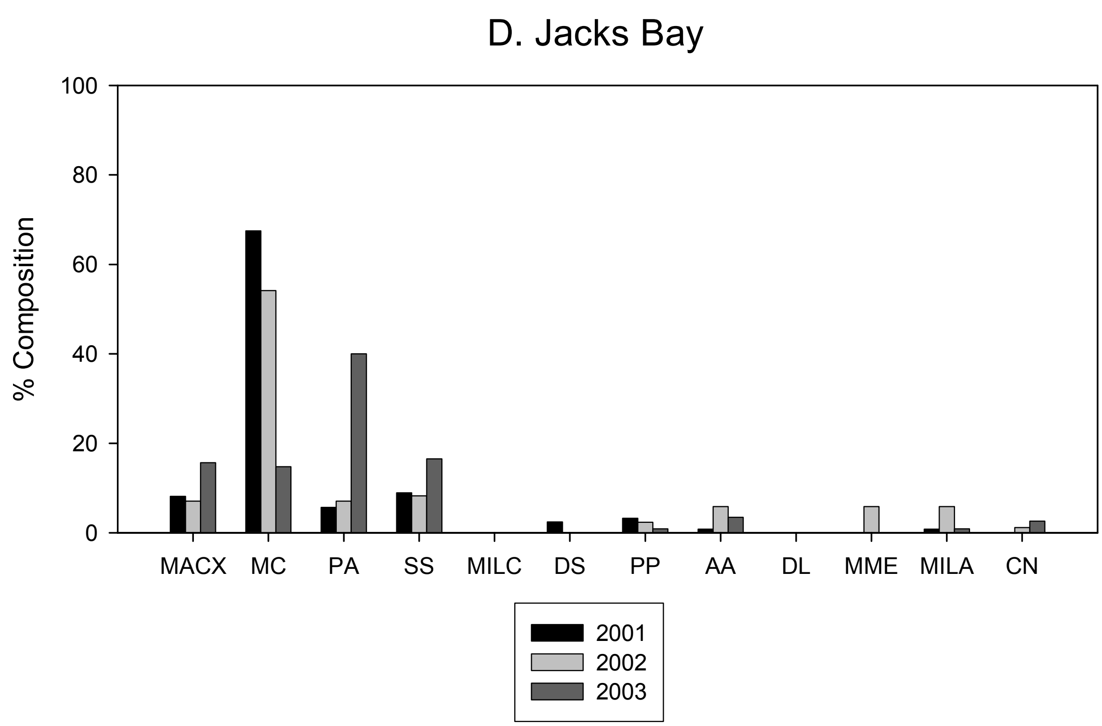
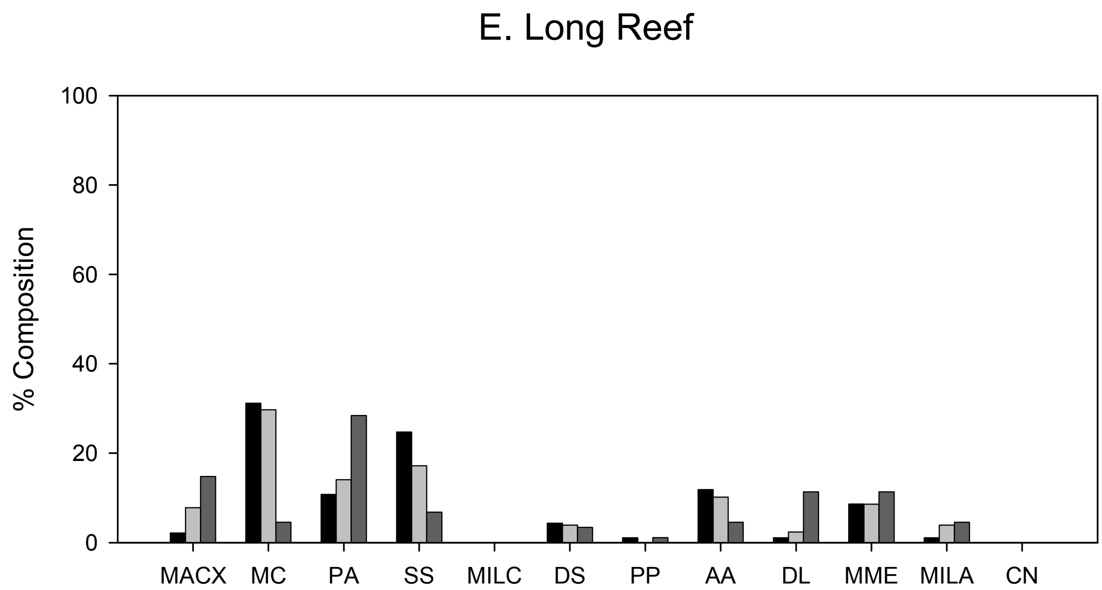


Fig. 4C, D Percent of species composition of living coral cover of the most common coral species at C. Great Pond and D. Jacks Bay for years 2001, 2002, and 2003.
MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora complanata*; DS *Diploria strigosa*; PP *Porites porites*; AA *Agaricia agaricites*; DL *Diploria labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophylia natans*.
n = 6 transects for all samplings. Sampling of GP began in 2002.



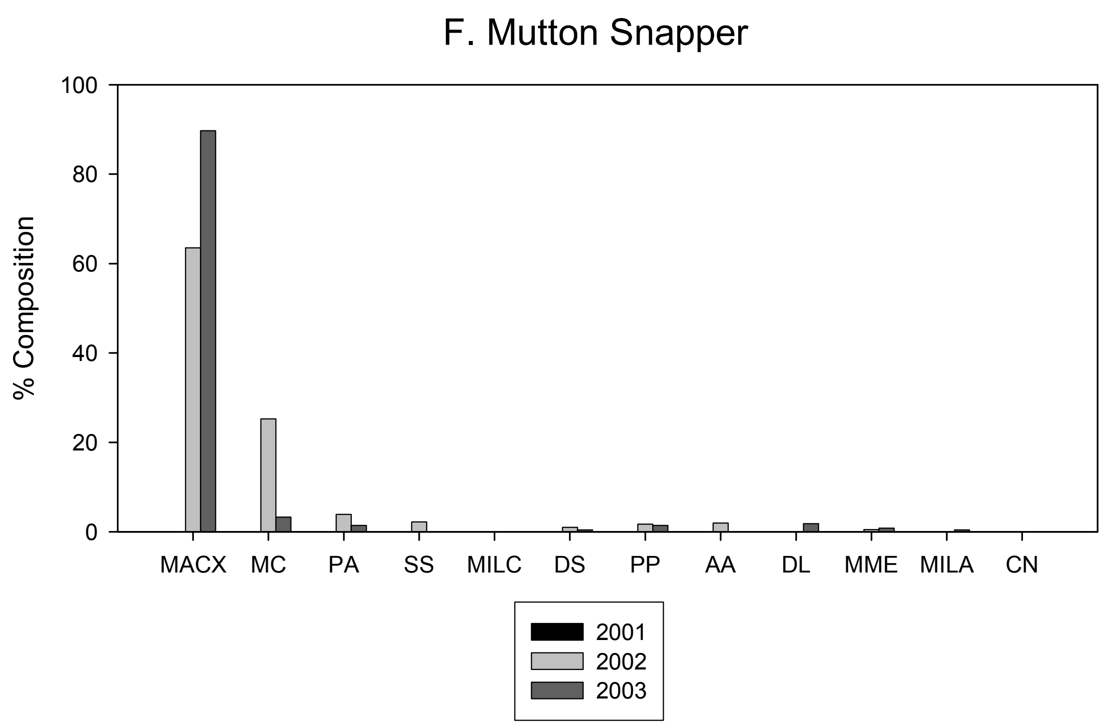


Fig. 4E, F Percent of species composition of living coral cover of the most common coral species at E. Long Reef and F. Mutton Snapper for years 2001, 2002, and 2003.
MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora complanata*; DS *Diploria strigosa*; PP *Porites porites*; AA *Agaricia agaricites*; DL *Diploria labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophylia natans*.
Sampling of MS began in 2002.
n = 6 transects, except for n = 5 transects at MS in 2002.

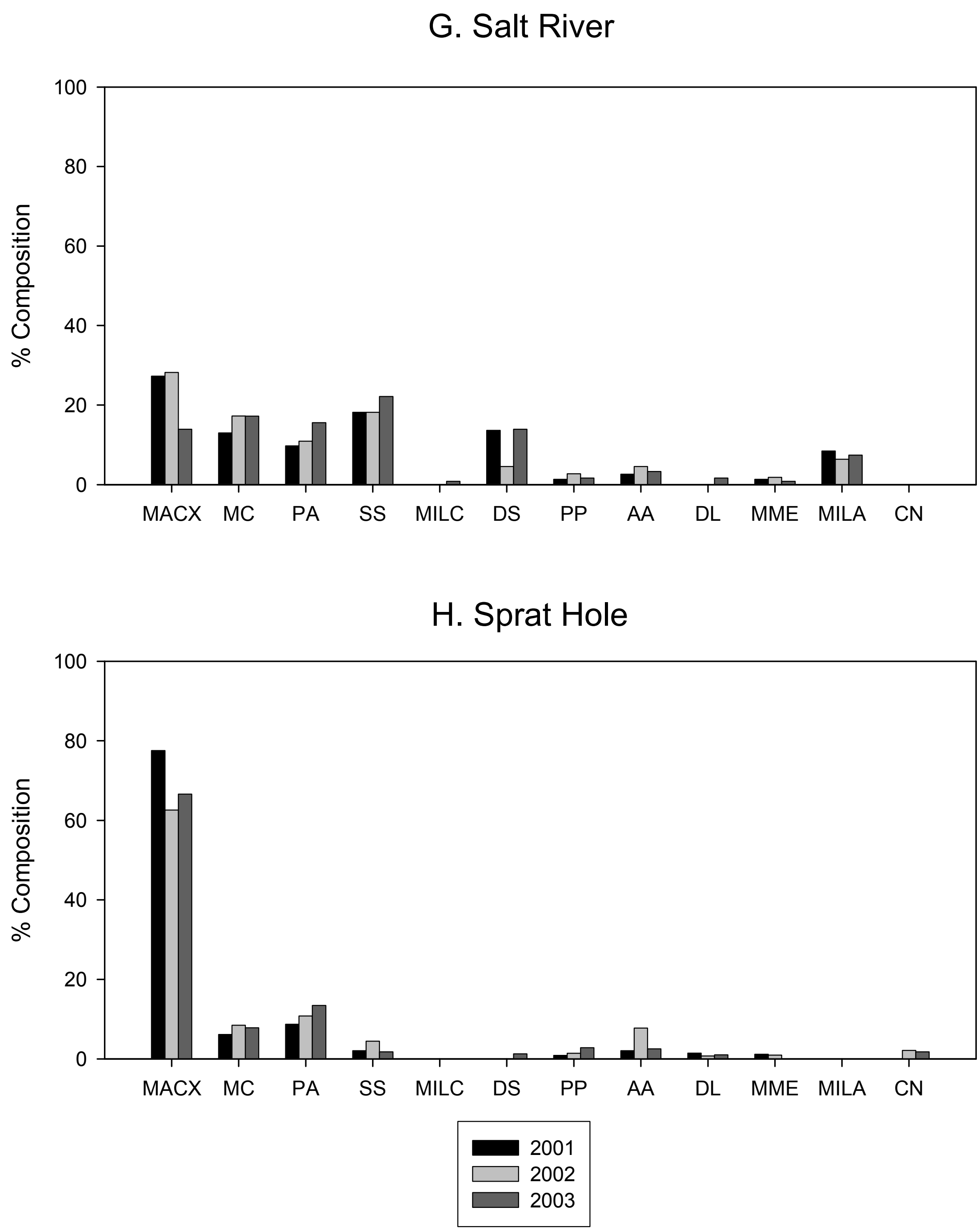


Fig. 4G, H Percent of species composition of living coral cover of the most common coral species at G. Salt River and H. Sprat Hole for years 2001, 2002, and 2003.
MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora complanata*; DS *Diploria strigosa*; PP *Porites porites*; AA *Agaricia agaricites*; DL *Diploria labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophylia natans*.
n = 6 transects for all samplings, except n = 5 transects for SH in 2002.

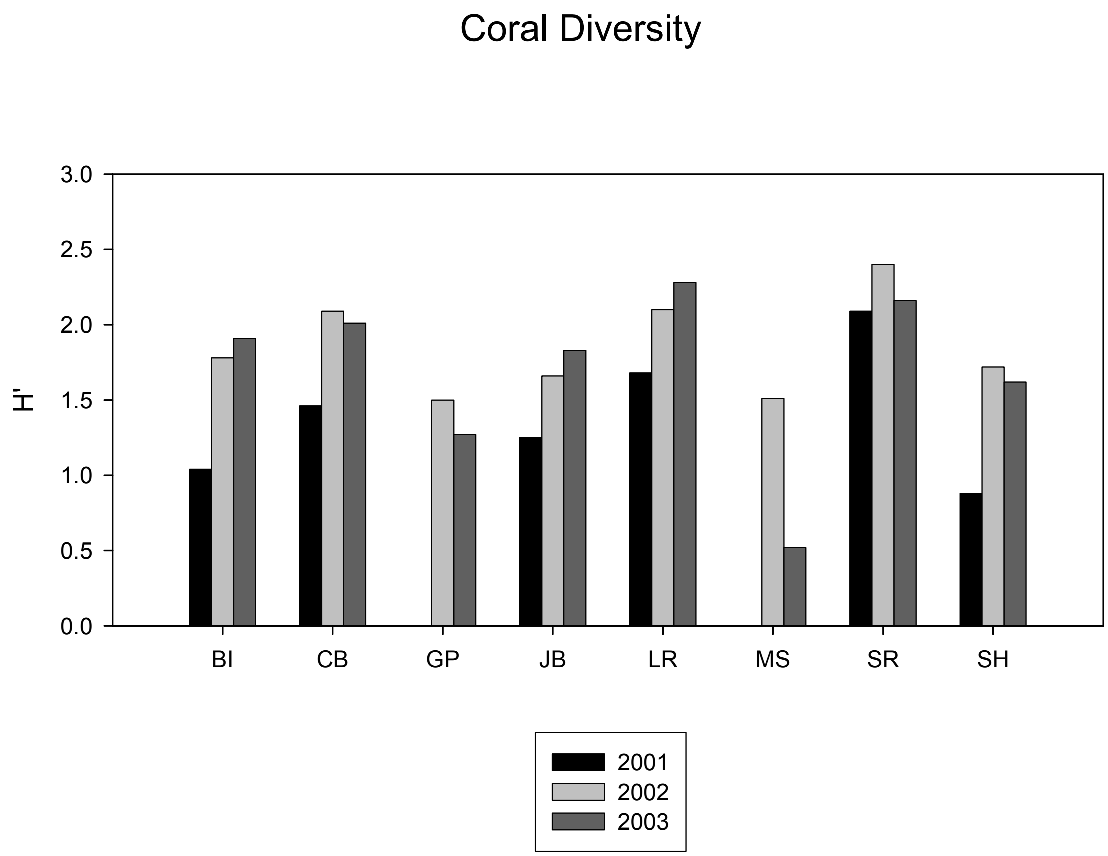


Fig. 5 Shannon - Weaver Diversity Index (H') for corals at eight monitored sites in St. Croix, USVI for years 2001, 2002, and 2003.
BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray; MS Mutton Snapper; SR Salt River; SH Sprat Hole
Sampling for Great Pond and Mutton Snapper began in 2002.

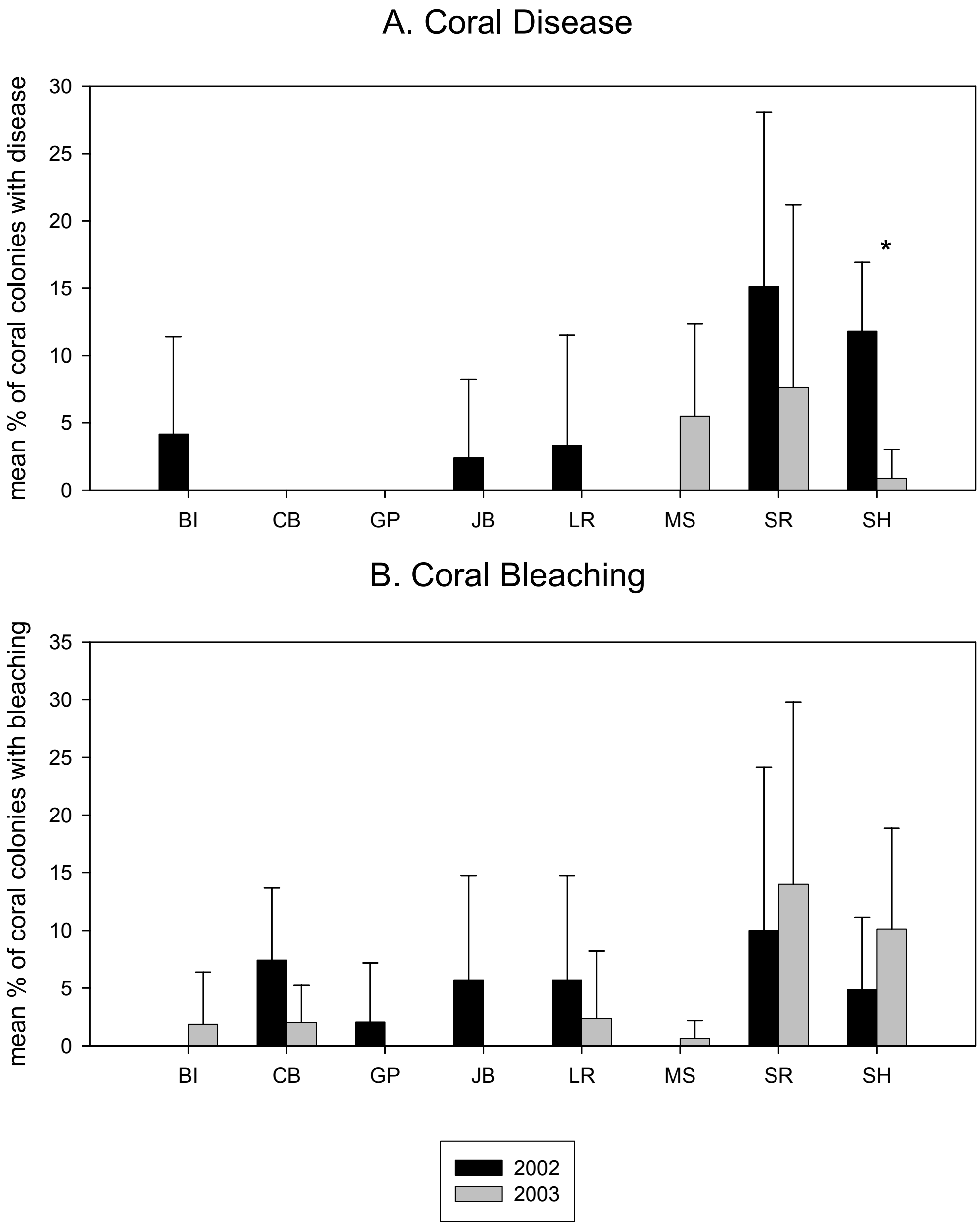


Fig. 6 Mean percentage of A. colonies with disease and B. colonies with bleaching of all coral colonies sampled at each monitoring site. Percentage calculated by dividing the number of diseased and bleached colonies on each transect by the total number of colonies sampled on each transect for each site. BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray; MS Mutton Snapper; SR Salt River; SH Sprat Hole
n = 6 transects for all sites, except for n = 3 transects for BI in 2001 and 2002 and n = 5 transects for MS in 2002. Asterisk denotes significant difference: * = P < 0.01

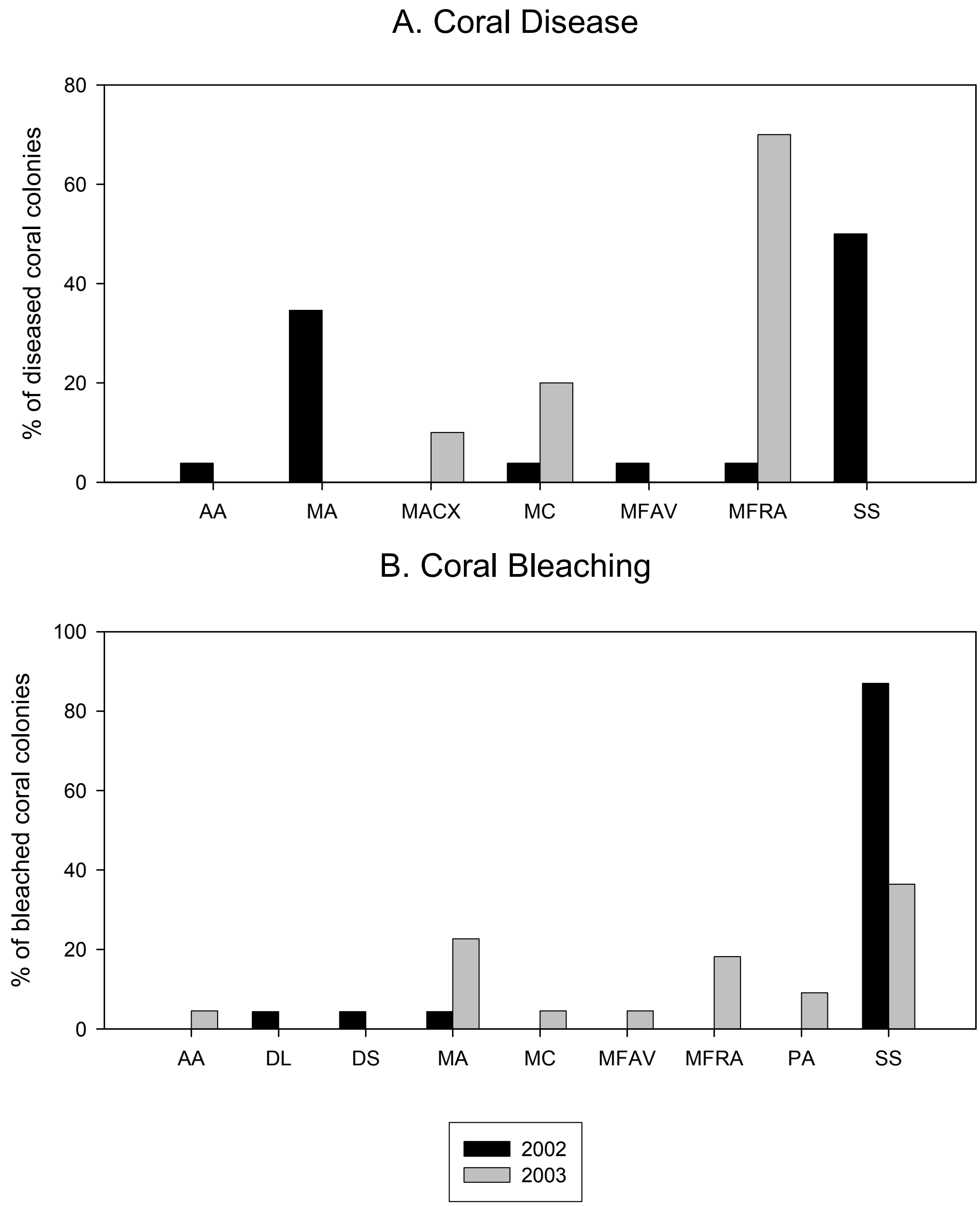


Fig. 7 Percentage of A. diseased colonies and B. bleached colonies of all coral species with disease and bleaching sampled at each St. Croix monitoring site (n = 8).
Percentage calculated by dividing the number of diseased and bleached colonies of each species by the total number of diseased and bleached coral colonies, respectively.
AA *Agaricea agaricites*; DL *Diploria labyrinthiformis*; DS *Diploria strigosa*; MA *Montastraea annularis*; MACX unidentified species belonging to the *M. annularis* complex; MC *M. cavernosa*; MFAV *M. faveolata*; MFRA *M. franksii*; PA *Porites astreoides*; SS *Siderastrea siderea*

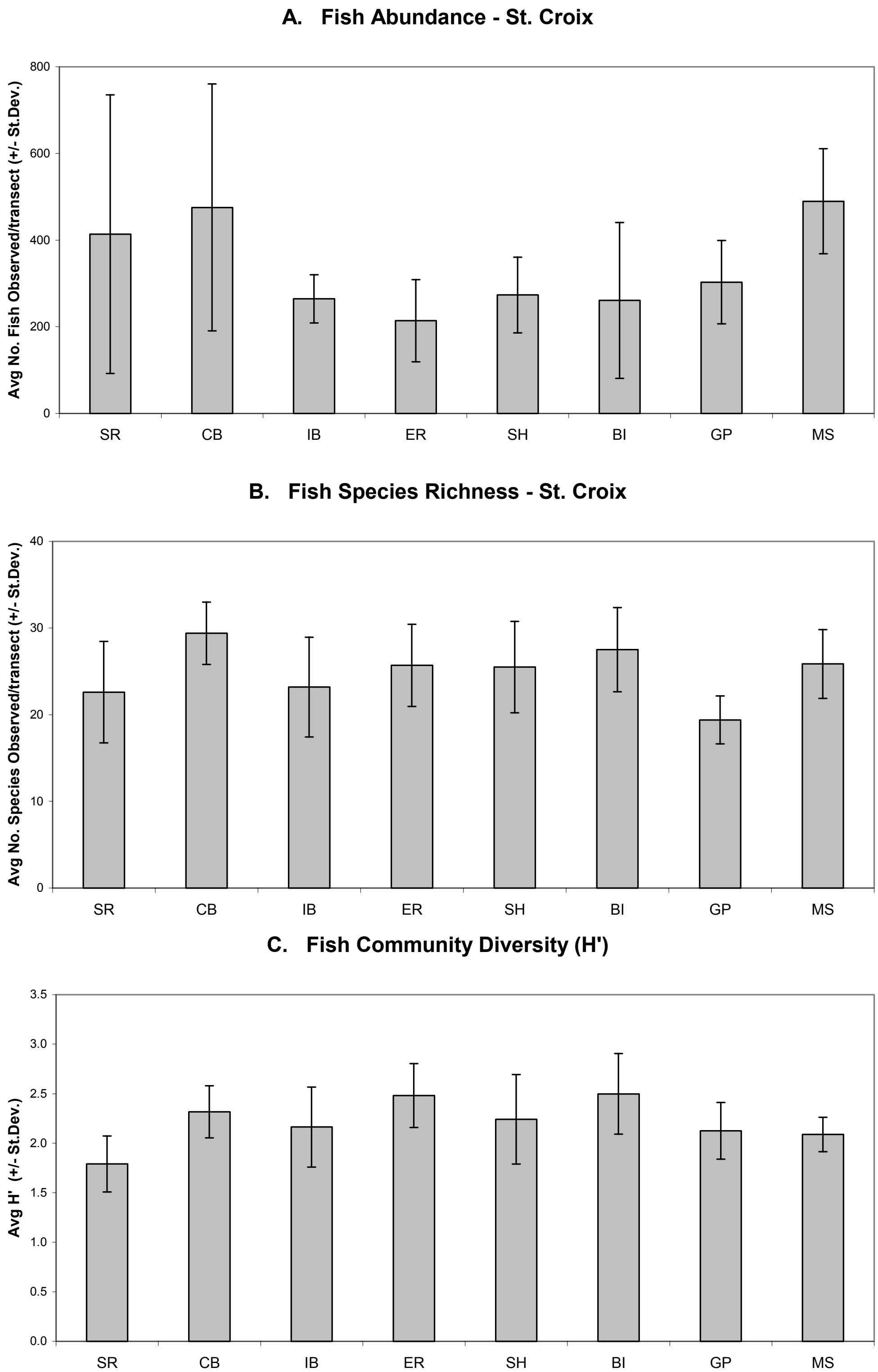


Fig. 8 Reef fish community structure across eight St. Croix reef sites.
A. average abundance; B. average species richness;
C. average Shannon-Weaver diversity (H').

		2.							
		SR	**CB**	**IB**	**ER**	**SH**	**BI**	**GP**	**MS**
1 .	**SR**	-	67 (6,16)	75 (15,24)	65 (11,14)	64 (9,13)	70 (16,19)	69 (6,18)	65 (12,14)
	CB	0.67	-	79 (19,18)	72 (18,11)	70 (15,9)	72 (18,11)	78 (31,17)	75 (22,14)
	IB	0.48	0.53	-	68 (14,8)	73 (18,13)	74 (20,14)	71 (24,11)	77 (24,17)
	ER	0.62	0.60	0.68	-	67 (12,13)	70 (16,16)	70 (23,16)	73 (20,19)
	SH	0.66	0.66	0.58	0.63	-	68 (14,13)	69 (22,14)	68 (15,13)
	BI	0.50	0.60	0.54	0.54	0.61	-	70 (23,16)	75 (22,21)
	GP	0.42	0.39	0.51	0.44	0.48	0.44	-	70 (17,23)
	MS	0.60	0.52	0.47	0.47	0.59	0.43	0.43	-

Above diagonal: Total No. of fish taxa observed at both sites combined,
(No. of unique taxa, site 1, site 2)
Below diagonal: Jacaard's Community Similarity Index

Fig. 9 Fish community similarity indices for St. Croix sites.

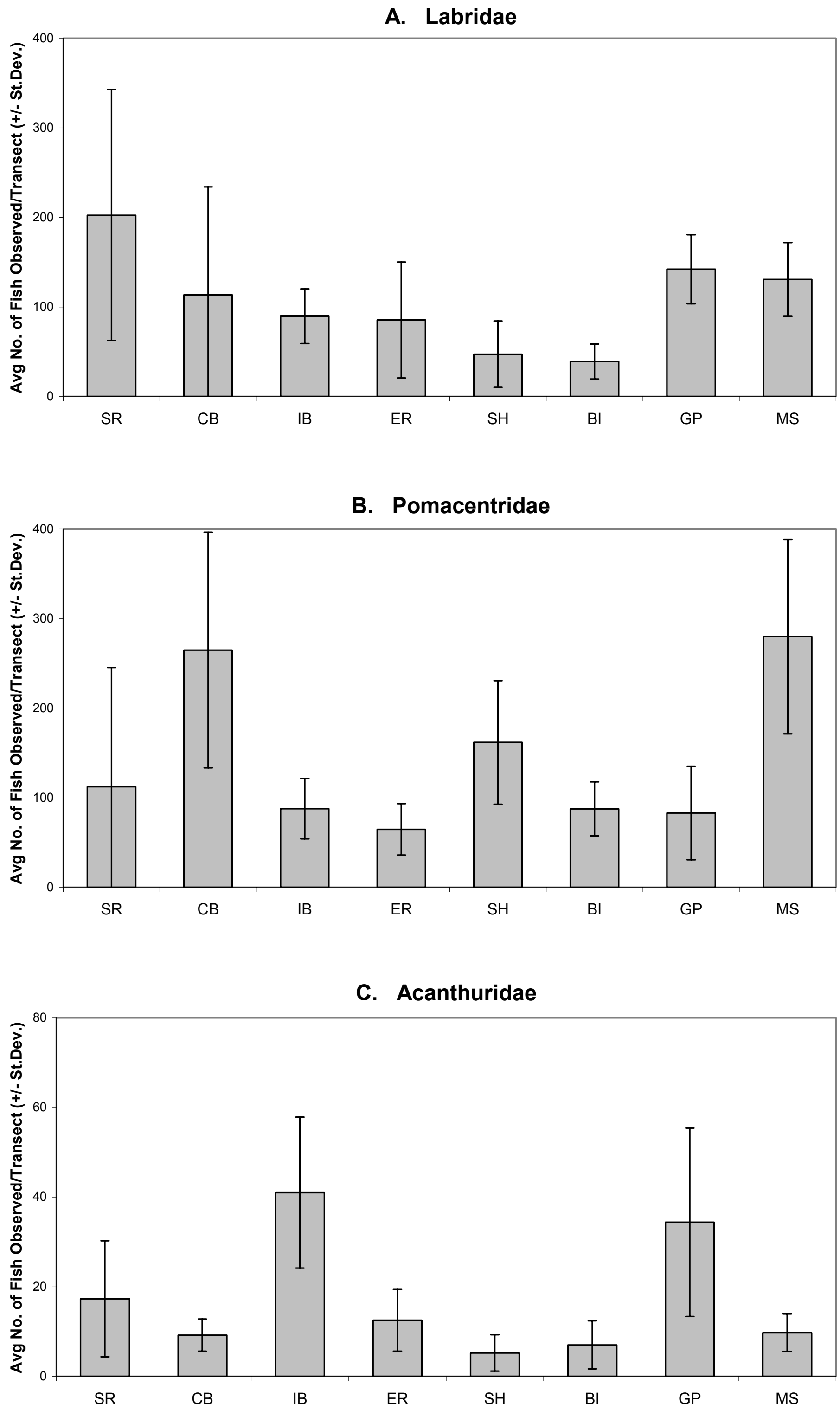


Fig. 10 Fish abundance by family across eight St. Croix reef sites.

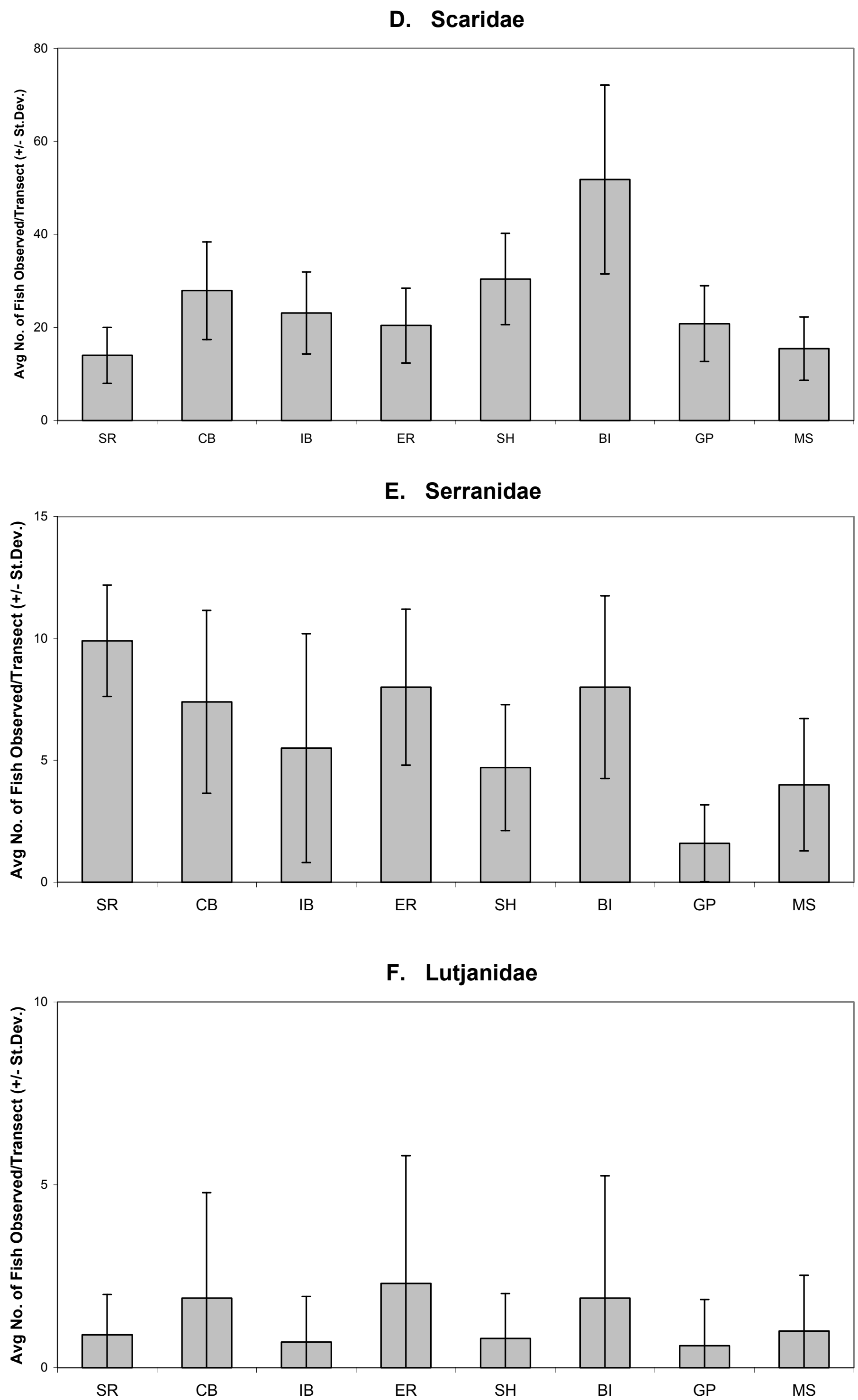


Fig. 10 (cont.) Fish abundance by family across eight St. Croix reef sites.

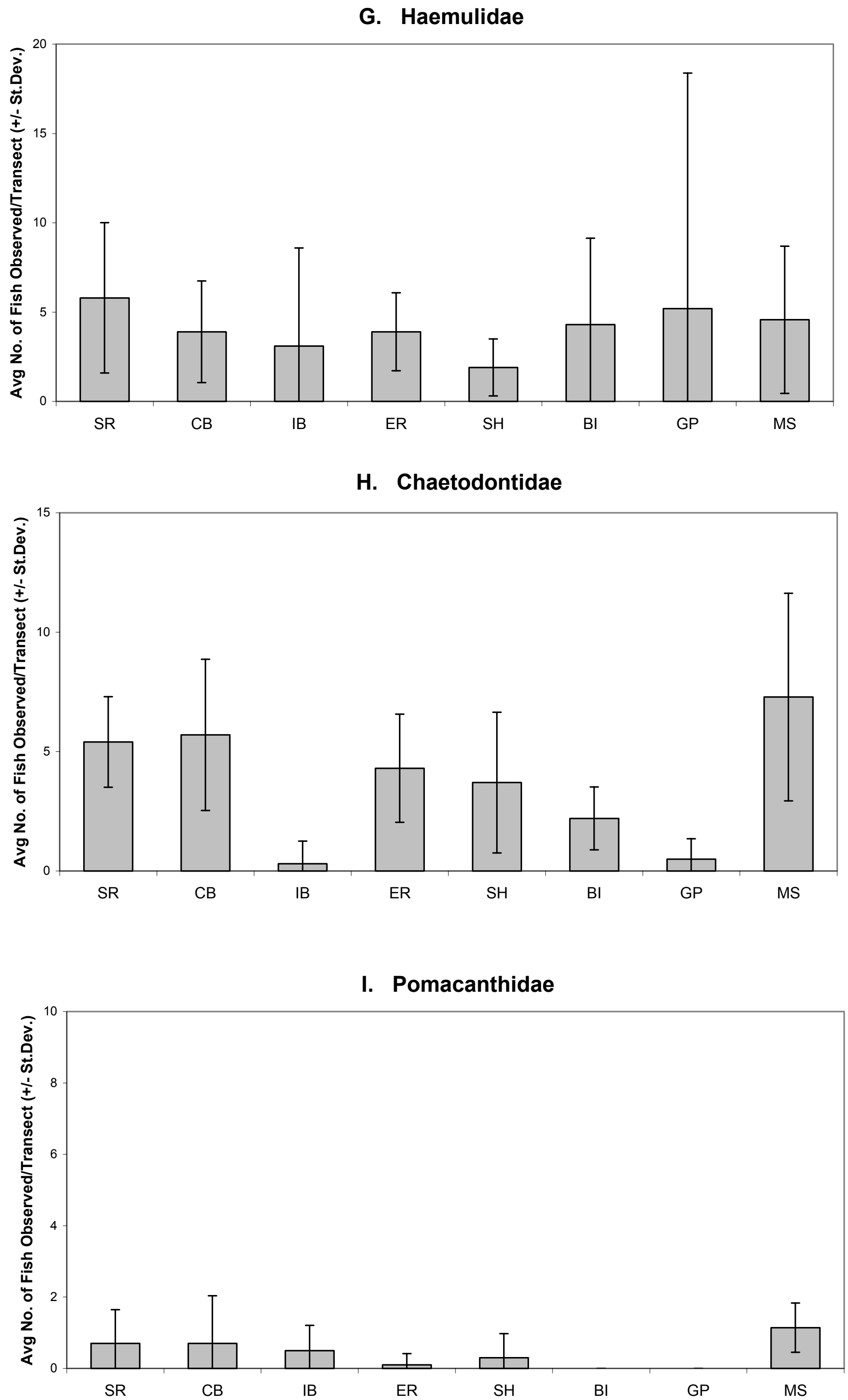


Fig. 10 (cont.) Fish abundance by family across eight St. Croix reef sites.

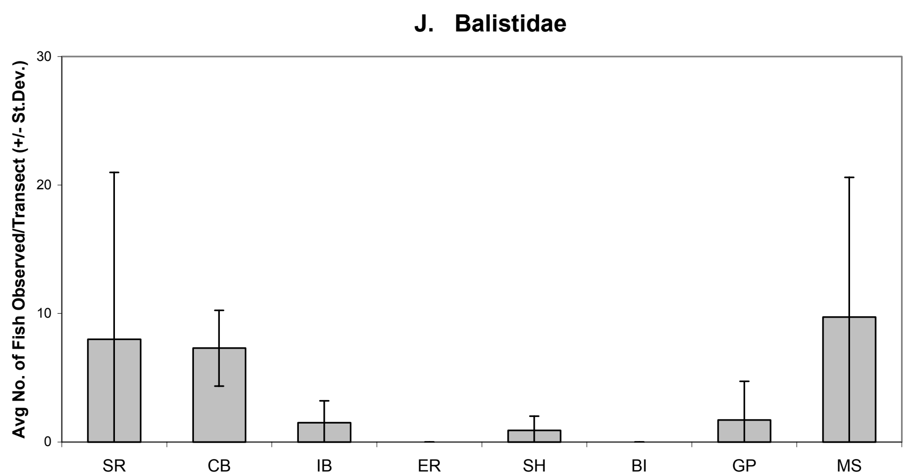


Fig. 10 (cont.) Fish abundance by family across eight St. Croix reef sites.

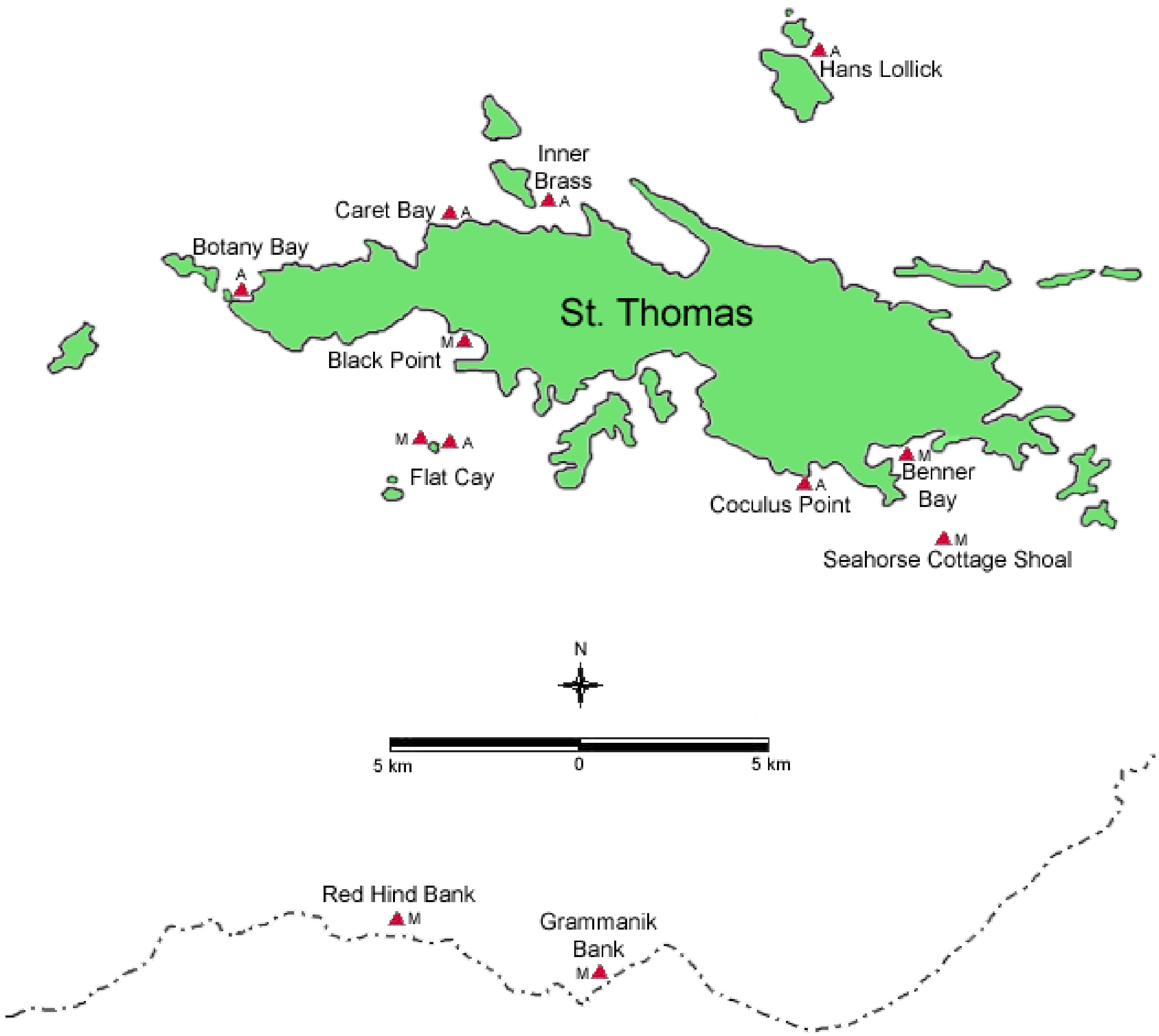


Fig. 11 Locations of monitoring sites in St. Thomas, USVI.
M denotes *Montastraea* reefs, A denotes *Acropora* reefs.
The Red Hind Bank is located within the Red Hind Bank Marine Conservation District. Botany Bay and Benner Bay are designated Areas of Particular Concern.

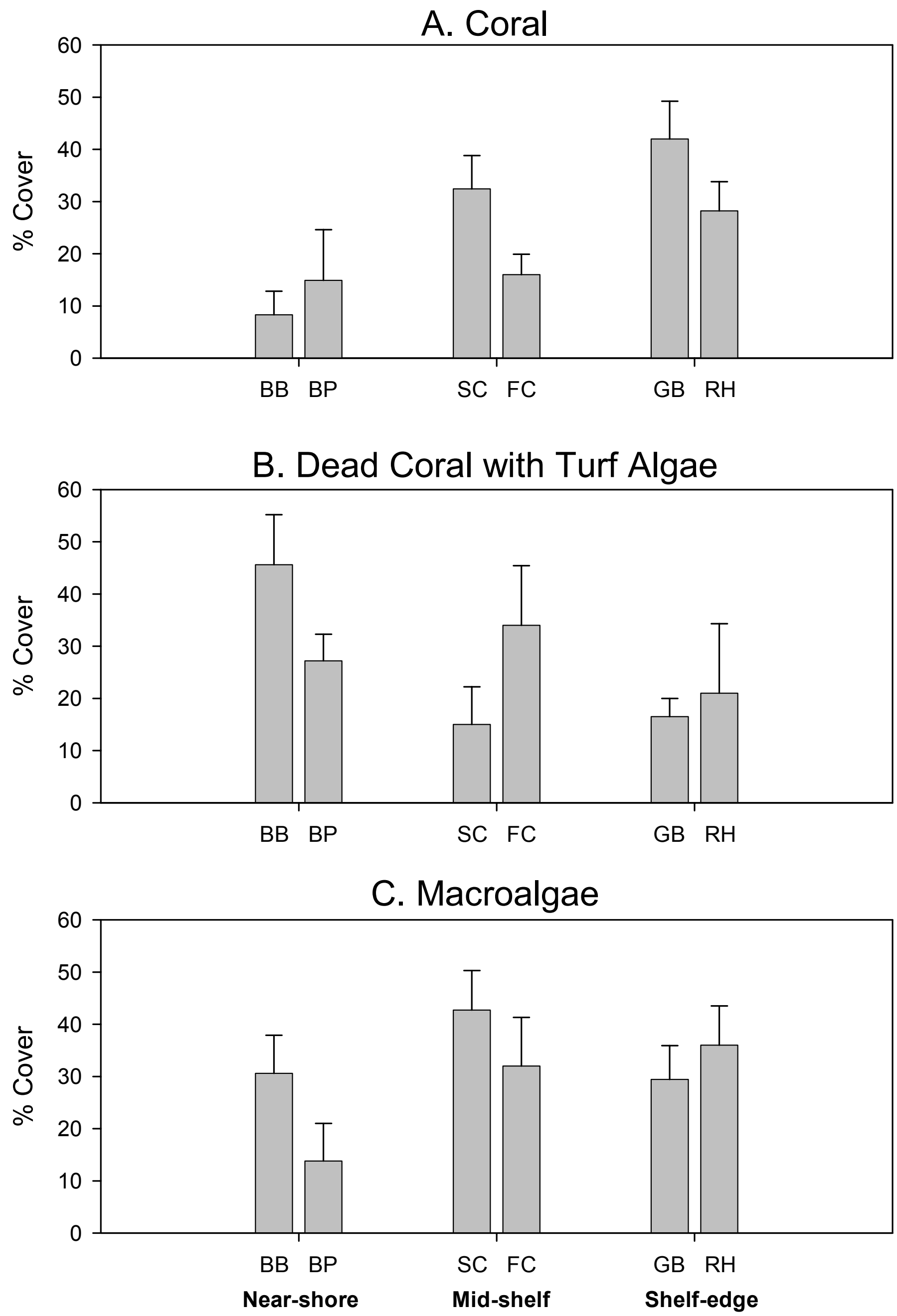


Fig. 12A, B, C Mean percent cover of A. Scleractinian corals, B. Dead coral with turf algae, and C. Macroalgae for St. Thomas monitored sites:
BB Benner Bay; BP Black Point; SC Seahorse Cottage Shoal; FC Flat Cay;
GB Grammanik Bank; RH Red Hind Bank.
BB and BP are near-shore sites, SC and FC are mid-shelf sites, and GB and RH are shelf-edge sites.
n = 6 transects for all sites. Error bars represent standard deviation.

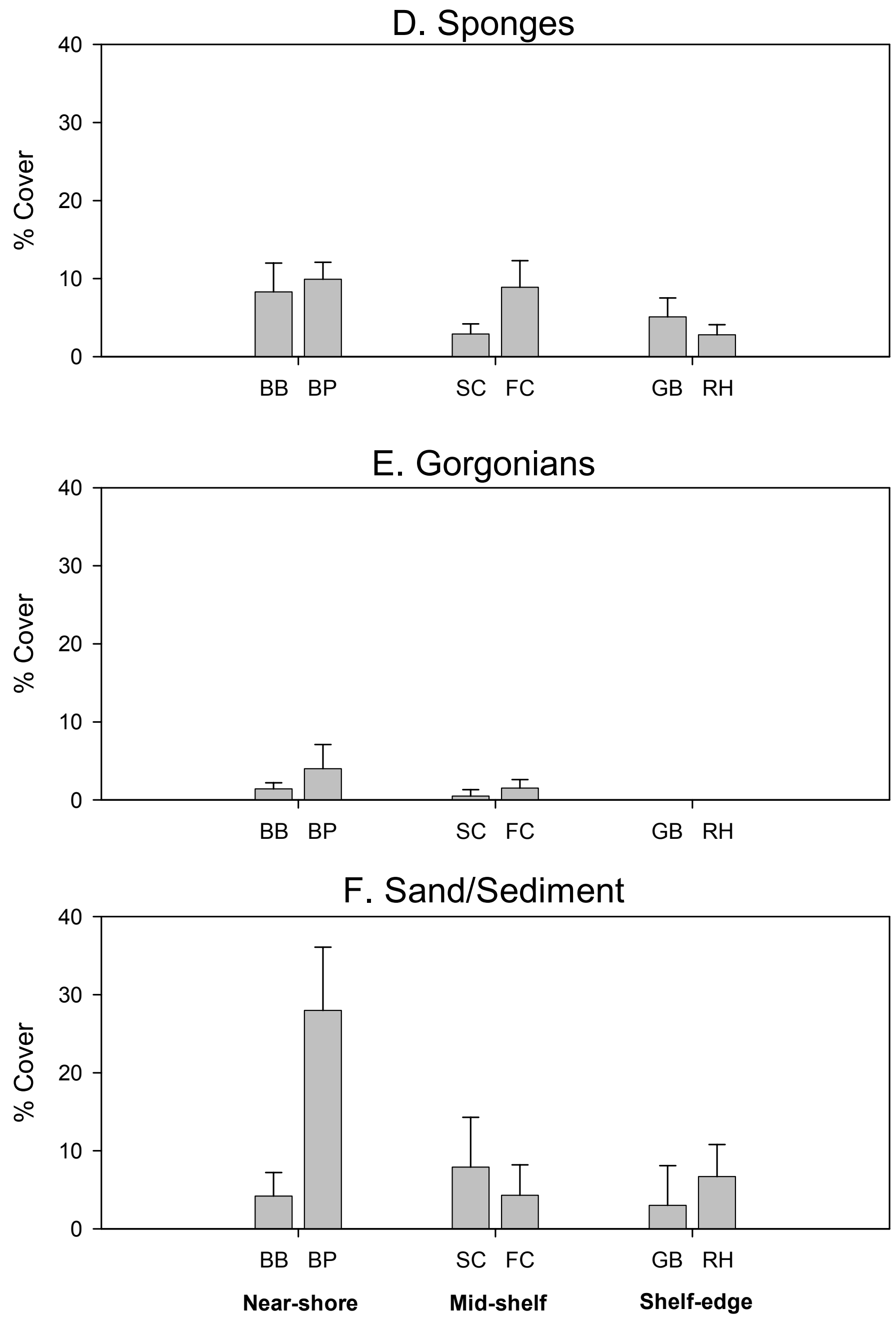


Fig. 12D, E, F Mean percent cover of D. Sponges, E. Gorgonians, and F. Sand/Sediment for St. Thomas monitored sites: BB Benner Bay; BP Black Point; SC Seahorse Cottage Shoal; FC Flat Cay; GB Grammanik Bank; RH Red Hind Bank. BB and BP are near-shore sites, SC and FC are mid-shelf sites, and GB and RH are shelf-edge sites. n = 6 transects for all sites. Error bars represent standard deviation.

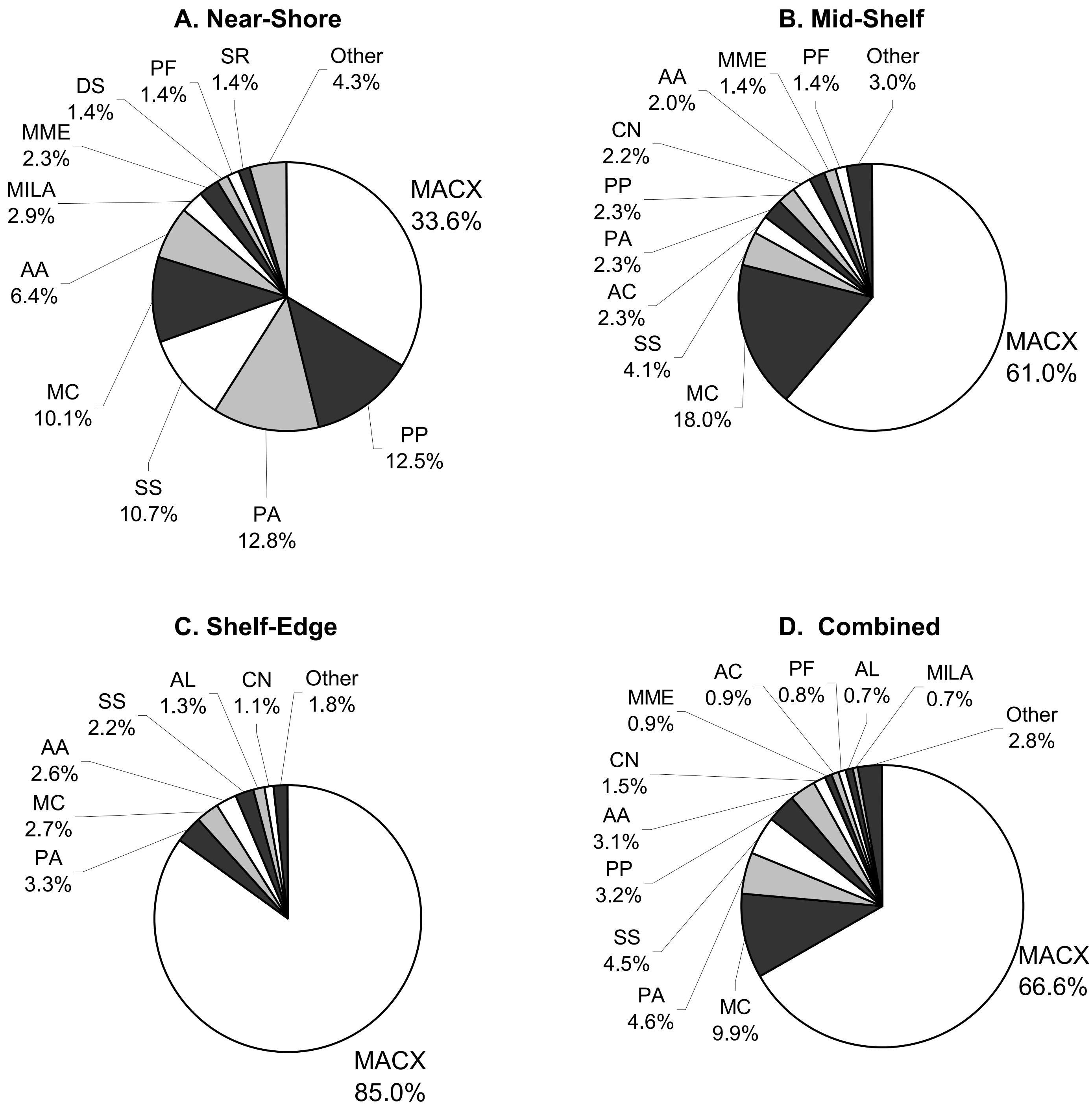
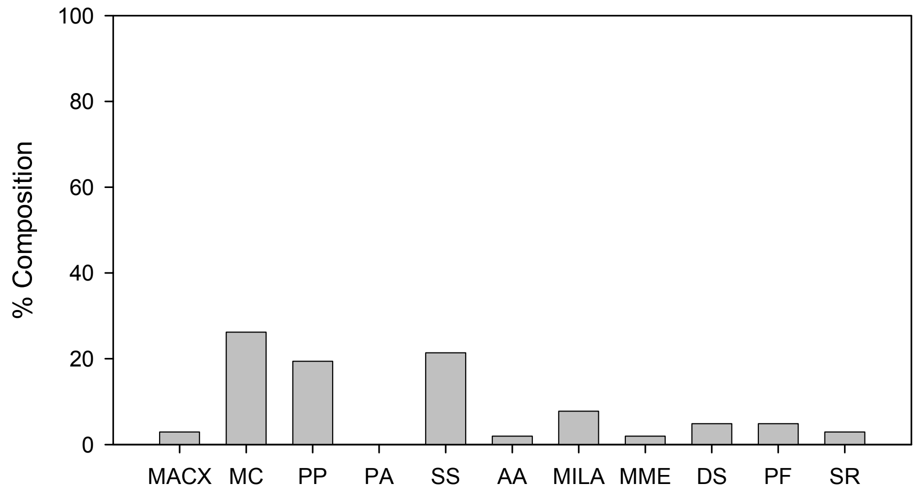


Fig. 13 Percentage coral species composition at A. Near-shore sites, B. Mid-shelf sites, C. Shelf-edge sites and D. all sites combined for St. Thomas, USVI.
MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; PP *P. porites*; AA *Agaricia agaricites*; CN *Colpophyllia natans*; MME *Meandrina meandrites*; AC *Acropora cervicornis*; PF *P. furcata*; AL *Agaricia lamarcki*; MILA *Millepora alcicornis*; DS *Diploria strigosa*; SR *S. radians*. Other denotes percent of all other coral species combined and includes: *Agaricia grahamae, A. humilis, Dendrogyra cylindrus, Diploria clivosa, D. labyrinthiformis, Eusmilia fastigiata, Manicina areolata, Mycetophyllia aliciae, My. danaana, My. lamarckiana, P. divaricata, Solenastrea bournoni, S. hyades,* and *Stephanocoenia michelinii*.

A. Benner Bay



B. Black Point

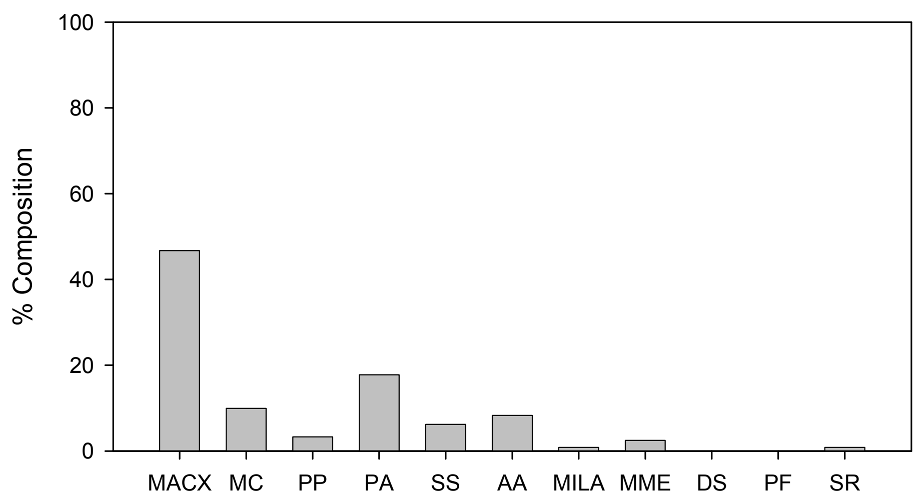


Fig. 14A, B Percent of species composition of living coral cover of the most common coral species at St. Thomas near-shore sites: A. Benner Bay and B. Black Point.
Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of doats on all living coral at each site.
MACX *Montastraea annularis* complex; MC *M. cavernosa*; PP *Porites porites*; PA *P.astreoides*; SS *Siderastrea siderea*; AA *Agaricia agaricites*; MILA *Millepora alcicornis*; MME *Meandrina meandrites*; DS *Diploria strigosa*; PF *P. furcata*; SR *S. radians*

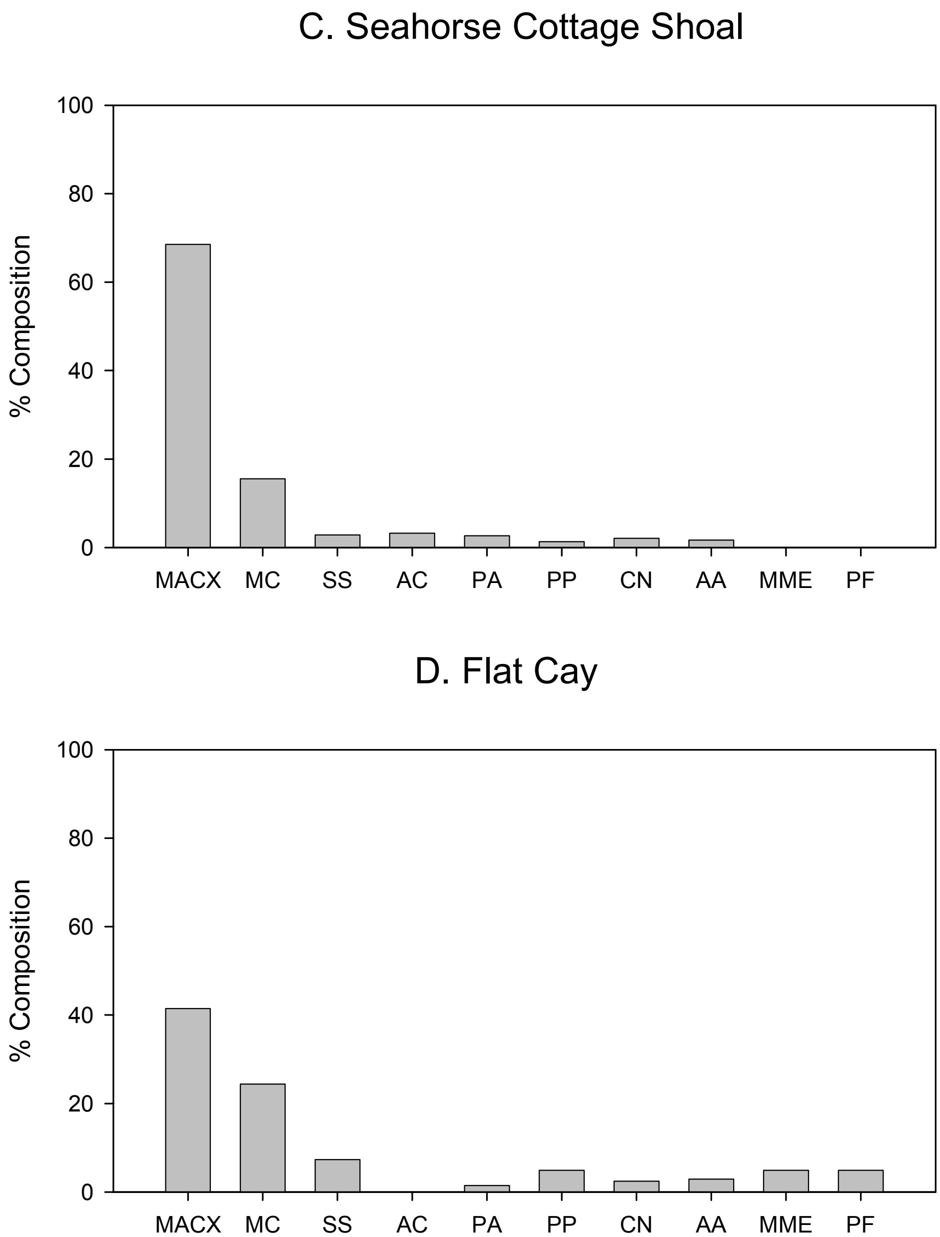
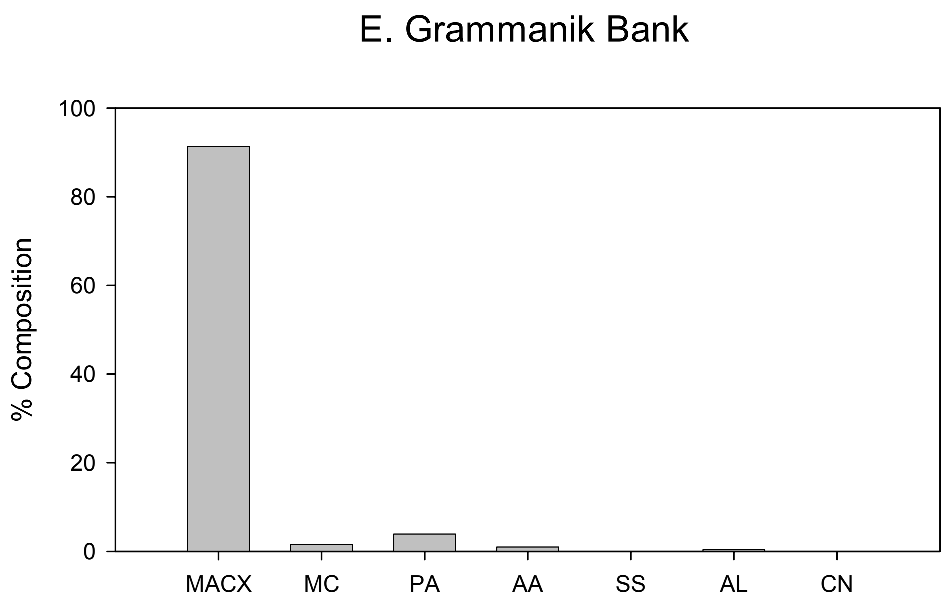


Fig. 14C, D Percent of species composition of living coral cover of the most common coral species at St. Thomas mid-shelf sites:C. Seahorse Cottage Shoal and D. Flat Cay.
Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of doats on all living coral at each site.
MACX *Montastraea annularis* complex; MC *M. cavernos*a; SS *Siderastrea siderea*; AC *Acropora cervicornis*; PA *Porites astreoides*; PP *P. porites*; CN *Colpophylia natans*; AA *Agaricia agaricites*; MME *Meandrina meandrites*; PF *P. furcata.*



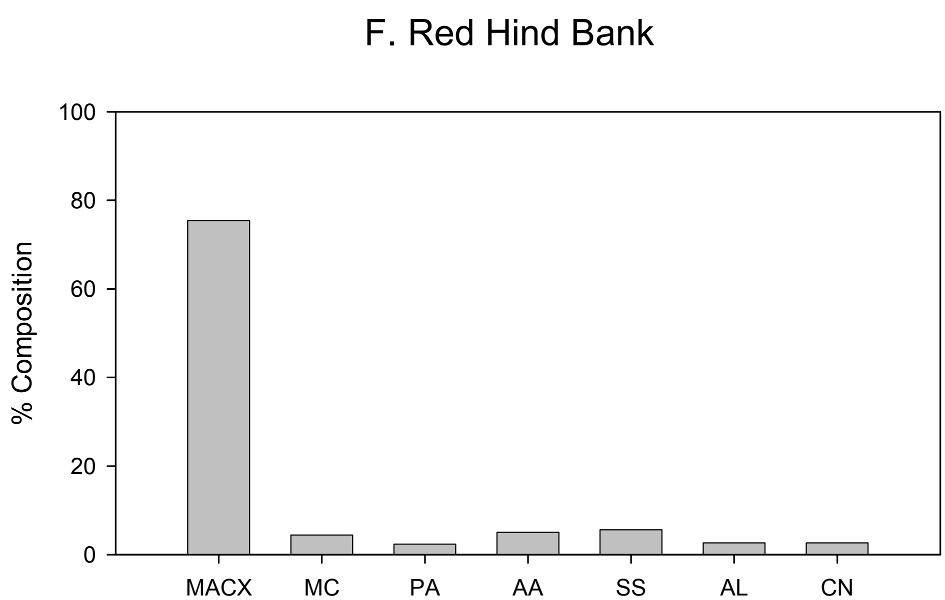


Fig. 14E, F Percent of species composition of living coral cover of the most common coral species at St. Thomas shelf-edge sites: E. Grammanik Bank and F. Red Hind Bank.
Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of doats on all living coral at each site.
MACX *Montastraea annularis* complex; MC *M. cavernos*a; PA *Porites astreoides*;
AA *Agaricia agaricites*; SS *Siderastrea siderea*; AL *A. lamarcki*; CN *Colpophylia natans.*

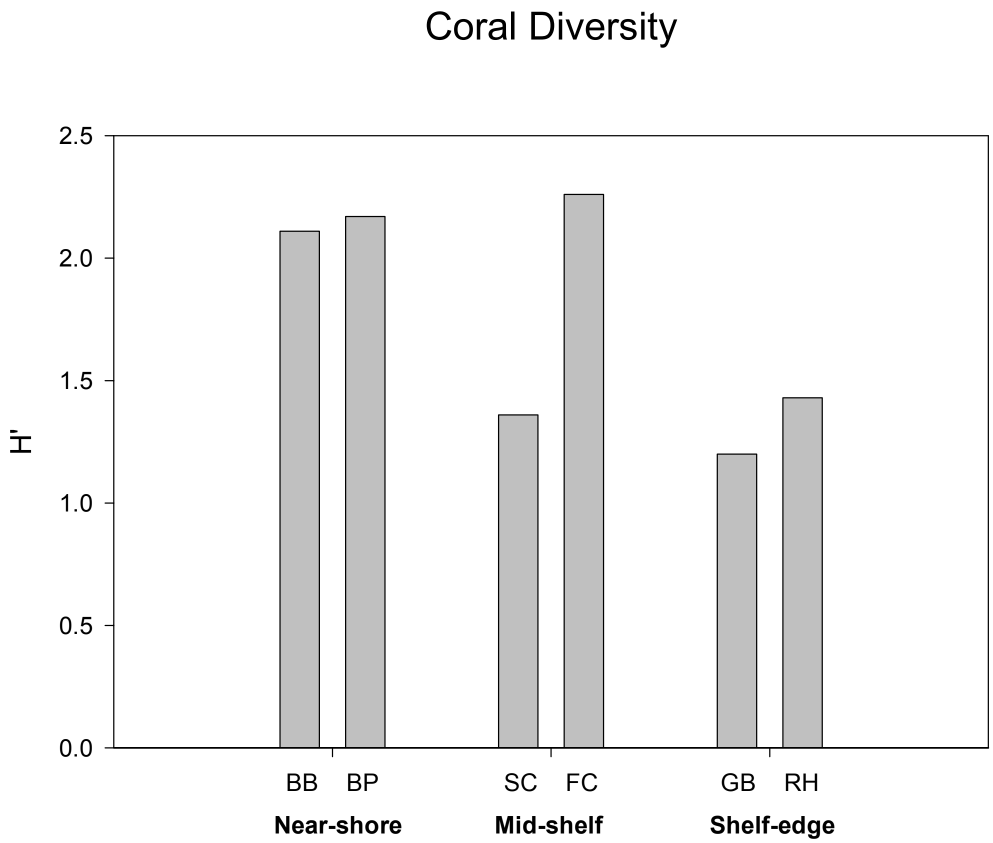


Fig. 15 Shannon - Weaver Diversity Index (H') for corals at eight monitored sites in St. Thomas, USVI. BB Benner Bay; BP Black Point; SC Seahorse Cottage Shoal; FC Flat Cay; GB Grammanik Bank RH Red Hind Bank. BB and BP are near-shore sites, SC and FC are mid-shelf sites, and GB and RH are shelf-edge sites. n = 6 transects for all sites.

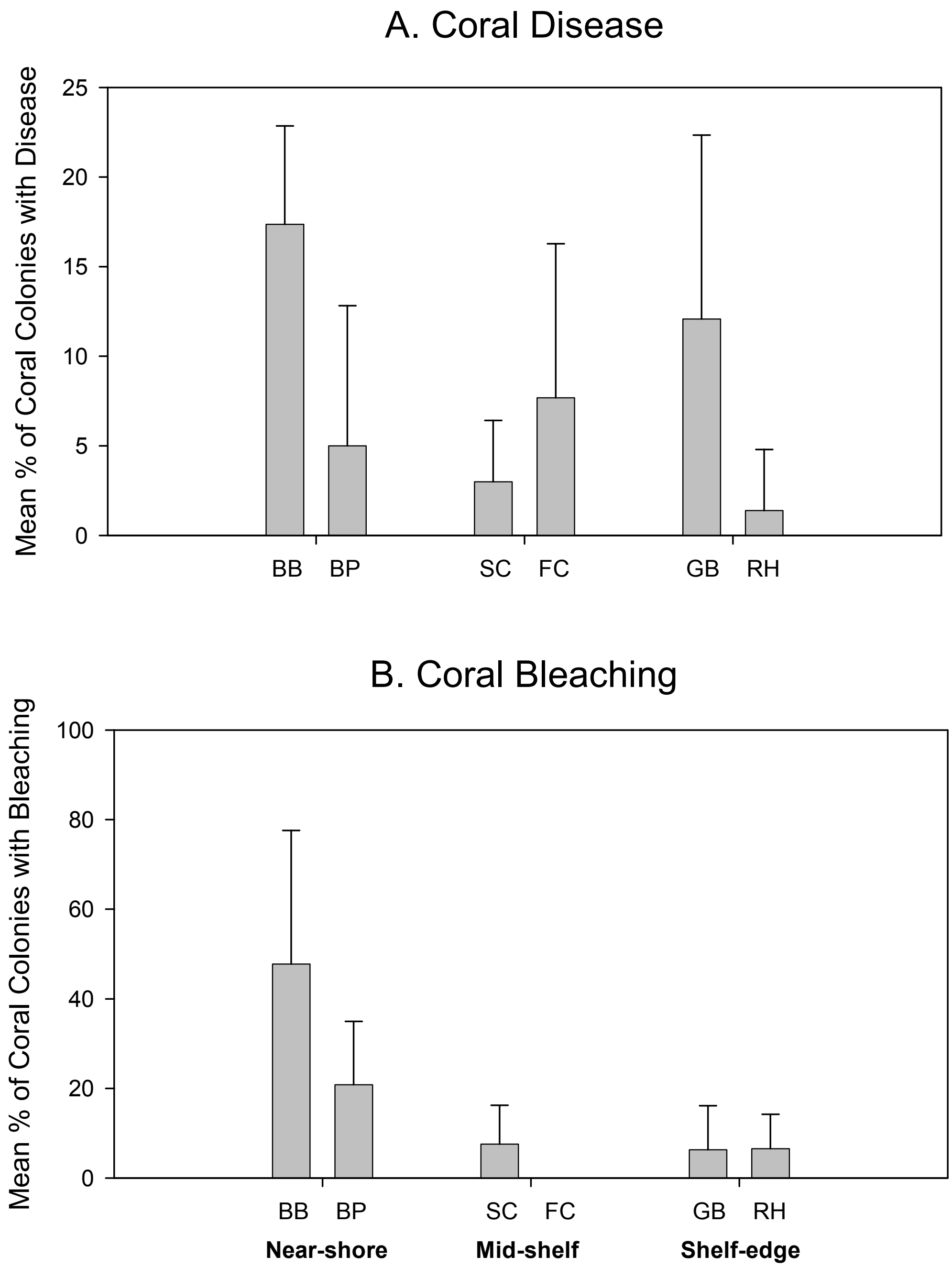
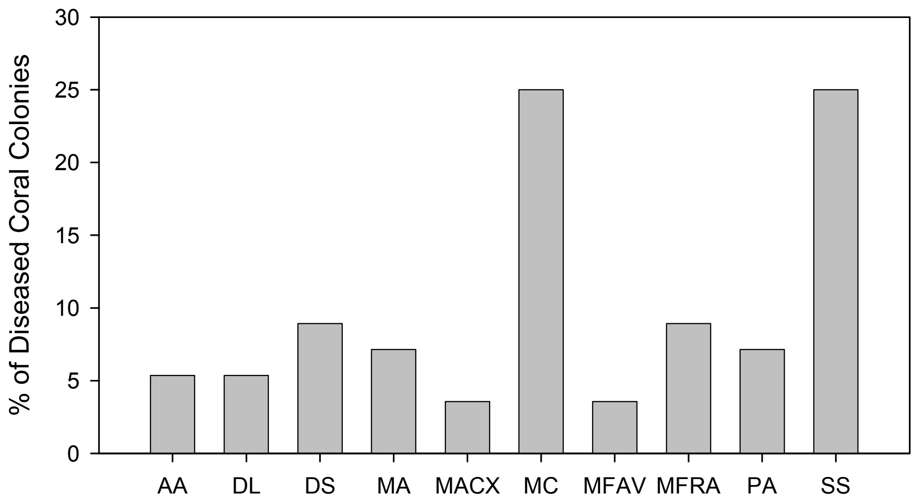


Fig. 16 Mean percentage of A. colonies with disease and B. colonies with bleaching of all coral colonies sampled at each monitoring site. Percentage calculated by dividing the number of diseased and bleached colonies on each transect by the total number of colonies sampled on each transect for each site.
BB Benner Bay; BP Black Point; SC Seahorse Cottage Shoal; FC Flat Cay; GB Grammanik Bank; RH Red Hind Bank. n = 6 transects for all sites. Error bars represent standard deviation.

A. Coral Disease



B. Coral Bleaching

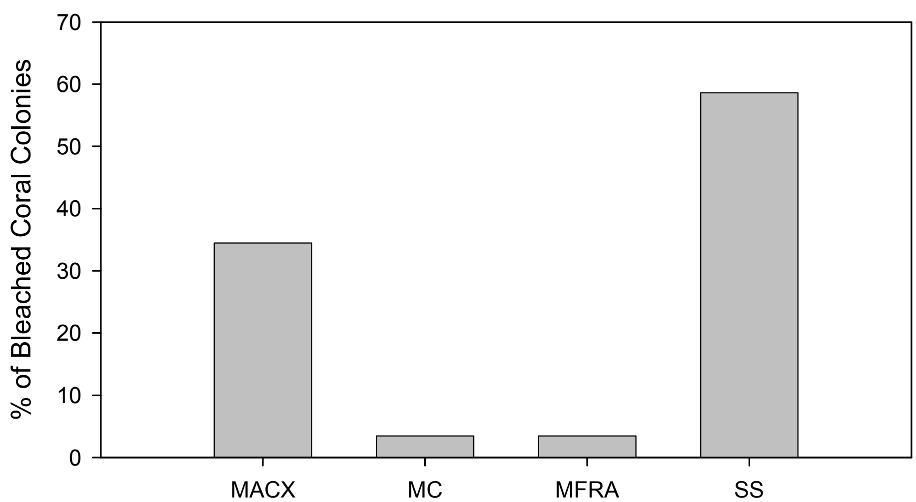


Fig. 17 Percentage of A. diseased colonies and B. bleached colonies of all coral species with disease and bleaching sampled at each St. Thomas monitoring site (n = 6).
Percentage calculated by dividing the number of diseased and bleached colonies of each species by the total number of diseased and bleached coral colonies, respectively.
AA *Agaricea agaricites*; DL *Diploria labyrinthiformis*; DS *Diploria strigosa*; MA *Montastraea annularis*; MACX unidentified species belonging to the *M. annularis* complex; MC *M. cavernosa*; MFAV *M. faveolata*; MFRA *M. franksii*; PA *Porites astreoides*; SS *Siderastrea siderea*

Current Speed and Direction - Flat Cay

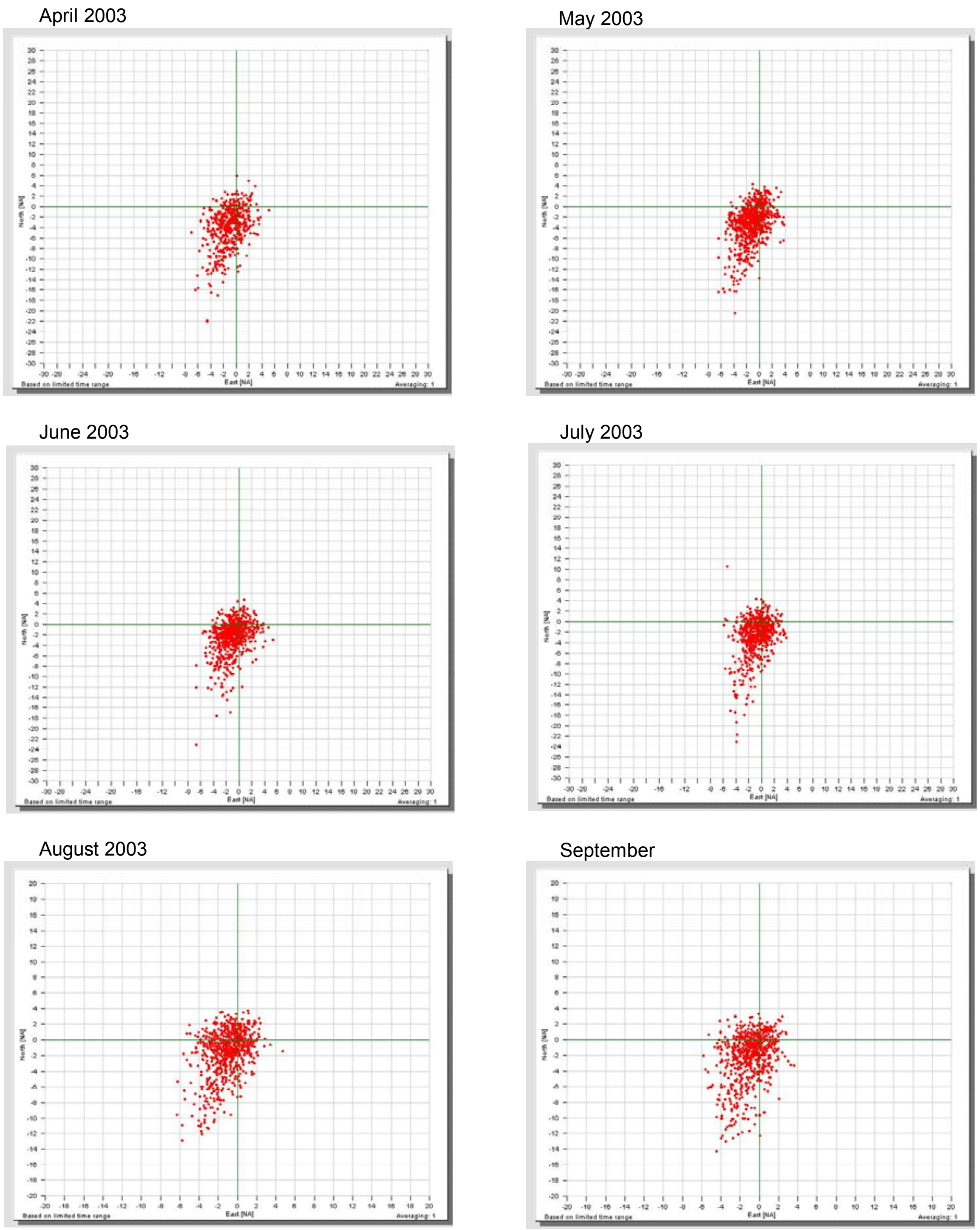
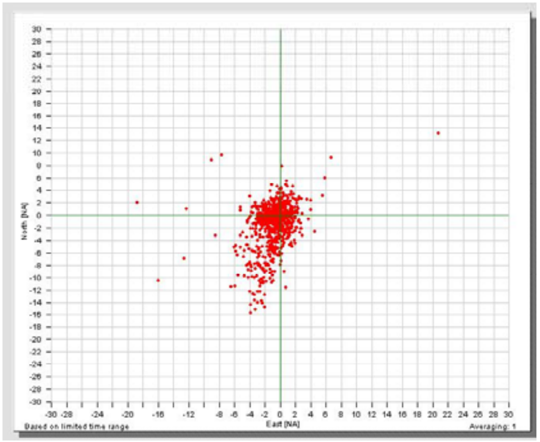


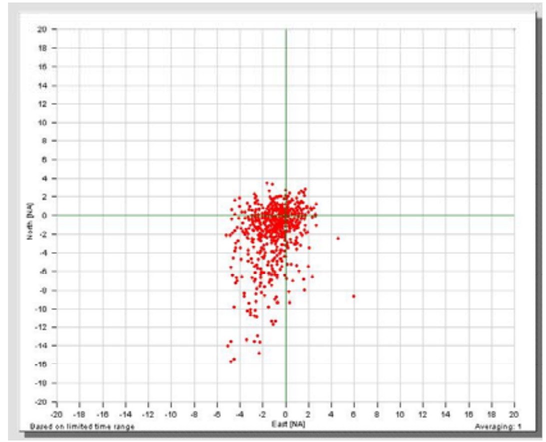
Fig. 18 Current speed and direction at Flat Cay, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction - Flat Cay

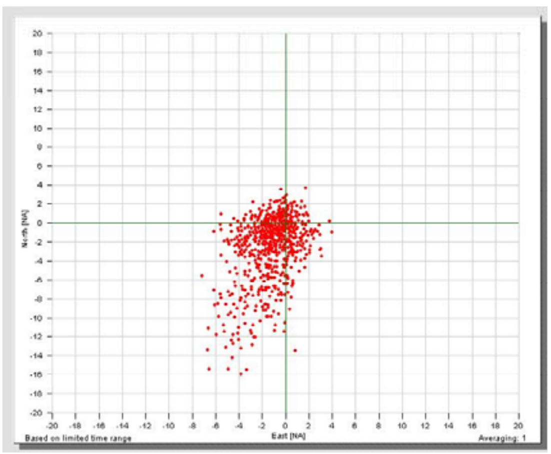
October 2003



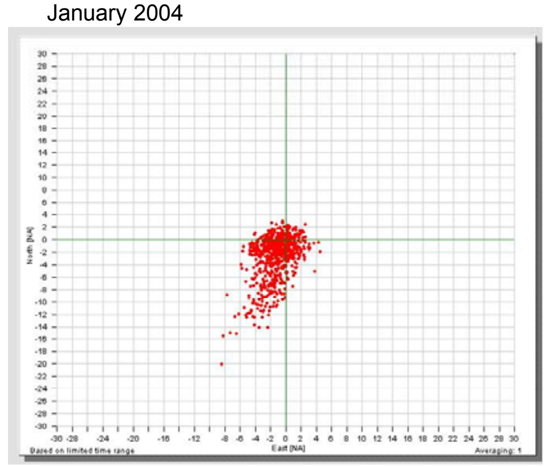
November 2003



December 2003



January 2004



February 2004

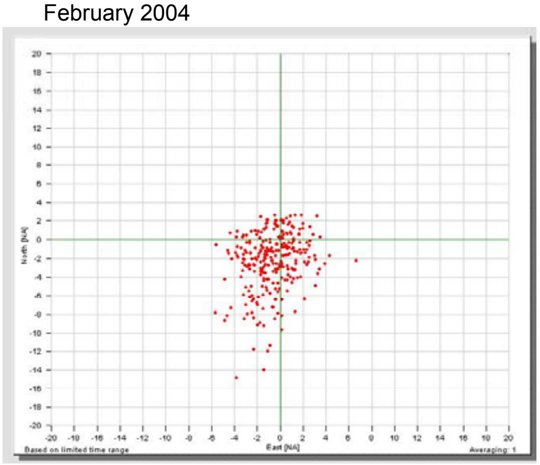


Fig. 18 (cont.) Current speed and direction at Flat Cay, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction - Red Hind Bank

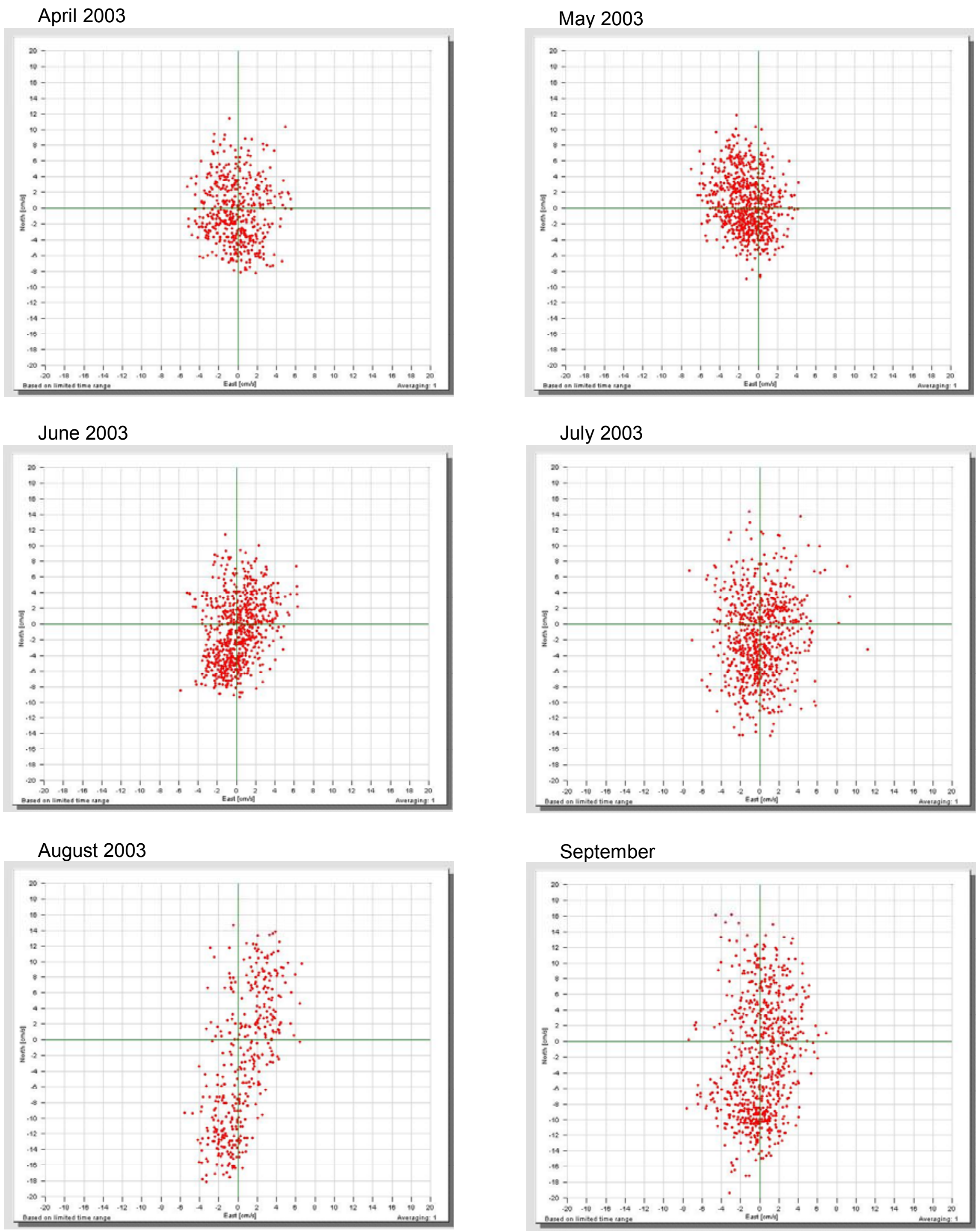
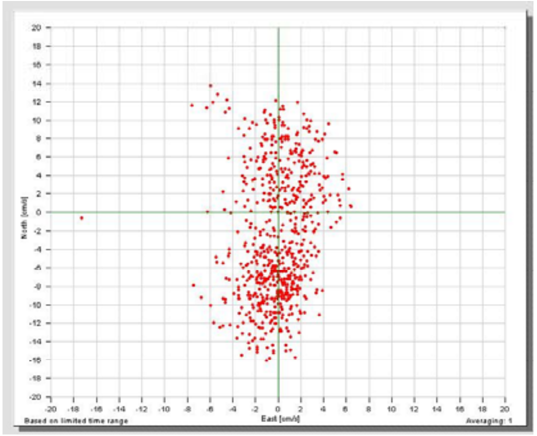


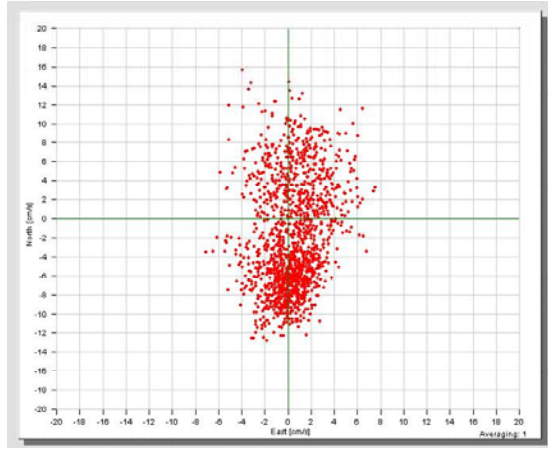
Fig. 19 Current speed and direction at the Red Hind Bank, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction - Red Hind Bank

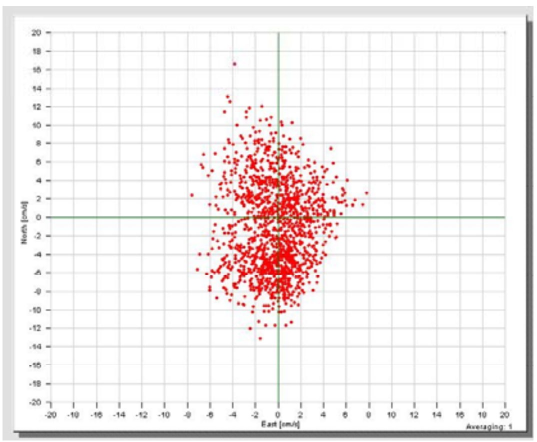
October 2003



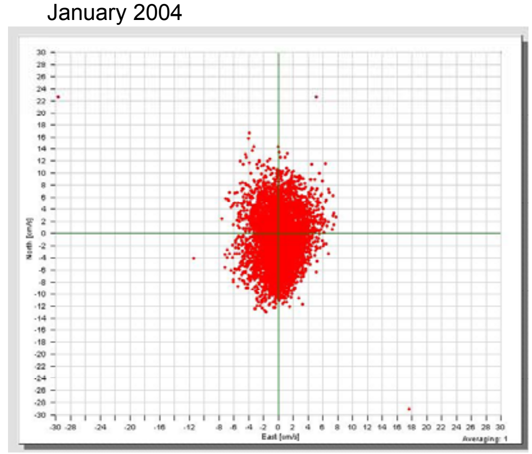
November 2003



December 2003



January 2004



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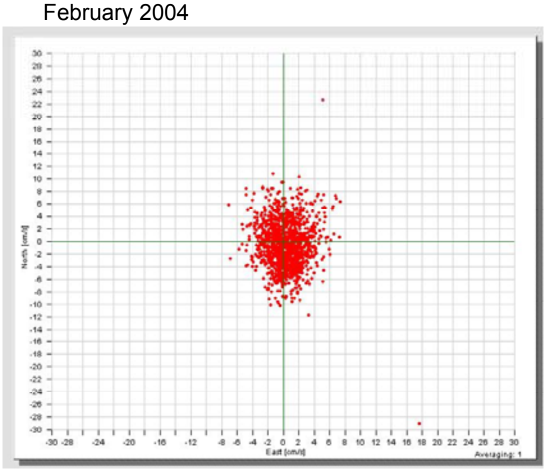


Fig. 19 (cont.) Current speed and direction at the Red Hind Bank, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

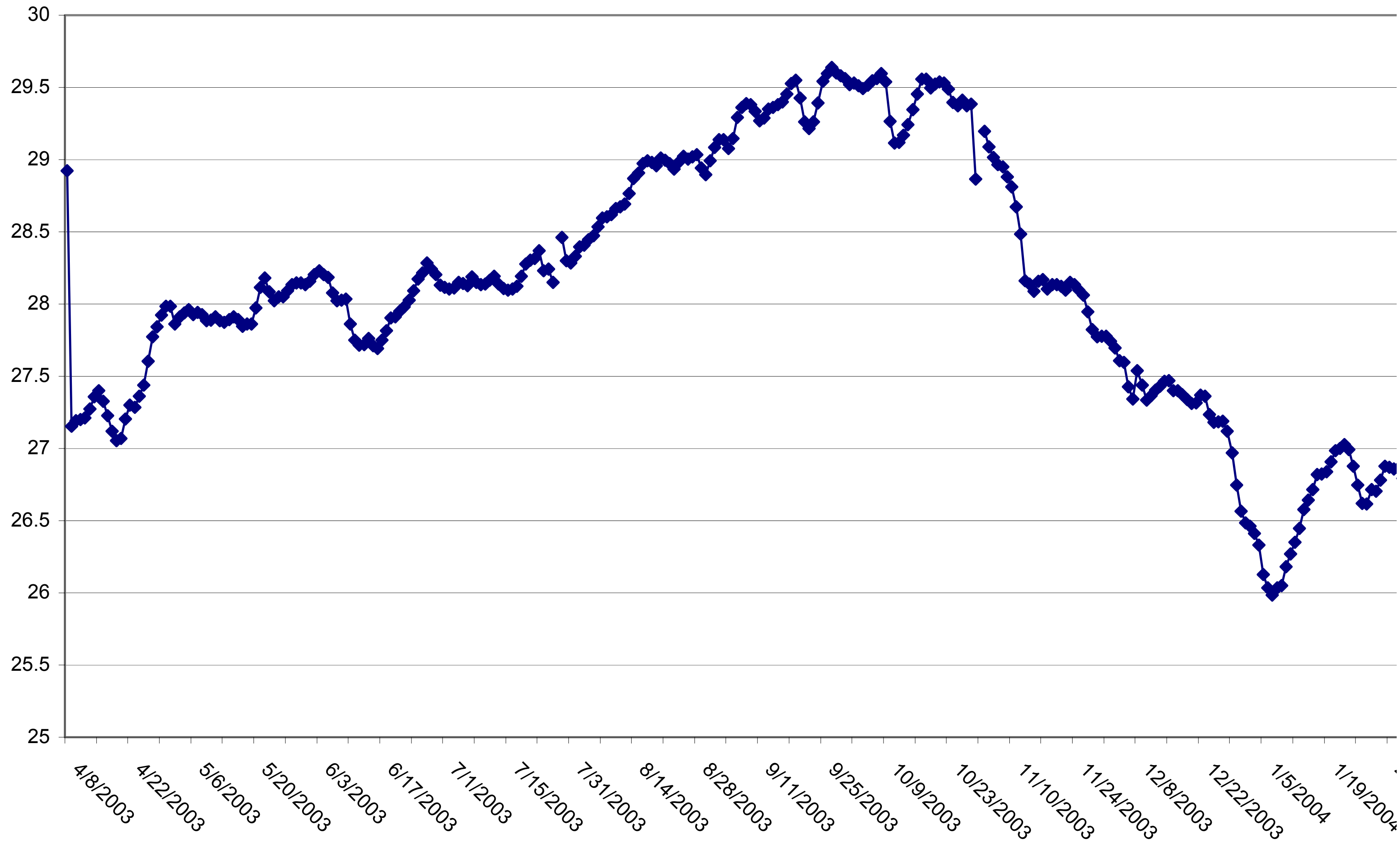


Fig. 20 Daily mean temperature (^oC) recorded at Flat Cay, St. Thomas USVI, between 8 April 2003 and 12 February 2004.

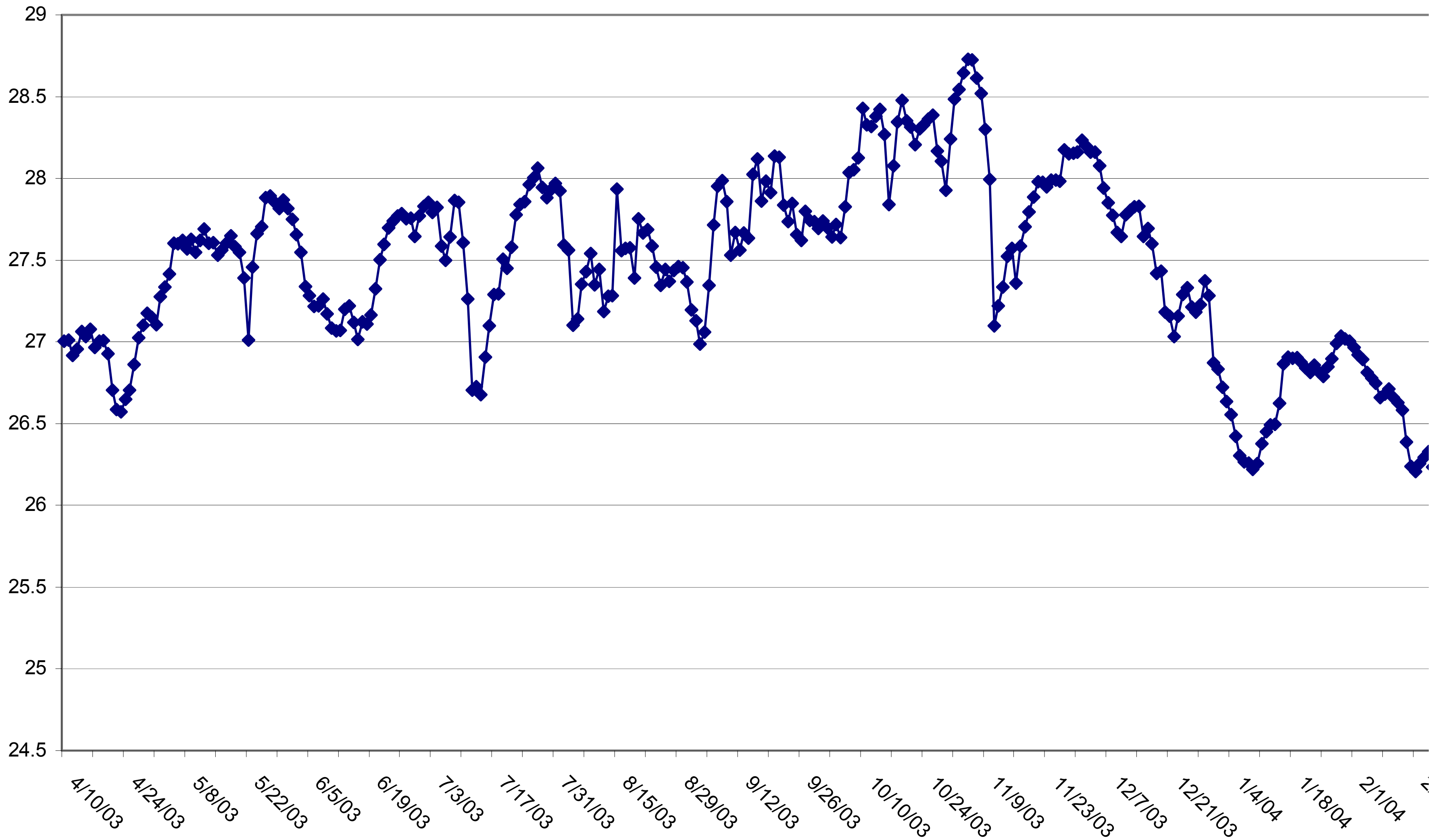


Fig. 21 Daily mean temperature (^{o}C) at the Hind Bank between 10 April 2003 and 27 February 2003.

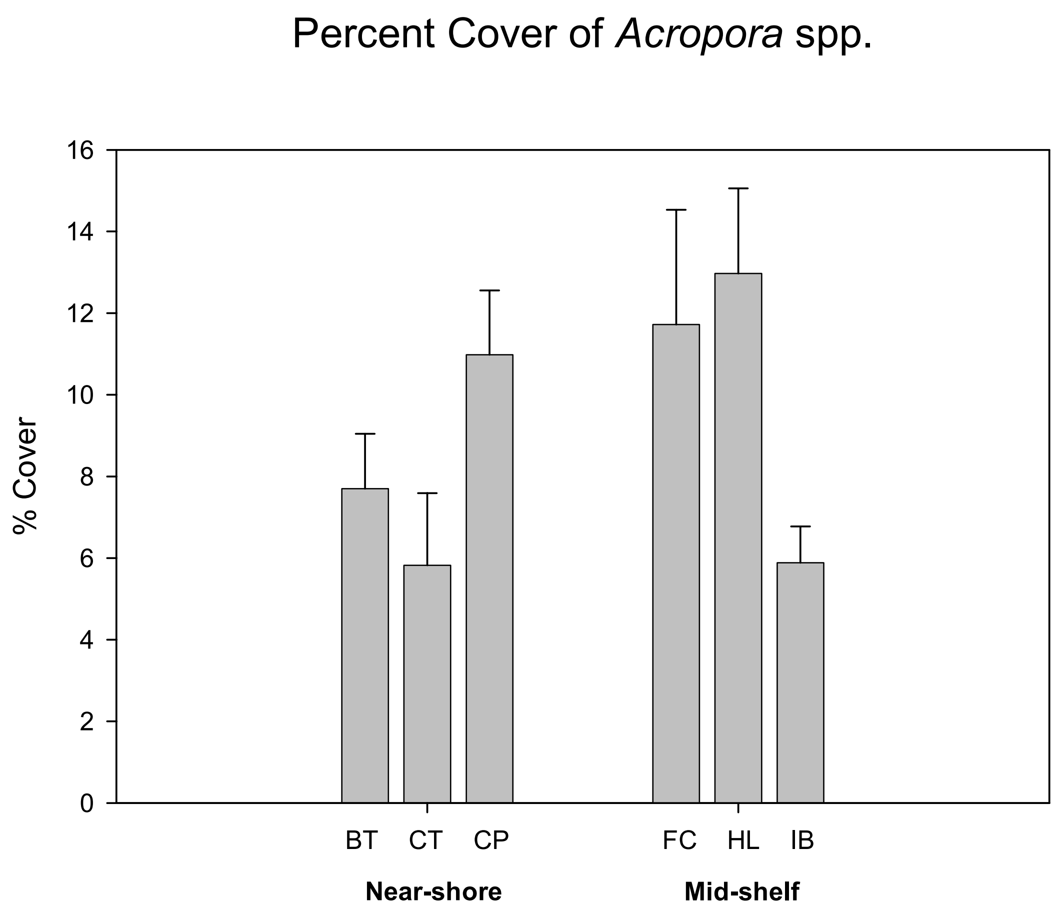


Fig. 22 Percent cover of all *Acropora* corals combined (*A. cervicornis*, *A. palmata*, and *A. prolifera*) for St. Thomas sites: BT Botany Bay; CT Caret Bay; CP Coculus Point; FC Flat Cay; HL Hans Lollik; IB Inner Brass Island. BT, CT, and CP are near-shore sites. FC, HL, and IB are mid-shelf sites. n = 5 transects for all sites. Error bars represent standard deviation.

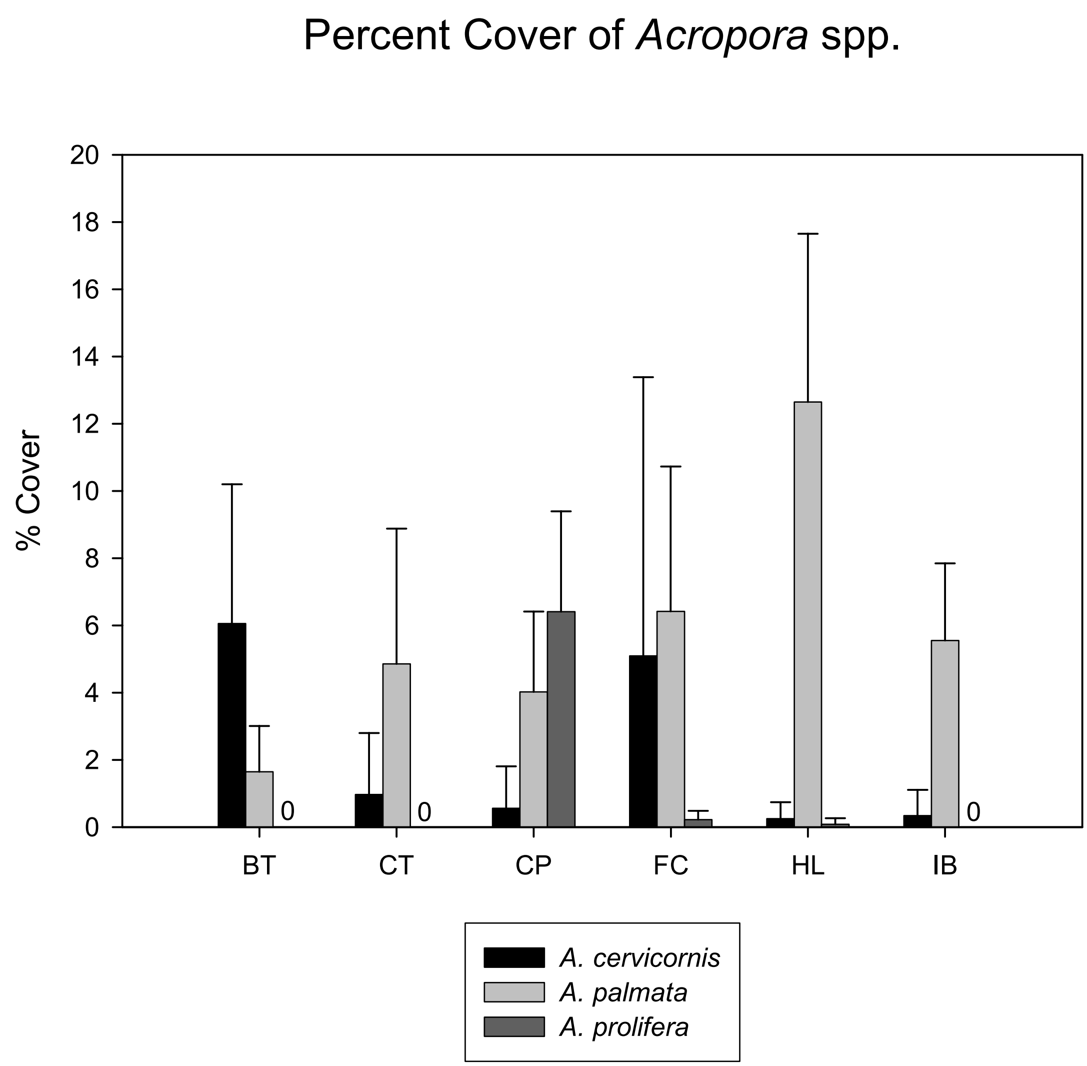


Fig. 23 Percent cover of *A. cervicornis*, *A. palmata*, and *A. prolifera* for all St. Thomas sites.
BT Botany Bay; CT Caret Bay; CP Coculus Point;
FC Flat Cay; HL Hans Lollik; IB Inner Brass Island.
BT, CT, and CP are near-shore sites. FC, HL, and IB are mid-shelf sites.
n = 5 transects for all sites. Error bars represent standard deviation.

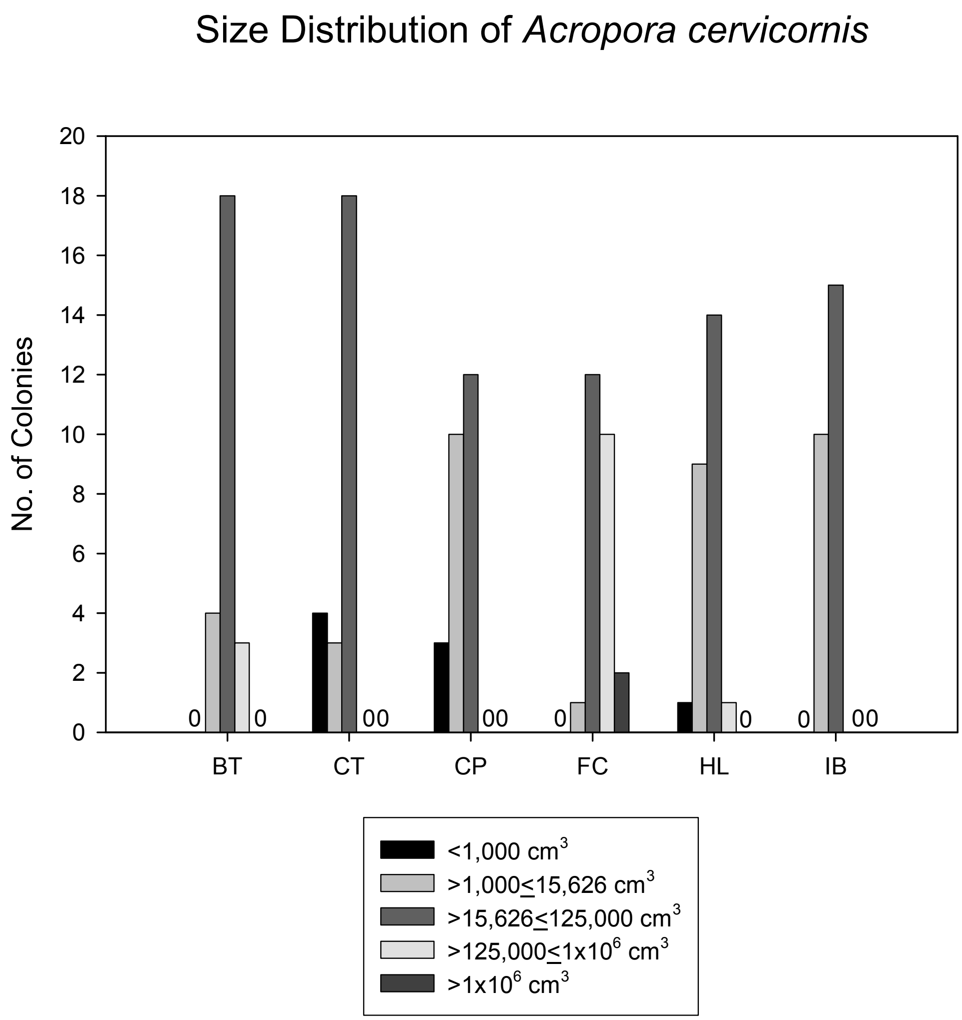


Fig. 24 Size distribution for *Acropora cervicornis* at St. Thomas sites.
BT Botany Bay; CT Caret Bay; CP Coculus Point; FC Flat Cay; HL Hans Lollik; IB Inner Brass Island
n = 25 colonies at all sites.

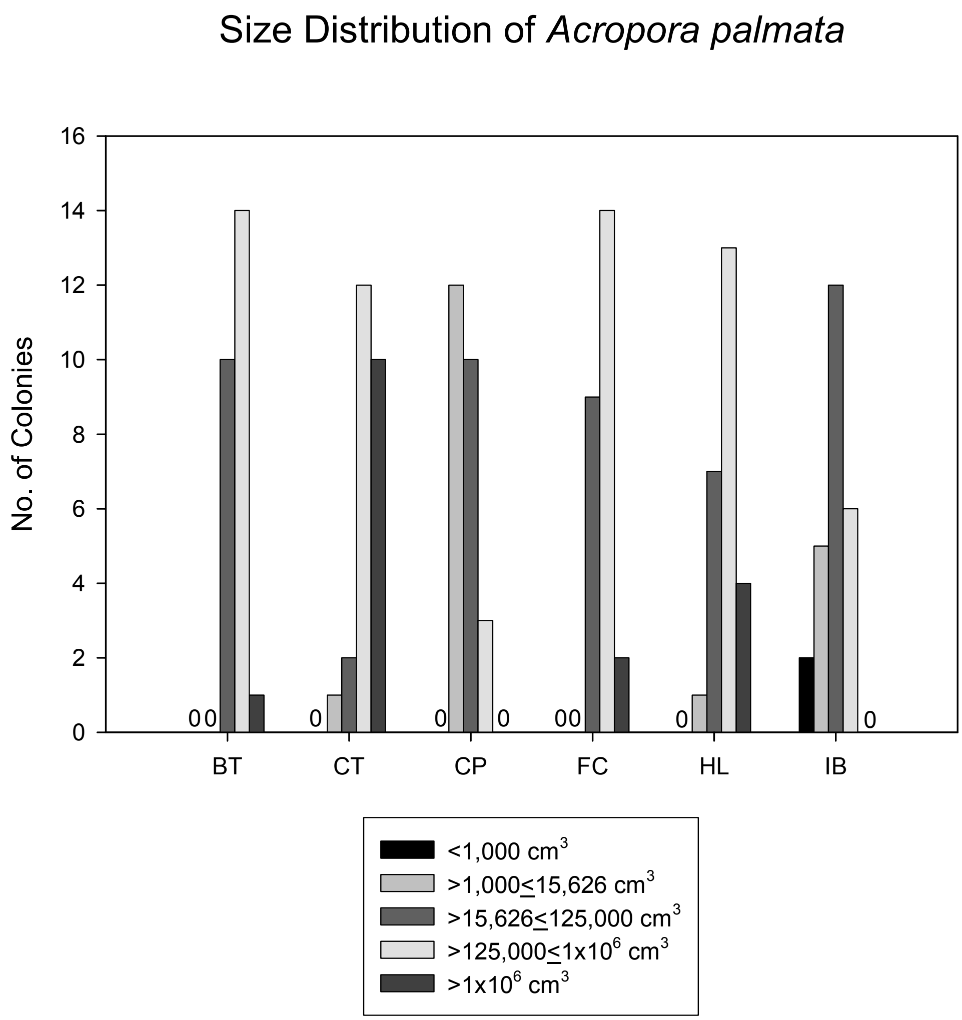


Fig. 25 Size distribution for *Acropora palmata* at St. Thomas sites.
BT Botany Bay; CT Caret Bay; CP Coculus Point; FC Flat Cay; HL Hans Lollik; IB Inner Brass Island
n = 25 colonies at all sites.

Size Distribution of *Acropora prolifera*

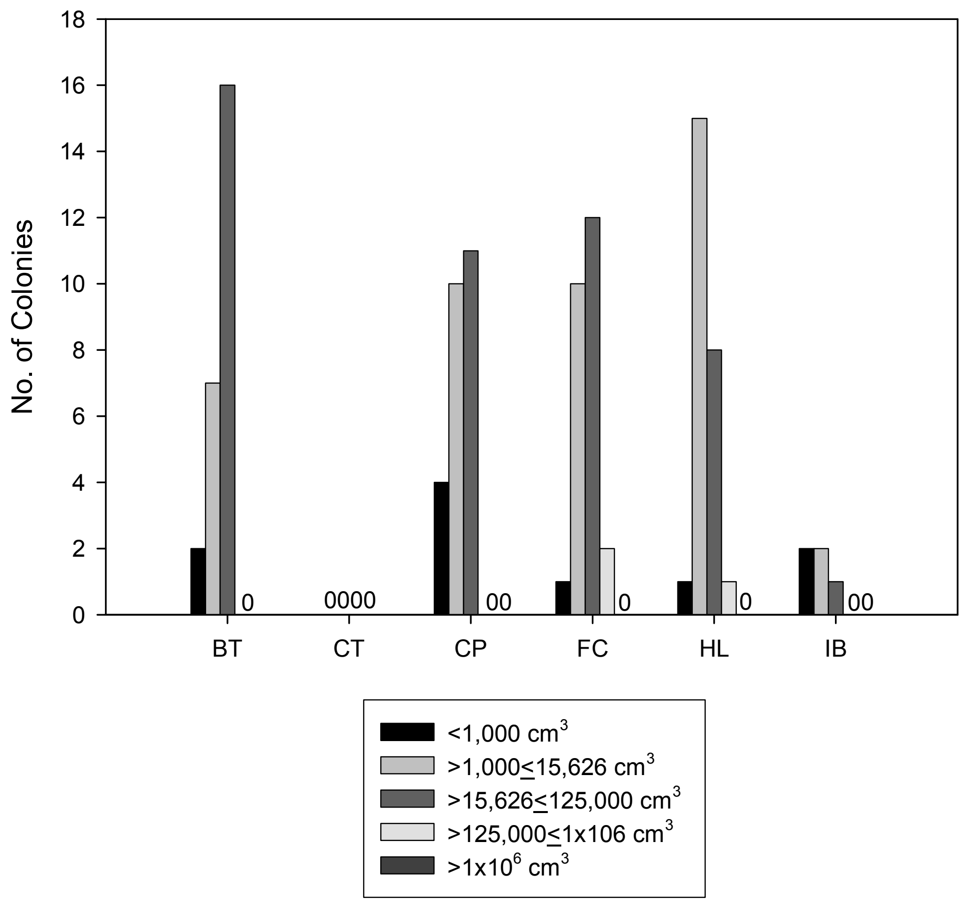


Fig. 26 Size distribution for *Acropora prolifera* at St. Thomas sites.
BT Botany Bay; CT Caret Bay; CP Coculus Point; FC Flat Cay; HL Hans Lollik; IB Inner Brass Island
n = 25 colonies at all sites, except for n = 0 colonies at CT and n = 5 colonies at IB.

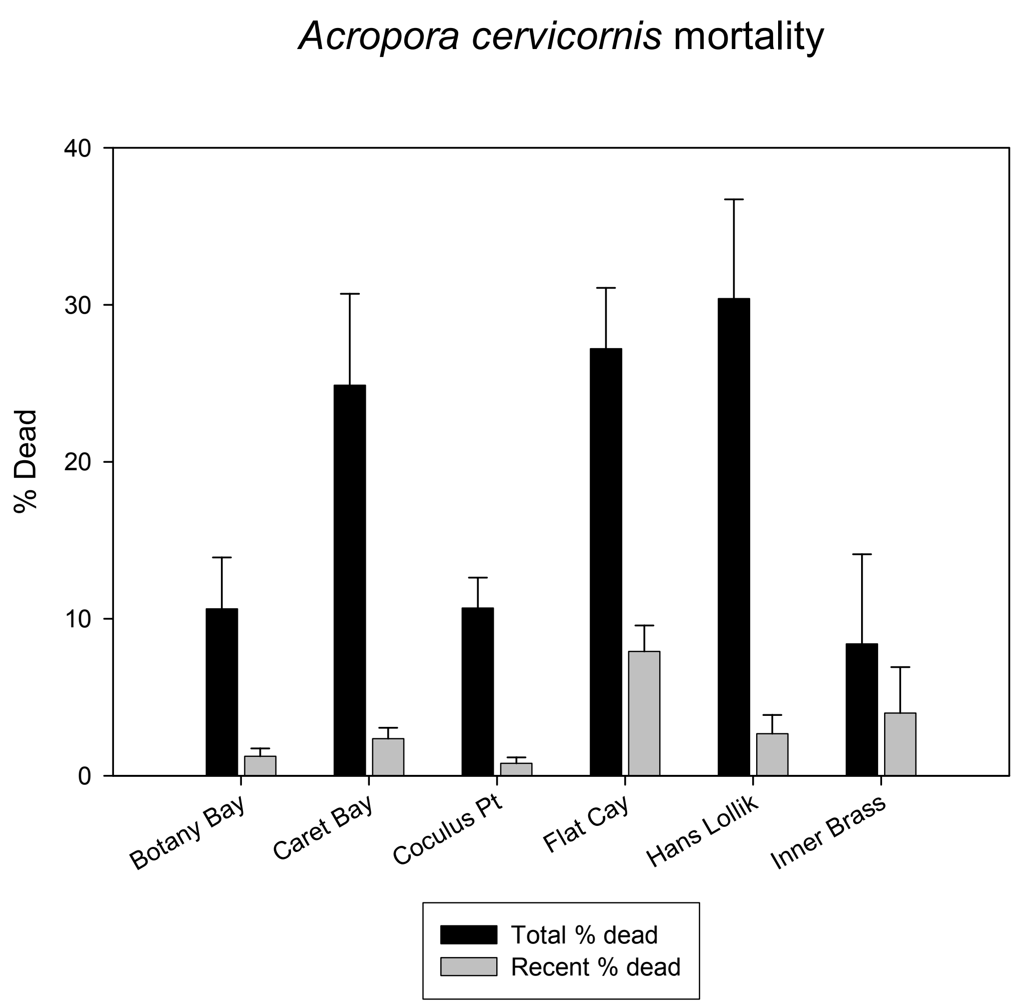


Fig. 27 Mean percent dead tissue on *Acropora cervicornis* colonies at all St. Thomas sites. n = 25 colonies at all sites. Error bars represent standard error.

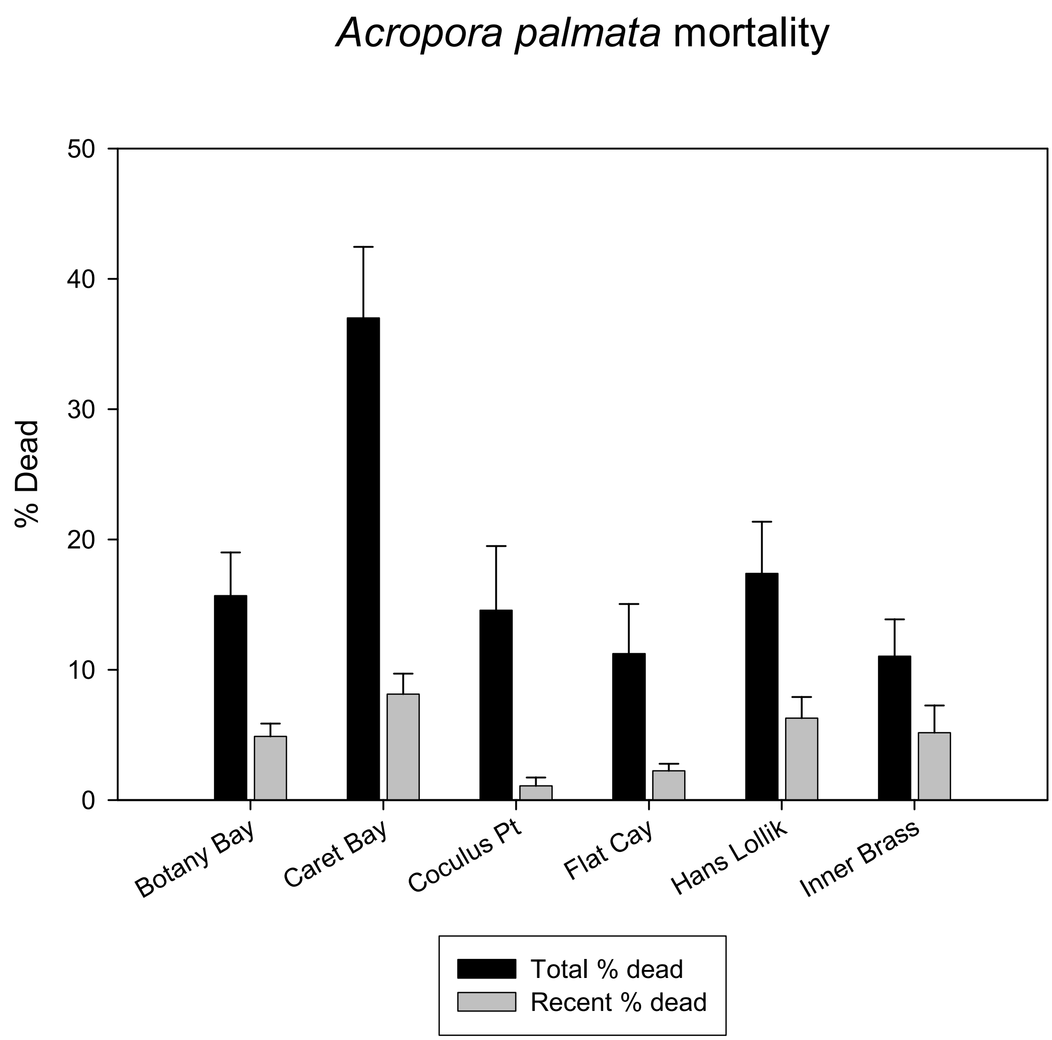


Fig. 28 Mean percent dead tissue on *Acropora palmata* colonies at all St. Thomas sites. n = 25 colonies at all sites. Error bars represent standard error.

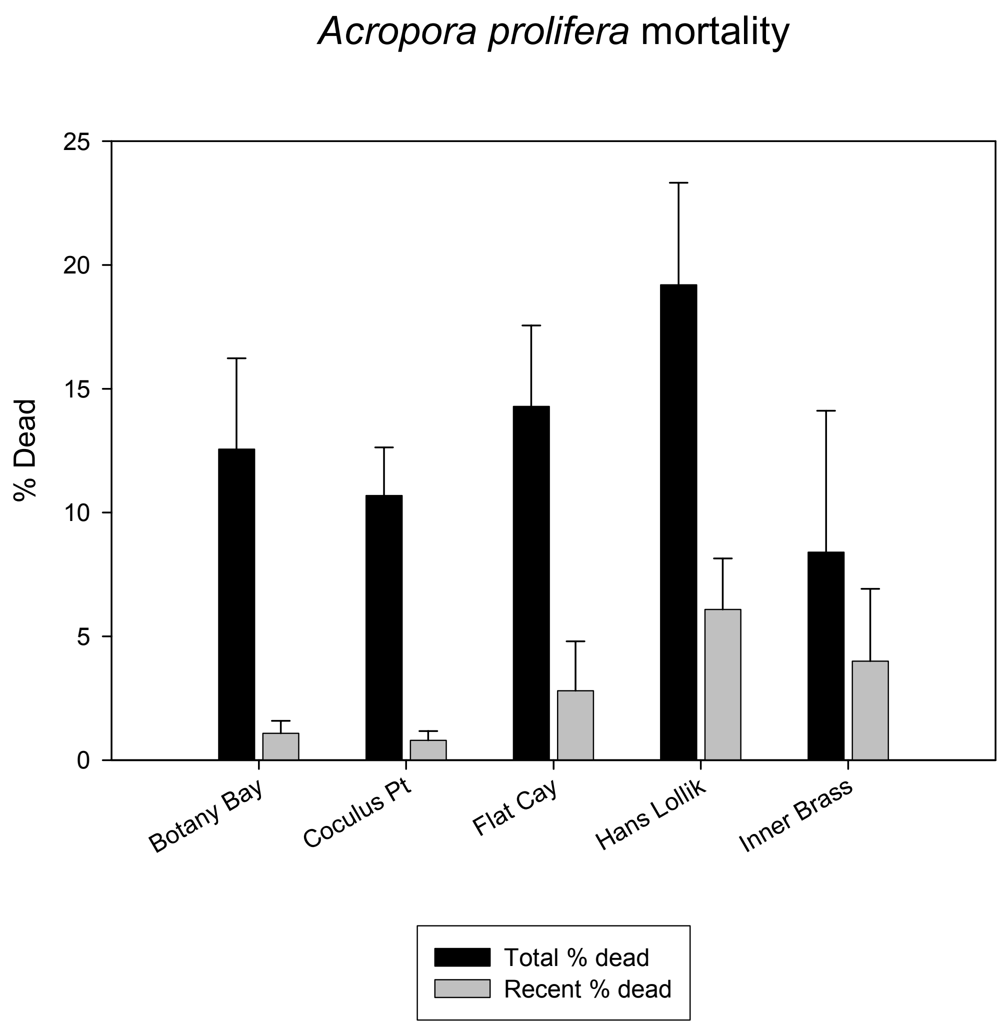


Fig. 29 Mean percent dead tissue on *Acropora prolifera* colonies at all St. Thomas sites. n = 25 colonies at all sites, except n = 5 colonies at Inner Brass Island. Error bars represent standard error.

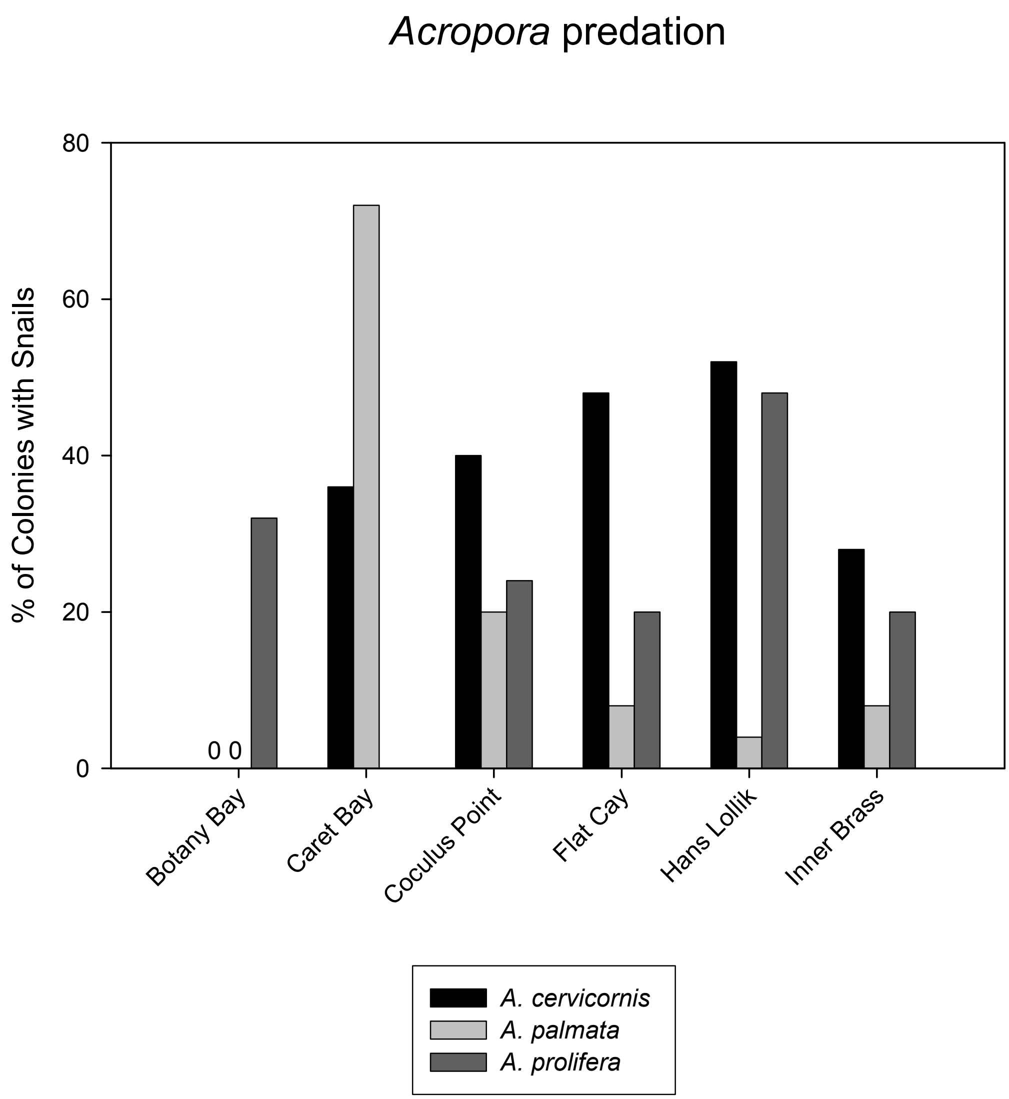


Fig. 30 Percentage of *Acropora* colonies infested with *Coralliophila* snails at all St. Thomas sites. n = 25 colonies for all *Acropora* species at all sites, except for n = 0 for *A. prolifera* at Caret Bay and n = 5 for *A. prolifera* at Inner Brass Island.

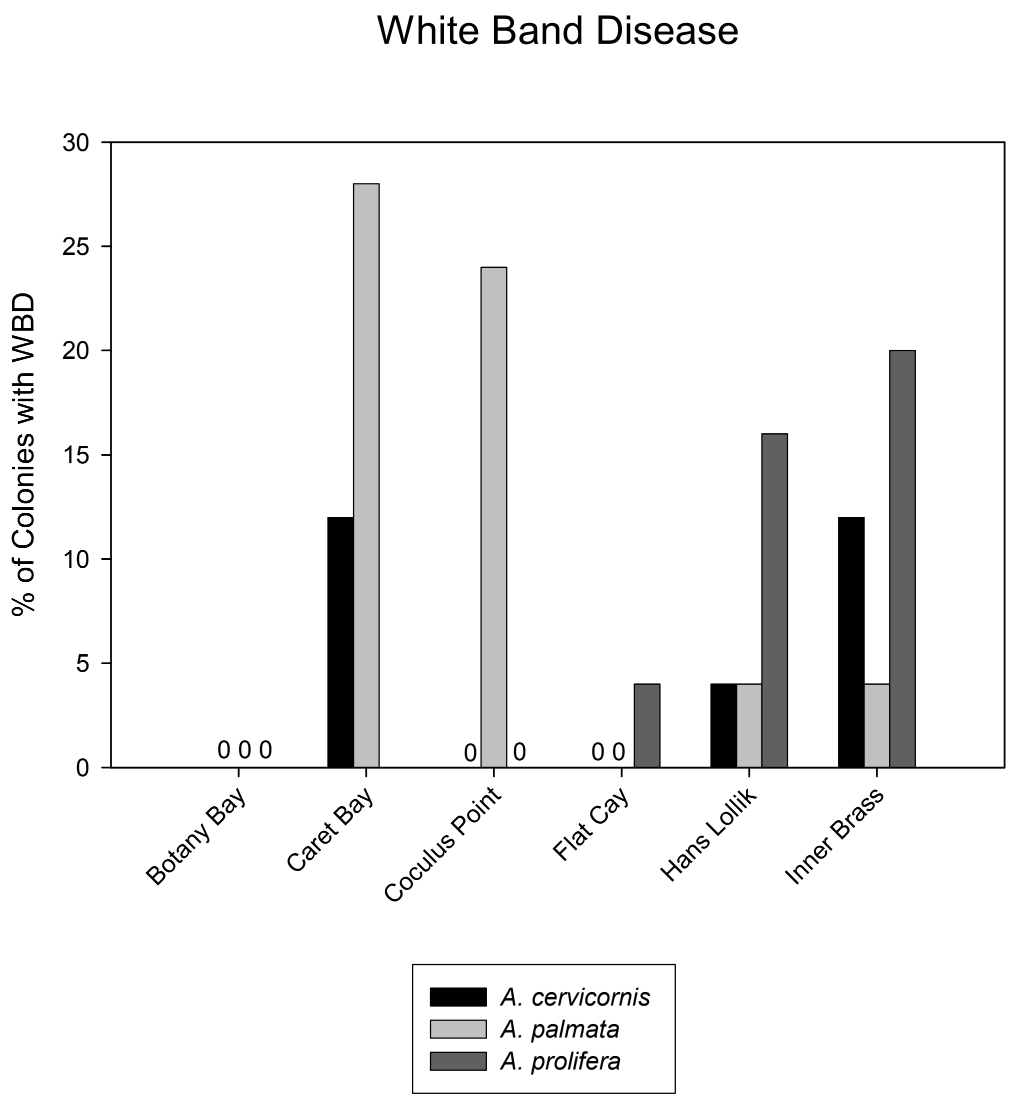


Fig. 31 Percentage of *Acropora* colonies with white band disease at all St. Thomas sites. n = 25 colonies for all *Acropora* species at all sites, except for n = 0 for *A. prolifera* at Caret Bay and n = 5 for *A. prolifera* at Inner Brass Island.

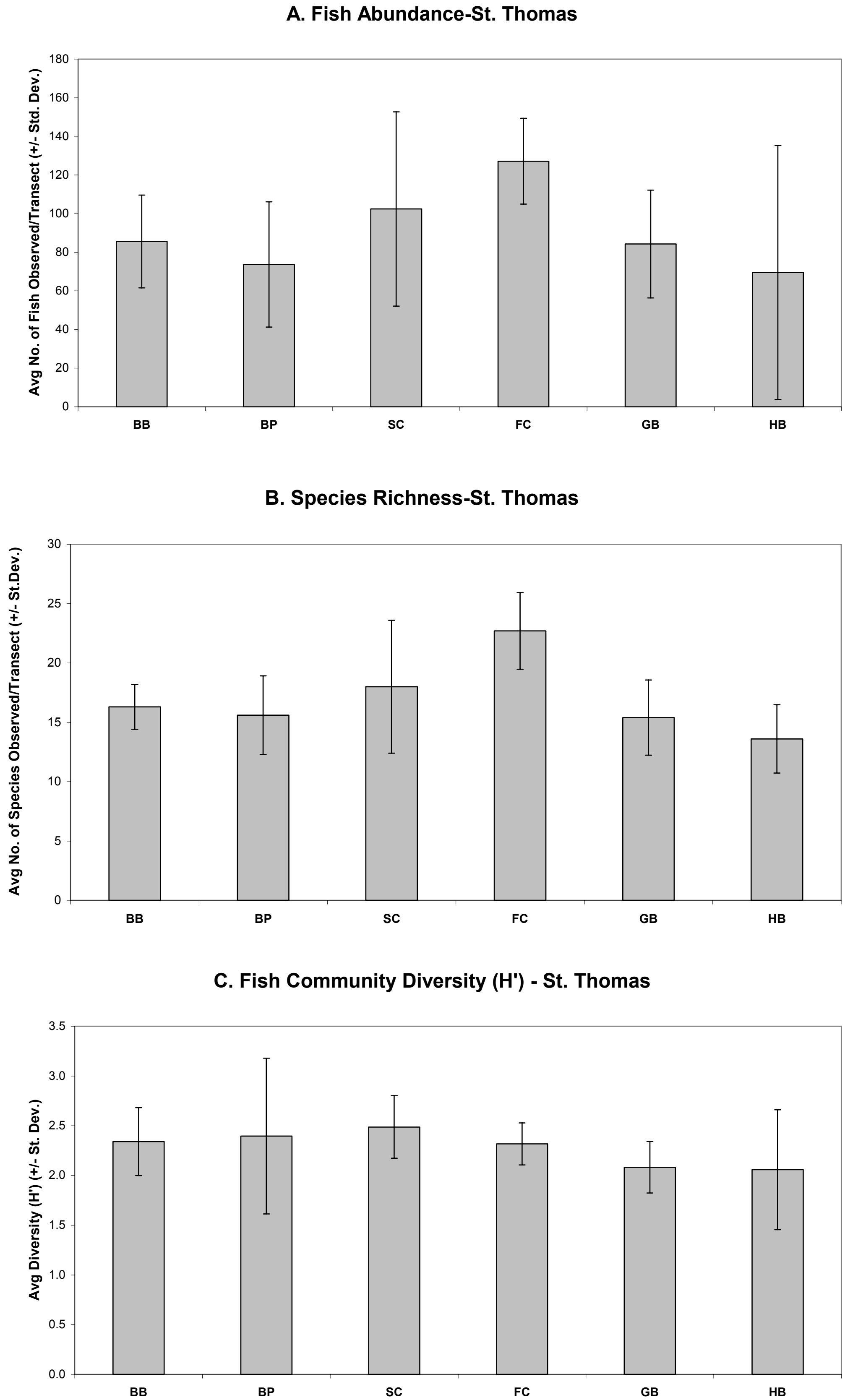


Fig. 32 Reef fish community structure across six St. Thomas reef sites.
A. average abundance; B. average species richness;
C. average Shannon-Weaver diversity (H').

A. Belt Transects

		2.					
		BB	BP	SC	FC	GB	RH
1.	BB	-	54 (18,16)	55 (15,17)	65 (11,27)	57 (10,27)	61 (19,23)
	BP	0.37	-	51 (11,15)	57 (4,21)	60 (14,22)	57 (15,21)
	SC	0.42	0.49	-	64 (10,24)	59 (17,19)	58 (16,18)
	FC	0.42	0.56	0.47	-	68 (26, 14)	66 (24,12)
	GB	0.35	0.40	0.39	0.45	-	56 (14,14)
	RH	0.31	0.37	0.41	0.45	0.50	-

Above diagonal: Total No. of fish taxa observed at both sites combined,
(No. of unique taxa, site1, site 2)
Below diagonal: Jaccard's Community Similarity Index

B. Roving Diver

		2.					
		BB	BP	SC	FC	GB	RH
1.	BB	-	95 (31, 13)	98 (26,21)	106 (21,24)	104 (46,22)	105 (37, 23)
	BP	0.54	-	92 (16,29)	91 (6, 27)	85 (27, 21)	88 (20, 24)
	SC	0.54	0.51	-	101 (16,25)	97 (39,19)	97 (29,21)
	FC	0.58	0.64	0.59	-	101 (43,16)	104 (36,19)
	GB	0.35	0.44	0.40	0.42	-	80 (12,22)
	HB	0.43	0.50	0.48	0.47	0.58	-

Above diagonal: Total No. of fish taxa observed at both sites combined,
(No. of unique taxa, site1, site 2)
Below diagonal: Jaccard's Community Similarity Index

Fig. 33 Fish community similarity across six St. Thomas reef sites calculated using: A. belt transects and B. roving diver surveys.

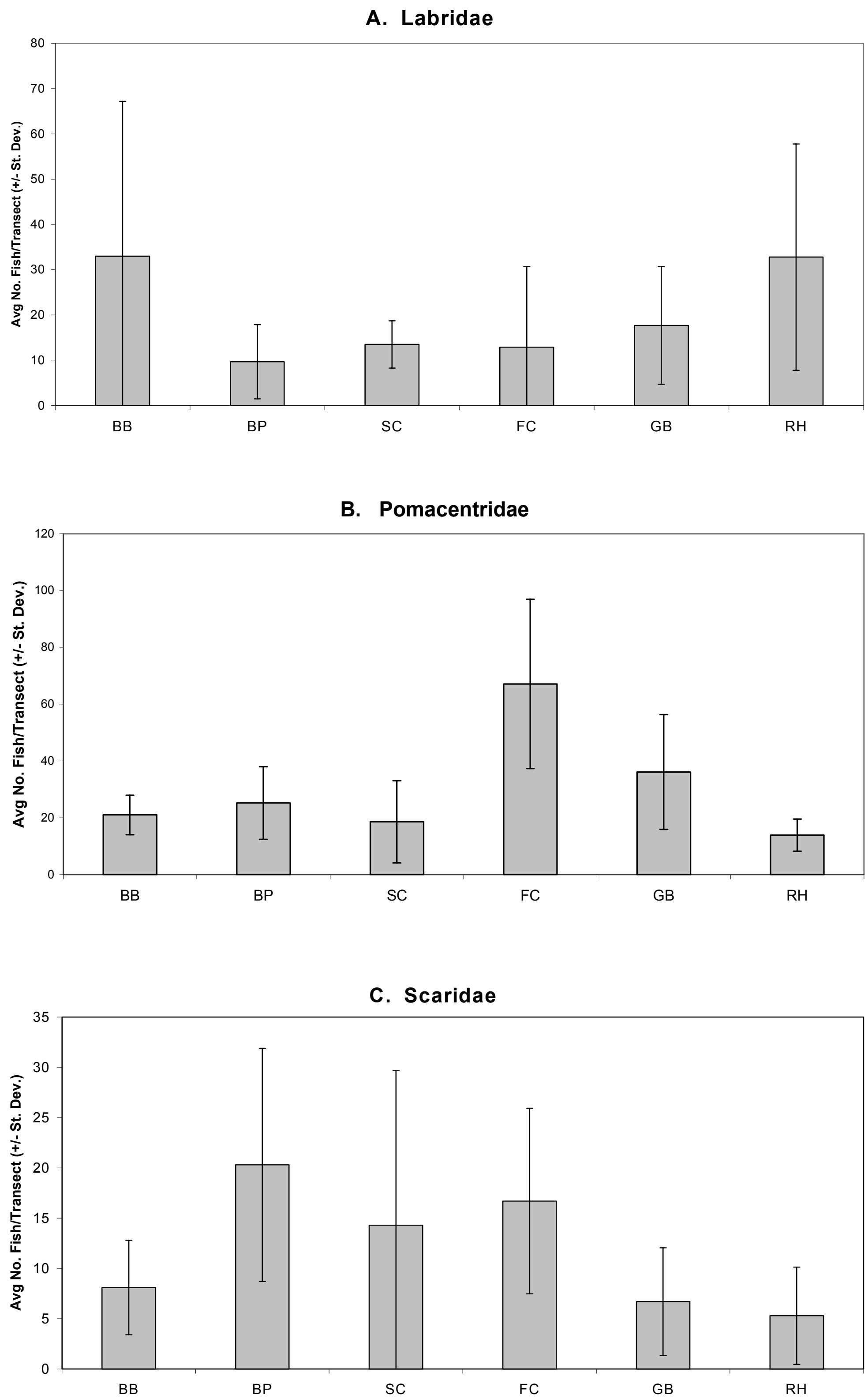


Fig. 34 Fish abundance by family across six St. Thomas reef sites.

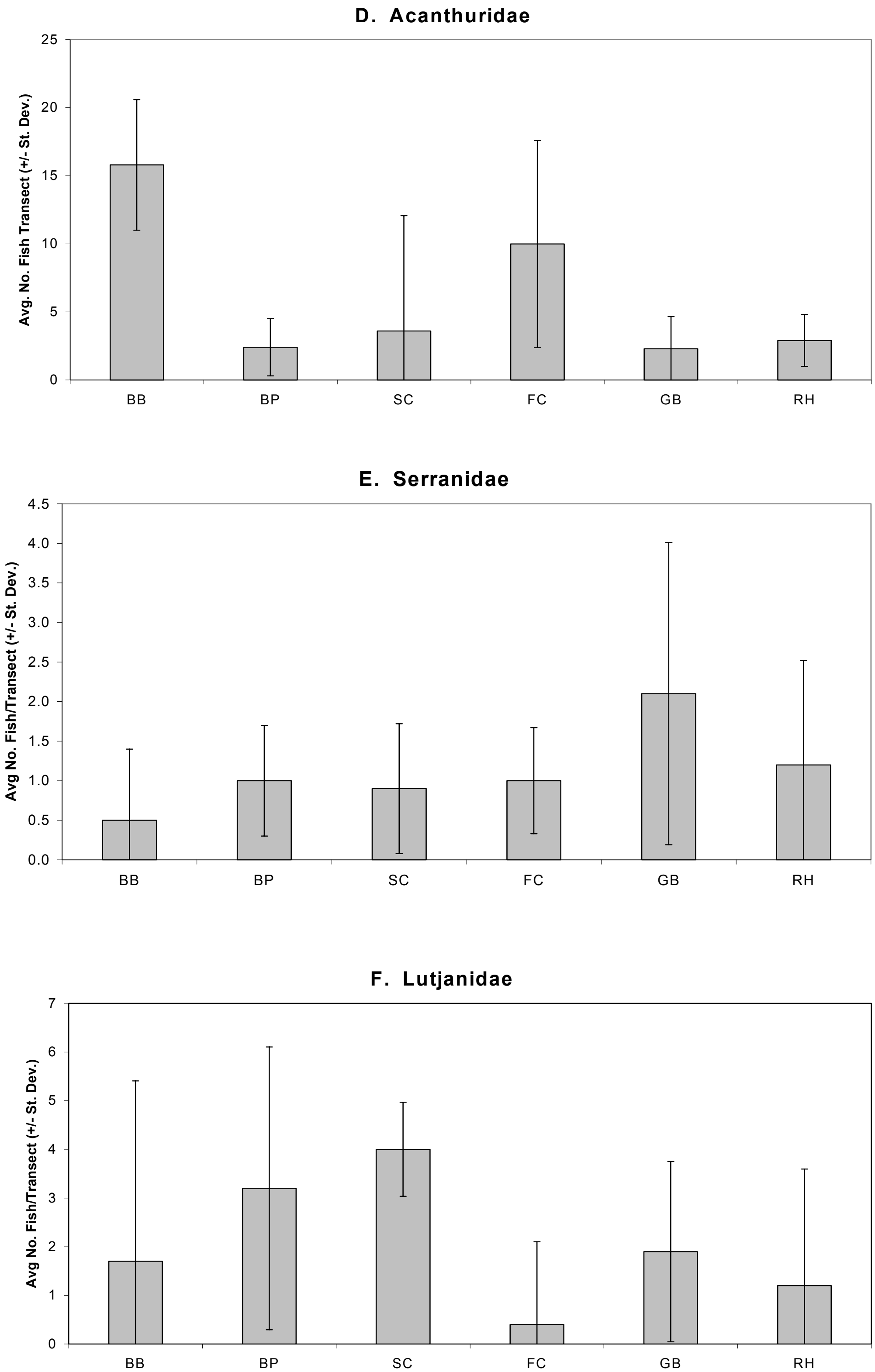
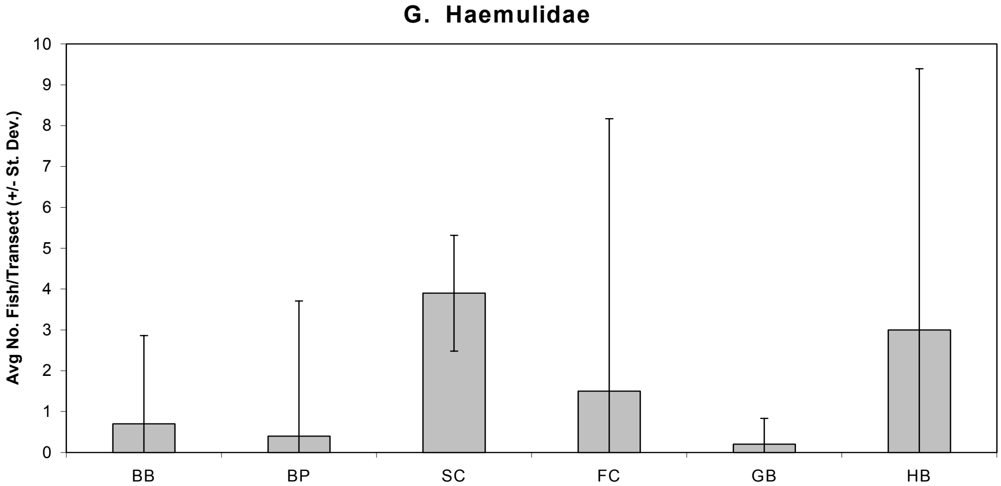
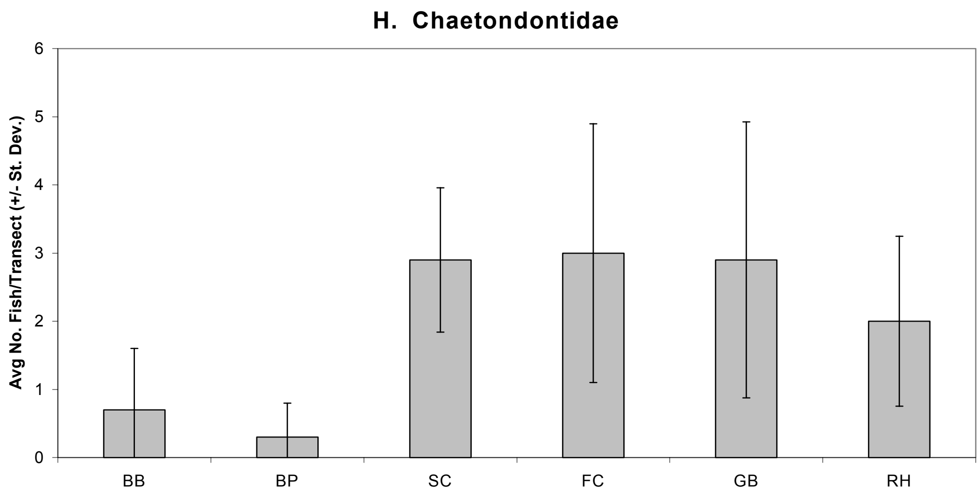


Fig. 34 (cont.) Fish abundance by family across six St. Thomas reef sites.





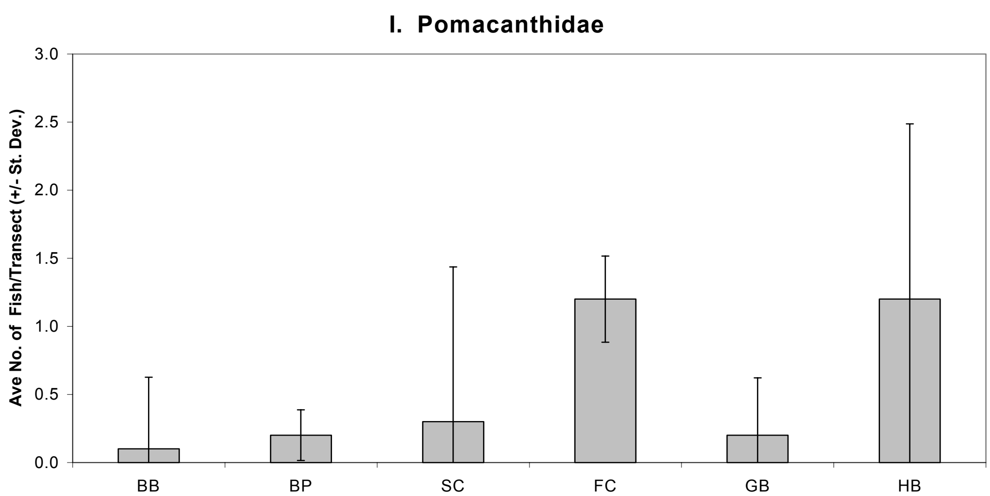


Fig. 34 (cont.) Fish abundance by family across six St. Thomas reef sites.

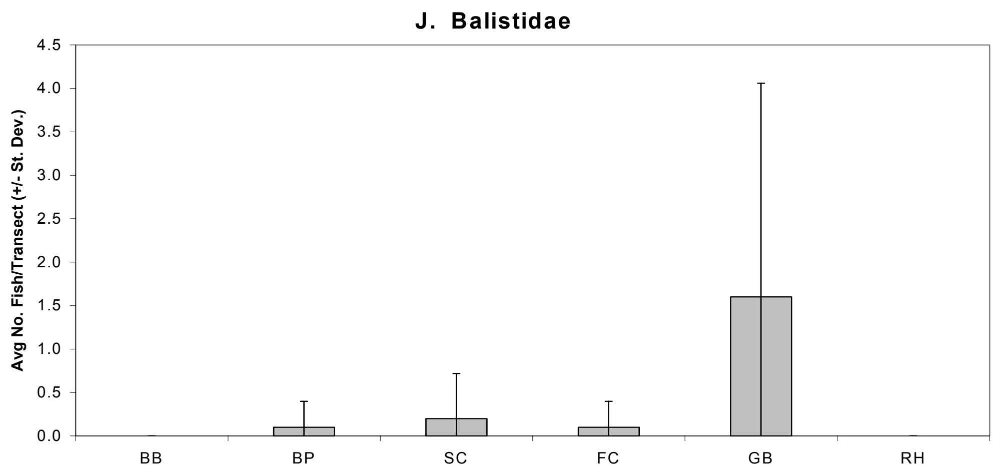


Fig. 34 (cont.) Fish abundance by family across six St. Thomas reef sites.