Methods

BENTHIC ASSESSMENTS

The University of the Virgin Islands determined the benthic composition at 33 long-term monitoring sites between 2001 and 2012 (Fig. 4). Around St. Croix the following 14 sites were assessed: Buck Island-St. Croix, Cane Bay, Cane Bay Deep, Castle, Eagle Ray, Great Pond, Jacks/Isaacs Bay, Kings Corner, Lang Bank East End Marine Park (Lang EEMP), Lang Bank Red Hind Fish Spawning Aggregation (Lang Hind), Mutton Snapper, Salt River, Salt River Deep, and Sprat Hole. Four of these sites are within the St. Croix East End Marine Park boundary (Castle, Great Pond, Jacks Bay, Lang EEMP), three sites are within National Park Service boundaries (Buck Island-St. Croix, Salt River West , and Salt River Deep), two sites are within federal fisheries marine protected areas (Lang Hind, Mutton Snapper), and four sites can be considered mesophotic coral reefs (Cane Bay Deep, Lang Bank EEMP, Lang Hind FSA, Salt River Deep; sensu Ginsburg 2007) (Ginsburg

2007)(Ginsburg 2007). Salt River Deep transects 1-4 were moved from 40 m depth at the April 2009 sampling to 30 m in the January 2010 sampling due to low coral cover in the deeper transects.

Around St. John-St. Thomas the following 19 sites were assessed: Black Point, Botany Bay, Brewers Bay, Buck Island-St. Thomas, Coculus Rock, College Shoal East, Coral Bay, Fish Bay, Flat Cay, Ginsburgs Fringe, Grammanik Tiger FSA, Hind Bank FSA, Little St. James, Magens Bay, Savana Island, Seahorse Cottage Shoal (Seahorse), Meri Shoal, South Capella, and South Water Island. One site is the within the St. Thomas East End Reserve (Coculus Rock), four sites are within federal fisheries marine protected areas (College Shoal, Ginsburgs Fringe, Grammanik Tiger, Hind Bank), and five sites can be considered mesophotic coral reefs (College Shoal, Ginsburgs Fringe, Grammanik Tiger, Hind Bank, Meri Shoal). Four sites are also part of the Ciguatera Fish Monitoring Program and have been surveyed monthly for benthic structure and coral health since 2010 (Black Point, Coculus Rock, Flat Cay, Seahorse).

Benthic Cover. At each site benthic cover and coral health surveys were conducted along six 10 m long permanent transects marked with steel or brass rods. Video sampling consisted of one diver traversing each transect videotaping the benthic cover using a high definition video cassette recorder (Sony FX-7 in Light and Motion housing) or an HD digital video recorder with wide angle lens (Canon XF in Light and Motion 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 or dropper weight attached to the camera housing was used to help the diver maintain the camera a constant distance above the reef. After taping, approximately 20 - 50 non-overlapping images per transect were captured and saved as JPEG files (Fig. 5). Captured images represented an area of reef approximately 0.31 m^2 (0.64 m x 0.48 m). Coral Point Count with Excel Extension software (Kohler and Gil 2006) was used to superimpose ten

randomly located dots on each image. The substrate type located under each of the dots was then identified to the most descriptive level possible and entered into a database. Where multiple benthic cover categories fell under a single point, for example macroalgae over bedrock, the upper benthic category was assessed. For each transect, the percent cover of coral, epilithic algae (formerly called 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. Epilithic algae (sensu Hatcher and Larkum 1983) are diminutive turfs and filamentous algae without thallus structure that cover all rock surfaces of coral reefs not occupied by larger epibenthic organisms. They can also be considered to be grazed surfaces are often an indicator of healthy grazing communities and high animal cover.

Figure 5. A screen grab of benthic video used for the determination of percent cover of coral reef organisms and non-living substrate.

Table 1. TCRMP site reef complex type, location coordinates, and depths. FSA = Fish Spawning Aggregation. EEMP = East End Marine Park.

Island	Site	Reef Complex	Lat	Long	Depth (m)
St. Croix	Buck Island-St. Croix	Offshore-Shallow	17.78500	-64.60917	15
	Cane Bay	Nearshore	17.77388	-64.81350	10
	Cane Bay Deep	Offshore-MCE	17.77661	-64.81522	38
	Castle	Offshore-Shallow	17.76278	-64.59743	7
	Eagle Ray	Offshore-Shallow	17.76150	-64.69880	10
	Great Pond	Nearshore	17.71097	-64.65221	6
	Jacks Bay	Nearshore	17.74337	-64.57160	14
	Kings Corner	Nearshore	17.69116	-64.90008	17
	Lang Bank EEMP	Offshore-MCE	17.72145	-64.54706	27
	Lang Bank Red Hind FSA	Offshore-MCE	17.82372	-64.44943	33
	Mutton Snapper FSA	Offshore-Shallow	17.63660	-64.86240	24
	Salt River Deep	Offshore-MCE	17.78523	-64.75917	30
	Salt River West	Offshore-Shallow	17.78530	-64.75940	11
	Sprat Hole	Nearshore	17.73400	-64.89540	8
St. John	Coral Bay	Nearshore-Shallow	18.33797	-64.70402	9
	Fish Bay	Nearshore	18.31417	-64.76408	6
	Meri Shoal	Offshore-MCE	18.24433	-64.75832	30
St. Thomas	Black Point	Nearshore	18.34450	-64.98595	9
	Botany Bay	Nearshore	18.35845	-65.03330	8
	Brewers Bay	Nearshore	18.34403	-64.98435	6
	Buck Island-St. Thomas	Offshore-Shallow	18.27883	-64.89833	14
	Coculus Rock	Nearshore	18.31257	-64.86058	7
	College Shoal East	Offshore-MCE	18.18568	-65.07677	30
	Flat Cay	Offshore-Shallow	18.31822	-64.99104	12
	Ginsburgs Fringe	Offshore-MCE	18.18770	-64.95998	63
	Grammanik Tiger FSA	Offshore-MCE	18.19113	-64.95032	38
	Hind Bank East FSA	Offshore-MCE	18.20217	-65.00158	39
	Magens Bay	Nearshore	18.37425	-64.93438	7
	Savana	Offshore-Shallow	18.34064	-65.08205	9
	Seahorse Cottage Shoal	Offshore-Shallow	18.29467	-64.86750	20
	South Capella	Offshore-Shallow	18.26267	-64.87237	20
	South Water	Offshore-Shallow	18.28068	-64.94592	20
	St James	Offshore-Shallow	18.29459	-64.83238	15

Table 2. TCRMP site date sampled (benthic/health) and type of sampling.

Island	Site	Date Sampled	Benthic	Health	Fish/Urchin
St. Croix	Buck Island STX	8/13/12	x	x	x
	Cane Bay	8/12/12	x	x	x
	Cane Bay Deep	8/12/12	x	x	x
	Castle	8/15/12	x	x	x
	Eagle Ray	8/17/12	x	x	x
	Great Pond	8/14/12	x	x	x
	Jacks Bay	8/13/12	x	x	x
	Kings Corner	8/16/12	x	x	x
	Lang Bank EEMP	8/14/12	x	x	x
	Lang Bank Red Hind FSA	8/15/12	x	x	x
	Mutton Snapper FSA	8/17/12	x	x	x
	Salt River Deep	8/11/12	x	x	x
	Salt River West	8/11/12	x	x	x
	Sprat Hole	8/16/12	x	x	x
St. John	Coral Bay	12/03/12	x	x	x
	Fish Bay	10/11/12	x	x	x
	Meri Shoal	12/03/12	x	x	x
St. Thomas	Black Point	10/25/12	x	x	x
	Botany Bay	11/19/12	x	x	x
	Brewers Bay	11/30/12	x	x	x
	Buck Island STT	12/16/12	x	x	x
	Coculus Rock	10/31/12	x	x	x
	College Shoal East	10/04/12	x	x	x
	Flat Cay	10/25/12	x	x	x
	Ginsburgs Fringe	02/21/13	x		
	Grammanik Tiger FSA	10/09/12	x	x	x
	Hind Bank East FSA	11/06/12	x	x	x
	Magens Bay	11/19/12	x	x	x
	Savana	11/19/12	x	x	x
	Seahorse Cottage Shoal	10/31/12	x	x	x
	South Capella	12/16/12	x	x	x
	South Water	10/02/12	x	x	x
	St James	11/30/12	x	x	x

METHODS

Coral Health. Coral health assessments follow methodologies outlined in (Calnan et al. 2008) and (Smith et al. 2008) and are briefly described here. All coral colonies located directly under the transect lines were assessed in situ for signs of mortality and disease following a modified Atlantic and Gulf Rapid Reef Assessment protocol (Kramer et al. 2005). In contrast to previous years where only colonies greater than 10 cm in maximum linear dimension were assessed, starting in 2008 all colonies were assessed, regardless of size. Partial mortality of coral colonies was broken into two categories. Recent partial mortality was characterized visually as skeleton not eroded (fine corallite structure still intact) and bare or with a thin veneer of sheeting or filamentous algae. Recent partial mortality is typically visible for up to three months following tissue loss. Old partial mortality was characterized as skeleton eroded and covered with turf or macroalgae. Old partial mortality is a transition from recent mortality and typically lasts up to 1–6 years (Smith et al. 2008, also see http://www.agrra.org/method/methodcor.html).

Diseases were conservatively categorized into recognized Caribbean scleractinian diseases and syndromes that included bleaching, black band disease, dark spots disease, white plague, and yellow band (blotch) disease (following Bruckner 2007). Acroporid corals were extremely rare at the study sites; thus, their associated diseases (white band and white pox) are not presented. Bleaching was assessed as abnormal paling of the colony, and, when present, the severity of the bleaching (paling or total whitening) and the area of the colony affected were assessed. A major bleaching event occurred between September and December 2005, affecting all monitored sites, and a mild bleaching event occurred September and October 2010 (Smith et al. 2013). On St. Croix, a subset of sites were assessed during the 2010 coral bleaching event, and included Cane Bay, Cane Bay Deep, and Jacks Bay.

For each transect, the prevalence of coral impairment categories was calculated as the number of colonies with partial mortality, disease, or bleaching divided by the number of

colonies assessed. Also, for affected colonies in each transect the average three-dimensional surface area (%) of the colony affected was also estimated for each impairment category.

FISH CENSUS

Fish surveys were conducted at 14 sites around St. Croix and 18 sites around St. Thomas (Table 2) in 2012. Ten replicate belt transects and three replicate roving dive surveys (RDS) were conducted at each site. Belt transects were 30m x 4m and were conducted in 15 min per replicate. All transects were begun at a random location on the site, and were swum in a random direction. RDS replicates were either 30 min (sites < 25 m depth) or 15 min (sites >25 m depth) (see Table 3). In addition to relative abundance data, specific total length estimates were made for each large grouper, large snapper or hogfish (*Lachnolaimus maximus*) encountered. In all surveys, all fish encountered were recorded except blennies and gobies. Data were transcribed to Microsoft Excel and Access spreadsheets, and were analyzed for descriptive statistics of reef fish assemblage structure.

Divers also counted the number of *Diadema antillarum* sea urchins within 1 m on either side of transects. From 2001 – 2008 this occurred along the 6 – 10 m long benthic transects. Starting in 2009, urchins were assessed along 25x2m belt transects corresponding to the return of the 10 fish transects. The mean number of sea urchins per 100 m^2 was calculated for each site.

Territorial Coral Reef Monitoring Summary

BENTHIC COVER & CORAL HEALTH

BENTHIC COMMUNITIES AND CORAL REEF HEALTH

Benthic cover was monitored at 33 monitoring sites and coral health was monitored at 32 sites in 2012. Coral health was not monitored at the deep (63m) Ginsburgs Fringe. Benthic cover raw data is presented in electronic Appendix I. Coral health raw data is presented in electronic Appendix II.

Coral Cover

The cover of hard corals decreased at most sites after the 2005 coral bleaching event, but showed little or no change as the results of the 2010 coral bleaching event (Fig. 6). Shallow (<25 m depth), nearshore and offshore sites with greater than about 20% coral cover showed declines in cover, but there was extreme variability in the degree of cover change. For example the Mutton Snapper site on St. Croix lost 87% of its coral cover between 2004 and 2006. Sites that had low coral cover prior to 2005 lost far less relative cover as the result of bleaching. While part of this may be due to detectability at values nearer to 0, these sites tend to dominated by small massive species that are more resistant to disease related mortality (Smith et al. 2013).

Mesophotic coral monitoring sites that were sampled before and after the 2005 coral bleaching event showed slight relative losses of coral cover. Losses ranged from 5.4% (Grammanik Tiger) to 36.0% (Meri Shoal). Since 2010, coral cover has declined slightly at some mesophotic sites, which may reflect the impact of white diseases and a mild bleaching event that occurred in 2012.

Recovery since bleaching was marginal at most sites. The majority of sites had apparently level coral cover with recovery potentially inhibited by disease and increased interactions with other organisms. However, slow upward trajectories are notable at some sites.

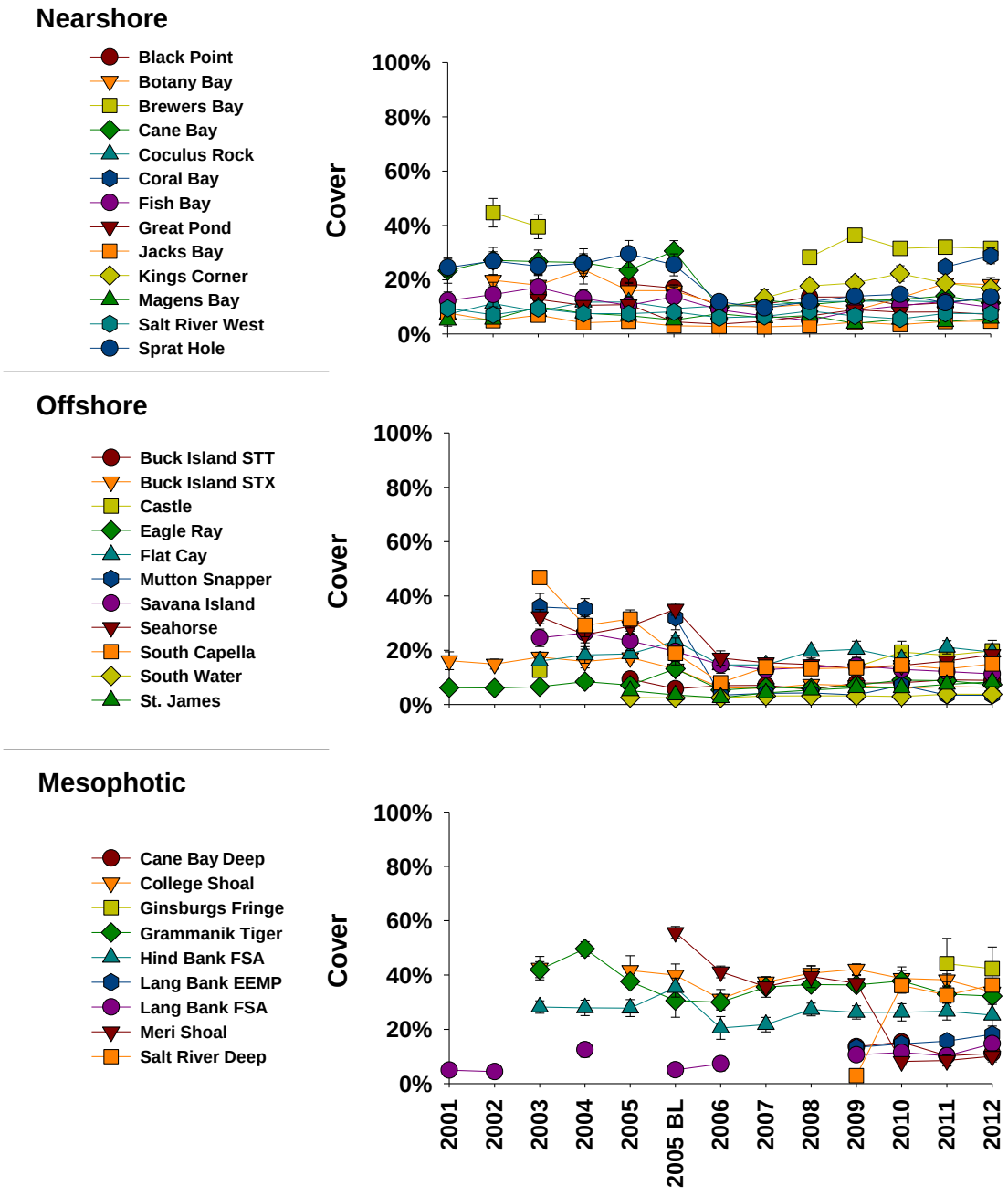

Figure 6. Coral cover (±SE) across TCRMP monitoring sites over time.

Epilithic Algal Community Cover

Algae show the highest inter-annual variability of any group of benthic organisms (Fig. 7). This is largely due to seasonality. The cover of epilithic algae is no exception, since it tends to negatively covary with more ephemeral macroalgae. Epilithic algae is important as it can indicate substrates grazed by herbivores and therefore open to the settlement of sessile epibenthic animals, including coral.

Nearshore and mesophotic sites showed little inter-annual trend in epilithic algal cover. Many offshore sites, such as Eagle Ray and Buck Island, St. Croix, appear to have a declining abundance of epilithic algae, indicating an increase in other benthic components, such as macroalgae and filamentous cyanobacteria, and possibly indicating declining grazing.

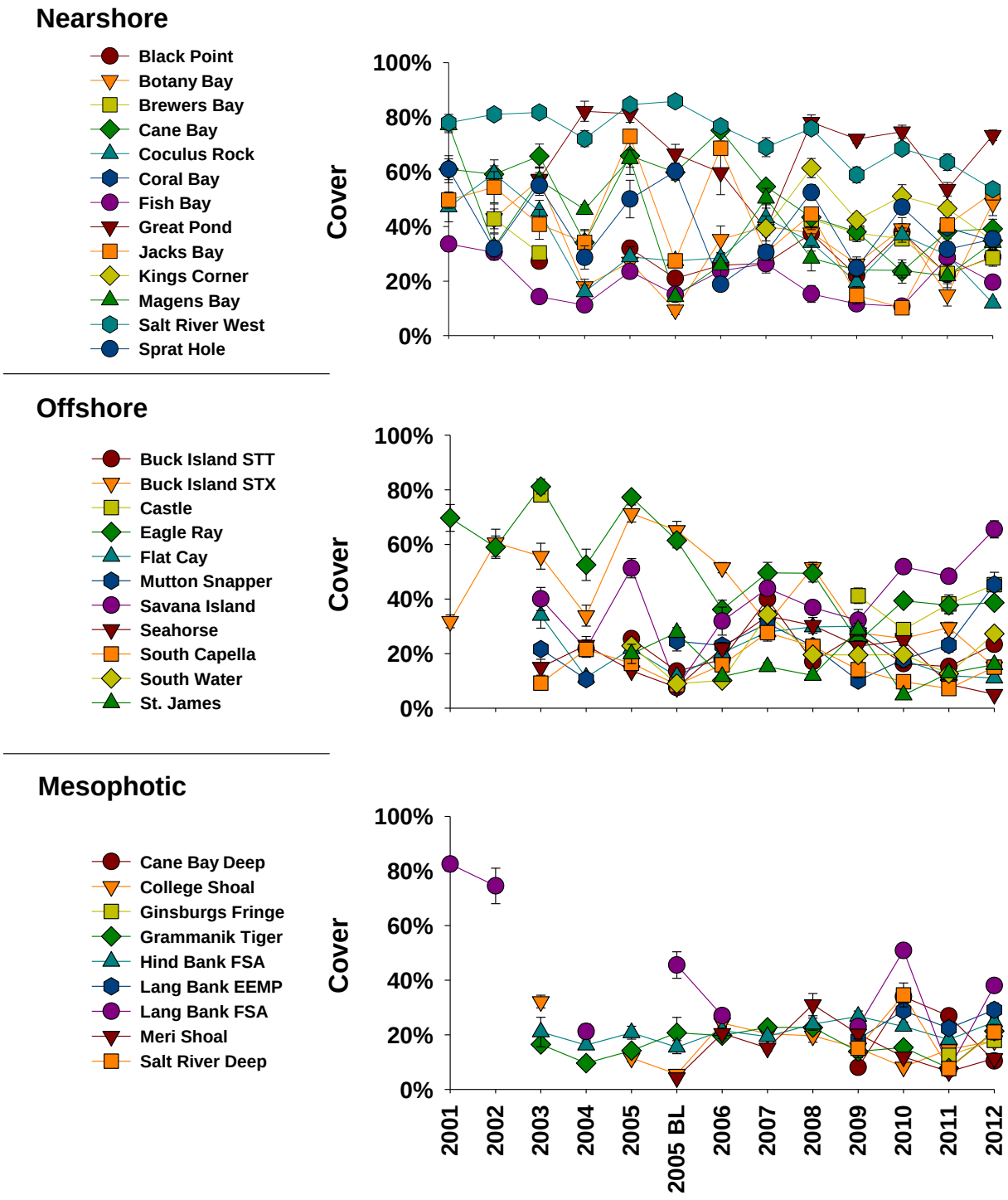

Figure 7. Epilithic algal community cover (±SE) across TCRMP monitoring sites over time.

Macroalgal Cover

Macroalgae have been increasing at many reefs, particularly after the 2005 bleaching event (Fig. 8). At sites where there was no loss of coral cover, increased macroalgae may be due to declining grazing, such as at Eagle Ray. At other sites where coral cover dropped after 2005, space opened for algal colonization by coral die-off may not have been grazed in reefs where resident herbivores communities are already at the threshold of maximum grazing rates (Williams et al. 2001). These reefs include, the Buck Islands (St. Thomas and St. Croix), Cane Bay, Meri Shoal, South Capella, and Sprat Hole. The same explanation may also apply for filamentous cyanobacteria (see following section).

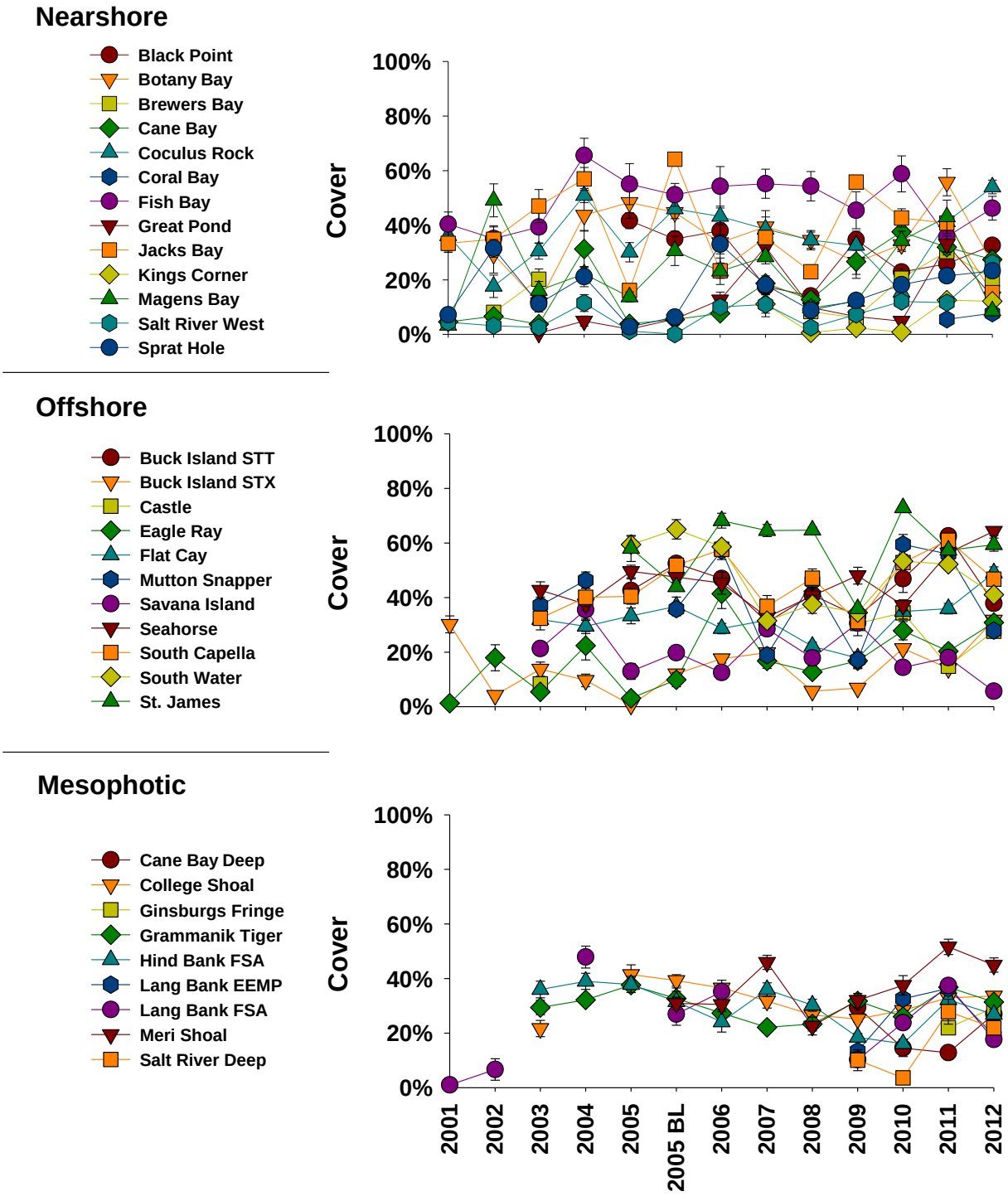

Figure 8. Macroalgae cover (±SE) across TCRMP monitoring sites over time.

Filamentous Cyanobacteria

Filamentous cyanobacteria cover has been increasing at many sites in the TCRMP since the 2005 coral bleaching event (Fig. 9). This is particularly true at many sites on St. Croix that have attained very high cover values in recent years. For example, Salt River West, Jacks Bay, Cane Bay, Sprat Hole, Mutton Snapper, Buck Island (St. Croix), Eagle Ray, Lang Bank EEMP, and Lang Bank Hind have all seen cover of filamentous cyanobacteria from 10 – 60%, with 2009 as a particularly high abundance year for offshore sites.

The increased incidence of filamentous cyanobacteria can be an indication of disturbance, increased nutrient inputs, and insufficient grazing (Fong and Paul 2011). In addition, filamentous cyanobacteria can promote increases in palatable macroalgae in coral reefs by coating and protecting algae with secondary metabolites that deter grazing (Fong et al. 2006, Smith et al. 2010b). Filamentous cyanobacteria can inhibit the recruitment of coral larvae (Kuffner et al. 2006) and have been observed interacting at the borders of adult coral (Authors, unpub. data). Monitoring the trends of filamentous cyanobacteria in USVI reef systems will be increasingly important in future years in an effort to understand the factors influencing bloom formation and which reefs are most vulnerable.

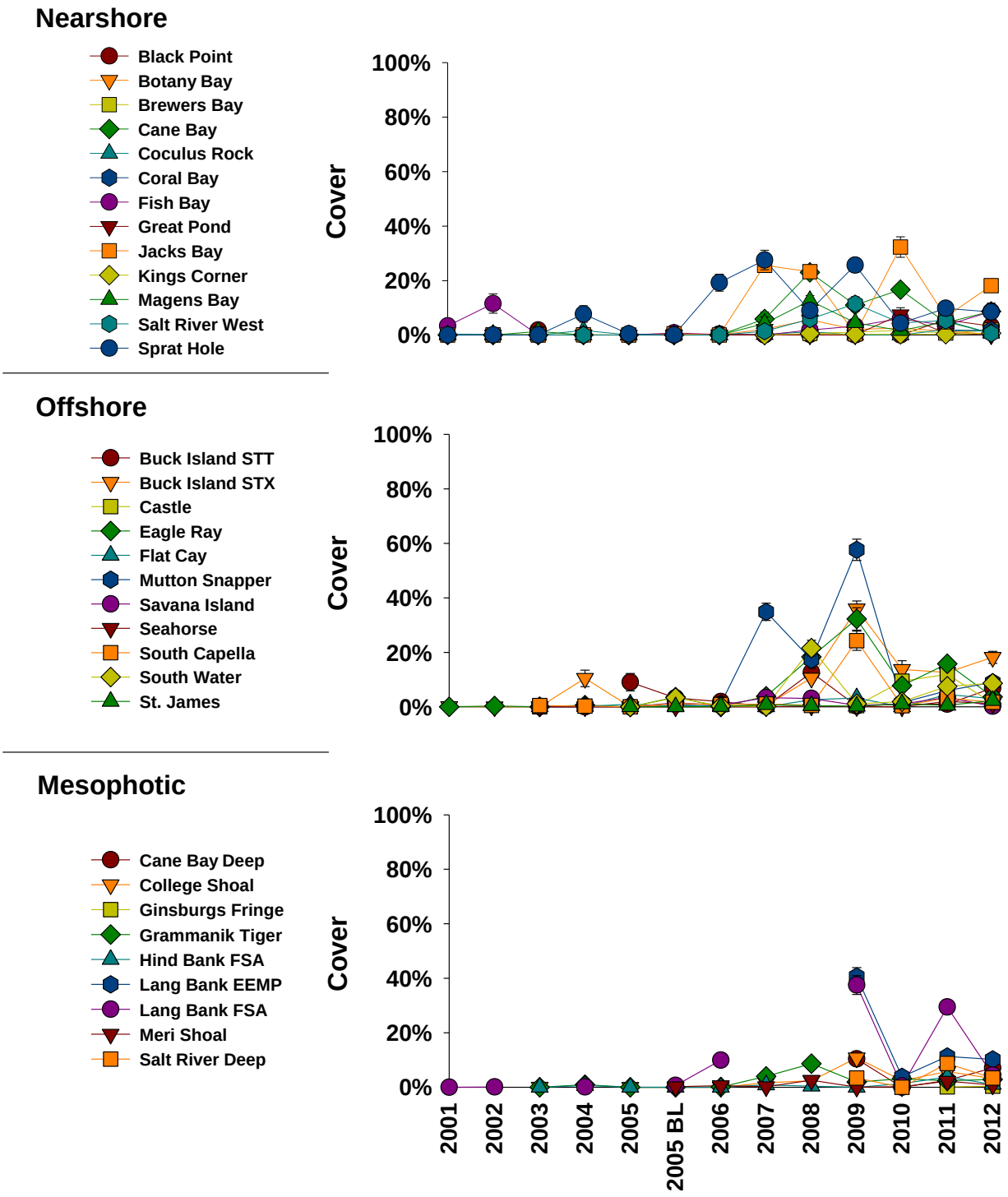

Figure 9. Filamentous cyanobacteria cover (±SE) across TCRMP monitoring sites over time.

Gorgonian and Antipatharian Cover

The cover of gorgonians and antipatharians has been fairly constant at most monitoring sites throughout the years of monitoring (Fig. 10). In most cases they are a relatively minor component of cover because of their upright growth form and small branches. However, there are sites that appear to be more favorable to the growth of gorgonians, including Magens Bay, Fish Bay, Coral Bay, Buck Island (St. Croix), Savana Island, South Water, Lang Bank Hind FSA, and Salt River Deep. Note that Black Corals (antipatharians) typically tend to be more prominent in deep monitoring sites, whilst gorgonians tend to be more dominant in shallower and wave-washed sites.

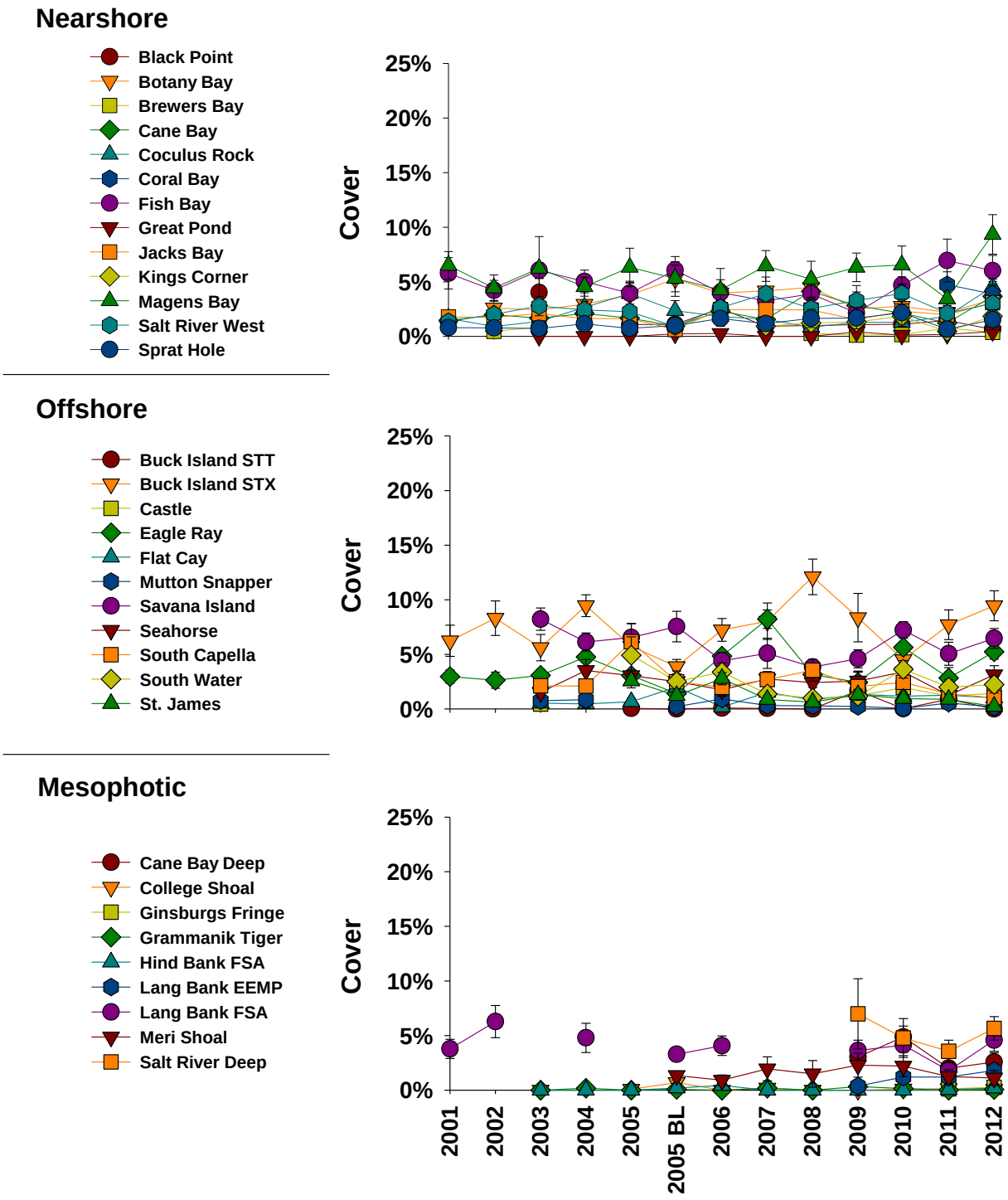

Figure 10. Gorgonian and Antipatharian cover (±SE) across TCRMP monitoring sites over time.

Sponge Cover

Sponge cover has been constant or variable at many offshore and mesophotic sites, but there is an indication of slightly increasing sponge cover at some nearshore sites (Fig. 11). This increase in epibenthic and boring sponges may indicate increasing supplies of food, such as bacteria and small eukaryotes, in nearshore environments. This may be a consequence of increasing nearshore nutrient pollution. Further study needs to be done to establish this linkage.

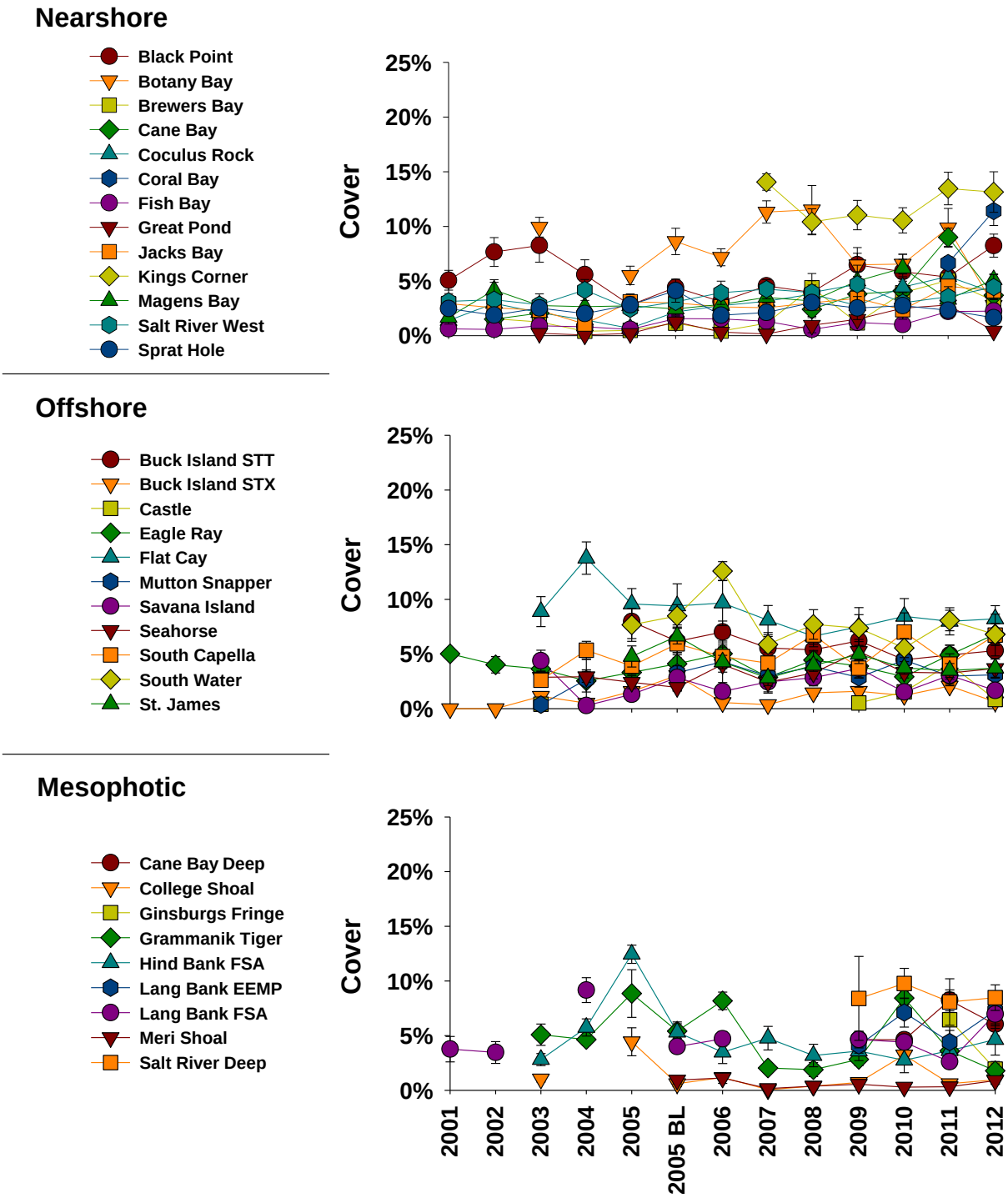

Figure 11. Sponge cover (±SE) across TCRMP monitoring sites over time.

FISH COMMUNITIES

FISH COMMUNITIES

In 2012 a total of 25,253 fish representing 121 species and 37 families were recorded during belt transects across all sites off St. Croix and 34,932 fish representing 132 species and 37 families across all sites off St Thomas. Using roving diver surveys (RDS) 119 species representing 33 families were observed in 2012 off St Croix and 117 species representing 32 families off St. Thomas (see Appendices III-VII). Species richness across most but not all sites was greatest in RDS, designed to capture rare and cryptic species (Table 3).

Overall fish size distribution on both St. Croix and St. Thomas followed trends seen in earlier years. Fish smaller than 10cm total length (TL) predominated at all sites. Fifty percent of the individuals counted off St. Croix were less than 5cm TL and 61% were less than 10cm TL. Off St. Thomas, 45% were smaller than 5cm and 80% were under 10cm TL. Large fish (> 40cm TL) constituted 0.2% (677 fish) of the numeric total of both islands combined. This was similar to data collected in 2011. St. Thomas sites produced more of this size class, with 527 or 1.5% of fish estimated over 40cm. Numerically the most dominant fish across St. Thomas reefs were striped parrotfish (*Scarus iserti*), bluehead wrasse (*Thalassoma bifaciatum*), blue chromis (*Chromis cyanae),* creole wrasse (*Clepticus parrae*) *,* bicolor damselfish (*Stegastes partitus*), and threespot damselfish (*Stegastes planifrons).* These six species made up over 58% of the numeric total of fish observed on all St. Thomas sites together. On St Croix reefs, blue chromis, creole wrasse, bluehead wrasse, yellowhead wrasse (*Halichoeres garnoti*), bicolor damselfish and brown chromis (*Chromis multilineata*) contributed over 62% to the numeric total of all sites together. Most of these species were ubiquitous and found at all sites. The exception was creole wrasse, which was abundant on offshore, mesophotic sites, and nearshore sites adjacent to walls, but was uncommon on other shallow water sites.

Table 3. Species richness across sites in belt transects and roving diver surveys (RDS). Sites are divided into nearshore, offshore and mesophotic sites as described in the text above.

		Belt Transects (25x4)		RDS
		Total Number of Species	Mean species per transect (±SE)	Total Number of Species
Nearshore	Cane Bay	49	21.5±1.3	63
	Great Pond	47	16.8±1.2	42
	Jacks Bay	45	16.5±1.3	54
	Kings Corner	63	27.9±1.0	67
	Salt River West	41	19.7±1.2	55
	Sprat Hole	61	23.7±0.8	64
	Coculus Rock	45	20.9±1.2	48
	Black Point	48	21.6±1.3	44
	Brewers Bay	58	23.4±1.4	57
	Botany Bay	53	22.6±1.3	59
	Buck Island, St. Thomas	66	29.8±3.5	62
	Coral Bay	39	16.3±0.4	54
	Fish Bay	41	17.2±0.7	25
	Magens Bay	48	22.2±1.7	49
Offshore	Eagle Ray	56	23.2±1.2	62
	Buck Island, St. Croix	56	18.9±0.9	60
	Castle	60	23.6±1.1	64
	Mutton Snapper	57	21.8±0.5	51
	Seahorse Cottage	62	26.3±1.4	70
	South Capella	61	21.8±1.2	69
	South Water Island	54	21.1±1.3	57
	Flat Cay	60	27.4±2.2	61
	Meri Shoal	51	24.6±1.1	46
	Savana Cay	61	24.4±2.3	69
	Little St. James	58	21.2±1.7	59
Mesophotic	Cane Bay Deep	53	19.6±0.9	47
	Lang EEMP	56	21.5±1.7	62
	Lang Bank	51	20.8±1.4	53
	Salt River Deep	52	15.8±2.3	51
	College Shoal East	64	23.4±1.0	55
	Grammanik Tiger	63	23.2±1.4	47
	Hind Bank	66	26.9±1.1	51

FISH COMMUNITIES

Fish Abundance

Total fish abundances across nearshore, offshore and mesophotic sites and years are shown in Fig.12. Abundance was variable across sites and years and shows no obvious pattern across time or space. Slight decreases in abundance since 2005 on St. Croix sites are thought to be an artifact of a slightly altered methodology and different survey teams. Sites are highly dominated by small pomacentrids (damselfish) and labrids (wrasses), which tend to mask numeric trends in other fish taxa. Abundance peaks (such as Eagle Ray, 2005 and College Shoal, 2008) are generally a result of large schools of creole wrasse on the site. No change has been detected in fish communities since the coral bleaching of 2005 and subsequent high coral mortality event. Fish abundance in 2012 was similar across all sites to data collected in previous years.

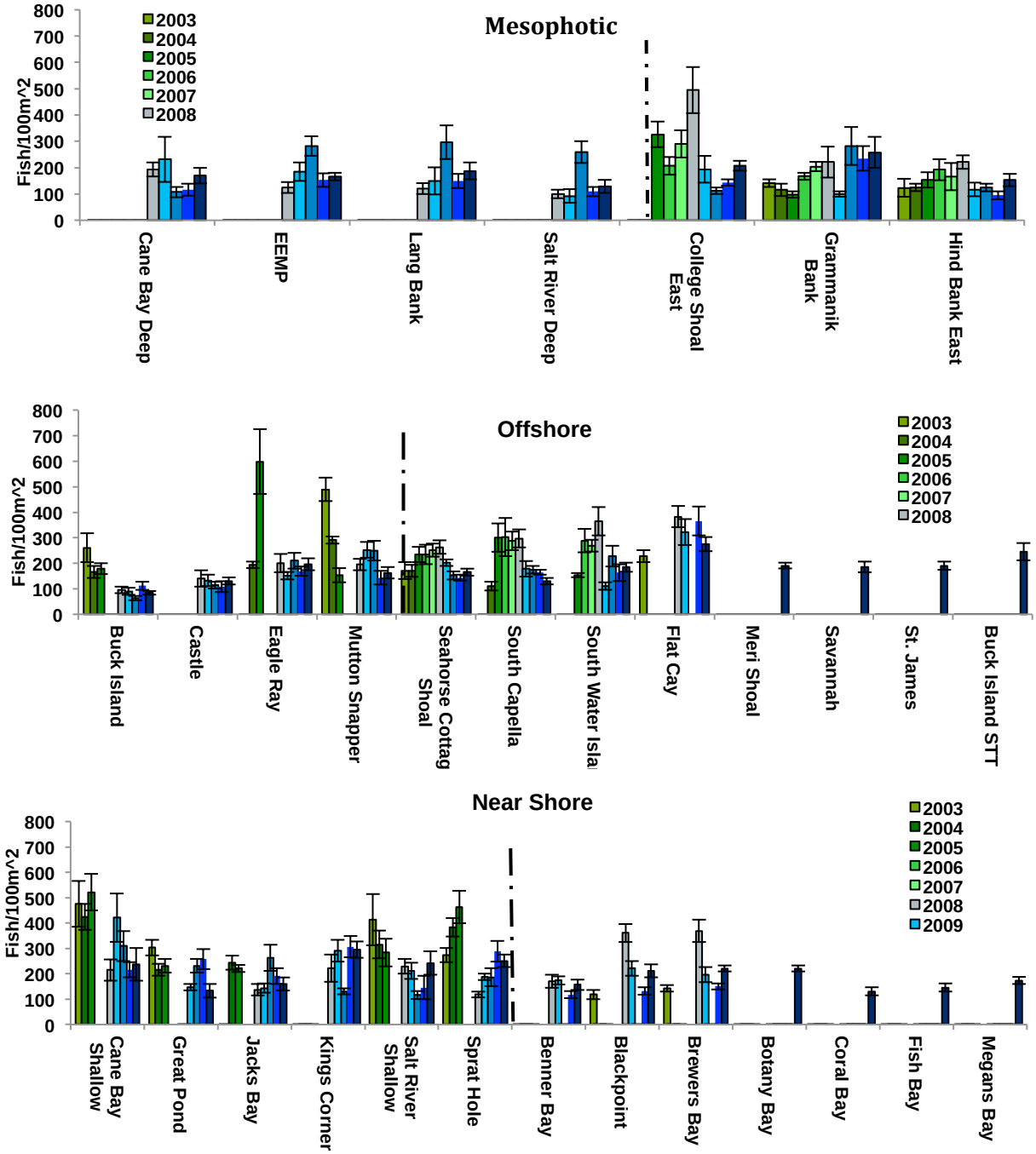

Figure 12. Fish abundance (±SE) across TCRMP monitoring sites over time. Dotted line separates St. Croix sites (left) from St. Thomas (right).

FISH COMMUNITIES

Fish Biomass

Fish biomass across sites is shown in Fig.13. The mesophotic sites off St. Thomas (Grammanik Bank, Hind Bank and College Shoal East) have higher and some years dramatically higher average biomass of fish throughout the sampling period than the more shallow sites across the territory and across the St. Croix mesophotic sites. Abundance is similar or lower on these deep St. Thomas reefs, indicating a larger average fish size. Juveniles of several species that occur in shallow water are nearly absent on the mesophotic reefs, and pomacentrids and wrasses (except creole wrasse) are much less common. The three mesophotic sites off St. Thomas are all within marine protected areas and are well offshore, away from direct land based pollution. In addition the Grammanik Tiger and Hind Bank sites are near or on multispecies spawning aggregation sites for groupers and snapper. Sampling periods often overlap slightly aggregation periods for cubera snapper (*Lutjanus cyanopterus*) and this influences biomass estimates. In contrast, two of the mesophotic sites off St. Croix (Salt River Deep and Cane Bay Deep) are very close to shore and are fished regularly. As with abundance, biomass is highly variable between years. No temporal pattern is evident, and differences in time appear to be seasonal or natural variation. The fish biomass surveyed in 2012 was similar to data collected in previous years.

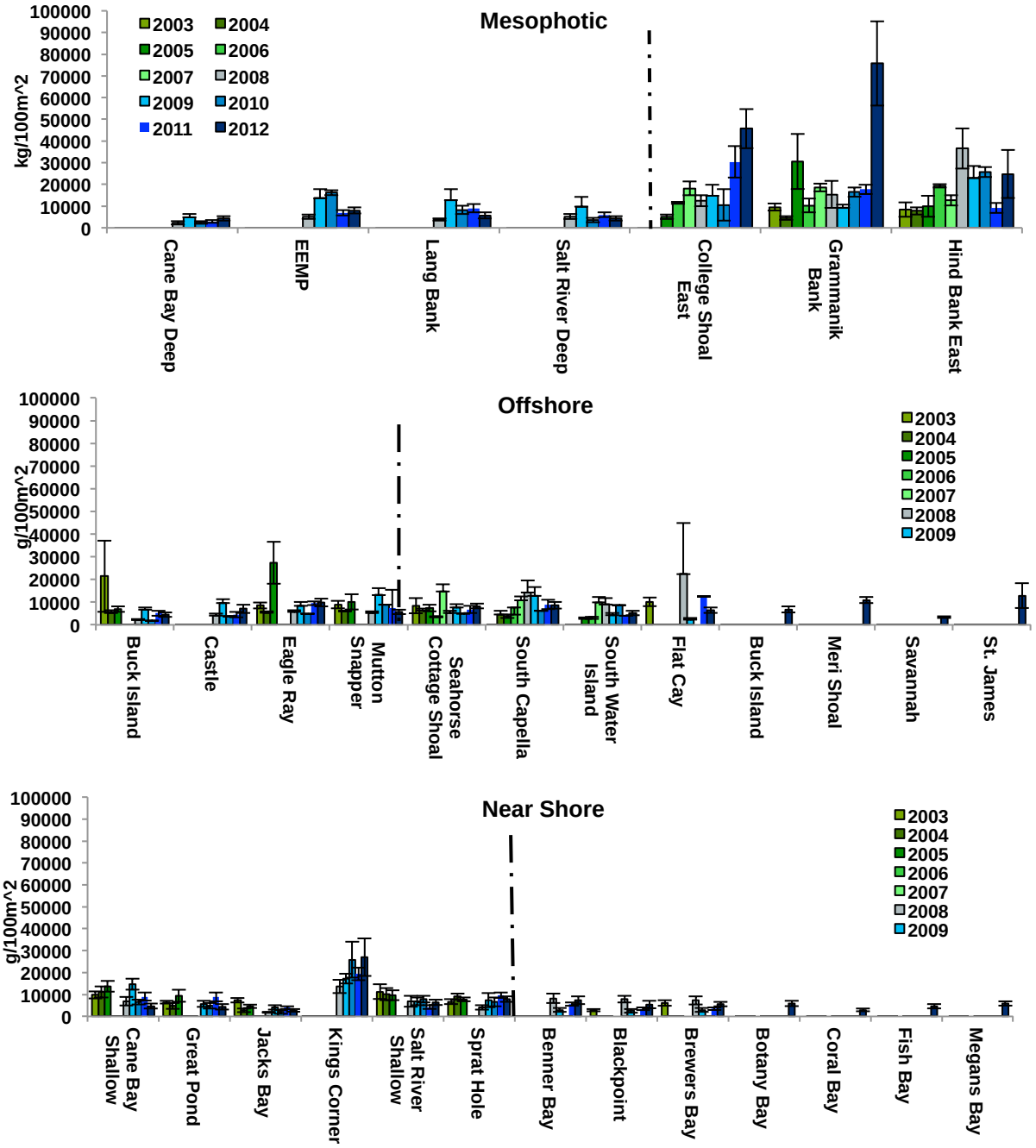

Figure 13. Mean fish biomass (±SE) across TCRMP monitoring sites over time. Dotted line separates St. Croix sites (left) from St. Thomas (right).

BLACK SPINY SEA URCHIN *DIADEMA ANTILLARUM*

The abundance of the black spiny sea urchin *Diadema antillarum* shows tremendous site-to-site variability (Fig. 14). In general the shallowest sites, e.g., Great Pond, support the greatest abundance of *D. antillarum*. Sites with high abundance of *D. antillarum* also tend to have very low macroalgal cover. Trends are not presented as year-to-year variability is generally low. Note that urchins have not yet been assessed at the deep site Ginsburgs Fringe. At Coral Bay there is a high abundance of *Echinometra* spp., which seems to be the dominant grazer that effectively removes macroalgal cover. Future monitoring should take measurements of the abundance of this species.

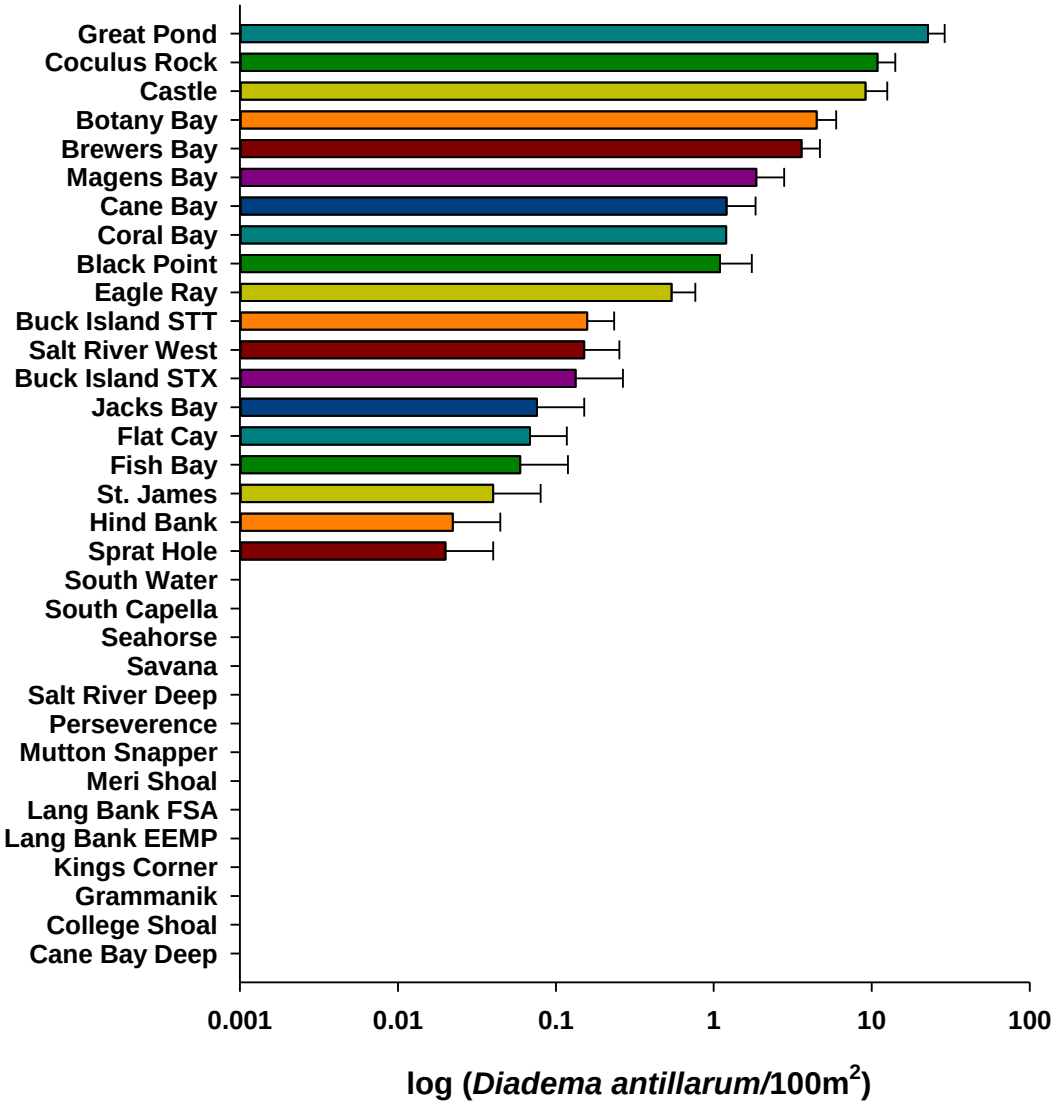

Figure 14. Abundance of the black spiny sea urchin (*Diadema antillarum*) at TCRMP monitoring sites. Note the log scale.