

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

Year Four 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, implemented a long-term coral reef monitoring and assessment program in 2001. This program has established 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 fourth year of monitoring in St. Croix and the second year of monitoring in St. Thomas, with comparisons to previous years. St. Thomas monitoring and assessment employed a stratified design based upon the position of reefs along the insular platform (mid-shelf and shelf-edge). This design was implemented to complement other ongoing monitoring studies and to facilitate a systematic evaluation of the effects of natural and human-induced stresses influencing the decline or recovery of 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 (Buck Island, Cane Bay, Great Pond, Jacks/Isaacs Bay, Long Reef/Eagle Ray, Mutton Snapper, Salt River, and Sprat Hole) and four permanent sites surrounding the island of St. Thomas (Seahorse Cottage Shoal, South Capella, the Grammanik Bank, and the Red Hind Bank). Current speed and direction and water temperature were assessed at two St. Thomas sites (Flat Cay and the Red Hind Bank) using data recorders.

In St. Croix, turf algae covering dead coral was the predominant benthic cover at most sites. Percent cover of living coral changed little over the four years of monitoring. Percent cover of dead coral covered with turf algae and macroalgae varied, with significant differences between years. Levels of coral disease were lower in 2004 than previous years, while levels of bleaching were variable between sites and years. Sea urchin densities were low and showed little change between years. In 2004, fish diversity ranged from 68 to 80 species, while fish abundance averaged ~ 200 to 400 fish per census. The majority of fish observed on belt transects were small (≤ 5 cm). Commercially important large groupers, snappers, and angelfishes were uncommon to absent at all sites. Four St. Croix monitoring sites showed changes in fish community structure between 2003 and 2004. The changes at one of these sites (Jacks/Isaacs Bay) can be attributed to fishing pressure.

In St. Thomas, living coral was the predominant substrate type at the Grammanik Bank and macroalgae was predominant at all other sites. Benthic composition, levels of coral disease and bleaching, and sea urchin density were similar between mid-shelf and shelf-edge reef systems. Benthic composition showed little change between 2003 and 2004. In 2004, levels of bleaching were significantly higher than 2003 at two of the sites and tended to be higher at one site. Sea urchins were observed only at one site, with similar densities to 2003. Current patterns and temperature differed between the mid-shelf and shelf-edge sites, but were similar between years. St. Thomas fish diversity ranged from 40 to 72 species, while fish abundance averaged ~ 60 to 100 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. Densities of commercially important fishes decreased between 2003 and 2004 and may be the result of fishing pressure at spawning aggregation sites and other habitats around the territory.

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. Sixty-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 mid-shelf reefs (5 – 30 m depth) located 2 to 10 km from the shore of the main islands and shelf-edge reefs (>30 m depth) located 10 to 15 km offshore along the edge of the insular platform. A systematic approach to investigating these cross-shelf coral reef systems allows us to evaluate the variable impacts and synergistic effects of natural impacts and human-induced stress that influence the decline or recovery of Caribbean coral reef systems. The first two years of this project (2001 and 2002) concentrated on the fringing reefs surrounding St. Croix (Nemeth *et al.* 2002; Nemeth *et al.* 2003a). In 2003, monitoring continued at St. Croix reefs and began at reef systems distributed across the insular platform surrounding St. Thomas. In 2004, monitoring is continued at reefs surrounding both islands.

Objectives for Monitoring Coral Reefs

Effective management is necessary to maintain the resources in the territorial and federal waters of the Virgin Islands in an ecologically and economically sustainable manner. Monitoring programs are essential for successful management because they provide managers with fundamental information with which to make and enforce decisions. Standards for resource protection can be measured by comparison to baseline data established by monitoring. Monitoring also provides the means to assess the status and trends of ecological resources, allowing managers to determine the effectiveness of current management and to develop effective management plans for the future. The 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 St. Thomas. This report presents results from the fourth year of monitoring in St. Croix and the second year of monitoring in St. Thomas. For both islands, temporal changes from year to year in the conditions of the reef communities are assessed. In addition, biotic and abiotic parameters are compared among the mid-shelf and shelf-edge reefs of St. Thomas.

Section I: St. Croix

Methods

Benthic Assessments:

Between May and July 2004, the University of the Virgin Islands determined the benthic composition at eight long-term monitoring sites previously established off the island of St. Croix. Two of the sites (Great Pond and Jacks Bay) are within the East End Marine Park Boundary (Figure 1, Table 1). Details on site selection and prior sampling methodology can be found in Nemeth *et al.* (2004).

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
Buck Island	5/5/04	N 17° 47.122, W 64° 36.550	35	6
Cane Bay	5/25/04	N 17° 46.433, W 64° 48.810	30	6
Great Pond	6/2/04	N 17° 42.668, W 64° 39.148	14	6
Jacks/Isaac Bay	5/28/04	N 17° 44.588, W 64° 34.309	35	6
Long Reef/Eagle Ray	5/3/04	N 17° 45.688, W 64° 41.929	30	6
Mutton Snapper	7/20/04	N 17° 38.217, W 64° 51.683	75	6
Salt River West Wall	5/12/04	N 17° 47.116, W 64° 45.564	20	6
Sprat Hole	5/10/04	N 17° 44.038, W 64° 53.722	40	6

At all sites except 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. For Mutton Snapper, transects were marked 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 different years do not represent the exact area of reef, but do correspond to the same general area. In addition, due to logistical challenges presented by the depth of the Mutton Snapper site, the dive team was unable to perform coral disease and bleaching and sea urchin density transects.

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 m² (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. Repeated measures ANOVA tests were performed to determine if there were significant differences in the percent cover of these benthic categories at each site between years.

At all sites except Mutton Snapper, all coral colonies ≥ 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. Repeated measures ANOVA tests were used to determine if there were significant differences in the percent of diseased and bleached colonies between years two through four. 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 sites, with the exception of Mutton Snapper. The mean number of sea urchins per 10 m² was calculated for each site and repeated measures ANOVA tests were performed to determine if there were differences in the mean density of sea urchins at each site between years.

Fish Census:

In 2004, fish communities were surveyed on St. Croix using two census methods. The first was the belt transect method of Brock (1954) as described previously (Nemeth *et al.* 2004). Belt transects were 30 x 2 m (60 m²). 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. During surveys, divers estimated fish length by reference to a PVC measuring “T-bar” marked in 1 cm increments (Bohnsack and Bannerot 1986). 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 [MS] site (6 transects). An attempt was made to standardize the duration of each belt transect to 20 minutes on St. Croix (Table 2).

In 2004, we also expanded the use of a second fish census method - the Roving Diver Survey (RDS; Kimmel 1985, Kramer and Lang 2003) - to compliment the use of belt transects at each site. In the RDS method, divers swam a haphazard circuit in the immediate vicinity of the survey site while listing all observed fish species into one of five abundance categories as follows: 1 fish; 2-10 fish; 11-100 fish; 101-1000 fish; and > 1000 fish. Observations were recorded onto blank underwater sheets, rather than pre-printed forms (i.e. divers generated a new species list for each survey). Each RDS was 30 minutes in duration and three to five replicate surveys were conducted at each site. RDS were not conducted at MS due to limited bottom time.

On St. Croix, eight sites were surveyed between June 24 and August 24, 2004 (Table 2). The same eight sites were surveyed in 2003 (Nemeth *et al.* 2004), and five of these were surveyed in 2002 as well (Toller 2002). See Nemeth *et al.* (2004) for complete site descriptions and locations. 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 Diversity [H']).

Table 2. Summary of fish census effort on St. Croix, 2004.

SR = Salt River, CB = Cane Bay, ER = Long Reef/Eagle Ray,
SH = Sprat Hole, BI = Buck Island, IB = Jacks/Isaacs Bay,
GP = Great Pond, MS = Mutton Snapper

Survey Method	Site	Survey Date	Total No. of Replicates	Cumul. Survey Time (min)	Avg Time per Transect (min)
Belt Transect	SR	24-Jun-04	10	185	18.5
	CB	29-Jun-04	10	193	19.3
	ER	9-Jul-04	10	173	17.3
	SH	20-Jul-04	10	184	18.4
	BI	23-Jul-04	10	164	16.4
	IB	27-Jul-04	10	168	16.8
	GP	30-Jul-04	10	180	18.0
	MS	24-Aug-04	6	110	18.3
Roving Diver	SR	24-Jun-04	4	120	30
	CB	29-Jun-04	5	150	30
	ER	9 & 27-Jul-04	4	120	30
	SH	20-Jul-04	4	120	30
	BI	23-Jul-04	3	90	30
	IB	27-Jul-04	3	90	30
	GP	30-Jul-04	5	150	30
	MS	na	0	-	-

Results and Recommendations

Benthic Assessments:

In 2004, the percent cover of living coral at the St. Croix sites ranged from a low of 4.2% at Jack's Bay to a high of 35.2% at Mutton Snapper. The percent cover of living coral remained fairly constant at each site from 2001 to 2004, with no significant differences between years at any site (Figure 2A). In 2004, turf algae covering dead coral was the most dominant substrate type at most sites, except Jacks Bay, Mutton Snapper and Sprat Hole, where macroalgae was the most abundant substrate type. Dead coral with turf algae ranged from a low of 10.7% at the Mutton Snapper site to a high of 82.2% at Great Pond. At most sites, dead coral covered with turf algae varied between years, with significant differences at Buck Island between all years except between 2002 and 2003 and between 2001 and 2004; Cane Bay between 2004 and all previous years; Great Pond between 2002 and all other years; Jacks Bay between 2002 and 2004; Long Reef/Eagle Ray between 2002 and 2003 and between 2003 and 2004; Mutton Snapper between all years; and Sprat Hole between all years except years 2001 and 2003 and years 2002 and 2004 (Figure 2B). In 2004, macroalgae ranged from a low of 4.9% at Great Pond to a high of 57.0% at Jacks Bay. Macroalgae varied between years with significant differences at Buck Island between all years; Cane Bay between 2004 and years 2001 and 2003; Jacks Bay between 2004 and years 2001 and 2002; Long Reef between 2001 and years 2002 and 2004, and between years 2002 and 2003; Mutton Snapper between years 2002 and 2004; Salt River between 2004 and years 2002 and 2003; and Sprat Hole between all years except between 2001 and 2003 and between 2002 and 2004 (Figure 2C). In most cases, significant increases/decreases in turf algal cover corresponded with significant decreases/increases in macroalgal cover. Seasonal variations in macroalgal cover can affect the integrity of annual comparisons. See *et al.* (2002, 2003a, and 2004) for detailed discussion involving the collection and analysis of turf and macroalgae video transect data. Sponges and gorgonians each comprised less than 10% of the benthic cover at all sites, with sponge cover increasing significantly at Buck Island between 2003 and years 2001 and 2002 (Figure 2D, E). Sand/sediment was the only non-living substrate type found at the sites, ranging from 0.1% at Salt River to 20.1% at Buck Island. Percent cover sand/sediment was fairly constant at most sites between years, with significant differences only at Buck Island between year 2004 and years 2002 and 2003; Long Reef/Eagle Ray between 2003 and all other years; and Sprat Hole between years 2001 and 2004 (Figure 2F).

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 2004, *Montastraea* spp. were the most abundant corals at six of the eight sites. *Millepora complanata* was the most abundant at Great Pond and *Porites astreoides* was the most abundant at Sprat Hole. At all sites, species composition tended to differ between years (Figure 4A-H). At several sites, trends noted in percent composition of corals during previous years (see Nemeth *et al.* 2004) were reversed. Buck Island, Cane Bay, Mutton Snapper and Sprat Hole showed increases in the percent composition for corals in the *M. annularis* complex. In many cases, increases in *Montastraea* complex corals corresponded with decreases or only marginal increases of the stress tolerant corals *Porites astreoides* and *Siderastrea siderea*. This is encouraging, as it may indicate an improvement in overall reef quality at these sites. However, *Montastraea* complex corals continued to decrease at Salt River, corresponding with increases of ubiquitous stress-tolerant corals, such

as *P. astreoides* and *Millepora alcicornis* (fire coral). This trend may indicate a decrease in overall reef quality at this site (Figure 4A-H). See Nemeth *et al.* (2004) for a more detailed discussion regarding these types of changes in reef community structure.

For 2004, the Shannon – Weaver Diversity Index (H') for coral ranged from a high of 2.23 at Salt River to a low of 0.78 at Mutton Snapper. Coral diversity increased at most sites from 2003 to 2004, with the exception of Buck Island, Jacks Bay, and Long Reef/Eagle Ray (Figure 5).

In 2004, Salt River showed the highest incidence of disease, with diseased corals comprising 5.6% of the sampled colonies. Cane Bay was the only other site with disease. Sprat Hole had the highest incidence of bleaching with 9.8% of the sampled colonies showing signs of bleaching. Buck Island had the lowest incidence of bleaching with 1.5%. In general, levels of disease decreased in 2004, while changes in bleaching levels increased at some sites, decreased at some sites and remained similar at others between 2003 and 2004. As no disease and bleaching assessments were performed at the Mutton Snapper site in 2004, comparisons between 2004 and previous years are not possible (Figure 6). In 2004, *Siderastrea siderea* was the only coral species with disease, while *Montastraea franksii* and *S. siderea* were the most common corals with bleaching (Figure 7). Dark spots disease was the only disease observed.

No *Diadema antillarum* sea urchins were present at most sites in 2004, the exceptions being Great Pond (5.7 urchins/10 m²) and Salt River (0.2 urchins/10 m²). No significant differences in urchin density were found between years.

Detailed summaries of the benthic data from each St. Croix site are included in Appendix I: Summary of Coral Video Data, Appendix II: Summary of Non-coral Video data, and Appendix III: Summary of Urchin, Bleaching, and Disease Data. These data will be also made available on the University of the Virgin Islands web site <http://rps.uvi.edu/VIMAS/reefs.htm>.

Fish Census:

A general description of the fish communities found at the eight St. Croix survey sites has already been given (Nemeth *et al.* 2002, Toller 2002, Nemeth *et al.* 2003a, Nemeth *et al.* 2004). Most of these characteristics were again observed in 2004 and they are only discussed briefly here. In terms of reef fish abundance, richness, and diversity (Figure 8A-C), variability was again high within and among sites [see Appendix IV for a more detailed description of species composition], however observations at each site remained relatively consistent between years. As reported for 2003, small fish predominated in 2004 surveys (Appendix V). Most fish (10,654 fish or 50.3 %) fell into the smallest size category (≤ 5 cm). Few large fish (30-40 cm) were observed (65 fish or 0.3 %) and even fewer very large fish (> 40 cm) were observed (46 fish or 0.2 %). Fish abundance, from 10 families (Figure 9A-J) was also similar between years. For example, small planktivores (labrids and pomacentrids) were numerically dominant at all sites in 2003 and 2004 (Figure 9A, B). Groupers (Serranidae) and snappers (Lutjanidae) were relatively rare (Figure 9E, F) and small in size (Appendix V, Appendix VI). Typically, observations were of diminutive serranids, such as hamletfish (*Hypoplectrus* spp.) and harlequin bass (*Serranus tigrinis*) or smallish species

such as coney (*Cephalopholis fulvus*) and graysby (*C. cruentatus*). When compared between years, most other fish families showed no obvious change except as discussed below.

Observed Changes in Reef Fish Communities

Changes at four sites were evident in St. Croix reef fish communities based upon the comparison of data from 2003 and 2004 (Table 3). The observed changes at three sites [SH, MS, BI] are attributed to natural variation. Changes at a fourth site [IB] are interpreted to result from fishing pressure. Each site is presented individually below.

Table 3. Observed trends in fish communities on St. Croix between 2003 and 2004

Site	Fish Family	Affected Species	Observed Trend: 2003 to 2004	Affected Size Class	Most Probable Explanation (see text)
SH	Labridae	creole wrasse	increase	all	natural variation, schooling
MS	Pomacentridae	blue chromis	decrease	all	natural variation, schooling
		brown chromis	decrease	all	natural variation, schooling
		bicolor damsel	decrease	all	natural variation, mortality(?)
BI	Scaridae	striped parrotfish	decrease	< 5 cm	variation in recruitment
		princess parrotfish	decrease	< 5 cm	variation in recruitment
		redband parrotfish	decrease	< 5 cm	variation in recruitment
IB	Acanthuridae	ocean surgeon	decrease	10-20 cm	fishing pressure
	Scaridae	various scarids	decrease	> 10 cm (?)	fishing pressure

At Sprat Hole, wrasses (Labridae) showed a marked increase in density in 2004 (Figure 9A). Wrasse diversity is relatively low at SH, with only four species - bluehead wrasse (*Thalassoma bifasciatum*), yellowhead wrasse, (*Halichoeres garnoti*), Spanish hogfish (*Bodianus rufus*), and creole wrasse (*Clepticus parrae*) – commonly observed during the two years. Creole wrasse abundance increased significantly in 2004 and no change was observed for the other three wrasses (Figure 10A). Data from RDS supported the substantial abundance of creole wrasse at SH in 2004, with an Average AI of 4.8 – the highest in this survey (Appendix VII). Creole wrasses are only loosely associated with reefs (Randall 1967) and this inter-annual variation may be partly explained by the foraging movements of large schools of adults. However abundance increased proportionally across three size classes (< 5 cm, 5-10 cm, 10-20 cm) relative to 2003 (not shown) suggesting that a recent and substantial creole wrasse recruitment event has contributed to their numbers as well.

The average abundance of fish at the Mutton Snapper [MS] site declined from 2003 to 2004 (Figure 9A). This decline was largely restricted to the damselfishes (Pomacentridae), as shown in Figure 9B. Of the 7 or 8 common damselfish species at MS, three species – blue chromis (*Chromis cyanea*), brown chromis (*C. multilineata*) and bicolor damselfish (*Stegastes partitus*) – accounted for most of the inter-annual disparity (Figure 10B). Blue and brown chromis are small planktivores that routinely feed in schools high above the reef (Randall 1967). A decrease in their numbers might be explained by movement of schools out of the immediate survey area. The 2004 survey at MS was conducted under conditions of strong current (~2 knots), which may have influenced *Chromis* foraging behavior. Bicolor damselfish are territorial and more strongly associated with reef features so their observed decline in their abundance is not explicable by movement. In 2003, bicolor damselfish populations were predominated by small fish (78.8% were < 5 cm) compared to 2004, when

size distributions were almost equal (58.3% < 5 cm, 41.7% 5-10 cm). This suggests that young bicolor damselfish experienced high levels of mortality during the intervening time period.

At Buck Island [BI], parrotfish (Scaridae) showed a marked decrease in overall abundance from 2003 to 2004 (Figure 9D). Parrotfish diversity remained relatively high (7-9 species) at BI and species composition was similar across years (not shown). Examination of scarid size distribution (Figure 11) showed a significant difference in the smallest size class (< 5 cm). For both years, the recruits were primarily from three species: striped parrotfish (*Scarus croicensis*), princess parrotfish (*Scarus taeniopterus*), and redband parrotfish (*Sparisoma aurofrenatum*). Collectively, the three species comprised 89.2% and 86.4% of scarid recruits at BI in 2003 and 2004, respectively. Larger scarid size classes were comparable between years (Figure 11). Together, these data suggest that the observed decrease in abundance of parrotfish at BI is best explained as natural, inter-annual variation in recruitment processes.

In contrast to the previous three sites, the abrupt decrease in surgeonfish (Acanthuridae) abundance at Isaacs Bay [IB] from 2003 to 2004 (Figure 9C) suggests that fishing has impacted the fish communities there. Three acanthurid species occur at IB - ocean surgeonfish (*Acanthurus bahianus*), blue tang (*A. coeruleus*) and doctorfish (*A. chirurgus*). Between 2003 and 2004 surveys, ocean surgeonfish declined significantly in abundance (Figure 12A) while blue tang and doctorfish remained relatively constant. The size distribution of ocean surgeonfish (Figure 12B) indicates that the decline occurred in the largest size class (10-20 cm). However, if this species had formed large roaming schools as suggested by RDS data, they may have been underestimated by belt transect surveys (Nemeth *et al.* 2003b). Parrotfishes from the same site (Figure 12C) also decreased in relative abundance. For three larger scarid species - queen (*Scarus vetula*), redband (*Sparisoma chrysotum*) and yellowtail (*Sp. rubripinne*) parrotfishes - no individuals ≥ 10 cm were observed in 2004 (Figure 12C). Parrotfishes are a common target of the local commercial fishery, as are blue tang and doctorfish. Ocean surgeonfish may not be targeted but they are frequently harvested as bycatch with nets, after which they may be consumed or discarded (Tobias 2004). During the past three years of fish surveys at IB, there were no recorded observations of parrotfish > 30 cm. At least two common species (*Sc. vetula* and *Sp. viride*) grow larger than 40 cm and individuals larger than 30 cm were common in St. Croix commercial landings (Appeldoorn *et al.* 1992). Collectively, these observations suggest that commercial fishing with traps and/or trammel nets (Tobias 2004) are having a measurable impact upon acanthurids and scarids. The ecological consequences of over-harvesting the predominant vertebrate herbivores from a coral reef ecosystem are probably detrimental (Hughes 1994, Pennings 1996). For this reason, St. Croix's populations of scarids and acanthurids should be monitored carefully in the future.

Utility of RDS to assess rare species

The RDS method was incorporated into the St. Croix annual fish survey to provide greater detection of rare species. In particular, it was suggested that RDS would enable quantification of the larger, long-lived resident reef fishes (e.g. some grouper and snapper species) that were nearly absent from previous years' fish surveys on St. Croix.

Compared to the belt transect method, RDS enabled a slightly greater enumeration of fish species - a total of 119 species representing 41 families were observed in 28 RDS surveys at seven sites (Appendix VII). By contrast, the belt transect method yielded 103 species from 33 families in 76 belt transects at eight survey sites (Appendix IV). As expected (Roger *et al.* 1994), at each site the RDS yielded higher estimates of species richness (Table 4). At no site, however, did the RDS enumerate all species that were observed in belt transects. From cumulative site lists, RDS (3-5 replicates) identified about 90% of the fish species (range 83% - 96%) and belt transects (10 replicates) identified about 73% (range 65% - 81%) at each site. These surveys are not meant to be exhaustive species lists for these sites (see Nemeth *et al.* 2003b) but the data do indicate that use of the RDS method increased our ability to enumerate species.

Table 4. Comparison of reef fish community richness estimates obtained using belt transects and roving diver surveys (RDS) at seven St. Croix sites, 2004.

Site	Total No. Spp. Obs. at Site (either method)	Belt Transects				RDS			
		Total Survey Time (min)	No. Spp. Observed	Avg. No. Per Repl. (St.Dev)	% of Total Obs. at site	Total Survey Time (min)	No. Spp. Observed	Avg. No. Per Repl. (St.Dev)	% of Total Obs. at site
SR	77	185	54	21.1 (5.9)	70.1%	120	73	35.0 (13.8)	94.8%
CB	75	193	55	27.1 (3.1)	73.3%	150	72	41.6 (7.6)	96.0%
ER	80	173	52	24.7 (3.5)	65.0%	120	73	47.0 (9.2)	91.3%
SH	78	184	61	28.3 (3.9)	78.2%	120	65	40.0 (13.3)	83.3%
BI	70	164	57	24 (3.5)	81.4%	90	59	36.3 (11.2)	84.3%
IB	68	168	49	20.3 (4.8)	72.1%	90	63	40.7 (11.5)	92.6%
GP	69	180	51	20.8 (3.2)	73.9%	150	64	39.0 (7.8)	92.8%
Avg	73.9	178.1	54.1	23.8	73.4%	120.0	67.0	39.9	90.7%

In terms of quantifying commercially important, rare, and/or vulnerable fishes, the results from RDS were rather disappointing (Table 5). From a list of 12 selected fishes, only four species were observed by either method: red hind (*Epinephelus guttatus*), tiger grouper (*Mycteroperca tigris*), mutton snapper (*Lutjanus analis*), and blue parrotfish (*Scarus coeruleus*). The low density of red hind as estimated from RDS at four sites (Abundance Index 0.2 to 0.7) was corroborated by belt transects at two sites (each with 1 fish observed in 600m²). Although RDS provided some “gain” in signal strength relative to belt transects (8 sightings vs. 2 sightings), results from both methods suggest that population densities for all 12 species are effectively near or at zero for the sites surveyed.

From a monitoring point of view, the data on rare species set a one-sided baseline - an increase in fish abundance should be easy to detect but a further decrease would be difficult to demonstrate for the selected species. More accurate censusing of these species could be accomplished by 1) expanding the spatial coverage of sampling, 2) sampling from a greater variety of habitats, and/or 3) the use of baited stations. Alternatively, some of these species could be censused during periods of spawning aggregations - if such a behavior applies and aggregation sites are known. For the purposes of this monitoring study, however, it is recommended that greater effort (sampling and analytical) be directed towards other fish species that are of present economic importance.

Table 5. Abundance of 12 commercially important, rare and/or vulnerable fish species on St. Croix, 2004

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
Salt River	belt	185	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	120	-	-	-	-	0.5 (1,0)	-	0.25 (1,0)	-	-	-	-	-
Cane Bay	belt	193	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	150	-	-	-	0.2 (1,0)	-	-	0.4 (2,0)	-	-	-	-	-
Isaac's Bay	belt	168	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	90	-	-	-	-	0.3 (1,0)	-	-	-	-	-	-	-
Eagle Ray	belt	173	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	120	-	-	-	-	-	-	-	-	-	-	-	-
Sprat Hole	belt	184	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	120	-	-	-	-	-	-	-	-	-	-	-	-
Buck Island	belt	164	-	-	-	-	1	-	-	-	-	-	-	-
	RDS	90	-	-	-	-	0.7 (1,0)	-	-	-	-	-	-	-
Great Pond	belt	180	-	-	-	-	1	-	-	-	-	-	-	-
	RDS	150	-	-	-	-	0.2 (1,0)	-	-	-	-	-	0.2 (1,0)	-
Mutton Snapper**	belt	110	-	-	-	-	-	-	-	-	-	-	-	-

*Belt transect observations reported as total number of fish in 10 replicate surveys. RDS observations reported as mean Abundance Index (AI) over 3 to 5 replicate surveys with maximum and minimum AI in parentheses. AI: 0=no fish, 1=1 fish, 2=2-10 fish, 3=11-100 fish, 4=101-1000 fish

**At Mutton Snapper site, only six belt transects were conducted. No RDS were performed.

Recommendations

The foregoing results indicate that our methodological approach is relatively robust for the study of coral reef fish communities and trends can be distinguished in some instances. Continued monitoring will undoubtedly reveal more temporal patterns. However, as noted previously (Nemeth *et al.* 2004), any conclusions about status and trends of St. Croix's coral reef fish communities are still compromised by lack of a stratified sampling design. The threat(s) under study should be identified explicitly and *a priori* so that appropriate data are collected to test for correlations. Most of the salient threats to USVI coral reef ecosystems have been identified (Catanzaro *et al.* 2002).

With respect to coral reef fish communities of St. Croix, a rather obvious threat is overfishing. Fishing pressure may alter reef fish community structure in numerous ways (e.g. Dayton *et al.* 2002) however two impacts are likely to be detected using visual census methods: 1) the reduction in absolute abundance of targeted species, and 2) the selective removal of the largest individuals from populations of targeted species. Data collected in this study to date, however, have treated either the entire diversity of fish assemblages at specific reef sites or trends within individual families of fish. Instead, an emphasis should be placed on species-level information for fish that are targeted by the local fishery. Fisheries-dependent information is directly applicable to our monitoring study design and analyses. The last stock assessment for the USVI was conducted 12 years ago (Appeldoorn *et al.* 1992) and harvest patterns may have changed in the interim. However, biostatistical data from the USVI commercial fisher port sampling program have been collected for reef fish landings on St. Croix for over 20 years. This under-utilized database could be used to focus sampling and analytical efforts towards targeted fish species.

Section II: St. Thomas

Methods

Benthic Assessments and Abiotic Parameters:

In May and June 2004, the University of the Virgin Islands assessed the benthic composition at four sites and in St. Thomas, USVI (Figure 13, Table 6). Three of these sites were chosen from the monitoring sites established in 2003, with one new site added in 2004. Monitoring in St. Thomas was based upon a stratified design to test hypotheses involving differences between reef systems located at different points along the insular platform, as well as to fill gaps in existing knowledge on previously unstudied reef systems. See Nemeth *et al.* (2004) for a detailed description and rationale for site selection. In 2004, monitoring was discontinued at the near-shore sites and Flat Cay (a shallow mid-shelf reef associated with a small island) was replaced with South Capella (a deeper mid-shelf reef unassociated with a landmass). This was done to better complement other UVI monitoring activities and to achieve a more balanced experimental design. As part of the Territorial Biological Monitoring Program in 2004, UVI is incorporating a stratified design to monitor near-shore reefs and shallow mid-shelf reefs associated with landmasses. To develop the most effective and complementary balance between monitoring efforts, the State and Territory Coral Reef Ecosystem Monitoring Program will concentrate on mid-shelf reefs not associated with landmasses and shelf-edge reef systems. The changes in the monitoring sites for benthic composition in 2004 reflect this goal.

Table 6. St. Thomas site location information.

Site	Date Sampled	GPS Coordinates	Depth (ft.)	No. of Transects
Seahorse Cottage Shoal ¹	5/25/04	N 18° 17.680, W 64° 52.050	61 - 80	10
South Capella ¹	6/08/04	N 18° 15.760, W 64° 52.342	80	10
Grammanik Bank ²	6/15 & 6/16/04	N 18° 11.468, W 64° 57.019	126	10
Red Hind Bank ²	6/04 & 6/18/04	N 18° 12.130, W 65° 00.095	128 - 131	10

¹ mid-shelf sites

² shelf-edge sites

Video transects, coral disease and bleaching assessments, and sea urchin counts were all performed using the same methodology as 2003 (see Nemeth *et al.* 2003a). However, in 2004, the number of transects (of all types) completed at each site was increased from six to ten (Table 6). This was done to ensure that the parameters at each site were properly quantified, as the mid-shelf and shelf-edge transects were non-permanent and haphazardly established. All data were analyzed and statistically tested using the methodology previously described for St. Croix. In addition, one way ANOVA tests were used to test for significant differences in percent cover, coral disease and bleaching levels, and sea urchin densities between mid-shelf and shelf-edge reef systems.

Abiotic parameters were measured at the mid-shelf and shelf-edge in 2004 by Aanderaa RCM 9 MkII data recorders located at the sites established in 2003, Flat Cay and the Red Hind Bank (Figure 13, Table 7). While the Flat Cay site was replaced with South Capella for the assessments of biotic parameters in 2004, the nature of the installation of the data recorder prohibited relocation to the new site. The data recorders were set to record temperature, current speed, and current direction at hourly intervals.

Table 7. Dates Aanderaa data recorders deployed and retrieved.

Data recorders:	Set 1		Set 2	
	Deployed	Retrieved	Deployed	Retrieved
Flat Cay	2/24/04	5/26/04	5/28/04	9/13/04
Red Hind Bank	3/2/04	5/26/04	5/28/04	9/13/04

After retrieval, data from the data recorders were downloaded into a personal computer according to the manufacturer's instructions using software supplied by Aanderaa instruments.

Fish Census:

Fish communities at four sites were monitored in 2004, including three sites established the previous year, (Nemeth *et al.* 2004) and one new site, South Capella (SCP). Surveys were conducted from May 27, 2004 to June 30, 2004 (Table 8). Methods used to survey fish communities off St. Thomas were identical to those used off St. Croix with the following exceptions. On all sites, ten belt transect replicates and three roving diver survey (RDS) replicates were conducted (Table 8). Belt transects were standardized to a transect time of 7.5 minutes or 4-m/min. The duration of the RDS replicates was standardized depending on depth. On the mid-shelf reefs (SC and SCP) replicates were 30 minutes in duration and on shelf-edge sites (GB and RH) surveys were 10 minutes each. All species of fish observed were recorded during both survey types (belt transect and RDS) with the exception of the glass goby (*Coryphopterus personatus*).

Table 8. Summary of fish census effort on St. Thomas, 2004.

Survey Method	Site	Survey Date	Total No. of Replicates	Total Survey Time (min)	Ave. Time per Replicate (min)
Belt Transect	SH	17-Jun-04	10	75	7.5
	SC	8-Jun-04	10	75	7.5
	GB	27-May-04	10	75	7.5
	RH	28-May-02	10	75	7.5
Roving Diver	SH	23-Jun-04	3	90	30
	SC	17-Jun-04	3	90	30
	GB	2-Jul-04	3	30	10
	RH	30-Jun-04	3	30	10

Data was recorded, managed and analyzed using the same methodology, software and descriptive statistics as that for St Croix. Fish abundance and community structure was compared between 2003 and 2004 surveys, as well as between the mid-shelf and shelf-edge communities.

Results and Recommendations

Benthic Assessments:

For the St. Thomas sites, percent cover of living coral ranged from a low of 25.7% at Seahorse Cottage Shoal to a high of 49.6% at the Grammanik Bank. The percent cover of dead coral covered with turf algae ranged from 9.6% at the Grammanik Bank to 23.1% at Seahorse Cottage Shoal. The percent cover of macroalgae ranged from 33.1% at the Grammanik Bank to 40.4% at South Capella (Figure 14A-C). Sponges, gorgonians, and sand/sediment each comprised less than 10% of the benthic cover at all sites. (Figure 14D-F). There were no significant differences in percent cover of any benthic category between 2003 and 2004 or between mid-shelf and shelf-edge sites. Given the small sample size ($n = 2$) 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. In future monitoring, additional sites of each reef system will be added as resources allow.

The coral reefs of St. Thomas were dominated by coral species in the genus *Montastraea*. Coral species composition was similar between mid-shelf and shelf-edge sites and between years for all sites. Corals within the *M. annularis* complex were the most abundant corals at all sites (Figure 15, Figure 16).

In 2004, the Shannon – Weaver Diversity Index (H') for coral ranged from a high of 1.38 at the Red Hind Bank to a low of 0.90 at South Capella. Mid-shelf sites tended to have a lower diversity than the shelf-edge sites (Figure 17).

The Grammanik Bank showed the highest incidence of both diseased and bleached coral colonies, with diseased corals comprising 10.35% of the sampled colonies and bleached corals comprising 27.93% of the sampled colonies. The Red Hind Bank showed the lowest incidence of diseased corals (2.5%) and South Capella showed the lowest incidence of bleached corals (20.24%). There were no significant differences in incidence of disease between 2003 and 2004 or between the mid-shelf, and shelf-edge sites. There was significantly more bleaching at Seahorse Cottage Shoal and the Grammanik Bank in 2004 than 2003. Bleaching levels tended to be higher at the Red Hind Bank in 2004, but were not statistically different from 2003 (Figure 18). Levels of bleaching were similar between mid-shelf and shelf-edge reef systems. Once again, the small sample size and the high variation within each category made comparisons between reef types difficult. *Montastraea franksii* was the most common coral with disease and bleaching (Figure 19). Diseases observed by divers included black band disease, dark spots disease, yellow blotch disease and white plague.

D. antillarum sea urchins were observed only at the Grammanik Bank, with a density of 0.1 urchins/10 m². No significant differences in sea urchin density were found between years or reef systems.

Detailed summaries of the benthic data from each St. Thomas site are included in Appendix I: Summary of Coral Video Data, Appendix II: Summary of Non-coral Video data, and Appendix III: Summary of Urchin, Bleaching, and Disease Data. These data will be posted on the University of the Virgin Islands website in the near future.

Abiotic Parameters:

The current at Flat Cay flowed predominantly to the west in 2004, and as was observed in 2003, flowed strongest all year in the SSW direction (Figure 20). A minor exception in 2004 was the month of April, which also had some relatively strong currents to the W and WNW. On the Red Hind Bank, current flow was strongest and most often in a north or south direction, with highest velocities measured during the summer months (July, August and September; Figure 21). Very similar patterns were seen in 2003.

Daily mean water temperatures at Flat Cay and the Red Hind Bank in 2004 were fairly consistent with temperatures recorded during 2003 at those sites (Figure 22, Figure 23). The lowest daily mean temperature was recorded in the first week of March 2004 at Flat Cay (25.7°C) and in the first week of April 2004 at the Red Hind Bank (25.7°C). High daily mean temperatures were recorded at Flat Key in the last week of August 2004 (29.2°C) and at the Red Hind Bank between August 14 and August 21, 2004 (28.3°C). Daily mean temperatures were slightly higher at Flat Cay than the Red Hind Bank and less variable, with the exception of one cold spell in late February when temperatures dropped 1°C at Flat Cay in one week. This was not reflected in the Red Hind Bank temperature data.

Fish Census:

A total of 3106 fish representing 76 species and 20 families were observed in 40 belt transects during surveys off St. Thomas in 2004 (Appendix VIII). As in 2003, fish abundance, species richness and community diversity was variable within and between sites and with the exception of the Grammanik Bank, was fairly similar between years (Figure 24A-C). All three of these community structure indices were lower at the Grammanik Bank in 2004. The new mid-shelf site, South Capella had slightly lower average fish abundance than the three established sites, but similar species richness and community diversity.

During roving diver surveys a total of 98 species representing 25 families were observed in 2004. 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. As in 2003, species richness values were higher on RDS than belt transects at all sites, even when significantly less time was spent on the survey (Grammanik Bank and Red Hind Bank). Species richness values for RDS were not comparable across reef sites or years 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 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.)
SC	75	38	18.9 (4.0)	90	66	44.7 (6.7)
SCP	75	38	15.1 (2.8)	90	72	43.0 (6.0)
GB	75	35	9.6 (2.8)	30	49	25.0 (6.2)
RH	75	38	14.0 (5.4)	30	40	25.6 (0.6)

The size distribution of fishes surveyed in belt transects in 2004 was similar to that of 2003. The majority of fish observed in 2003 and 2004 were less than 10 cm TL (68.2% and 70.2% respectively). Fish intermediate in size (10-30 cm TL) made up 28.0% of the total in 2003 and 28.9% in 2004. Large fish (>30 cm) were rare in belt transects in 2003, but were rarer still in 2004. Large fish made up only 0.8% of the total fish observed in 2004, compared to 3.9% in 2003. Complete data for the size distribution of fish observed on St. Thomas in 2004 is given in Appendix IX.

As in 2003, planktivorous pomacentrids and labrids were predominant at all sites in the 2004 surveys (Figure 25A-J). Blue chromis (*Chromis cyanea*) numerically dominated all four sites, followed by bicolor damselfish (*Stegastes partitus*) on South Capella, and creole wrasse (*Clepticus parrae*) on the shelf-edge sites, the Grammanik Bank and the Red Hind Bank. Herbivorous damselfish and parrotfish were again seen in relatively high densities on Seahorse Cottage Shoal. Labrid densities were lower on the mid-shelf than shelf-edge sites, and were represented primarily by the omnivorous bluehead wrasse (*Thalassoma*

bifasciatum), yellowhead wrasse (*Halichoeres garnoti*) and slippery dick (*H. bivittatus*). As in 2003 surveys, Acanthurids (tang) were represented by three species (*Acanthurus coeruleus*, *A. bahianus* and *A. chirurgus*) in moderate numbers on all four sites. Scarids were most commonly represented by the princess parrotfish (*Scarus taeniopterus*) and striped parrotfish (*Sc. inserti*) and were again in 2004 more common on the mid-shelf than off-shore sites. The remaining families (Figure 25E-J) were observed at low densities on all four sites but were similar between years with the following exceptions. The commercially important serranids (groupers) were uncommon at all sites but were less common on the shelf-edge sites than in 2003. Groupers were represented only by the small coney (*Epinephelus fulvus*) and graysby (*Cephalopholis cruentatus*) on the mid-shelf sites. On the Grammanik Bank, large groupers observed during belt transects in 2004 included only one tiger grouper (*Mycteroperca tigris*), and two red hind (*E. guttatus*). On belt transects in 2003 by contrast, five red hind (*E. guttatus*) were observed on the site, as well as one Nassau grouper (*E. striates*) and three tiger grouper (*M. tigris*). Lutjanids (snappers) were also observed at low densities, if at all in 2004. A school of schoolmaster snapper (*Lutjanus epodes*) was observed at the Red Hind Bank, but other than that only a rare fish here and there was encountered. No lutjanids were seen on belt transects at the Grammanik Bank. The large variety of snapper species observed in 2003 at Seahorse Cottage Shoal was not seen in the belt transects in 2004. Balistids (triggerfishes) were very rare to absent on all sites in 2004. In 2003 the black surgeon (*Melichthyes niger*) represented the most common balistid, which was seen in low densities at the Grammanik Bank. This species was not observed on belt transects in 2004.

The most noticeable differences in terms of fish between the 2003 and 2004 surveys off St. Thomas were decreases of snapper and grouper observations on the shelf-edge sites. This was especially true on the Grammanik Bank and was reflected in the RDS observations as well (Table 10). The large groupers were also in lower numbers than the previous year at the Red Hind Bank. Because densities of these fish are generally very low, the differences that we observed between years could simply reflect natural variation. An alternative explanation may be fishing pressure. Although the Red Hind Bank is part of a marine protected area, the Grammanik Bank is fished for grouper regularly in the winter and spring months by both hook and line and trap fishers. The large groupers are highly mobile during the spawning season and many migrate to the Grammanik Bank to spawn. Decreases in observations at both shelf-edge sites may reflect fishing pressure at the spawning aggregation site or around the territory.

Table 10. Abundance of 12 commercially important, rare, and/or vulnerable fish species, ST. Thomas 2004.

Site	Method	Total Survey Time (min)	Rare Species Observed During Surveys											
			Nassau grouper	yellowfin grouper	yellowmouth grouper	tiger grouper	red hind	cubera snapper	mutton snapper	dog snapper	hogfish	rainbow parrotfish	blue parrotfish	midnight parrotfish
Seahorse Cottage	belt*	75	-	-	-	-	-	-	-	-	-	-	-	-
	RDS**	90	-	-	-	-	-	-	.07(0,2)	-	-	-	-	-
South Capella	belt	75	-	-	-	-	-	-	-	-	-	-	-	-
	RDS	90	-	-	0.3(0,1)	-	0.3(0,1)	-	.03(0,1)	1.0(0,2)	-	-	-	-
Grammanik Bank	belt	75	-	1	-	-	2	-	-	-	-	-	-	-
	RDS	30	.03(0,1)	0.3(0,1)	0.3(0,1)	0.7(0,1)	-	1.3(0,3)	-	0.3(0,1)	-	-	-	-
Red Hind Bank	belt	75	-	-	-	1	2	3	-	-	1	-	-	-
	RDS	30	-	-	-	-	-	-	-	-	-	-	-	-

*Belt transect occurrences reported as total number of fish observed over 10 repetitive surveys.

**RDS occurrences reported as mean Abundance Index (AI) over 3 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

St. Croix

On St. Croix, turf algae covering dead coral was the dominant substrate at most sampled sites, ranging from 10.7% to 82.2%. The percent cover of other benthic organisms ranged from 4.2% to 35.2% for living hard coral, 4.9% to 57.0% for macroalgae, 0.1% to 4.2% for sponges, and 0% to 9.5% for gorgonians. Coral species composition was similar between most sites. Coral diversity (H') varied between 0.78 and 2.19 between sites. Coral condition varied between sites with incidence of coral disease and bleaching ranging from 0% to 5.6% and 1.5% to 9.8%, respectively. *Diadema* sea urchins were uncommon and observed on transects at only two 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. At several sites, trends indicating possible decreases in reef quality reversed in 2004. At this stage, it is difficult to attribute these changes in species composition to a specific cause. Due to the slow growth rates of corals, assessments must continue over a greater time period to determine if these changes are the result of actual changes in coral community structure, or are the result of sampling variation. Coral diversity increased at most sites from 2001 to 2004. 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 between year 2003 and other sampled years. Percent cover of turf and macroalgae varied significantly between years at most sites. Between 2003 and 2004, percent cover turf algae tended to decrease at most sites, with corresponding increases in macroalgal cover. This trend warrants special attention, as macroalgae can overgrow or overshadow corals, leading to a loss of live coral and a phase shift to a macroalgal dominated reef.

Levels of disease tended to decrease in 2004, while levels of bleaching varied between sites and years. Only one type of disease (dark spots disease) was observed in 2004, in contrast to several diseases in previous years. No significant annual differences in sea urchin density were found.

Fish abundance averaged from approximately 200 to 400 fish per census. The number of fish species observed at the St. Croix sites ranged from 68 to 80 species. The St. Croix fish fauna was numerically dominated by planktivorous wrasses and damselfishes. The commercially important large groupers, snappers, and angelfishes were uncommon to absent at all sites. The majority of fish observed in 2004 were small, with most fish ≤ 5 cm. Relatively few large fish (30 – 40 cm) and very few larger fish (≥ 40 cm) were observed.

Changes in reef fish communities between 2003 and 2004 were evident at four of the St. Croix sites. Changes at three of these sites can be attributed to natural variation. Changes at the fourth site (a decrease in surgeonfish and parrotfish abundance at Jacks/Isaac Bay) can be attributed to fishing pressure from trap or trammel net commercial fishing. The ecological consequences of over-harvesting the predominant vertebrate herbivores from a coral reef ecosystem are detrimental and surgeonfish and parrotfish populations in St. Croix should be closely monitored in the future.

Results to date indicate that the approach being used to monitor St. Croix fish communities is relatively robust and trends can be distinguished in some instances. However, as noted previously (Nemeth *et al.* 2004), conclusions about the status and trends of these fish communities are compromised by the lack of a stratified sampling design. Also, more emphases should be placed on species-level information for locally targeted fisheries species. Incorporating biostatistical data from the USVI commercial fisher port sampling program to identify the most targeted species can enhance the effectiveness of this monitoring program.

St. Thomas

On St. Thomas, macroalgae was the predominant substrate at three of the four sites, and ranged from 33.1% to 40.4% across all sites. Living coral was the predominant substrate at one site (the Grammanik Bank) and ranged from 25.7% to 49.6% across all sites. The percent cover of sponges ranged from 2.9% to 5.7% and the percent cover of gorgonians ranged from 0% to 3.5%. There were no significant differences in percent cover for any benthic category between mid-shelf, and shelf-edge reefs. The coral reefs of St. Thomas were generally dominated by coral species in the genus *Montastraea*, with species composition being similar between reef systems. Coral diversity (H') ranged between 0.90 and 1.38, with mid-shelf sites tending to have lower diversity than shelf-edge sites. Levels of coral bleaching and disease were similar between reef systems and ranged from 2.5% to 10.4% and 20.2% to 27.93%, respectively. *Diadema* sea urchins were uncommon and observed only at one site, with no significant difference in sea urchin density between reef systems.

Benthic composition, coral community structure, and coral diversity were similar between 2003 and 2004. There were no significant differences in levels of coral disease between 2003 and 2004. Levels of bleaching tended to increase in 2004, with significant increases at two sites.

Abiotic factors at the St. Thomas reefs tended to differ between the sampled mid-shelf site (Flat Cay) and the shelf-edge site (the Red Hind Bank). Current headed predominantly west at Flat Cay and predominantly both north and south at the Red Hind Bank. Since Flat Cay is located east of the most heavily developed areas of St. Thomas, this reef may be significantly affected by terrigenous stresses despite the reef's mid-shelf location (see Nemeth *et al.* 2004 for a more detailed discussion). Daily mean temperature at Flat Cay tended to be higher than the Red Hind Bank. Higher current speeds occurred in late summer at both sites and the highest temperatures occurred in August at both sites. Current and temperature patterns in 2004 were very similar to those recorded in 2003 (see Nemeth *et al.* 2004).

Fish abundance averaged from approximately 60 to 100 fish per census. The number of fish species observed at the St. Thomas sites ranged from 40 to 72 species. The St. Thomas fish fauna was numerically dominated by planktivorous wrasse and damselfishes at all sites. The commercially important large groupers, snappers, angelfishes, and triggerfishes were observed at low densities at all sites. The majority of fish observed in 2004 were small or intermediate in size, with most falling into the 5 – 10 cm size category. Relatively few large fish were observed.

Three of the St. Thomas sites monitored in this study have been determined as spawning aggregation sites for grouper (Red Hind Bank, Grammanik Bank) and snapper (Seahorse Cottage Shoal, Red Hind Bank, and 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. The number of groupers and snappers observed in St. Thomas decreased from 2003 to 2004. Since densities of these fish are generally low, this difference may be a reflection of natural variation. However, it may be the result of fishing pressure. In particular, the Grammanik Bank is unprotected and regularly fished, especially during the spawning season. Over-harvesting of aggregating fishes at this site may have impacts throughout the territory and could be responsible for the decrease in the number of groupers observed in 2004. Protection of spawning aggregation sites is essential for the proper management of Virgin Islands fisheries.

Acknowledgments

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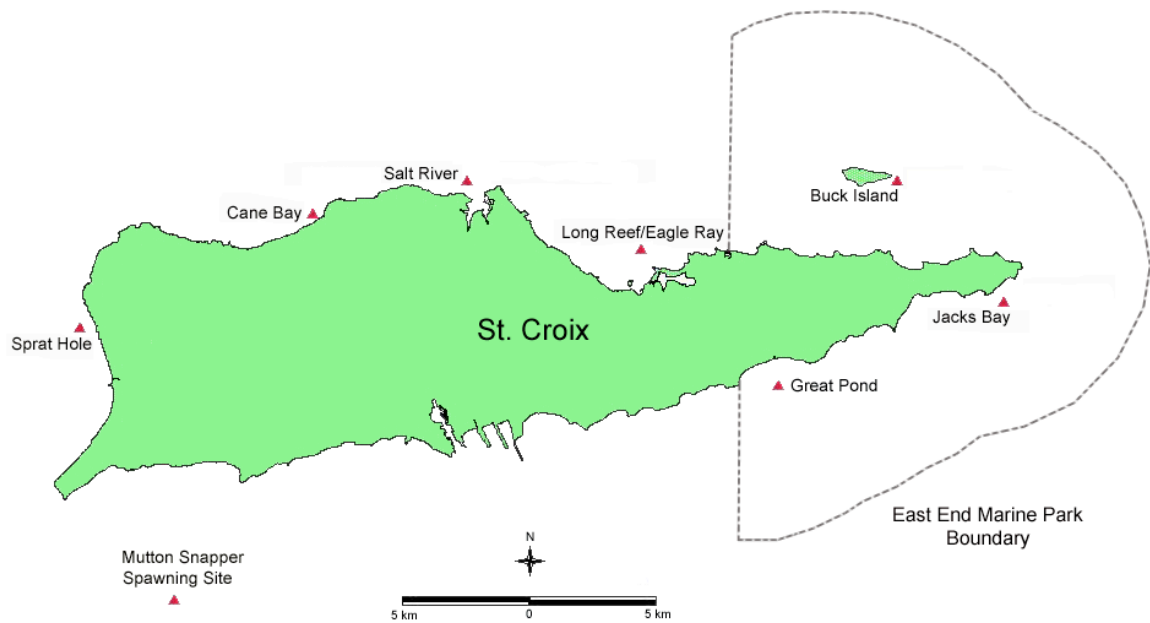


Fig. 1 Locations of monitoring sites in St. Croix, USVI. Great Pond and Jacks Bay are located within the East End Marine Park. Buck Island is located within the Buck Island Reef National Monument.

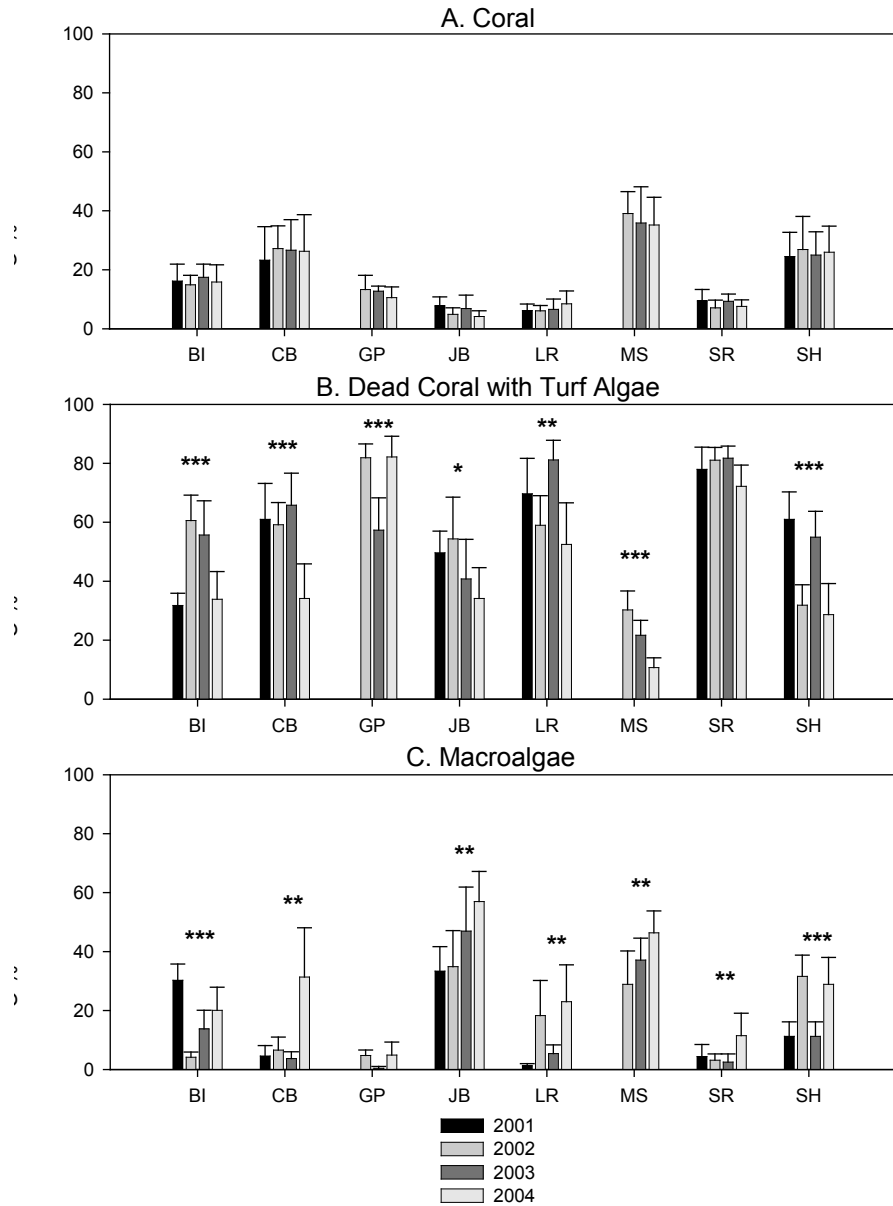


Fig. 2A, B, C Mean percent cover of A. Scleractinian corals, B. Dead coral with turf algae, and C. Macroalgae for 2001 - 2004 at eight monitored sites: BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray; MS Mutton Snapper; SR Salt River; SH Sprat Hole. GP and MS sampling 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

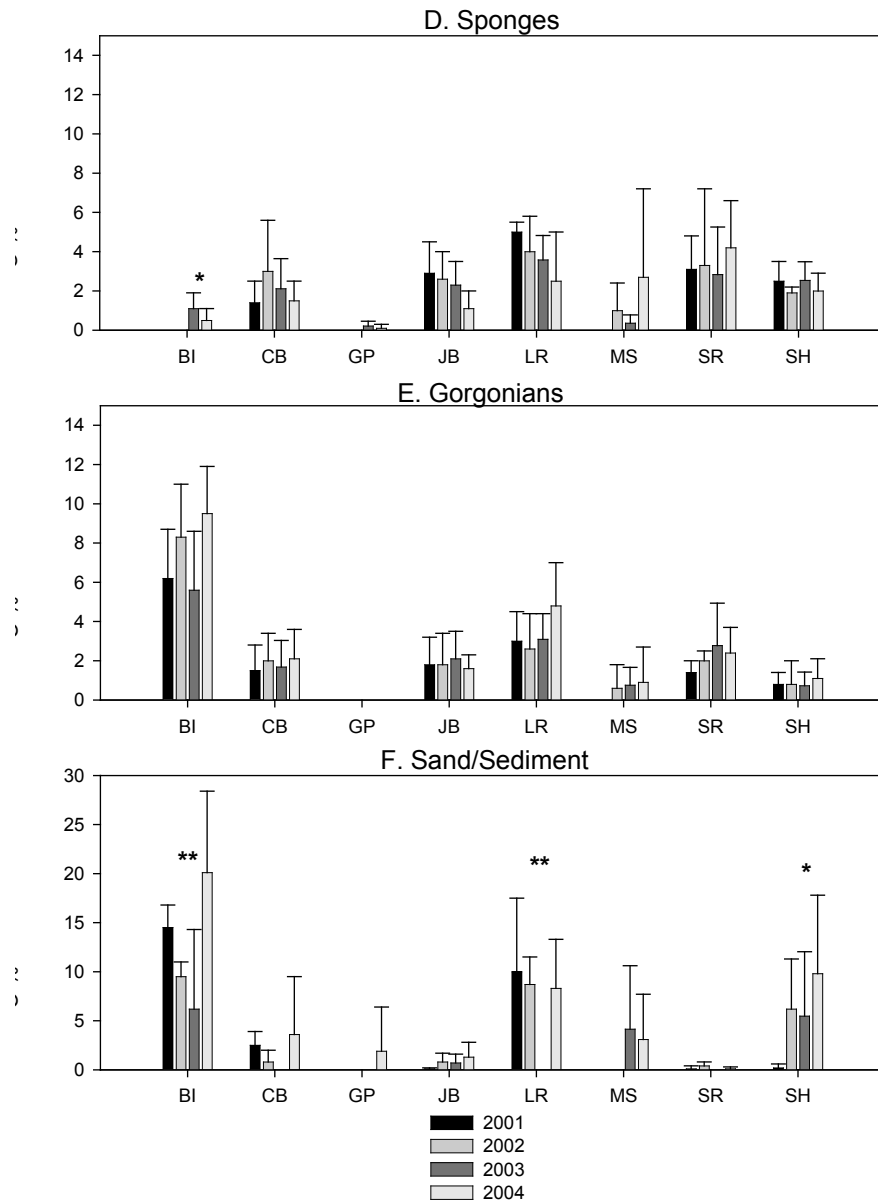


Fig. 2D, E, F Mean percent cover of D. Sponges, E. Gorgonians, and F. Sand/Sediment for 2001 - 2004 at eight monitored sites: BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray; MS Mutton Snapper; SRW Salt River; SH Sprat Hole. GP and MS sampling began in 2002. n = 6 transects 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: * = $P < 0.05$; ** = $P < 0.01$

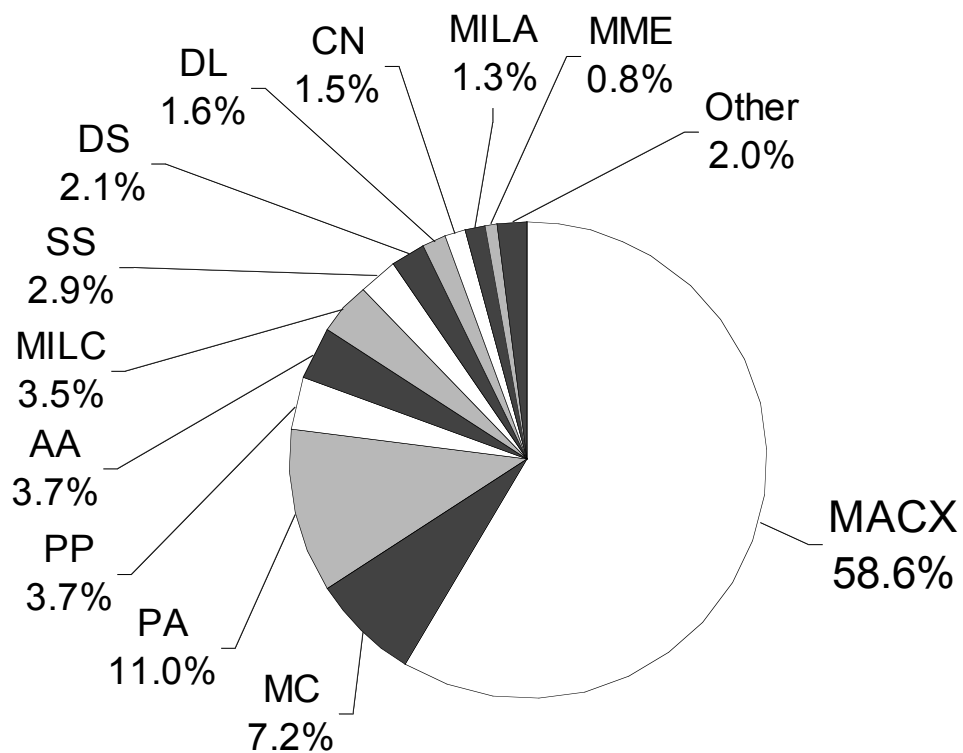


Fig. 3 Percentage coral species composition at all sampled sites in St. Croix, USVI. MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; PP *Porites porites*; AA *Agaricia agaricites*; MILC *Millepora complanata*; SS *Siderastrea siderea*; DS *Diploria strigosa*;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

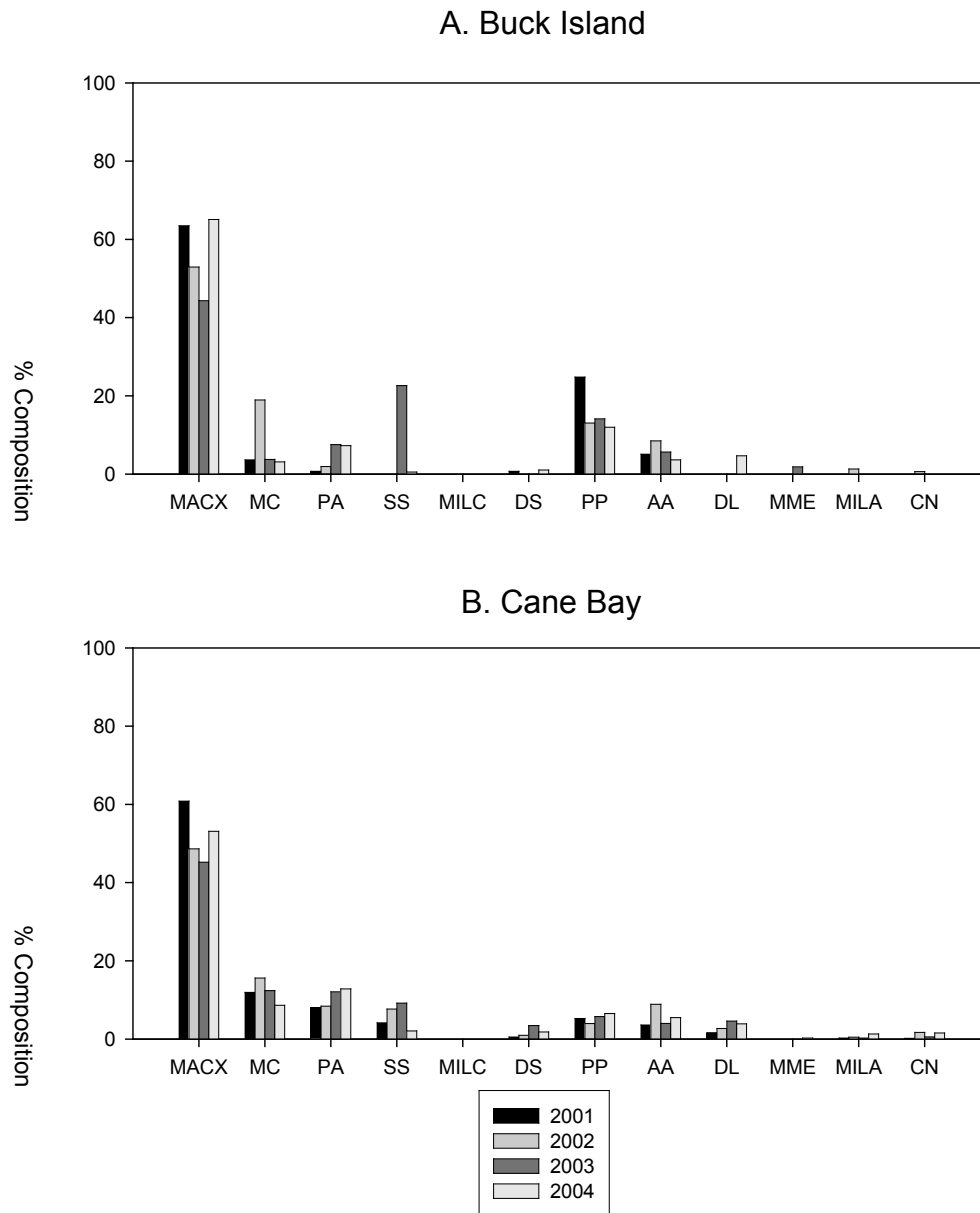
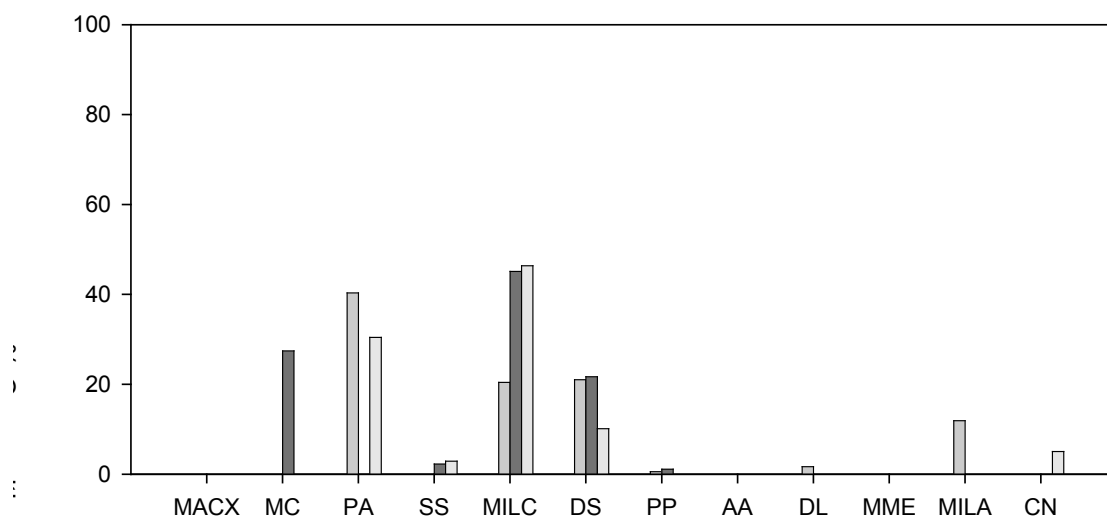


Fig. 4A, B Percent of species composition of living coral cover of the most common coral species at A. Buck Island and B. Cane Bay for years 2001, 2002, 2003 and 2004
 MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*;
 MILC *Millepora complanata*; DS *Diploria strigosa*; PP *P. porites*; AA *Agaricia agaricites*;
 DL *D. labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophyllia natans*.
 n = 6 transects for all samplings, except n = 3 transects for Buck Island in 2001 and 2002.

C. Great Pond



D. Jacks Bay

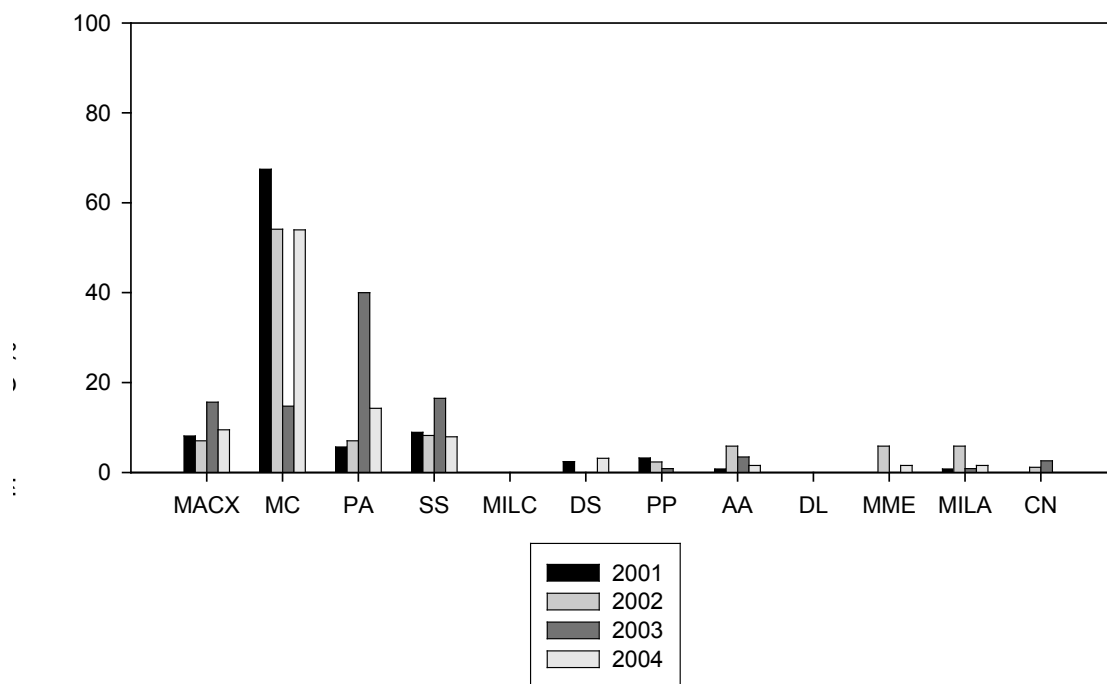
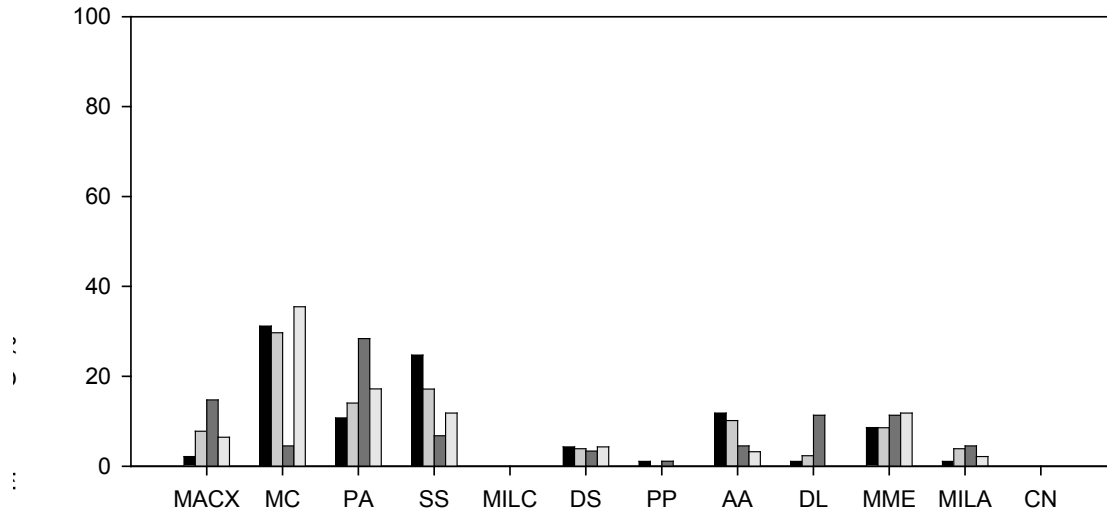


Fig. 4C, D Percent of species composition of living coral cover of the most common coral species at C. Great Pond and D. Jacks Bay for years 2001, 2002, 2003 and 2004.
 MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*;
 SS *Siderastrea siderea*; MILC *Millepora 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.

E. Long Reef



F. Mutton Snapper

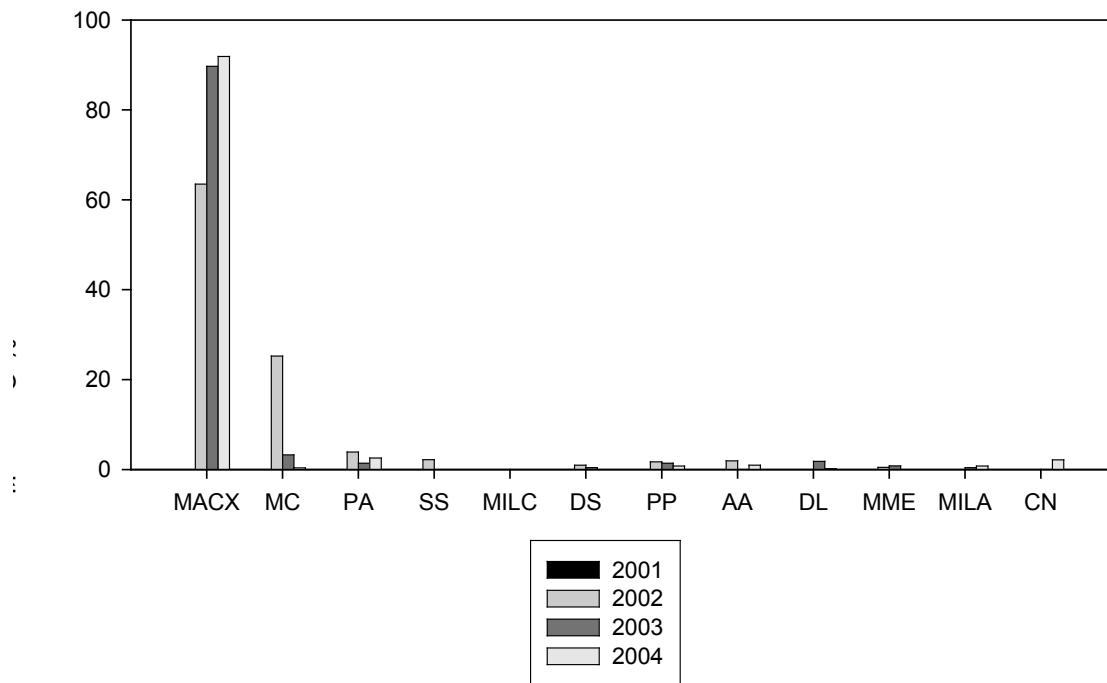
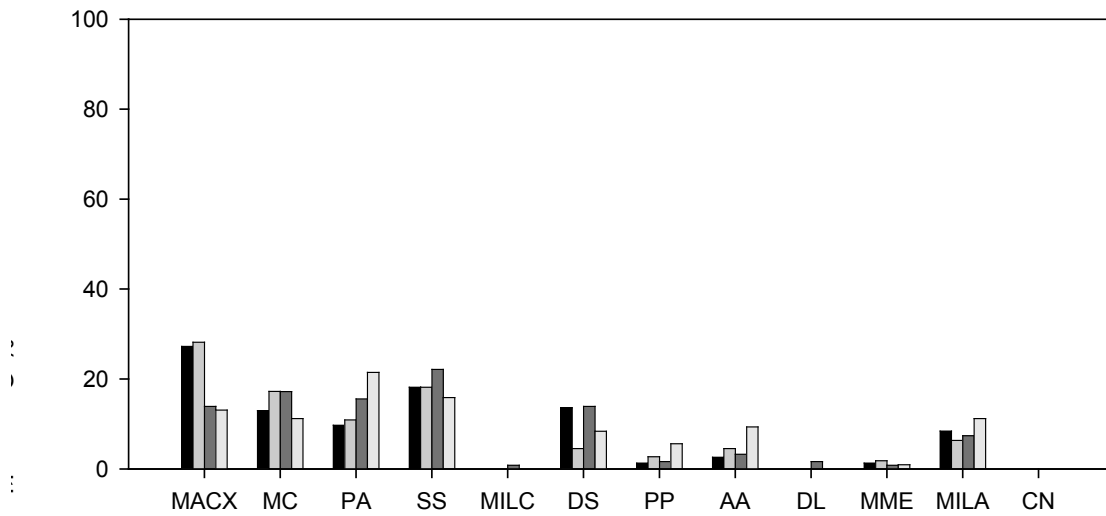


Fig. 4E, F Percent of species composition of living coral cover of the most common coral species at E. Long Reef and F. Mutton Snapper for years 2001, 2002, 2003 and 2004.
 MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora 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.

G. Salt River



H. Sprat Hole

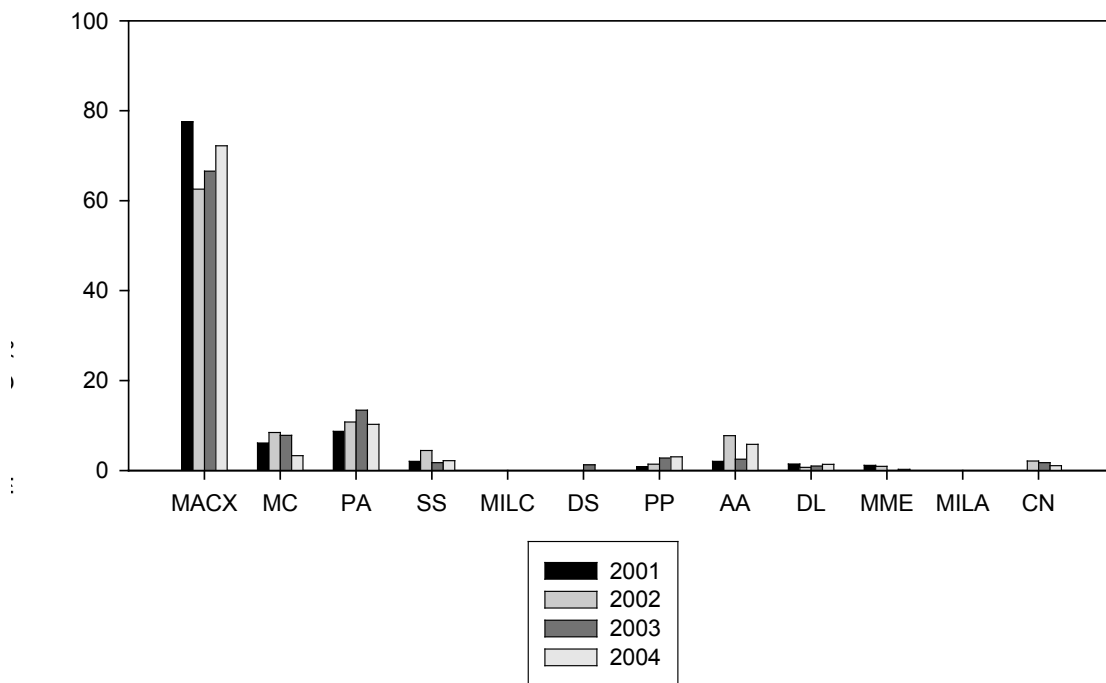


Fig. 4G, H Percent of species composition of living coral cover of the most common coral species at G. Salt River and H. Sprat Hole for years 2001, 2002, 2003 and 2004.
 MACX *Montastraea annularis* complex; MC *Montastraea cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; MILC *Millepora complanata*; DS *Diploria strigosa*; PP *Porites porites*; AA *Agaricia agaricites*; DL *Diploria labyrinthiformis*; MME *Meandrina meandrites*; MILA *Millepora alcicornis*; CN *Colpophyllia natans*.
 n = 6 transects for all samplings, except n = 5 transects for SH in 2002.

Coral Diversity

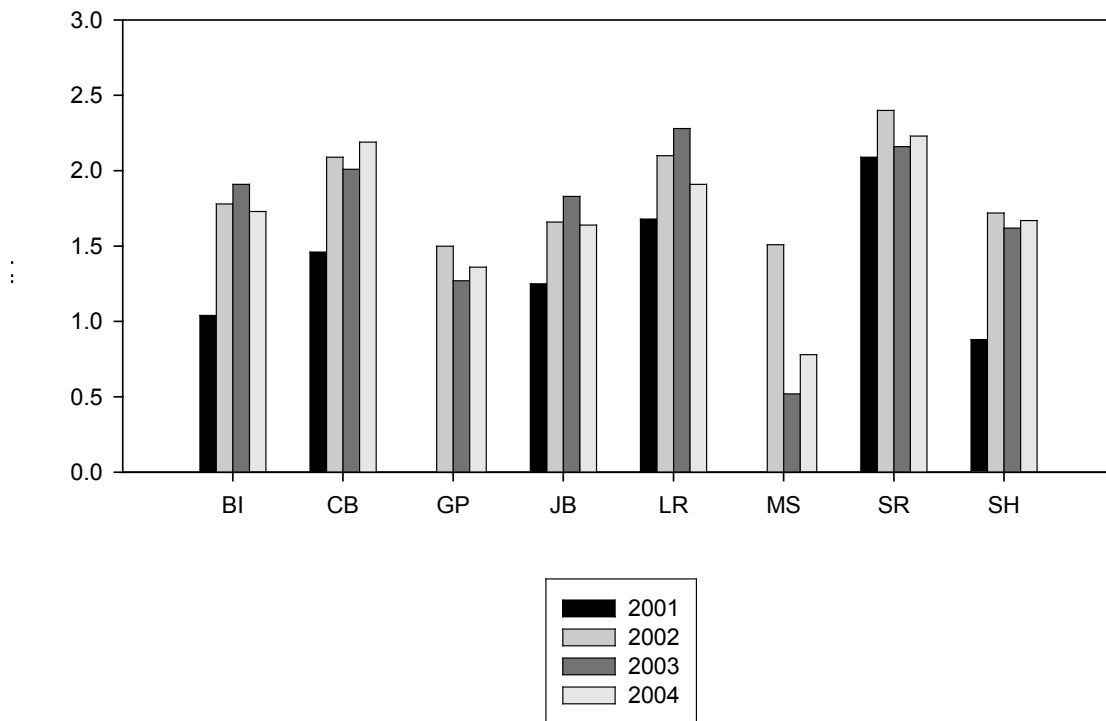
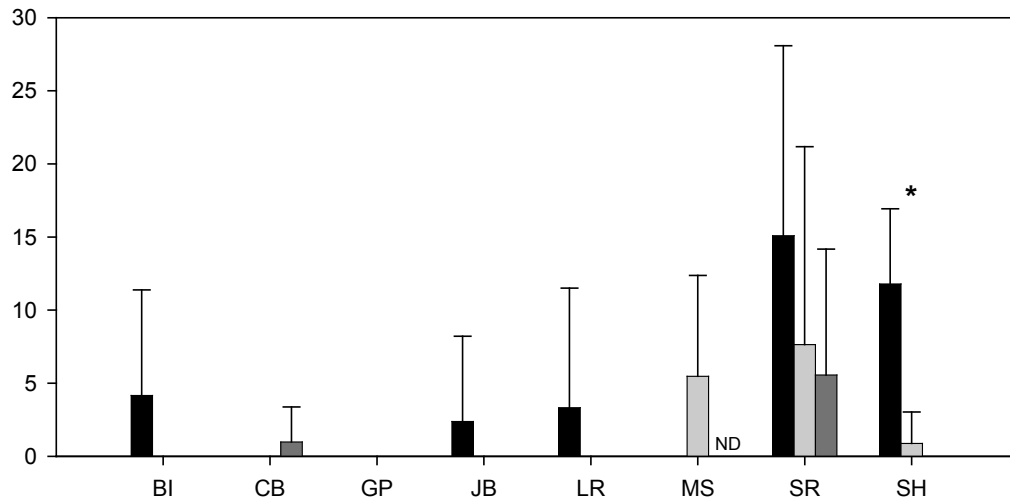


Fig. 5 Shannon - Weaver Diversity Index (H') for corals at eight monitored sites in St. Croix, USVI for years 2001- 2004.
 BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LR Long Reef/Eagle Ray;
 MS Mutton Snapper; SR Salt River; SH Sprat Hole
 Sampling for Great Pond and Mutton Snapper began in 2002.

A. Coral Disease



B. Coral Bleaching

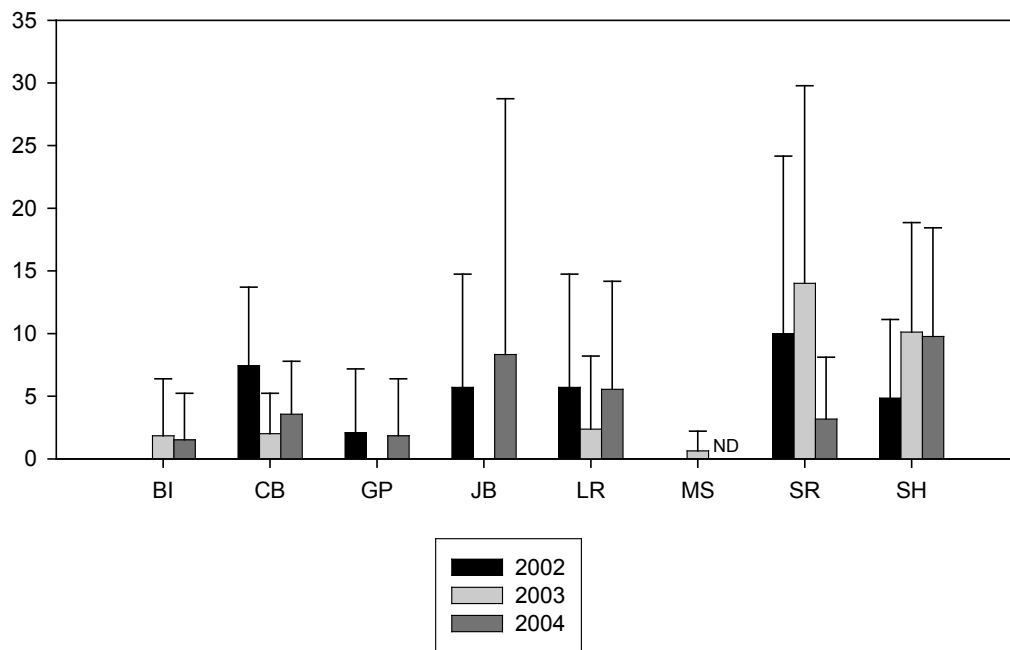


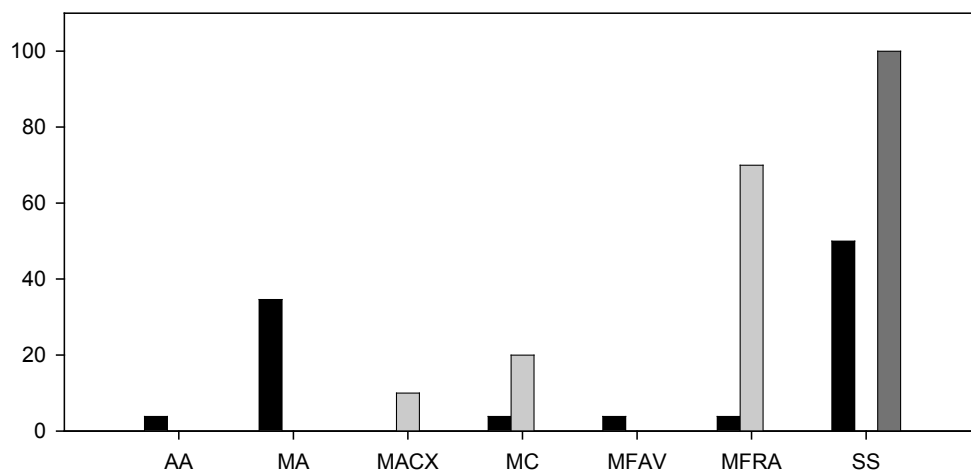
Fig. 6 Mean percentage of A. colonies with disease and B. colonies with bleaching of all coral colonies sampled at each monitoring site.

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. MS was not sampled in 2004. Asterisk denotes significant difference: * = $P < 0.01$

A. Coral Disease



B. Coral Bleaching

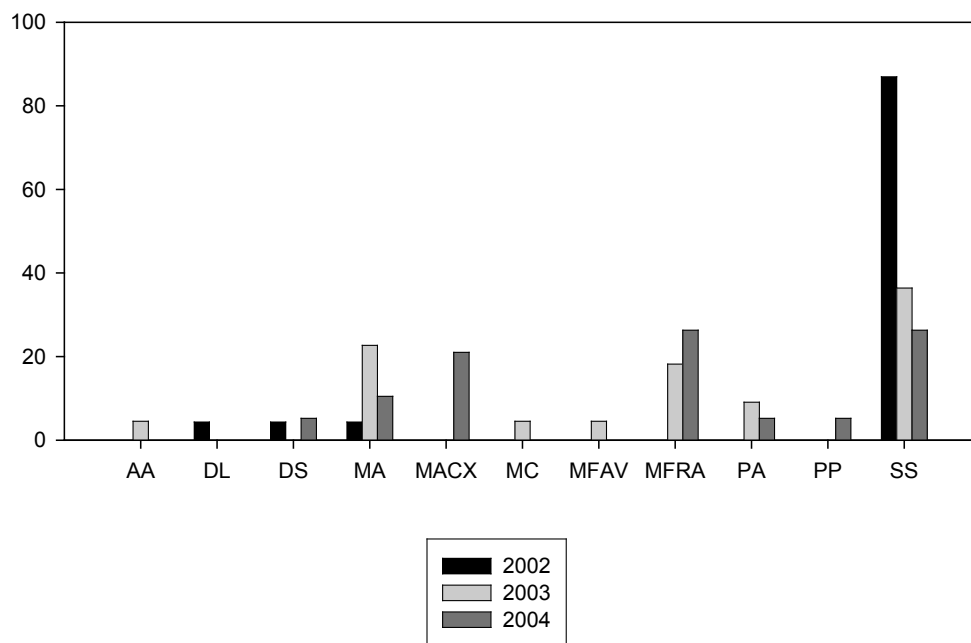
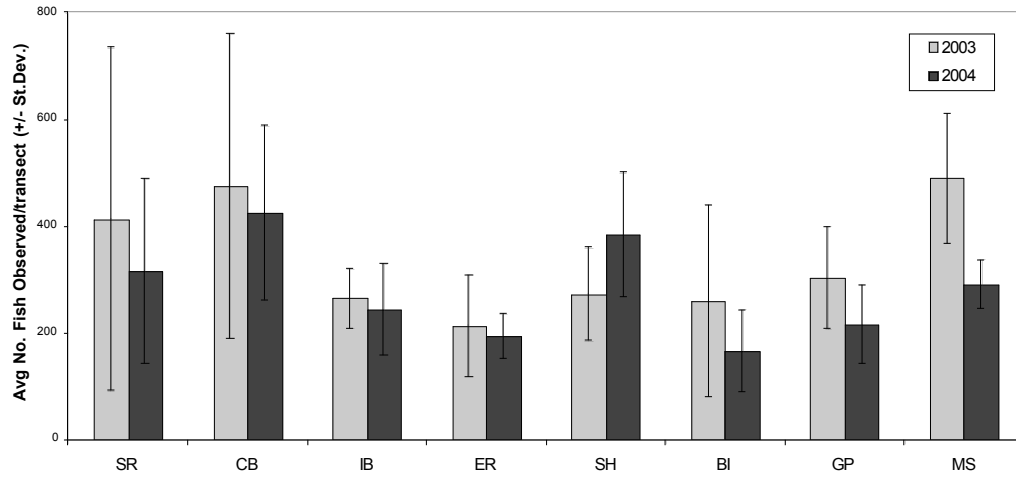
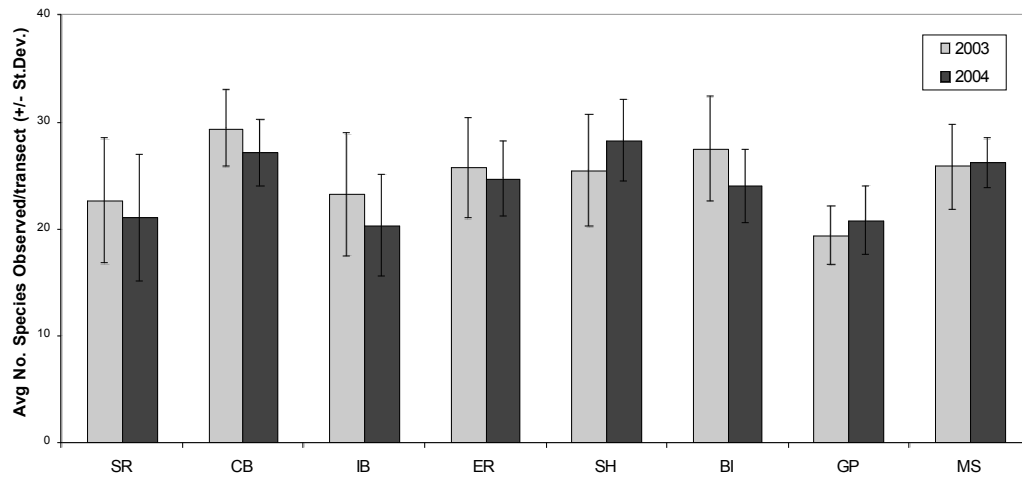


Fig. 7 Percentage of A. diseased colonies and B. bleached colonies of all coral species with disease and bleaching sampled at all St. Croix monitoring sites, with the exception of Mutton Snapper. AA *Agaricea agaricites*; DL *Diploria labyrinthiformis*; DS *Diploria strigosa*; MA *Montastraea annularis*; MACX unidentified species belonging to the *M. annularis* complex; MC *M. cavernosa*; MFAV *M. faveolata*; MFRA *M. franksii*; PA *Porites astreoides*; PP *Porites porites*; SS *Siderastrea siderea*

A. Fish Abundance - St. Croix



B. Fish Species Richness - St. Croix



C. Fish Community Diversity (H') - St. Croix

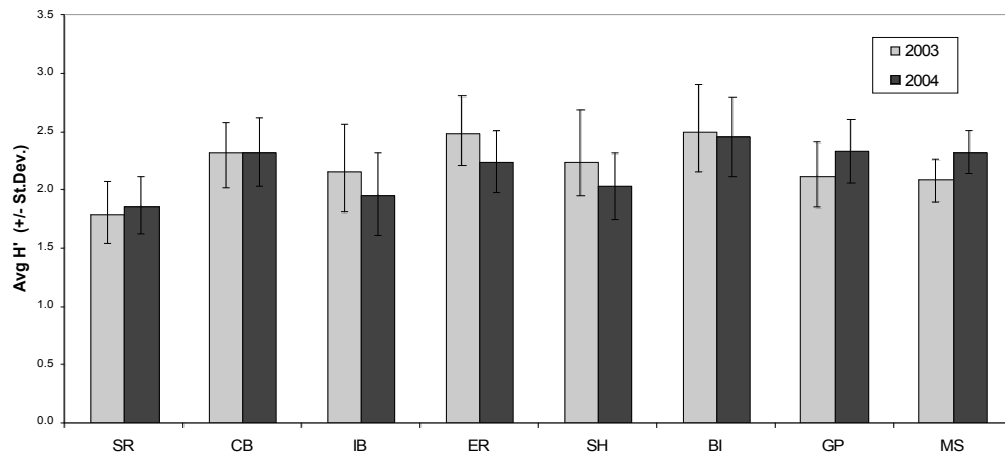


Fig. 8 Reef fish community structure across eight St. Croix reef sites. Data are from belt transect surveys conducted in 2003 and 2004. A. Average abundance. B. Average species richness. C. Average Shannon-Weaver diversity (H'). Reef sites are as follows: SR=Salt River, CB=Cane Bay, IB=Isaacs Bay, ER=Eagle Ray, SH=Sprat Hole, BI=Buck Island, GP=Great Pond, MS=Mutton Snapper

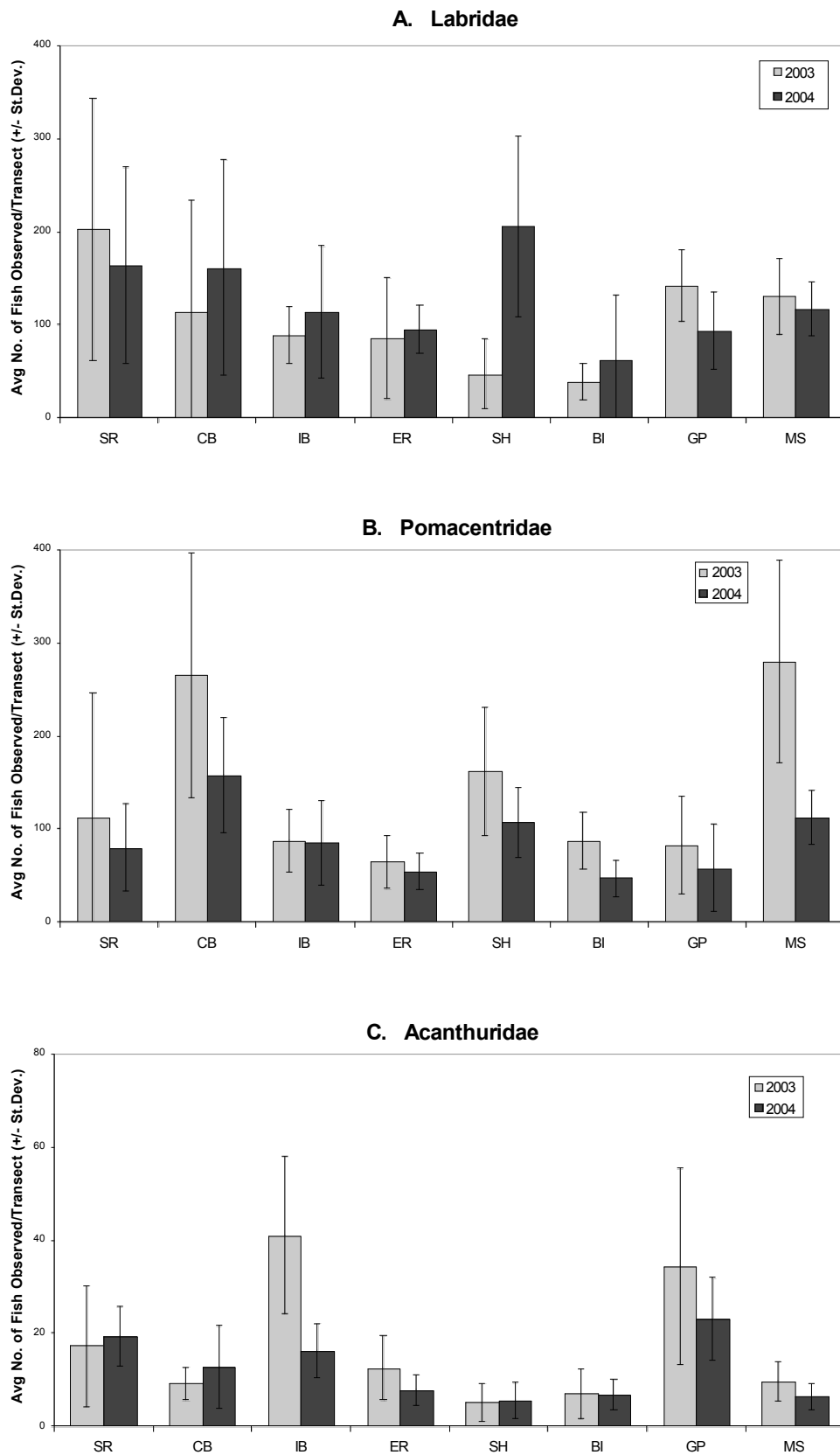


Fig. 9 Fish abundance by family across eight St. Croix reef sites. Data are from belt transect surveys in 2003 and 2004. Abbreviations as in Figure 8.

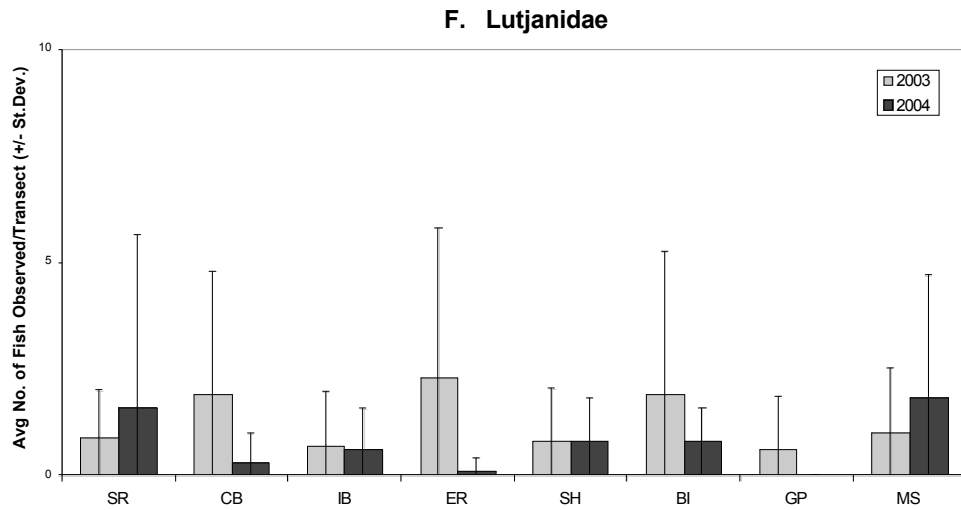
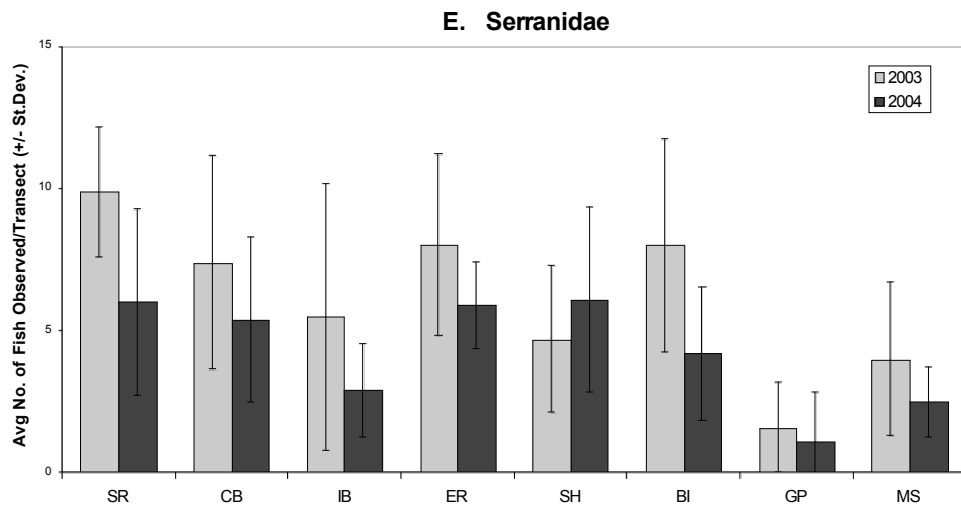
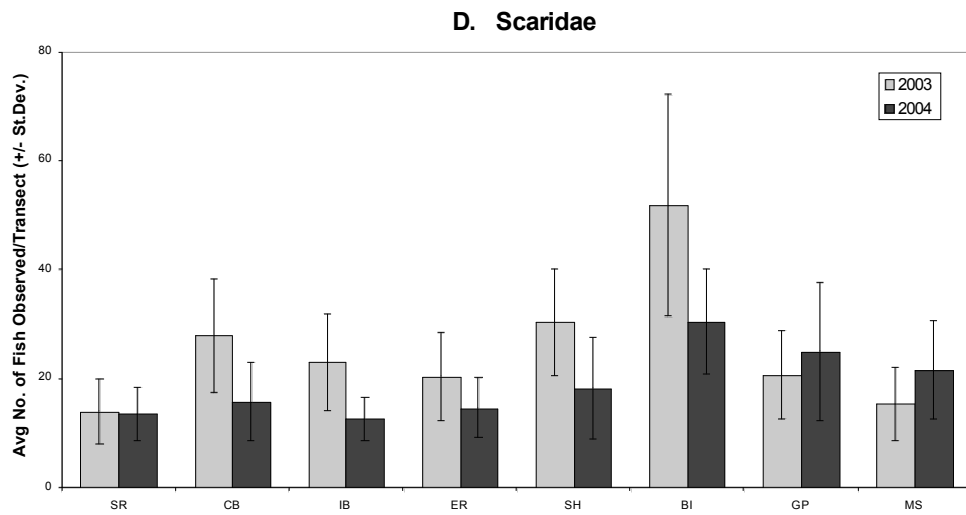


Fig. 9 (cont.) Fish abundance by family across eight St. Croix reef sites. Data are from belt transect surveys in 2003 and 2004. Abbreviations as in Figure 8.

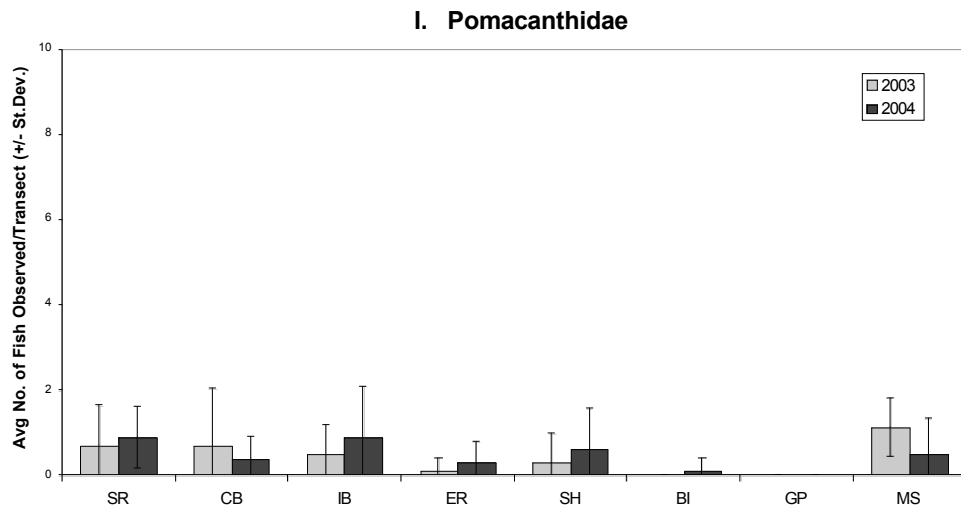
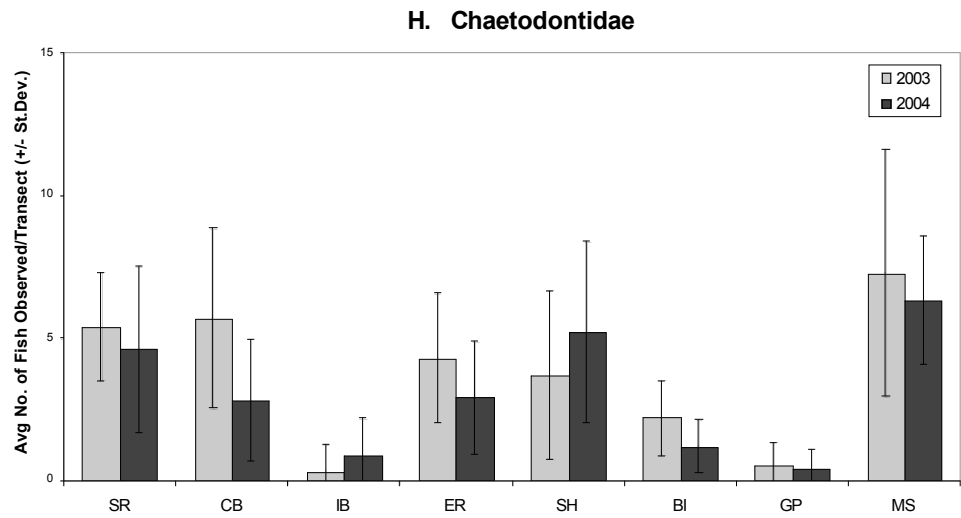
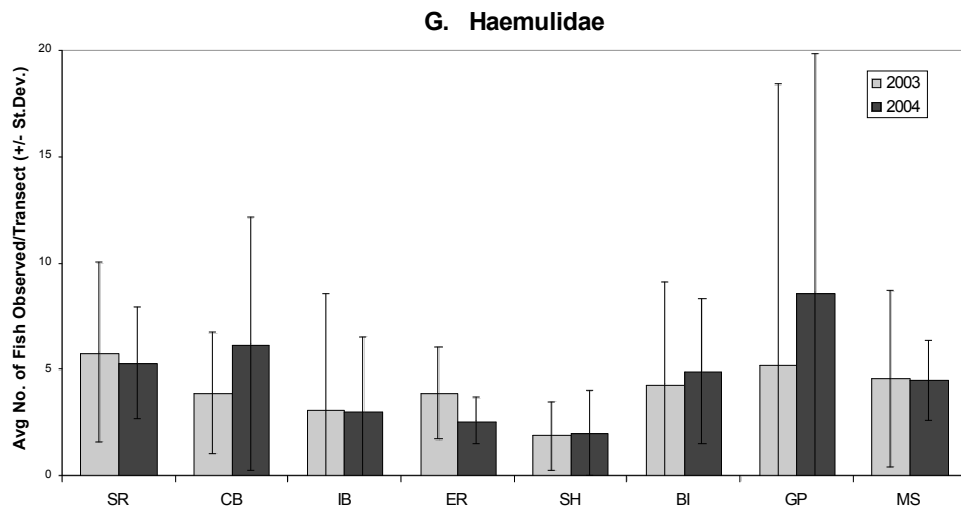


Fig. 9 (cont.) Fish abundance by family across eight St. Croix reef sites. Data are from belt transect surveys in 2003 and 2004. Abbreviations as in Figure 8.

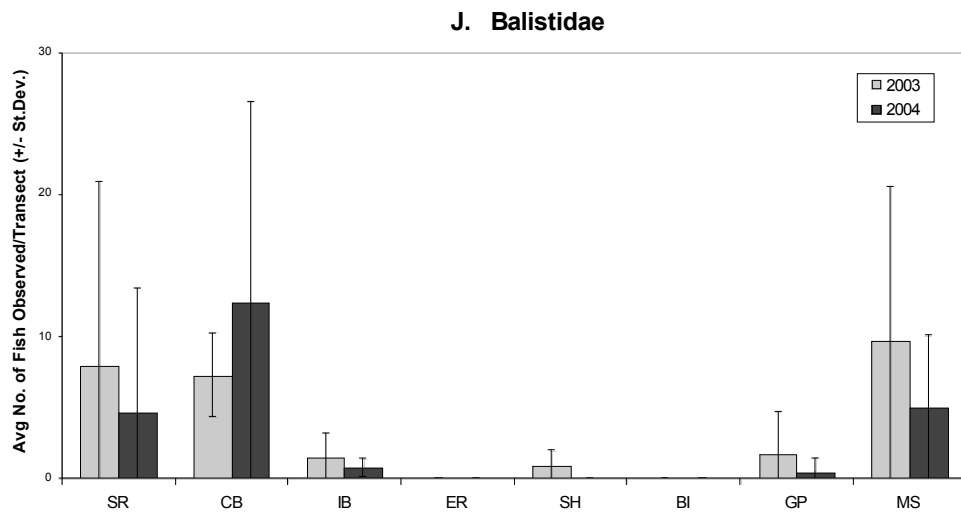


Fig. 9 (cont.) Fish abundance by family across eight St. Croix reef sites. Data are from belt transect surveys in 2003 and 2004. Abbreviations as in Figure 8.

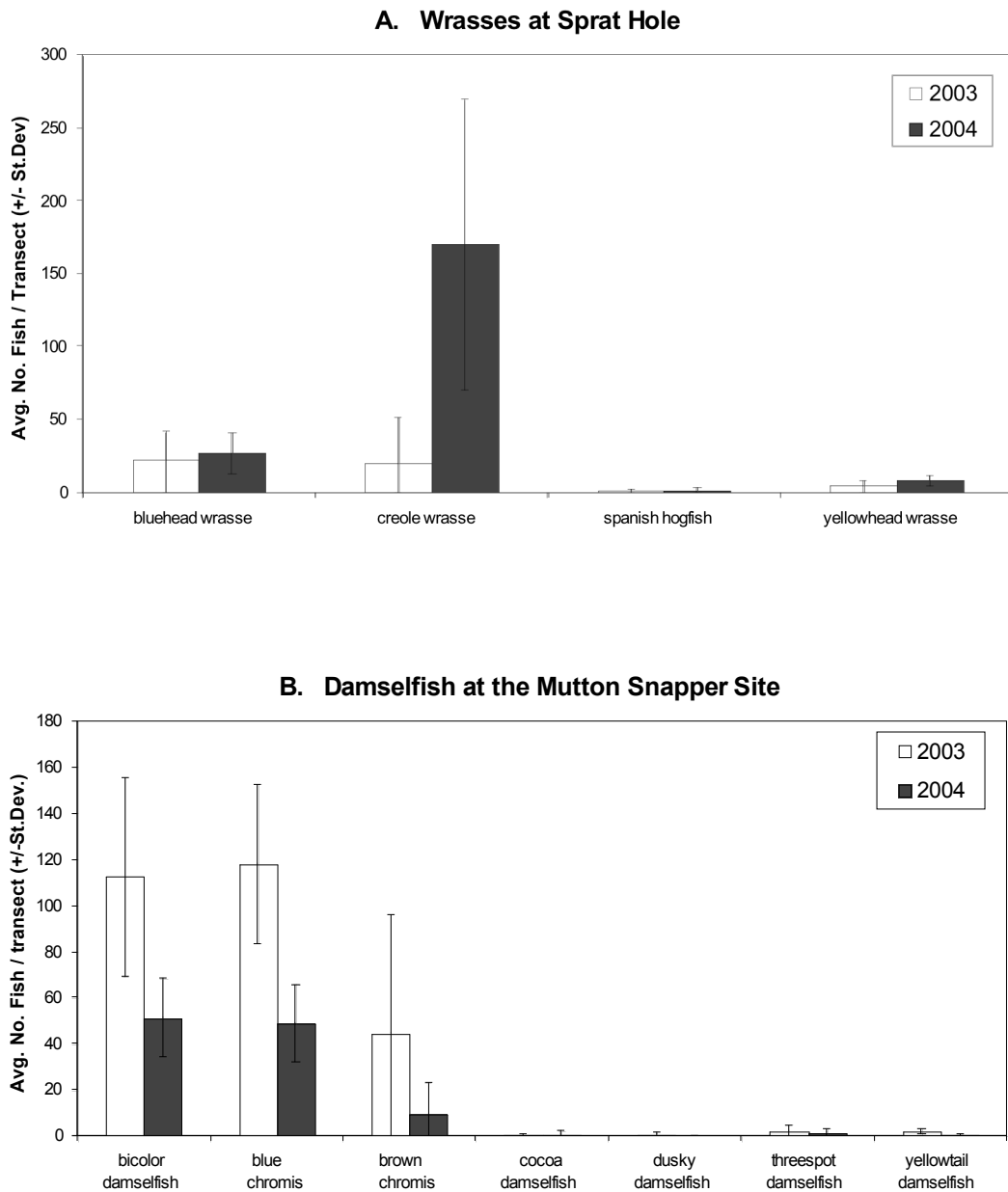


Fig. 10 Average fish abundance within selected families at two sites where population changes were observed between 2003 and 2004 surveys. A. Wrasses (Labridae) at Sprat Hole. B. Damselfish (Pomacentridae) at Mutton Snapper site.

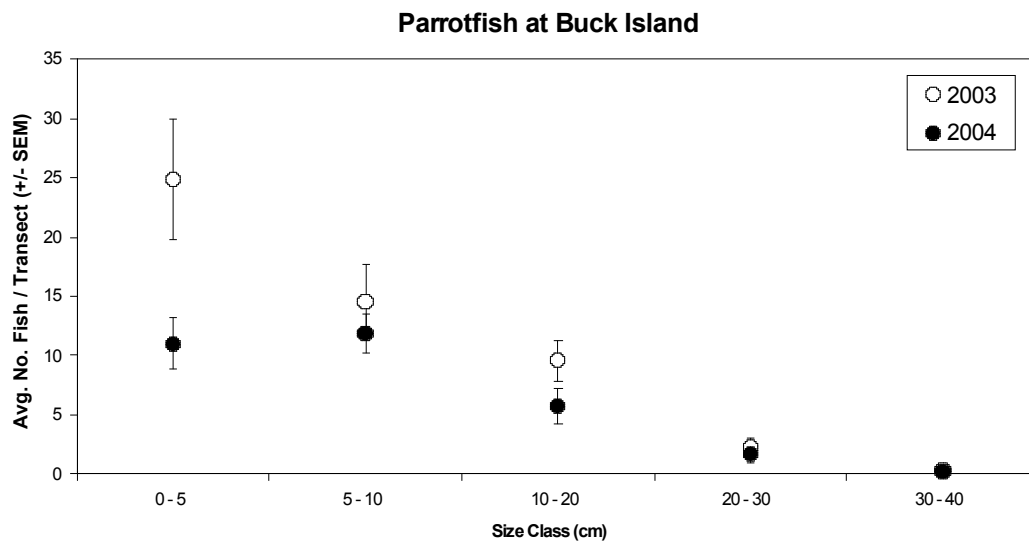


Fig. 11 Comparison of the size distribution of parrotfishes (Scaridae) at Buck Island in 2003 and 2004. Data from six predominant scarids were pooled for this analysis. A significant difference was observed in the smallest size class (< 5 cm).

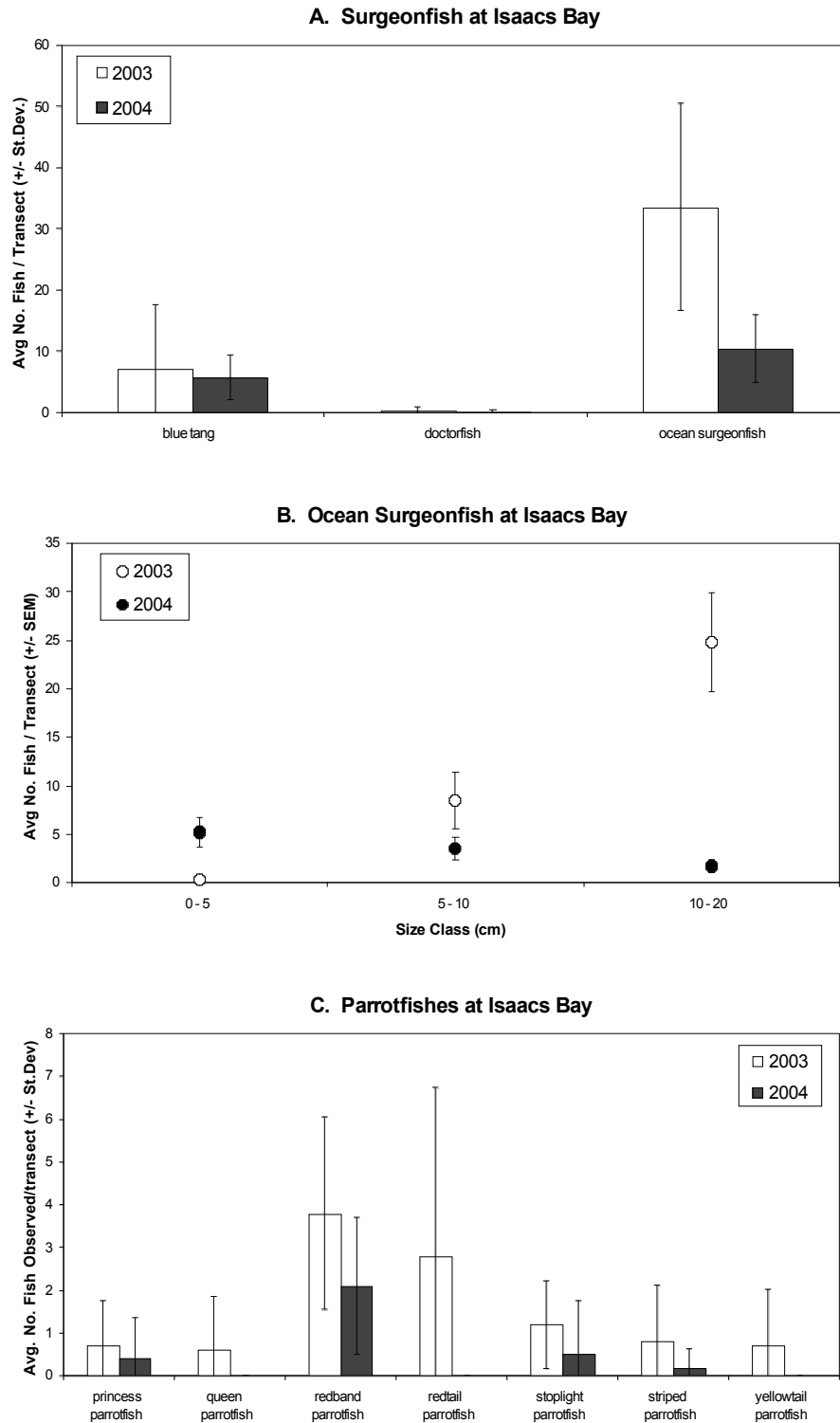


Fig. 12 Comparison of fish abundance at Isaacs Bay, St. Croix between 2003 and 2004. A. Average abundance of three species of surgeonfishes (Acanthuridae). B. Average abundance of the ocean surgeonfish, *Acanthurus bahianus*, by size class. C. Average abundance of seven parrotfish species (excluding fish < 10 cm).

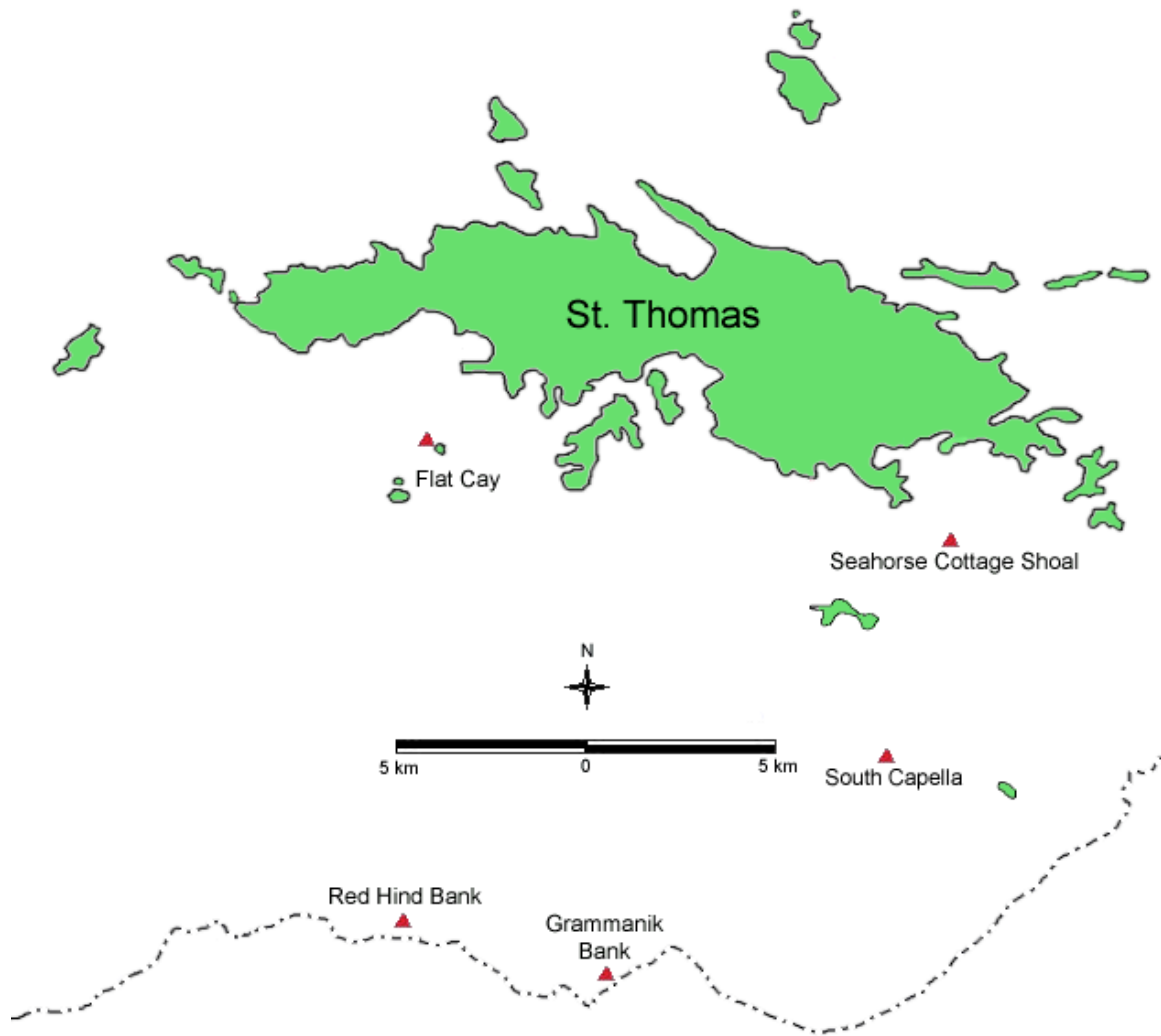


Fig. 13 Locations of monitoring sites in St. Thomas, USVI. Biotic assessments were performed at Seahorse Cottage Shoal, South Capella, Grammanik Bank, and the Red Hind Bank. Abiotic assessments were performed at Flat Cay and the Red Hind Bank. The Red Hind Bank is located within the Red Hind Bank Marine Conservation District.

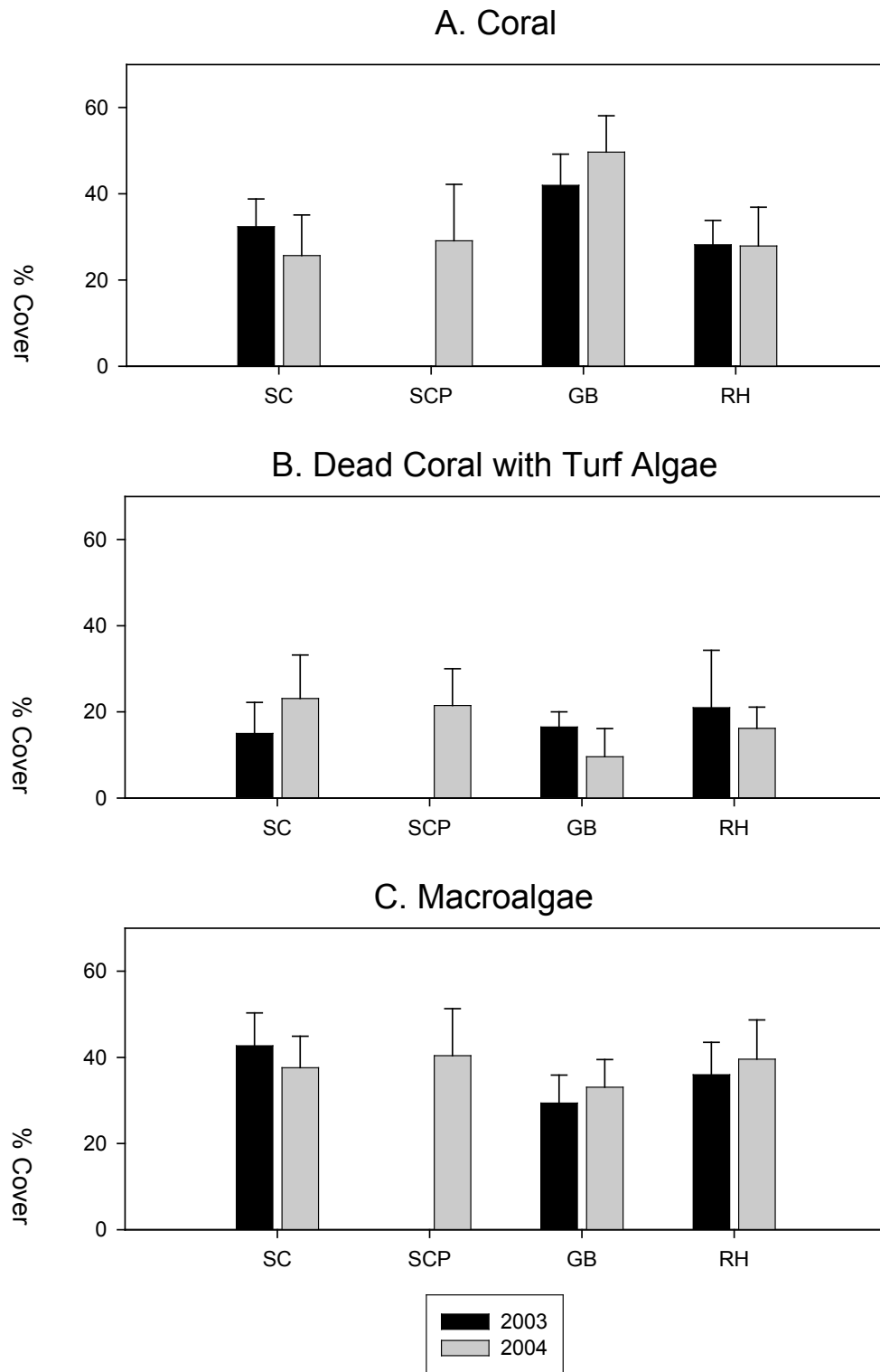


Fig. 14A, B, C Mean percent cover of A. Scleractinian corals, B. Dead coral with turf algae, and C. Macroalgae for St. Thomas monitored sites: SC Seahorse Cottage Shoal; SCP South Capella; GB Grammanik Bank; RH Red Hind Bank. SC and SCP are mid-shelf sites and GB and RH are shelf-edge sites. n = 6 transects for all sites sampled in 2003, n = 10 transects for all sites in 2004. Sampling for South Capella began in 2004. Error bars represent standard deviation.

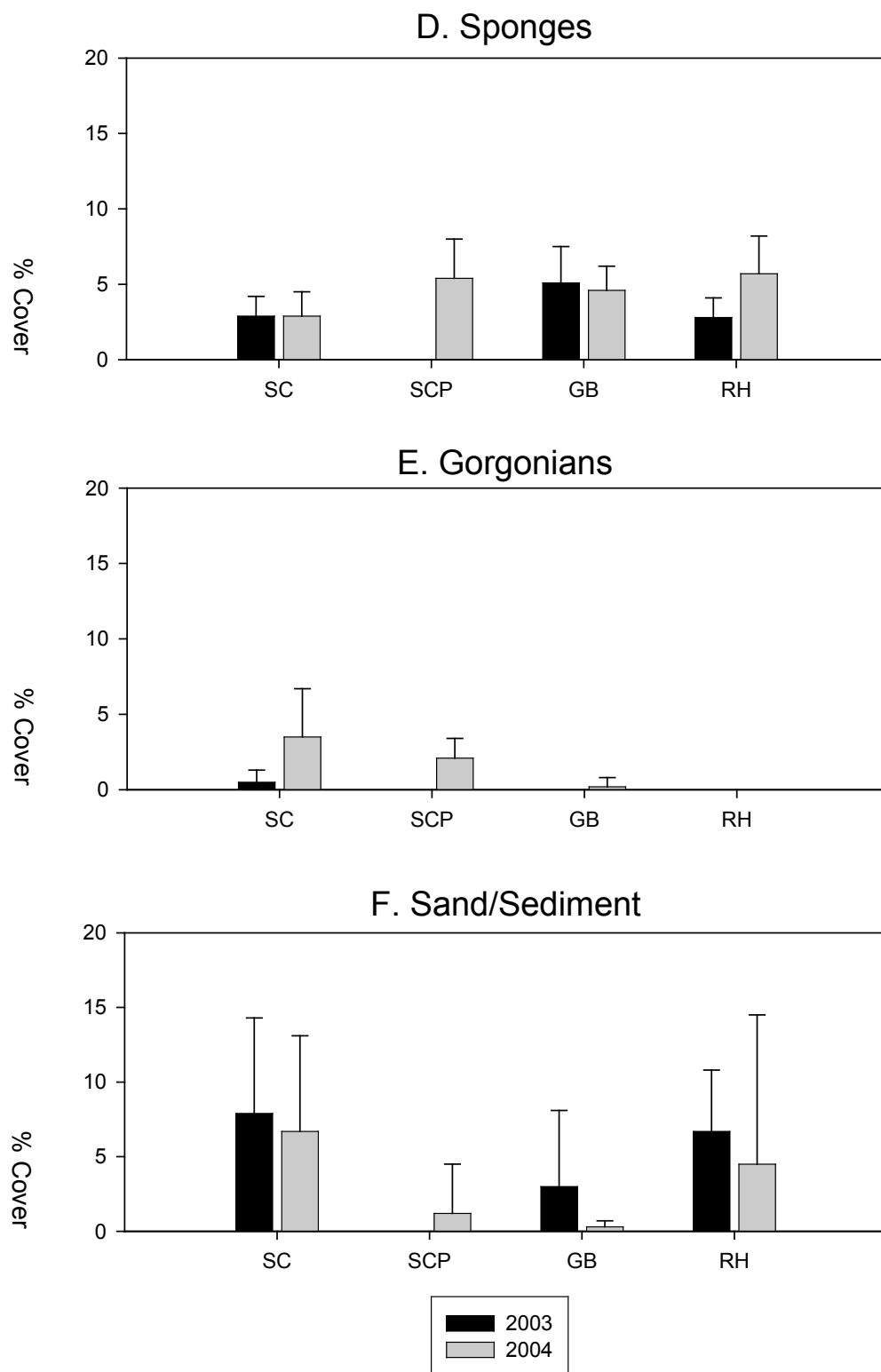


Fig. 14D, E, F Mean percent cover of D. Sponges, E. Gorgonians, and F. Sand/Sediment for St. Thomas monitored sites: SC Seahorse Cottage Shoal; SCP South Capella; GB Grammanik Bank; RH Red Hind Bank. SC and SCP are mid-shelf sites and GB and RH are shelf-edge sites. n = 6 transects for all sites sampled in 2003, n = 10 transects for all sites in 2004. Sampling for South Capella began in 2004. Error bars represent standard deviation.

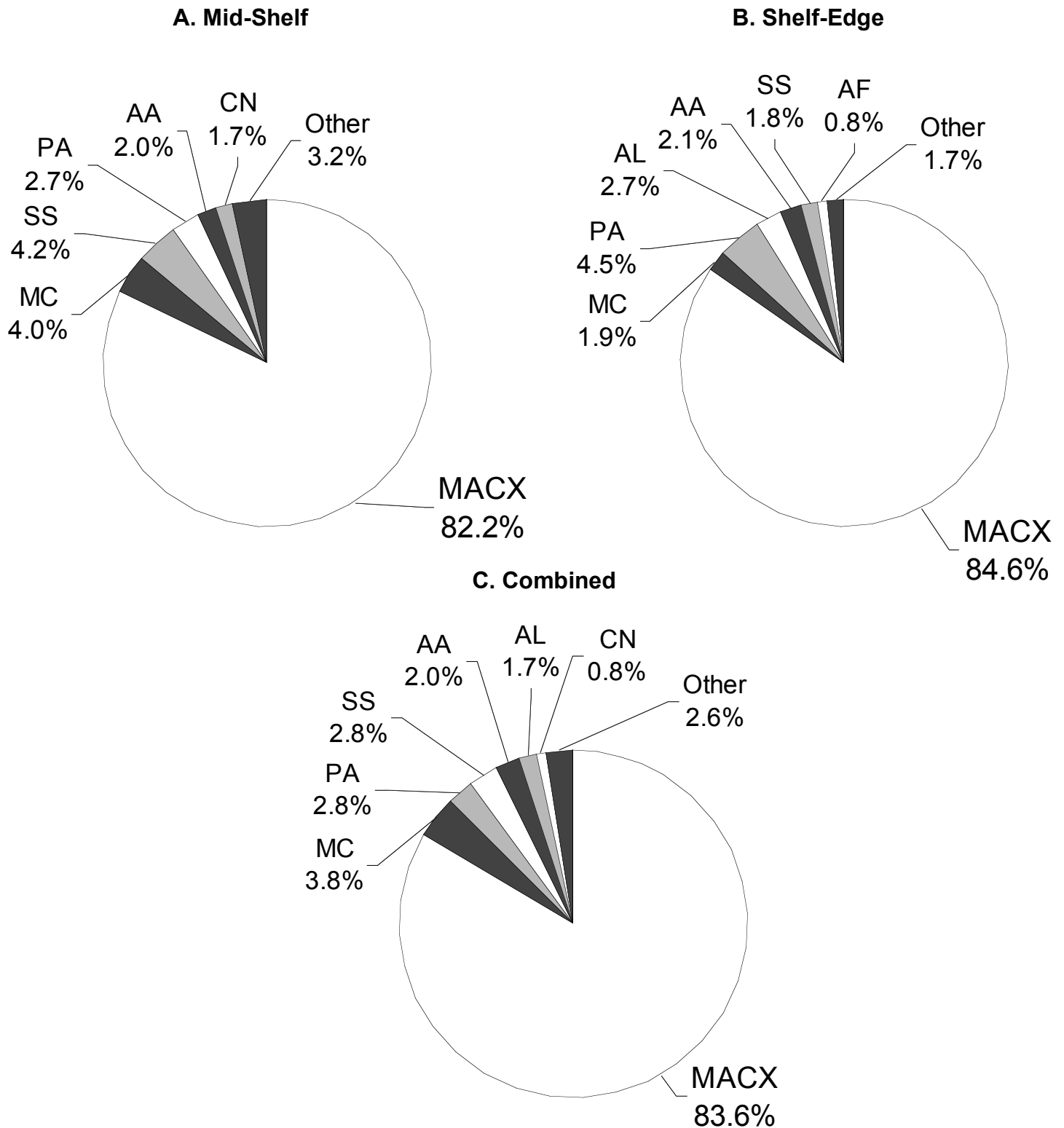


Fig. 15 Percentage coral species composition at A. Mid-shelf sites and B. Shelf-edge sites and C. all sites combined for St. Thomas, USVI. MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; SS *Siderastrea siderea*; AA *Agaricia agaricites*; AL *A. lamarcki*; AF *A. fragilis*; CN *Colpophyllia natans*. Other denotes percent of all other coral species combined and includes: *Acropora cervicornis*, *Agaricia grahamae*, *Diploria labyrinthiformis*, *D. strigosa*, *Eusmilia fastigiata*, *Madracis decactis*, *M. formosa*, *M. mirabilis*, *Millepora alcicornis*, *Mussa angulosa*, *Mycetophyllia aliciae*, *My. ferox*, *My. lamarckiana*, *Porites furcata*, *P. porites*.

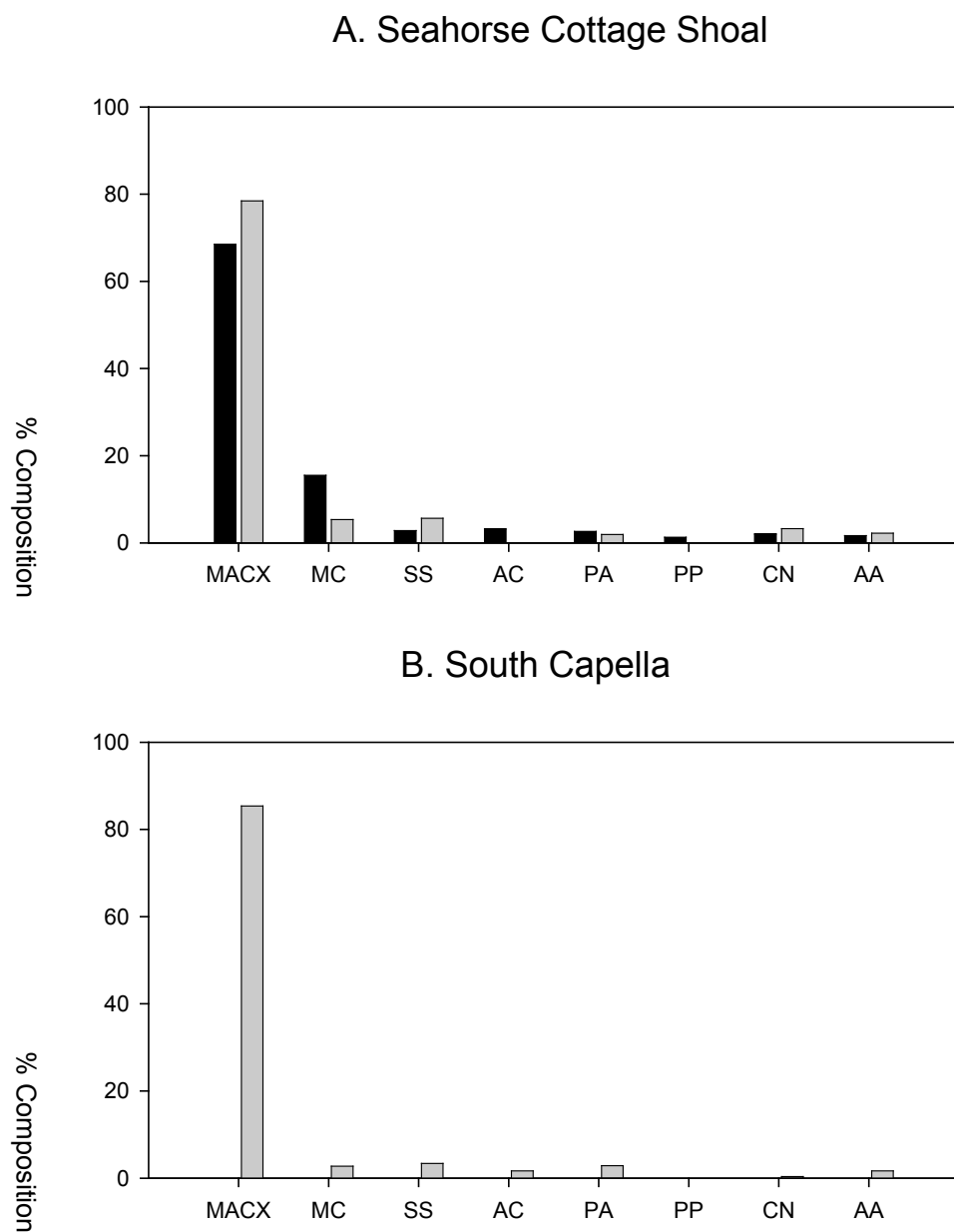
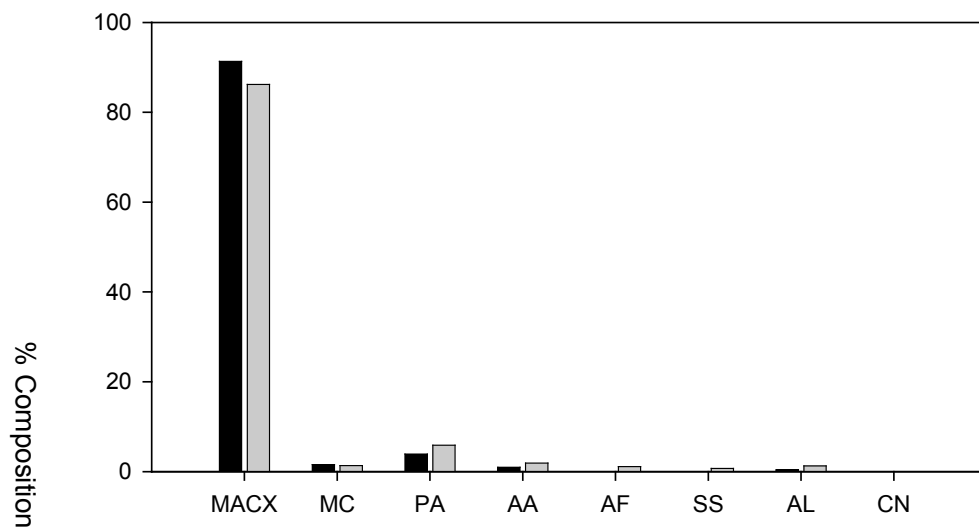


Fig. 16A, B Percent of species composition of living coral cover of the most common coral species at St. Thomas mid-shelf sites: A. Seahorse Cottage Shoal and B. South Capella. Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of dots on all living coral at each site. Sampling for South Capella began in 2004. MACX *Montastraea annularis* complex; MC *M. cavernosa*; SS *Siderastrea siderea*; AC *Acropora cervicornis*; PA *Porites astreoides*; PP *P. porites*; CN *Colpophyllia natans*; AA *Agaricia agaricites*.

C. Grammanik Bank



D. Red Hind Bank

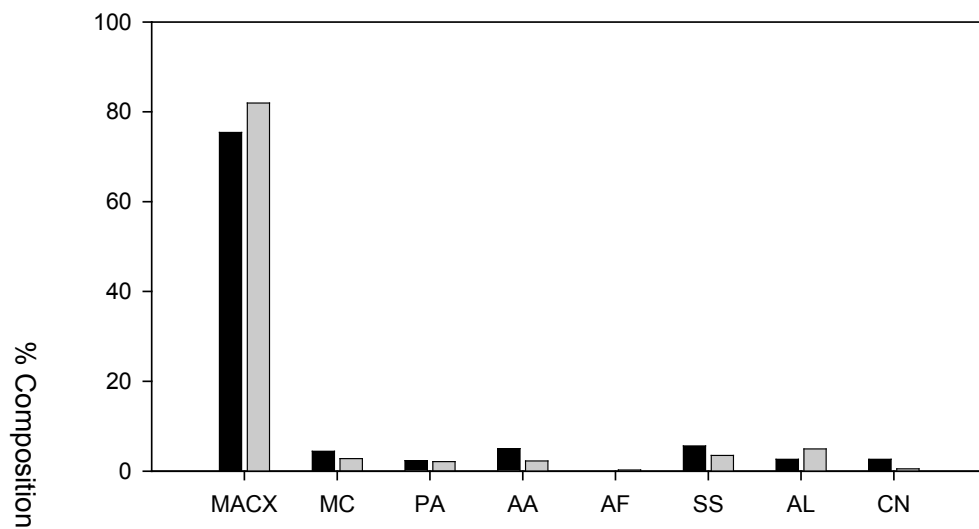


Fig. 16C, D Percent of species composition of living coral cover of the most common coral species at St. Thomas shelf-edge sites: E. Grammanik Bank and F. Red Hind Bank. Percent composition calculated by dividing the number of random dots falling on each coral species by the total number of dots on all living coral at each site.
 MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; AA *Agaricia agaricites*; AF *A. fragilis*; SS *Siderastrea siderea*; AL *A. lamarcki*; CN *Colpophyllia natans*.

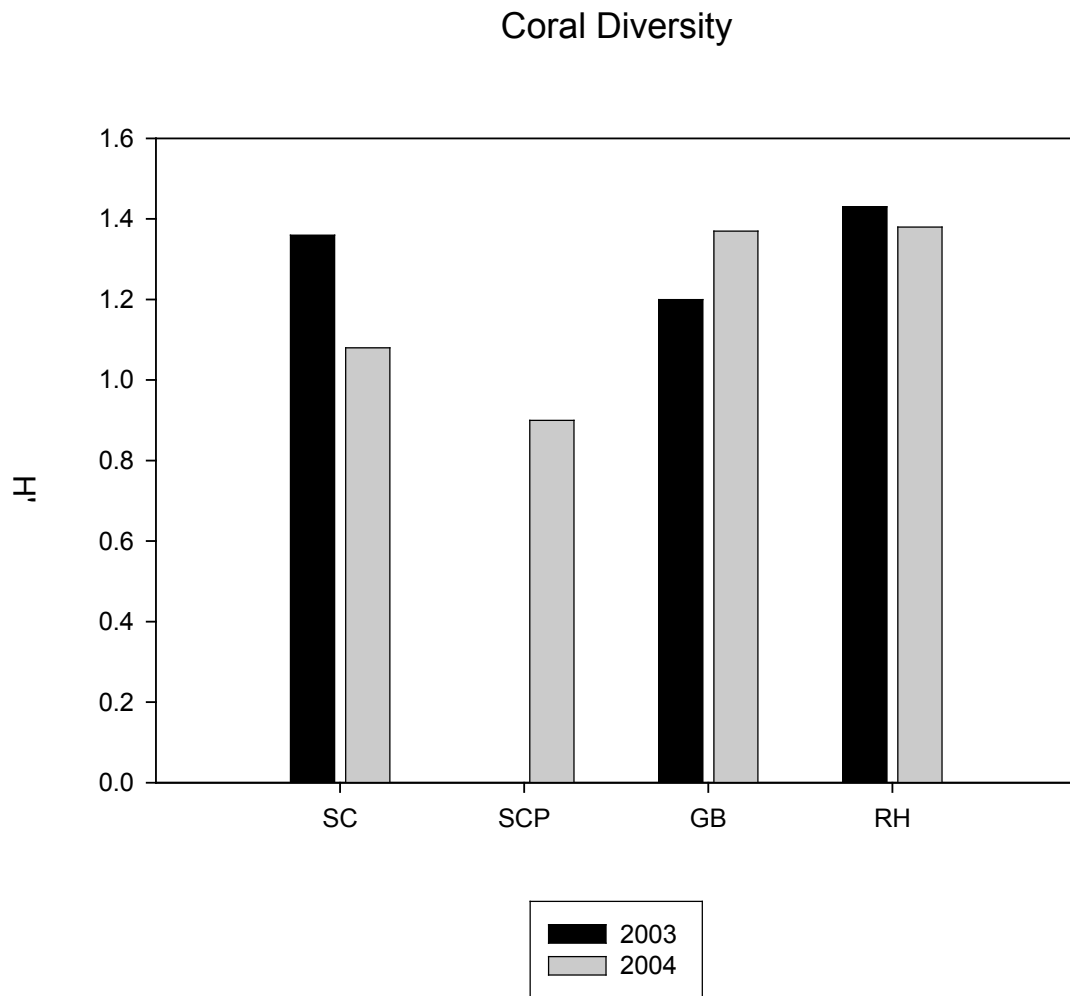
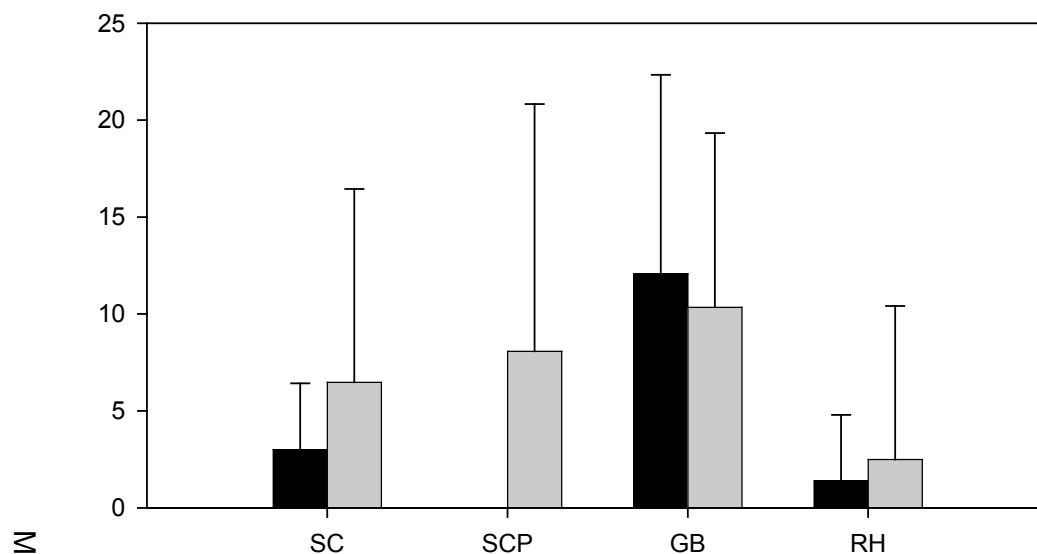


Fig. 17 Shannon - Weaver Diversity Index (H') for corals at four monitored sites in St. Thomas, USVI. SC Seahorse Cottage Shoal; SCP South Capella; GB Grammanik Bank RH Red Hind Bank. SC and SCP are mid-shelf sites and GB and RH are shelf-edge sites. $n = 6$ transects for all sites in 2003, $n = 10$ transects for all sites in 2004. Sampling for South Capella began in 2004.

A. Coral Disease



B. Coral Bleaching

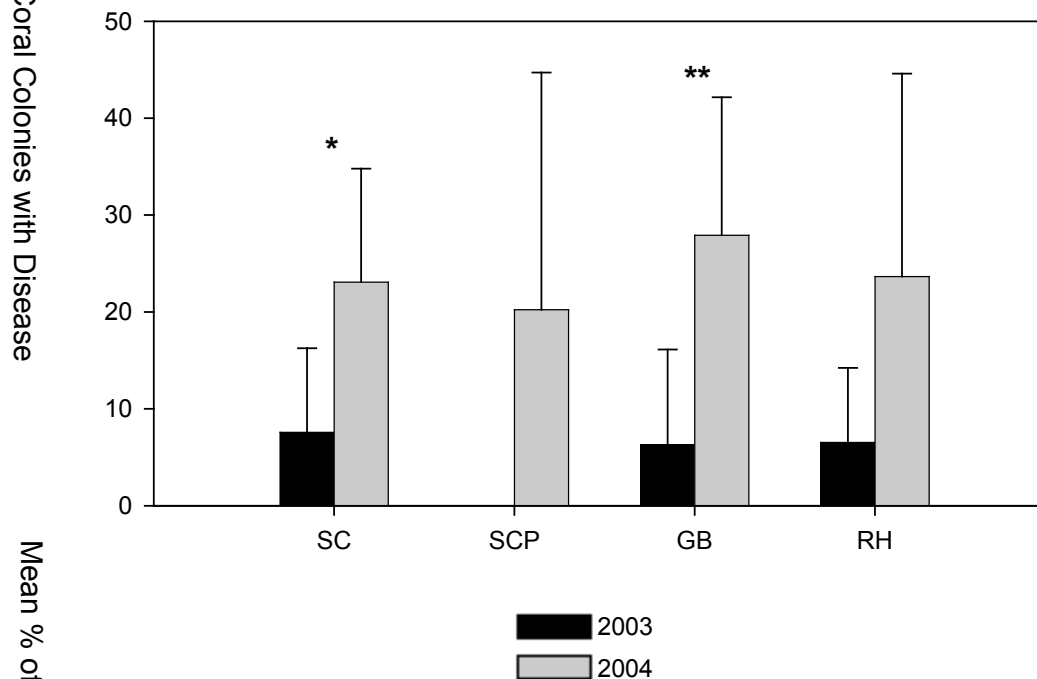
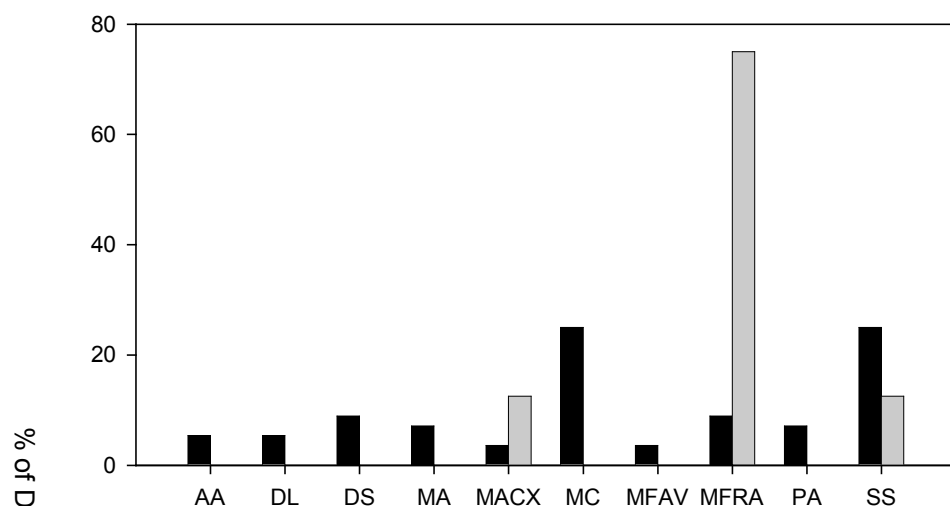


Fig. 18 Mean percentage of A. colonies with disease and B. colonies with bleaching of all coral colonies sampled at each monitoring site. SC Seahorse Cottage Shoal; SCP South Capella; GB Grammanik Bank; RH Red Hind Bank. Sampling for SCP began 2004. Error bars represent standard deviation. Asterisks denote significant differences: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

A. Coral Disease



B. Coral Bleaching

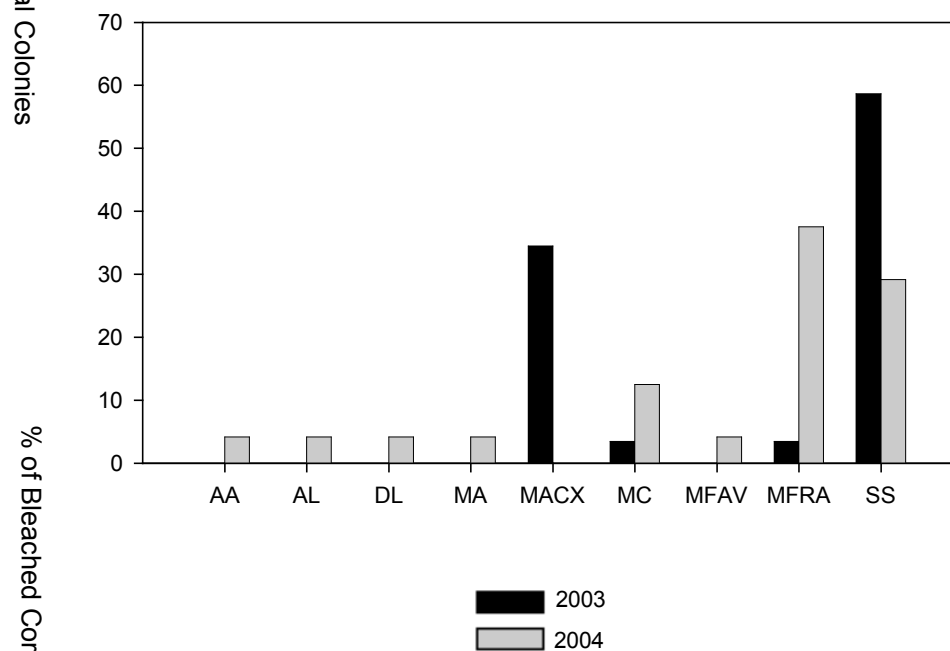
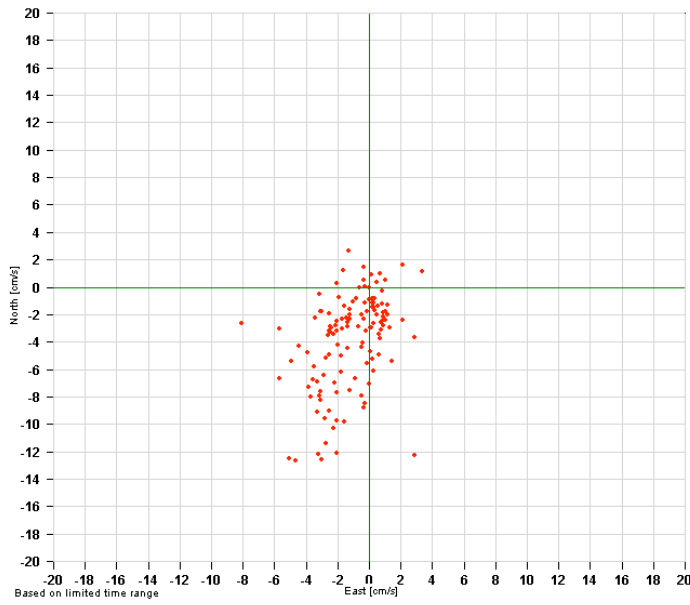


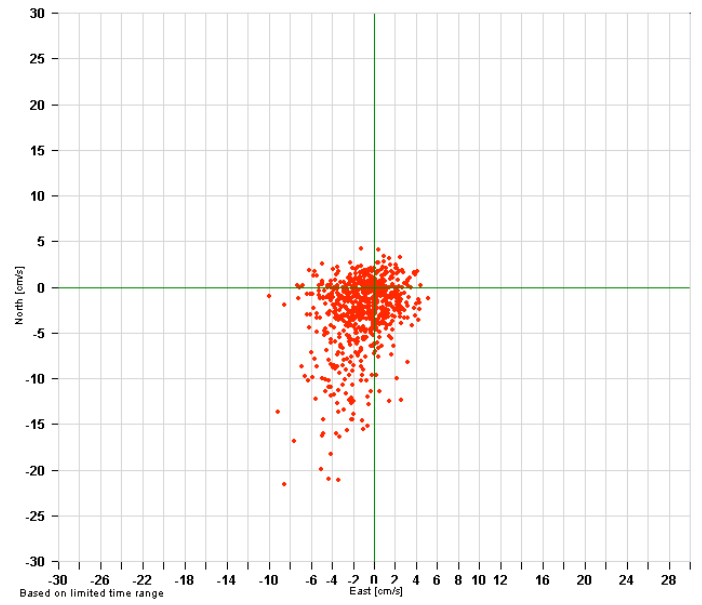
Fig. 19 Percentage of A. diseased colonies and B. bleached colonies of all coral species with disease and bleaching sampled at each St. Thomas monitoring site.
AA *Agaricea agaricites*; AL *Agaricea lamarcki*; DL *Diploria labyrinthiformis*; MA *Montastraea annularis*; MACX unidentified species belonging 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

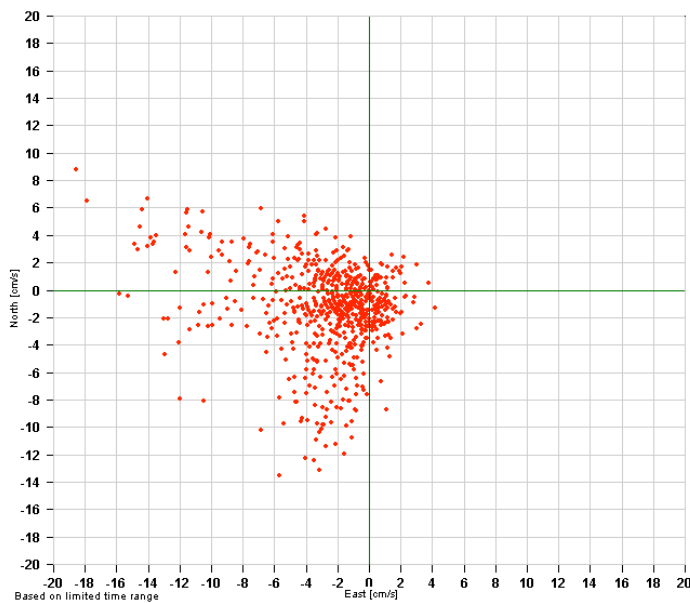
February 2004



March 2004



April 2004



May 2004

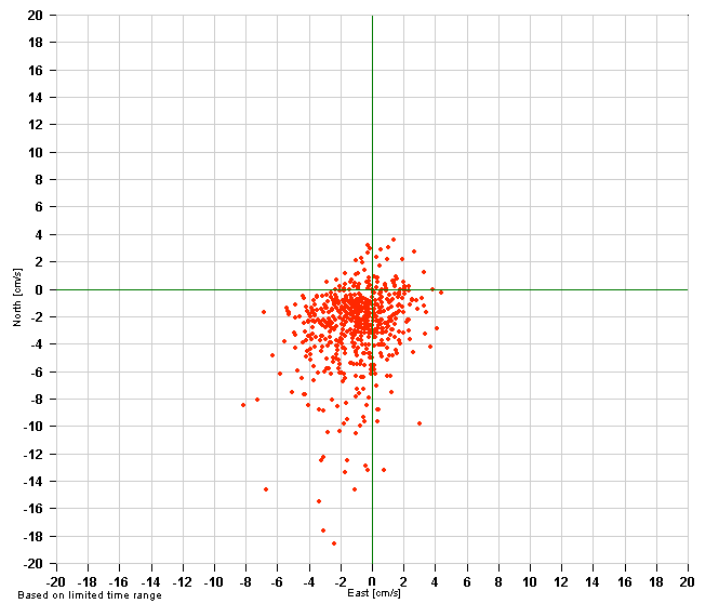
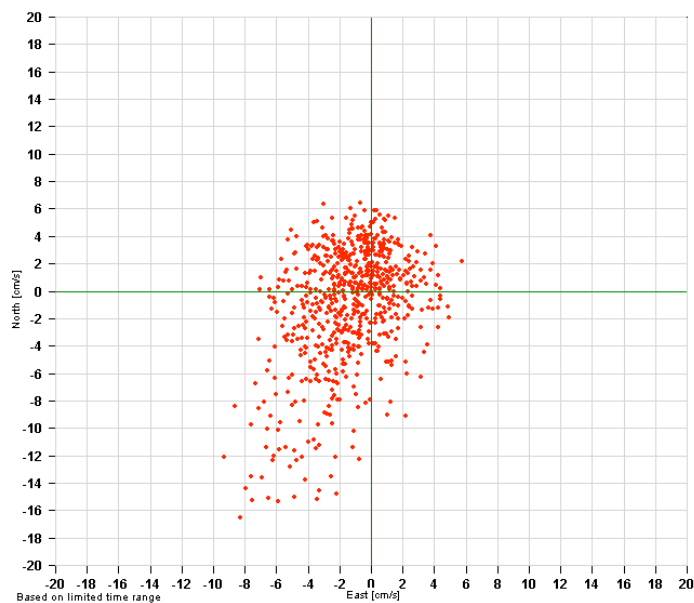


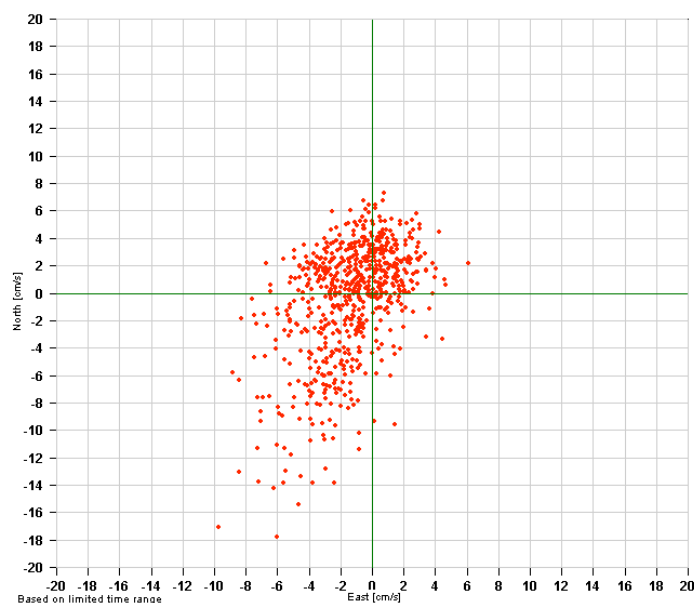
Fig. 20 Current speed and direction at Flat Cay, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction – Flat Cay

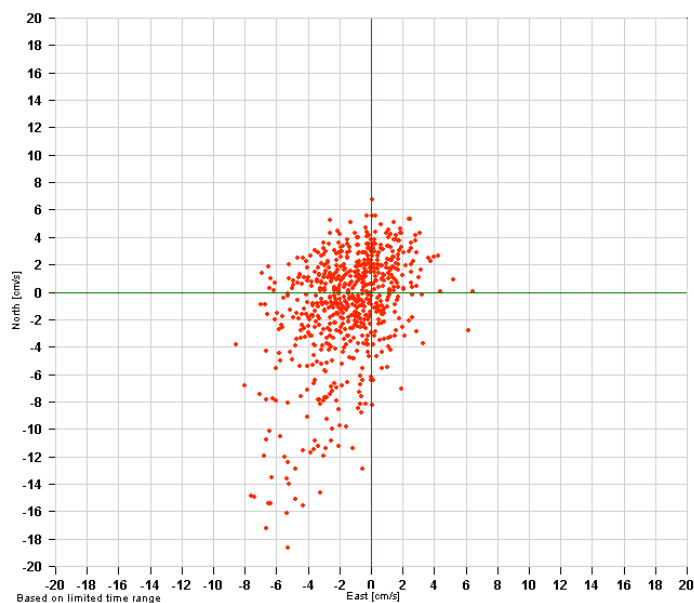
June 2004



July 2004



August 2004



September 2004

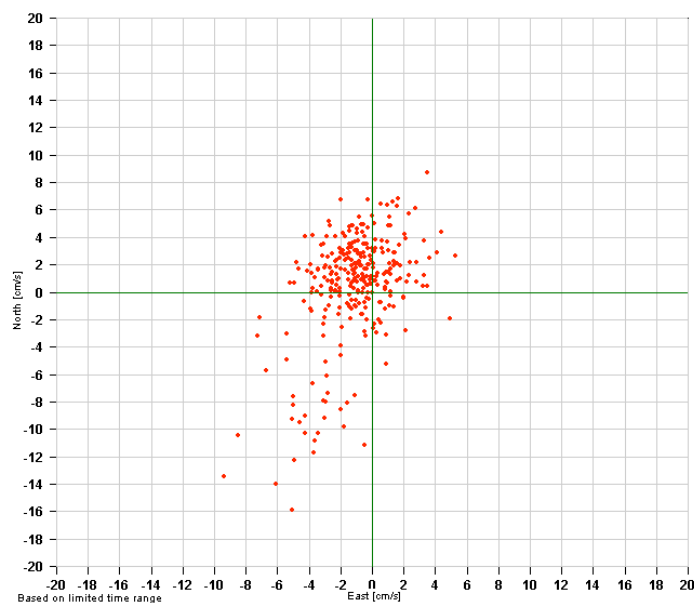
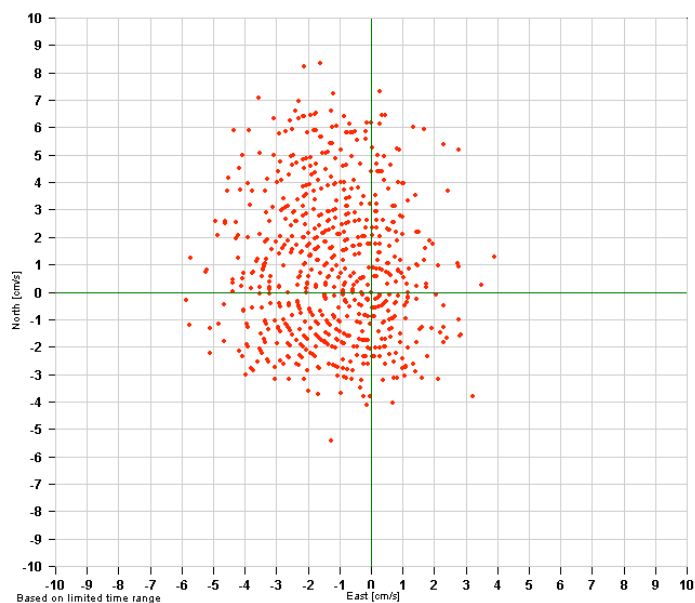


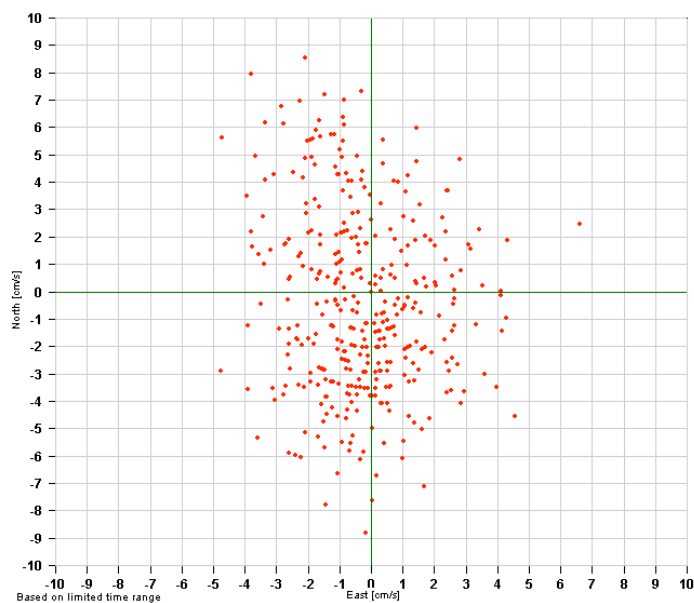
Fig. 20 (cont.) Current speed and direction at Flat Cay, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction – Red Hind Bank

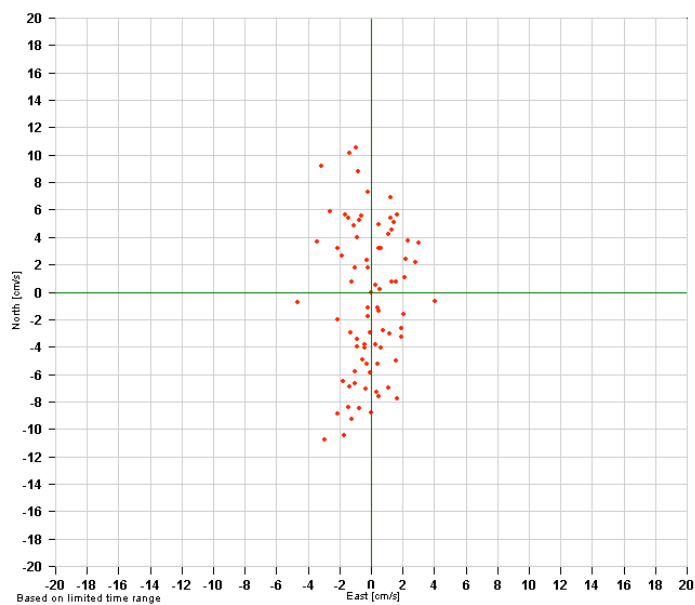
March 2004



April 2004



May 2004



June 2004

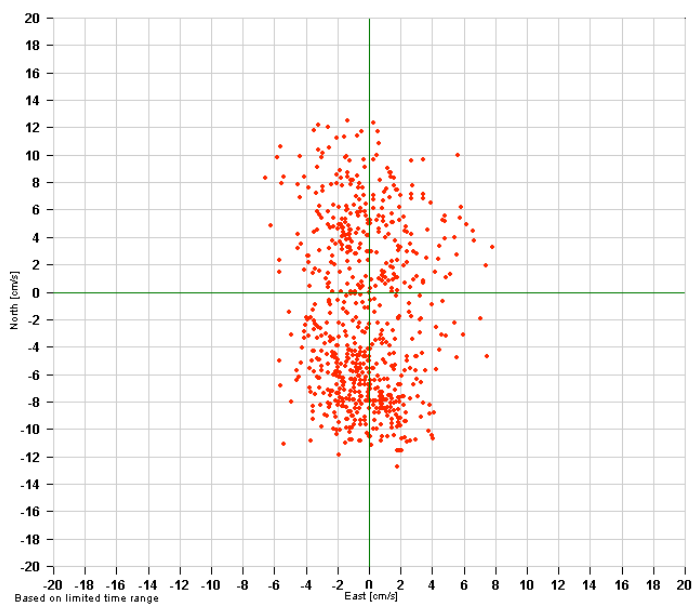
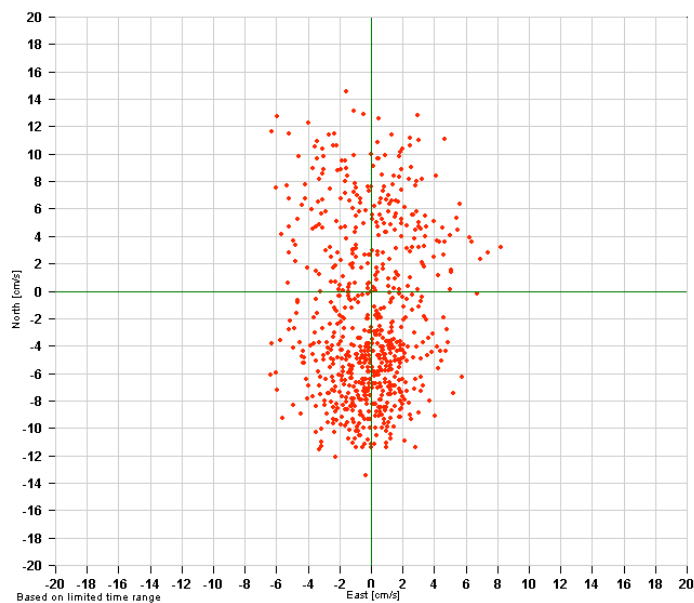


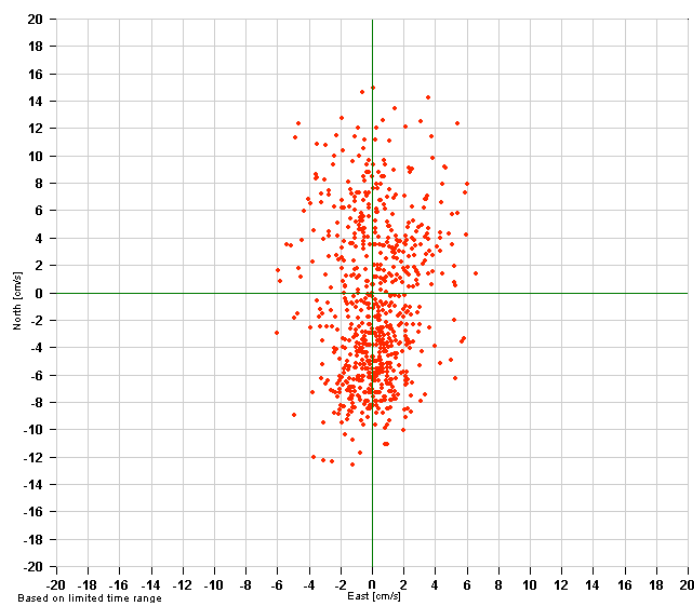
Fig. 21 Current speed and direction at the Red Hind Bank, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

Current Speed and Direction – Red Hind Bank

July 2004



August 2004



September 2004

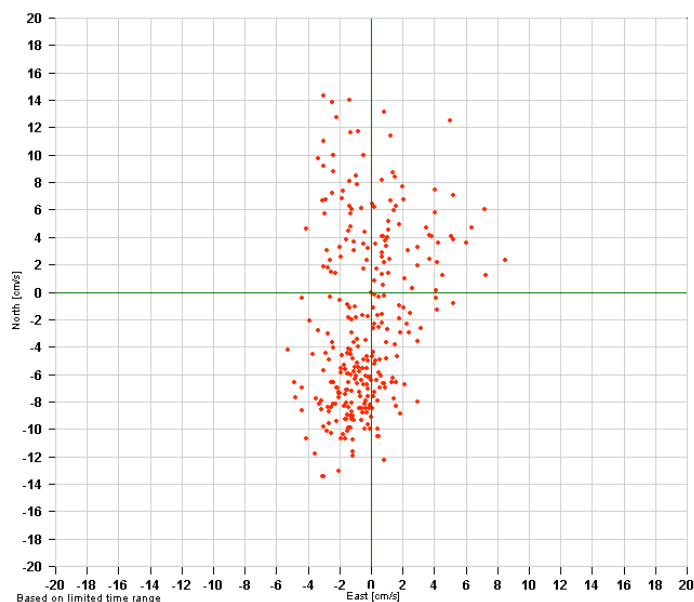


Fig. 21 (cont.) Current speed and direction at the Red Hind Bank, St. Thomas, USVI by month. Individual points represent hourly readings throughout each respective month.

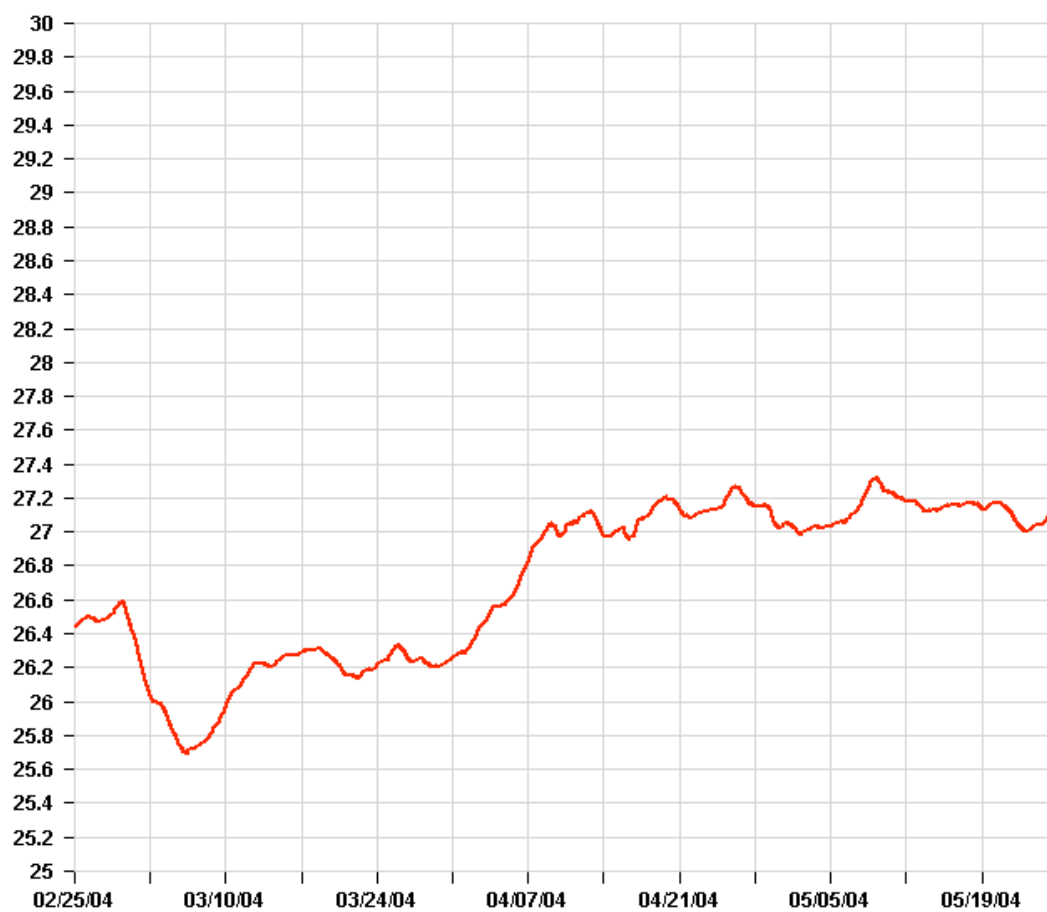


Fig. 22 Daily mean temperature (°C) recorded at Flat Cay, St. Thomas USVI, February to May 2004.

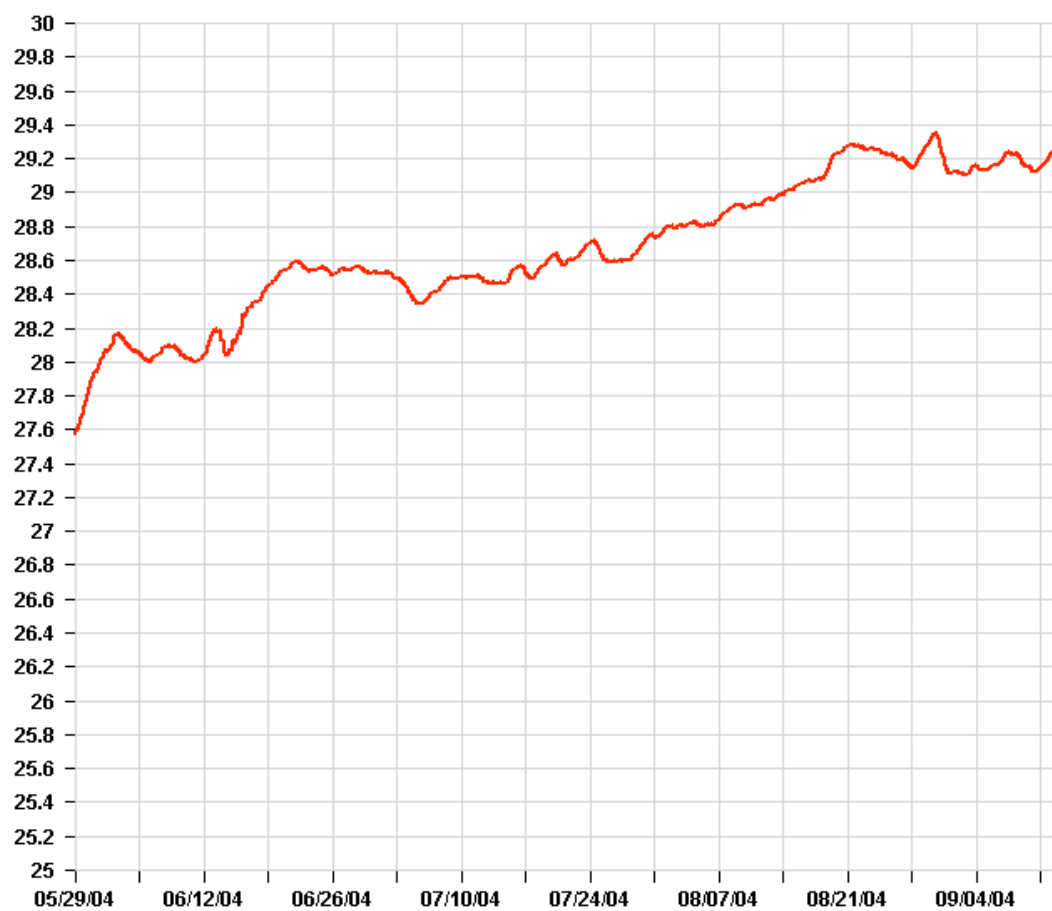


Fig. 22 (cont.) Daily mean temperature (°C) recorded at Flat Cay, St. Thomas USVI, May to September 2004.

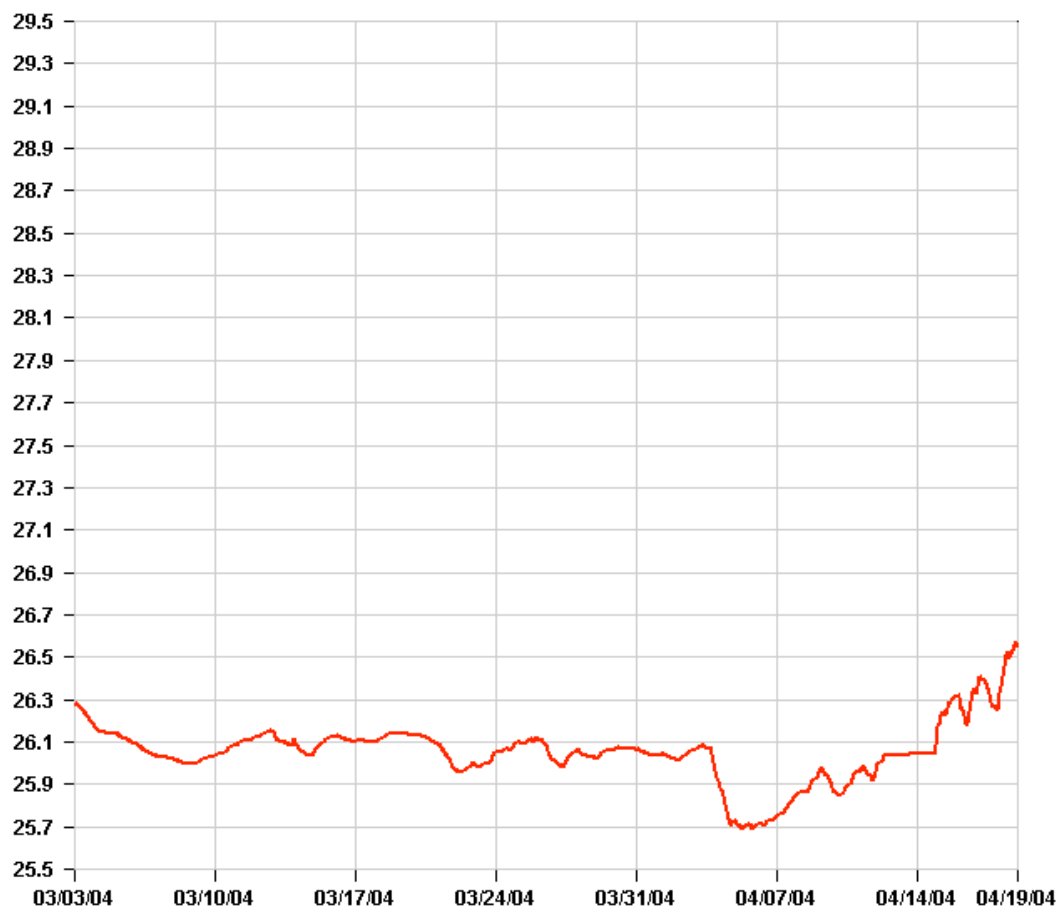


Fig. 23 Daily mean temperature (°C) recorded at the Red Hind Bank, St. Thomas USVI, March to April 2004.

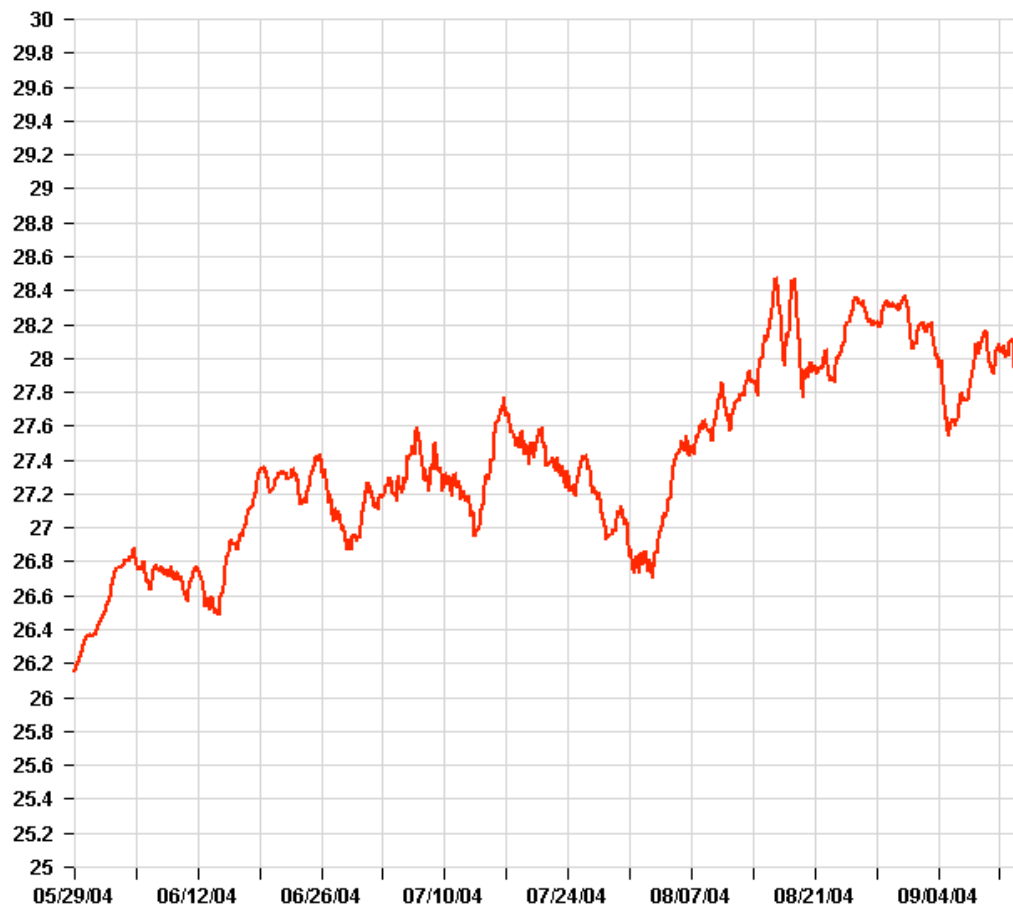


Fig. 23 (cont.) Daily mean temperature (°C) recorded at the Red Hind Bank, St. Thomas USVI, May to September 2004.

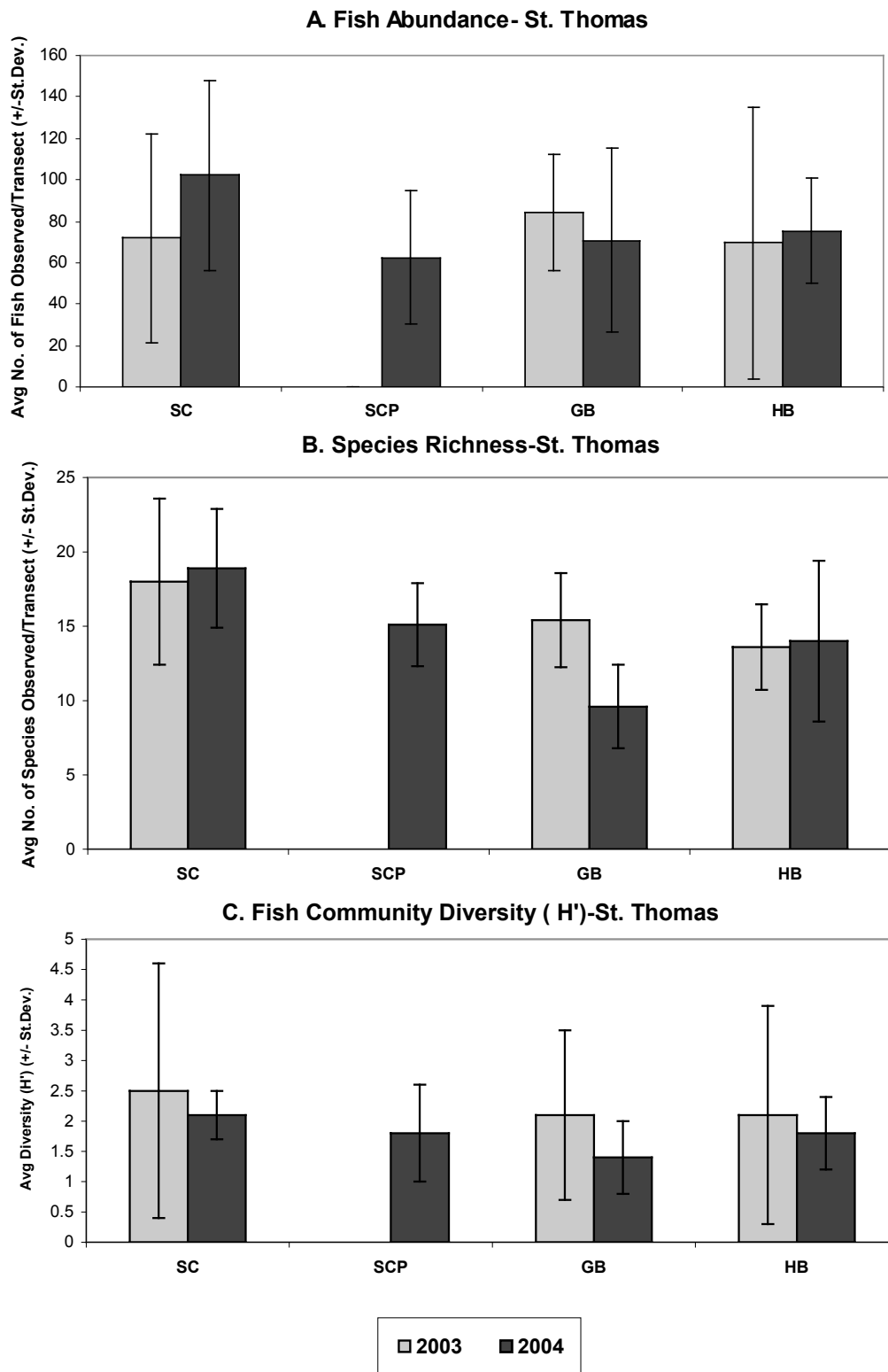


Fig. 24 Reef fish community structure across six St. Thomas reef sites.
 A. average abundance; B. average species richness;
 C. average Shannon-Weaver diversity (H').

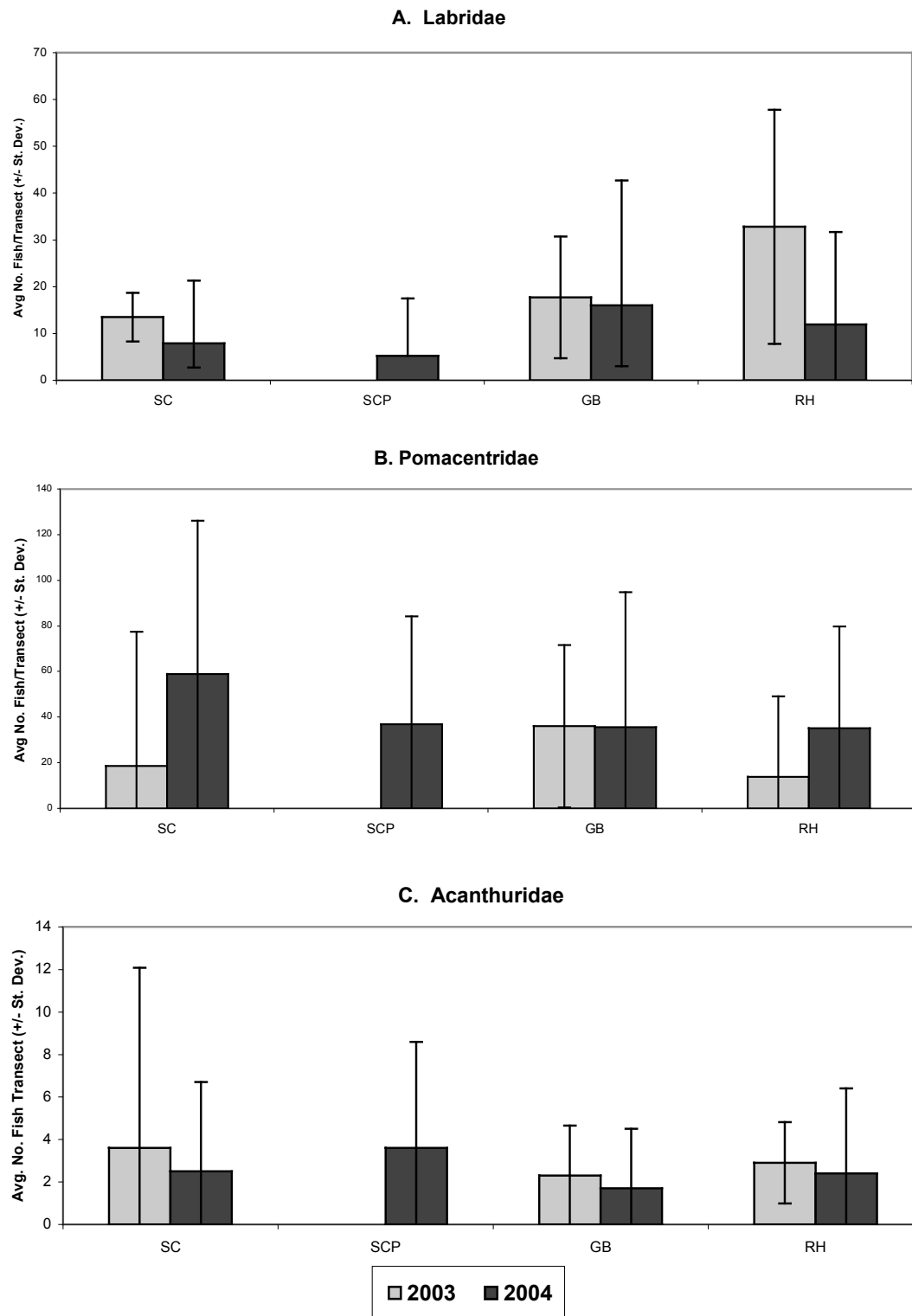


Fig. 25 Fish abundance by family across four St. Thomas reef sites, 2003 and 2004.

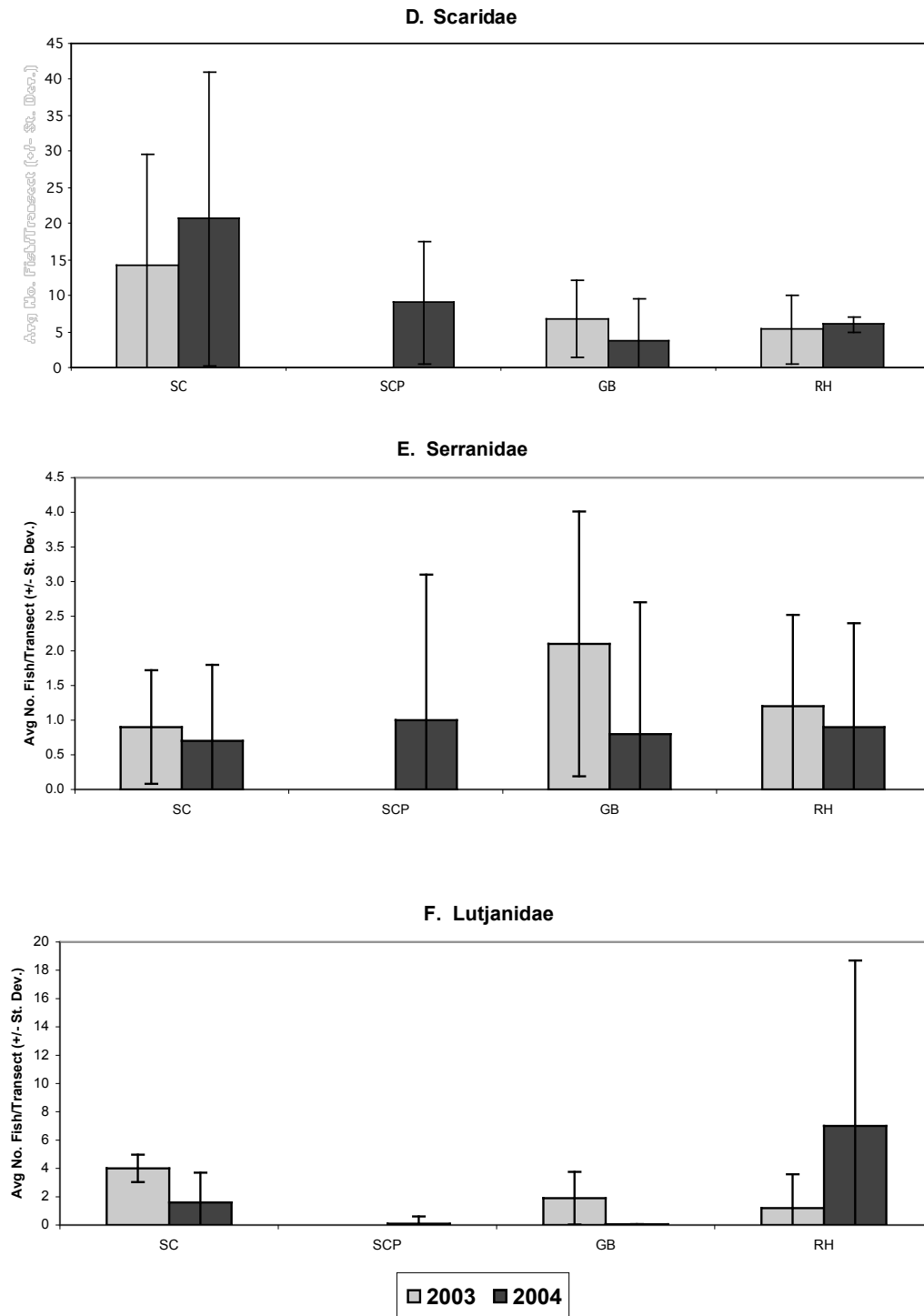


Fig. 25 (cont.) Fish abundance by family across four St. Thomas reef sites, 2003 and 2004.

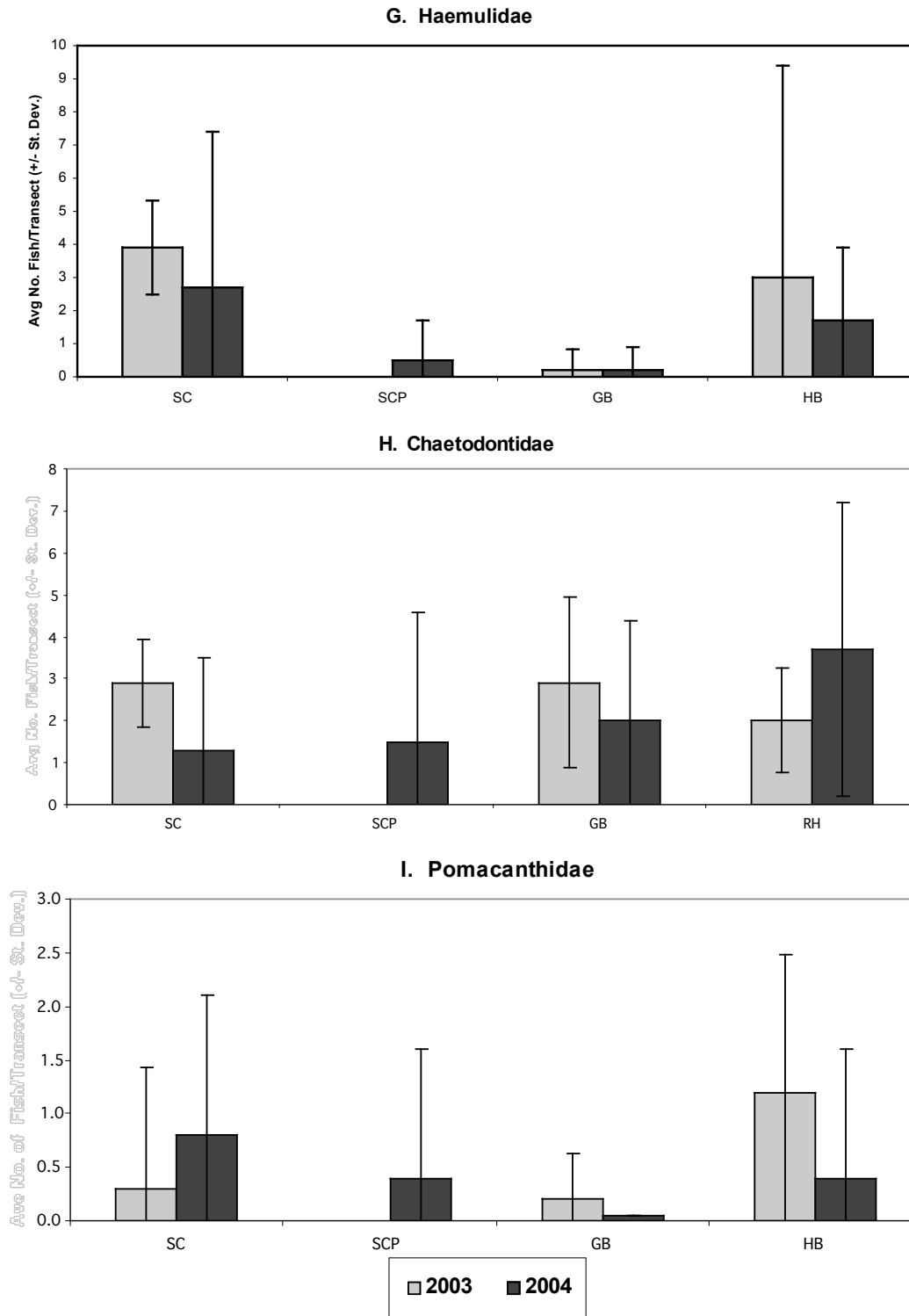


Fig. 25 (cont.) Fish abundance by family across four St. Thomas reef sites, 2003 and 2004.

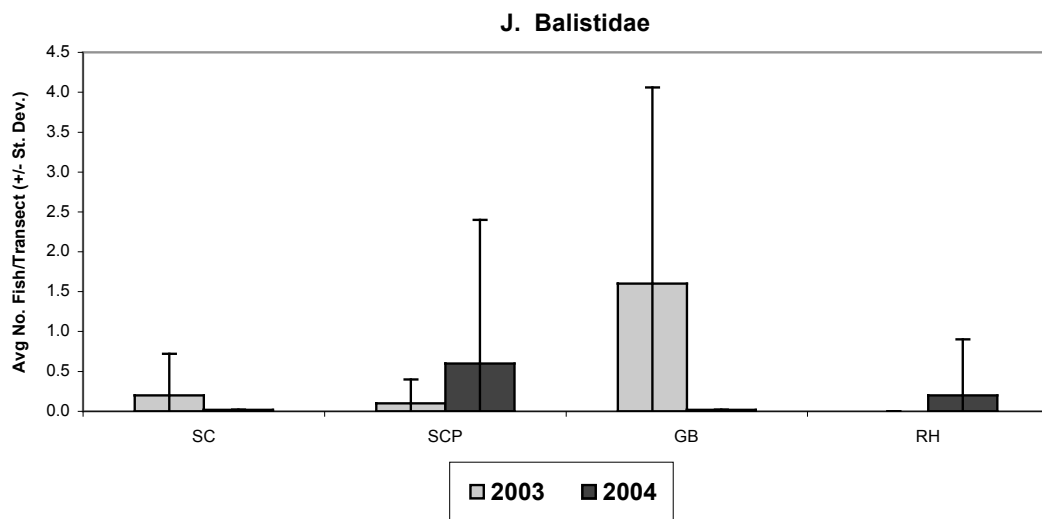


Fig. 25 (cont.) Fish abundance by family across four St. Thomas reef sites, 2003 and 2004.