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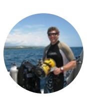

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TERRITORIAL CORAL REEF MONITORING PROGRAM

ANNUAL REPORT

2015

Smith TB, Ennis RS, Kadison E, Weinstein DW, Jossart J, Gyory J, Henderson L

A collaboration between:

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

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MISSION

Mission

OUR VISION

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

OBJECTIVES

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

EXECUTIVE SUMMARY

Executive Summary

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

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

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

CORAL REEFS OF THE VIRGIN ISLANDS: MANGEMENT ACTIONS NEEDED

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

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

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

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

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

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

CORAL REEFS OF THE VIRGIN ISLANDS: POSITIVE SIGNS

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

Reef Refuges. The USVI is blessed, perhaps uniquely for the Caribbean, with extensive areas of deep bank and slope reefs that may be buffered from the direct impacts of local pressures. The mesophotic (pronounced: me-zo-photik; meaning; "middle-light") reefs of the USVI are the best developed in the Caribbean from what is currently known. Mesophotic Coral Ecosystem (MCE) bank reefs with high populations of star corals (*Orbicella* spp.), which have recently been listed as threatened on the United States Endangered Species List (NOAA 2014), form extensive tracts on the south shelf of St. John and St. Thomas, from the British Virgin Islands to Vieques, Puerto Rico. Well-formed, but patchier mesophotic boulder coral reefs also form on the Lang Bank, St. Croix and the northern Puerto Rican Shelf. The lower MCE consists mostly of lettuce corals (primarily *Agaricia undata*) and form a semi-continuous ring on steep slopes and walls at depths between 50-70m. These reef are isolated from some local impacts, but may be susceptible to global climate change (see below).

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

Rebounding Fisheries Species. There are positive signs of recovery for certain fish species in some areas. At the Grammanik Bank grouper spawning aggregation site there have been increasing numbers of Nassau grouper present for annual spawning (Kadison et al.

2010; Jackson et al. 2014) and a red hind aggregation in the Red Hind Marine Conservation District (MCD) has dramatically rebounded (Nemeth 2005). Red hind caught in the fishery on the south side of St. Thomas are more numerous and larger (D. Olsen, pers. comm.). In 2015 there was a recruitment pulse of juvenile Nassau grouper to shallow nearshore environments of St. Thomas and St. John in 2015. In Brewers Bay, St. Thomas over 70 juvenile Nassau grouper were recorded (R. Nemeth, unpub. data), increasing evidence that the reproductive population is contributing to the recovery of the species. It is also the impression of the authors that stocks of grouper and snapper are increasing in the MCD, although TCRMP measurements are confounded to some degree by the rotating array of aggregating fishes. Other territorial and federal closed areas in St. Croix, St. John, and St. Thomas are more recently established and may not show effects for several years. In 2011 the TCRMP recorded the first ever sightings of two Nassau grouper in St. Croix, a positive sign. For species that are completely protected from fishing (Nassau grouper and blue, midnight, and rainbow parrotfish), educational campaigns for recreational and commercial fisherman are critical, as awareness of regulations appears to be lacking (Authors, unpub. obs.).

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

This report presents results of the 15th year of monitoring on reefs surrounding St. Croix, St. John, and St. Thomas (years 2001-2015). Monitoring sites were distributed across the insular platform in depths from 5 to 63 m (16 – 220') in an effort to capture the diversity of reef types present in the Virgin Islands. Long-term data is presented from 33 sites. While not exhaustive, the TCRMP is generally representative of the geographic areas and variety of reef types in the USVI. Digital video and diver surveys were used to quantify benthic cover and coral health at 14 permanent sites surrounding the island of St. Croix and 19 permanent sites on the Puerto Rican Shelf surrounding the island of St. John and St. Thomas. In addition, at 32 of these sites sea urchin density and fish community structure were evaluated.

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

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

Thermal Stress is Impacting Deep Mesophotic Coral Reefs

Bleaching responses and bleaching threshold temperatures were developed from coral monitoring sites. An unprecedented data set of benthic temperature records and coral bleaching responses collected by the TCRMP were used to develop bleaching threshold temperatures for monitoring sites dominated by star corals (genus *Orbicella*) and on one lower mesophotic site dominated by scroll coral (*Agaricia undata*). The resulting publication challenges the notion that mesophotic reefs will be refuges from a warming ocean without additional factors besides cooler temperatures with depth (Smith et al. in press). Previously, a more moderate bleaching and mortality response of USVI MCE reefs during seawater warming in 2005 and 2010 was thought to support the idea of the Deep Reef Refugia Hypothesis (Glynn 1996; Riegl and Piller 2003). This hypothesis states that the cooler temperatures at deeper depth suggest that these corals are buffered from the impacts of mass coral bleaching. However, recent work has shown that MCE corals are acclimatized to the moderate temperatures at depth in the USVI (Fig. 2). Because of this, temperatures above the MCE local maximum can cause bleaching, even if the same temperatures would not be stressful at shallow depths (Smith et al. in press). MCE bleaching and mortality was demonstrated during the 2005 northeastern Caribbean seawater warming event and MCE bleaching occurred in 2012 without any shallow water bleaching.

Of more practical importance to management of reefs in the USVI was the creation of bleaching threshold temperatures for many TCRMP coral monitoring sites and one site in the Virgin Islands National Park, St. John (Fig. 2, Table 1). These bleaching threshold temperatures can be used to more accurately assess the response of coral communities over years with potential thermal stress.

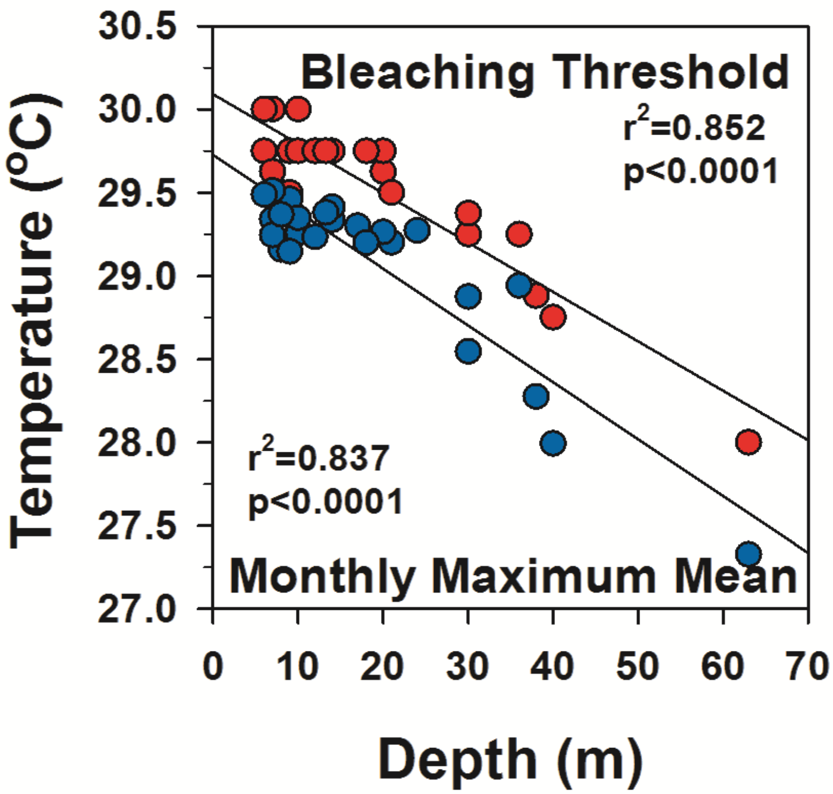

Figure 2. Coral tolerance to high temperatures declines with depth and this corresponds to the mean thermal conditions at the sites. Bleaching threshold temperatures and monthly maximum mean temperatures versus depth for 24 TCRMP sites and one National Park Service Monitoring site (Tektite). Temperatures are derived from star coral (*Orbicella* spp.) reefs, with the exception of the site at 63m depth that is dominated by lettuce corals (primarily *Agaricia undata*; Ginsburgs Fringe).

Table 1. Study site locations, strata, depths, *Orbicella* spp. cover (prior to 2005 bleaching mortality), and empirical bleaching thresholds for the United States Virgin Islands. See (Smith et al. in press) for methods.

Island	Location	Lat.	Long.	Depth (m)	*Orbicella* cover	Bleaching Threshold (°C)	Monthly Max. Mean (°C)
St. John	Fish Bay	18.31417	-64.76408	6	5.6	30.00	29.49
St. Thomas	Brewers Bay	18.34403	-64.98435	6	34.7	29.75	29.46
St. Thomas	Coculus Rock	18.31257	-64.86058	7	0.9	30.00	29.51
St. Thomas	Magens Bay	18.37425	-64.93438	7	2.1	29.63	29.24
St. Croix	Sprat Hole	17.734	-64.8954	8	18.6	---	29.37
St. Thomas	Botany Bay	18.35738	-65.03442	8	4.7	29.50	29.16
St. Thomas	Black Point	18.3445	-64.98595	9	8.1	29.75	29.46
St. Thomas	Savana	18.34064	-65.08205	9	13.3	29.50	29.15
St. Croix	Cane Bay	17.77388	-64.8135	10	14.3	29.75	29.26
St. Croix	Eagle Ray	17.7615	-64.6988	10	0.8	30.00	29.35
St. Thomas	Flat Cay	18.31822	-64.99104	12	8.9	29.75	29.23
St. John	Tektite	18.3095	-64.723	13	20.8	29.75	29.38
St. Croix	Jacks Bay	17.74337	-64.5716	14	0.4	29.75	29.41
St. Thomas	Buck Island	18.27883	-64.89833	14	5	29.75	29.34
St. Thomas	St James	18.29459	-64.83238	15	1.8	29.75	29.20
St. Thomas	Seahorse	18.29467	-64.8675	20	22.2	29.63	29.26
St. Thomas	South Water	18.28068	-64.94592	20	0.6	29.75	29.26
St. Thomas	South Capella	18.26267	-64.87237	21	22.5	29.50	29.20
St. Croix	Mutton Snapper	17.6366	-64.8624	24	28.5	---	29.27
St. John	Meri Shoal	18.24447	-64.75862	30	51.5	29.38	28.88
St. Thomas	College Shoal	18.18568	-65.07677	30	35.2	29.25	28.55
St. Croix	Cane Bay Deep	17.77661	-64.81522	36	1.4	29.25	28.94
St. Thomas	Tiger	18.19113	-64.95032	38	28.4	28.88	28.27
St. Thomas	Hind Bank	18.20217	-65.00158	40	24.6	28.75	27.99

INTRODUCTION

Update: Invasion of the Indo-Pacific Red Lionfish

The first Indo-Pacific lionfish (Fig. 3) reported in USVI waters was found in 2009 on the west end of St. Croix under the Frederiksted pier. The invasive species had been rapidly spreading throughout the Caribbean from the believed introduction point of Florida, and was already common in the Bahamas, Jamaica, and Hispanola. Several more of the fish were seen over the next few weeks; however, it was not until early 2010 that the first lionfish was reported in St. Thomas. By early 2011, divers and fishermen from around the territory were finding lionfish commonly, and although a concerted effort was made to eradicate the fish, at least initially, reports escalated. Today, the invader is quite prevalent throughout the territory and Caribbean region; however, both divers and fishermen say they are seeing fewer fish than 2011-2013, and they are smaller in general.

Figure 3. Indo-Pacific red lionfish (*Pterois volitans*) at the Grammanik Bank FSA TCRMP monitoring site, May 6, 2011. (credit: Tyler B. Smith)

There continues to be an effort to control the lionfish through fishing, and a growing market for the species as a food fish exists on all three islands. Ciguatoxin is present in many individuals (Robertson et al. 2013), but poisonings are not known.

The lionfish invasion is particularly important because of the ability of lionfish to consume large quantities of native reef fish. Lionfish are gape-limited stalking predators capable of consuming prey that are almost half their total length, yet lionfish are themselves largely protected from predation by venomous fin spines (Morris and Whitfield 2009). Lionfish have rapidly spread over more than 4,000,000 km^2 of marine habitat across the Western Atlantic, Caribbean and Gulf of Mexico, and are now undergoing exponential increases in abundance at many locations (Betancur-R et al. 2011; REEF 2012). Invasive lionfish occupy a range of habitat types and depths, where they consume an array native fishes and crustaceans at very high rates (Schofield 2009; Green et al. 2011). There is growing concern that predation by lionfish will nullify efforts to protect vulnerable fish populations from anthropogenic threats in the region.

In the TCRMP data, lionfish were first observed on roving dives at only two sites in 2010, Lang Bank and Kings Corner, both located off St. Croix. By 2011, seven sites out of 32 held lionfish, including four sites off St. Thomas. Fish were recorded in transects as well as roving dive surveys (Fig. 4). One year later, lionfish were recorded on transects at over half of all monitoring sites. On roving dives, they were observed on 20 out of 32 sites (data not shown). In the latest year of sampling (2015) lionfish were observed during roving dives on twelve out of 14 sites off St. Croix, and eight out of 18 on St Thomas. Lionfish encounters in 2015 were higher overall than in 2014 around the northern USVI (112 in 2015 and 81 in 2014); however, this was primarily due to a very large number observed on the mesophotic Hind Bank FSA and Ginsburgs Fringe[1] sites. Around St. Croix

[1] Note: Ginsburgs Fringe fish data is not formally incorporated into the TCRMP and is not presented in this summary, but is now included in the site summaries section.

numbers observed on transects were nearly the same in the last two years of monitoring (20 in 2015 and 18 in 2014).

Mesophotic sites off St. Thomas continue to have the highest abundances of lionfish, and two of these sites (Hind Bank FSA and Ginsburgs Fringe) had large increases in 2015. The Grammanik Bank had a notable decrease in lionfish in 2015, possibly due to the spawning aggregations of large piscivorous fish that use the reef. Lionfish across the territory ranged in estimated size from 6 to 40cm TL and the majority (~45%) of fish were between 11 and 20cm TL. In 2014, the majority of fish (41%) were estimated to be between 20 and 30cm TL. Only seventeen lionfish (13%) were recorded over 30 cm TL in 2015. This number was down 7% from 2014 data.

Little data has been collected and analyzed regarding preferential habitat for lionfish in the western Atlantic; however, based on the TCRMP data and many other dives conducted across the USVI shelves by the authors, it appears that the species utilizes a variety of habitats and use any available structure within the area. They are common on hard bottom areas (generally associated with the largest rock /coral around) as well as coral reefs, and are found to be particularly abundant on submerged man-made structures. They may be somewhat limited from turbulent or high current environments by their large fins. It is unknown if their high densities on mesophotic reefs represent a preference for deepwater habitats, or a reduced fishing pressure. The Grammanik Bank and Hind Bank are marine reserves where bottom fishing is prohibited and large snappers, groupers, and sharks are observed regularly. Predation by large piscivores could partially control the recruitment or growth of lionfish at the Grammanik Bank, but the data is equivocal.

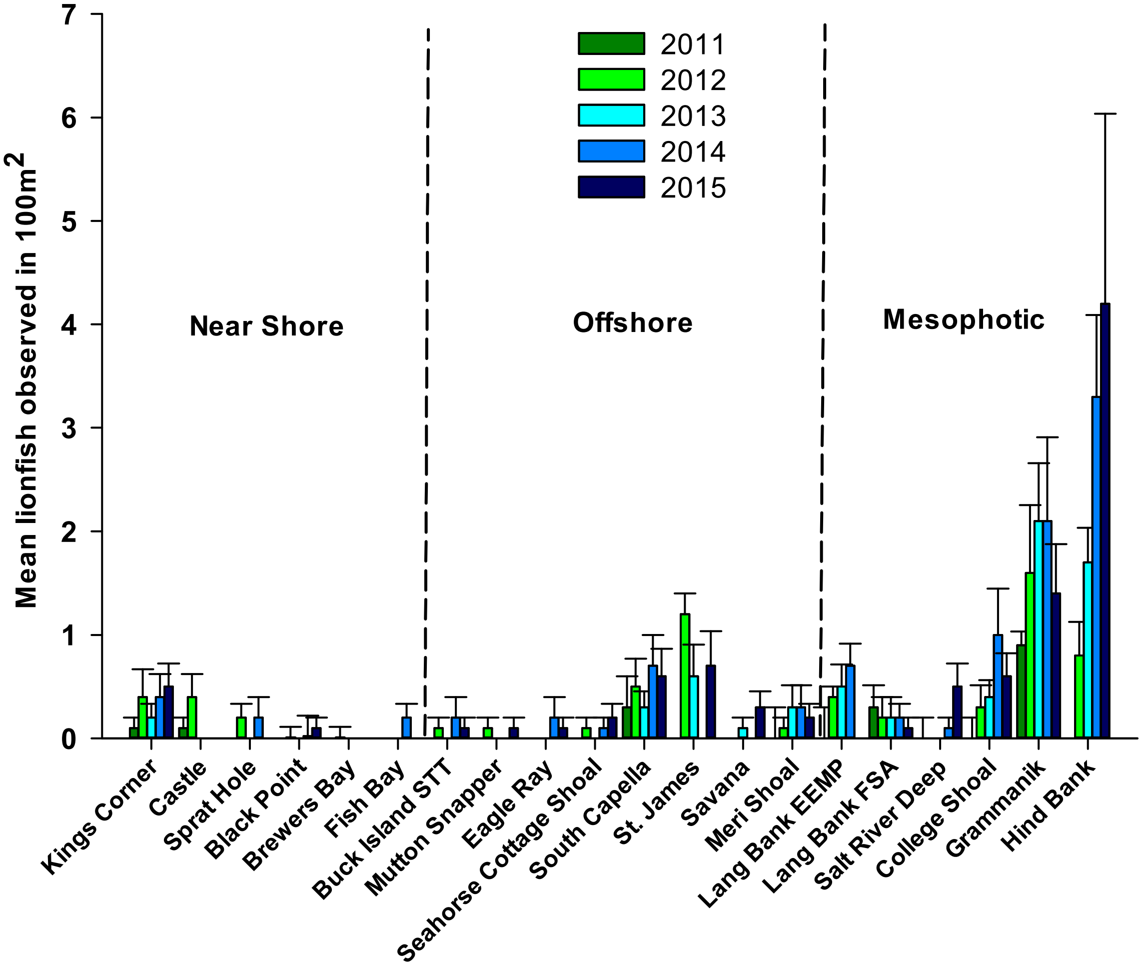

Figure 4. The abundance of red lionfish on TCRMP transects from 2011 to 2015.

INTRODUCTION

A Study of Coral Bioerosion at TCRMP Mesophotic Sites

Reef bioerosion, the breakdown of calcium carbonate reef structure and sediment by organisms, is a key process that determines the structure of reefs and their persistence with time. Constructional forces, such as coral and other organisms that form limestone skeletons, balance bioerosion and determine reef structural complexity and diversity. These factors are critical to coral reef ecosystem services, such as the provision of habitat to fish and invertebrates. The main biological component of modern coral reefs consists of a thin living veneer draped upon a biologically-produced non-living foundation. The non-living structural components of a coral reef consist of its framework, rubble, cement, and sediment. Although monitoring the health of the living coral cover is critical to short-term ecological management of the natural resource, long-term projections of coral structural sustainability require an understanding of how the non-living components of the reef are constructed, modified, and eroded. In some cases, when bioerosion outpaces the ability of reefs to add structure, the complexity of reefs can degrade and the coral ecosystem suffers.

Caribbean reefs have experienced significant declines in architectural complexity in the past four decades (Alvarez-Filip et al., 2009; Bozec et al., 2014). Despite the importance of bioerosion, little is known regarding this process in mesophotic coral reef habitats. Therefore, in conjunction with the TCRMP data sets, long-term and short-term bioerosional trends were evaluated in U.S. Virgin Islands mesophotic reefs and shallow water counterparts using a variety of techniques. TCRMP reef sites evaluated included (from deepest to shallowest) the Grammanik Bank, College Shoal, Seahorse Cottage Shoal, and Black Point. Two additional mesophotic sites with very different composition were also evaluated in the Hind Bank Marine Conservation District. Cylinders of shallow water star coral (*Orbicella* spp.) skeletons were deployed for up to three years to evaluate natural processes of bioerosion on dead coral substrate (Fig. 5), reef sediments were analyzed to understand if they reflect reef composition, and coral skeletons were analyzed to understand rates of growth of star corals in different mesophotic environments.

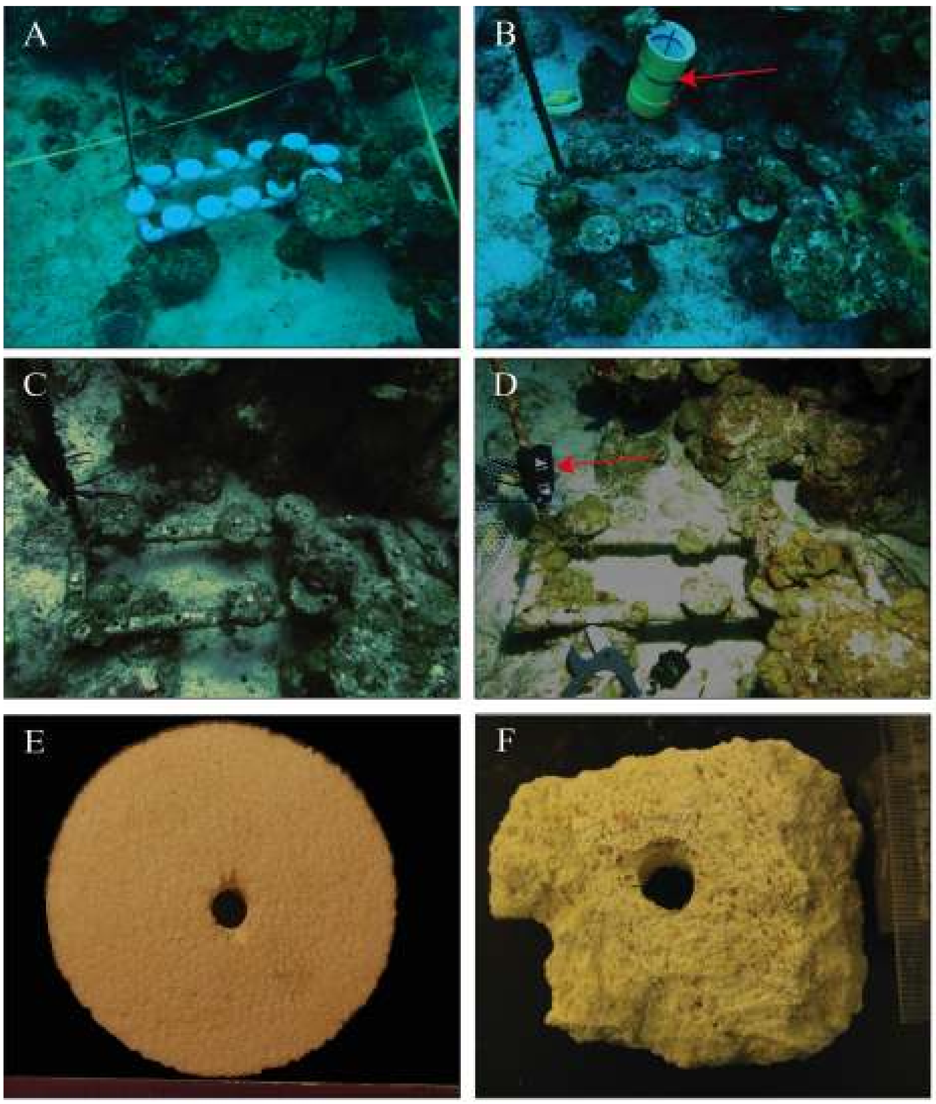

Figure 5. Bioerosion of dead coal skeletons. (A) Instillation occurred on Aug. 28, 2010, and was resampled (B) 352, (C) 637, and (D) 990 days later. Example of an (E) original disk before deployment and (F) after 990 days of exposure on the seafloor. This figure is modified from Weinstein 2014.

Bioerosion rates were different among TCMRP mesophotic sites sampled (Weinstein 2014; Weinstein et al. 2014). Most mesophotic reefs showed low rates of bioerosion relative to shallow reefs (Fig. 6). Parrotfish grazing was found to be the dominant initial bioerosion method for shallow and upper mesophotic zone coral reefs in the northern USVI. A reduction in parrotfish grazing was partially responsible for the low

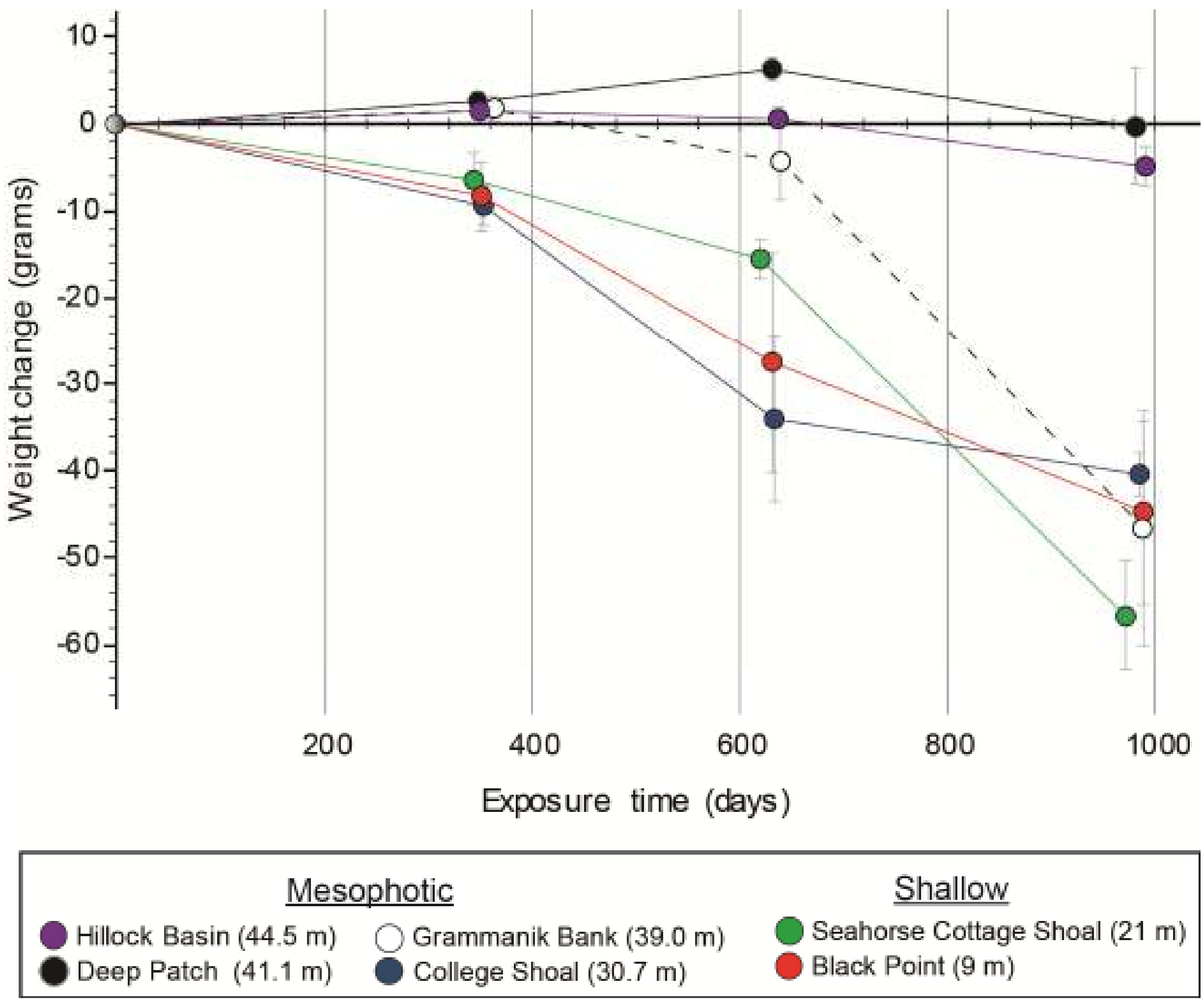

Figure 6. Mean weight change of experimental substrates with time (± 1 SEM). Slope of the lines provide rates of bioerosion between installation date and year one, year one and year two, and year two and year three. This figure is modified from Weinstein 2014.

substrate bioerosion rates of mesophotic reef communities in the middle to lower depths of the mesophotic reef zone. Sediment grain composition and bulk geochemistry were found to reflect the distribution and abundance of coral and macroalgae communities in mesophotic and shallow reefs (Weinstein et al. 2015). Sediment analyses also indicate that hydrodynamic forces do not transport a significant amount of potentially harmful terrigenous material to USVI mesophotic reefs, as was found previously from the Hind Bank FSA site (Smith et al. 2008). Also, sediment does not tend to be transported from areas outside of where they were formed on the reef. Coral growth rates of star corals were significantly slower in mesophotic depths than at shallow reefs, even at sites with very in mesophotic high coral cover (Weinstein et al. submitted). This suggests that fast coral growth is not needed to form extensive and vibrant mesophotic coral reefs, possibly because of the limited amount of bioerosion. However, slow growth may indicate the sensitivity of these reefs to loss of growth, such as from coral mortality, or any processes that increases bioerosion, such as nutrient pollution.

These data have been used to construct a model of reef carbonate budget that can show if the systems is growing or declining. Overall, results indicate that all mesophotic reefs analyzed have net positive production of carbonate, unlike shallow sites, which showed declines. Differences between the amounts of positive production also indicates that the habitats have different growth potential over long time scales and may partially explain the high variability and complexity of geomorphology at the different sites. This work is in preparation for publication.

INTRODUCTION

Introduction

The U.S. Virgin Islands consists of three large islands, St. Thomas, St. John and St. Croix, and numerous smaller islands surrounded by a diverse, tropical marine environment that includes coral reefs, seagrass beds, and mangrove forests (Fig. 7). The islands of St. Thomas and St. John lie on the Puerto Rican Shelf, an extensive shallow water platform that connects them to Puerto Rico to the west and the British Virgin Islands to the east. St. Croix lies on an isolated platform sixty-five kilometers to the south of St. Thomas and St. John and separated by the 4000m deep Anegada Passage and the Virgin Islands Trough. This forms an effective barrier to the migration of adult coral reef fishes and invertebrates. The coral reefs of the Virgin Islands represent a wide range of characteristic coral reef habitats of the Caribbean, including patch reefs, fringing reefs, barrier reefs, shelf reefs, and extensive bank and slope mesophotic coral reef ecosystems.

The economy of the US Virgin Islands is reliant to a large extent on maintenance of vibrant marine ecosystems. Tourism drives the economy of the Virgin Islands, famous for white sand beaches that give way to clean, clear marine waters. The diverse marine life of the coral reefs and other habitats attracts thousands of skin and scuba divers each year. Sport fishing on charter boats and private vessels also makes an important contribution to the economy. In addition, the coral reefs and other habitats in the Virgin Islands are essential to the lives of hundreds of thousands of species including economically important queen conch, whelk, spiny lobster, snapper, and grouper. Over three hundred full-time or part-time commercial fishermen work in territorial and federal waters surrounding all three islands (Tobias 1997). In tough economic times and after natural disasters, fishing is an important means of supplemental income or extra protein for many people.

Over the last few decades, major hurricanes, coral disease outbreaks, mass coral reef bleaching, and invasive species introductions have caused extensive coral mortality to the coral reefs surrounding the Virgin Islands (Gladfelter 1982; Edmunds and Witman 1991; Rogers et al. 1991; Rothenberger et al. 2008; Woody et al. 2008; Miller et al. 2009; Smith et al. 2013). Recovery from these disturbances is hindered by a multitude of human impacts that affect coral reefs, such as overfishing of ecologically important species, physical damage to reef structure, and pollution (Hatcher 1984; Pastorok and Bilyard 1985; Rogers and Garrison 2001; Mumby 2006; Mumby et al. 2006; Mumby and Harborne 2010). Moreover, rapid development of steep island slopes has dramatically increased soil erosion and sedimentation into nearshore waters (Brooks et al. 2007; Gray et al. 2008; Smith et al. 2008), particularly below unpaved road surfaces (Anderson and Macdonald 1998; Ramos-Scharrón and MacDonald 2007a). Chronic sedimentation affects the abundance and diversity of corals and other reef organisms, increases coral stress and susceptibility to diseases and bleaching, and reduces the ability of corals and other reef organisms to recover and regenerate after natural disturbances such as hurricanes (Acevedo and Morelock 1988; Rogers 1990; Nemeth and Sladeck Nowlis 2001; Fabricius 2005). The first sightings of the invasive Indo-Pacific lionfish (*Pterois volitans*) occurred in the US Virgin Islands in 2009. This predator has the ability to dramatically alter coral reef fish community structure (Cote and Maljkovic 2010) and these alterations may have additional, indirect impacts on benthic communities (Albins and Hixon 2011).

High thermal stress and coral bleaching events affected the northeastern Caribbean in 2005, 2010, and 2012, but these events had contrasting signatures in the United States Virgin Islands. These events and the species-specific responses of Caribbean corals are summarized in Smith et al. (2013) for shallow corals and Smith et al. (in press) for shallow and mesophotic corals. The year 2005 was the most severe high sea surface temperature (SST) event on record for the northeastern Caribbean (Eakin et al. 2010). In the Virgin Islands a peak of 10.25 Degree Heating Weeks (DHW) was registered from satellite SST records (NOAA, 2012) and a period of approximately 59 days above the local bleaching threshold of 29.5°C (Aug. 20 – Oct. 18); a level of thermal stress accumulation associated with severe coral bleaching and some mortality. The warm season of 2010 started as warm or warmer than 2005, with the bleaching threshold surpassed for 21 days between August 12 and September 2. In a clear example of ameliorative storm cooling (Manzello et al. 2007), the passing of the storm center of Hurricane Earl on August 30th, approximately 100 km to the northeast of the St. Thomas-St. John, caused a rapid decline in SST's below the bleaching threshold to 29.3°C, and then from October 5 - 8, the passage of Hurricane Otto caused windy and cloudy weather that further reduced SST below 29.1°C. Total DHW accumulated in 2010 began to decrease after the beginning of October, when it had reached 5.1 DHW, a level associated with some bleaching and limited mortality. Recent research developed bleaching threshold temperatures for 24 of 33 TCRMP monitoring sites dominated by star corals of the genus *Orbicella* (Smith et al. in press). This research showed that mesophotic reefs bleached in 2005 with shallow reefs and then bleached again during a mesophotic coral reef bleaching event in 2012, when shallow reefs were unaffected. The study concluded that mesophotic reefs of the USVI are unlikely to be long-term climate change refugia because they are not immune to high temperature thermal stress.

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

OBJECTIVES FOR MONITORING CORAL REEFS

Effective management is necessary to maintain the resources in the territorial and federal waters of the Virgin Islands in an ecologically and economically sustainable manner. Monitoring programs are essential for successful management because they provide managers with fundamental information with which to make and reinforce decisions. Standards for resource protection can be measured by comparison to baseline data established by monitoring. Monitoring also provides the means to assess the status and trends of ecological resources, allowing managers to determine the effectiveness of current management and to develop effective management plans for the future. The Territorial Coral Reef Monitoring Program monitors the condition of coral reefs throughout the U.S. Virgin Islands and provides key information to better manage these ecosystems. This report presents monitoring results from 2001-2015 in St. Croix and from 2003-2015 in St. Thomas. For both islands, temporal changes from year to year in the conditions of the reef communities are assessed.

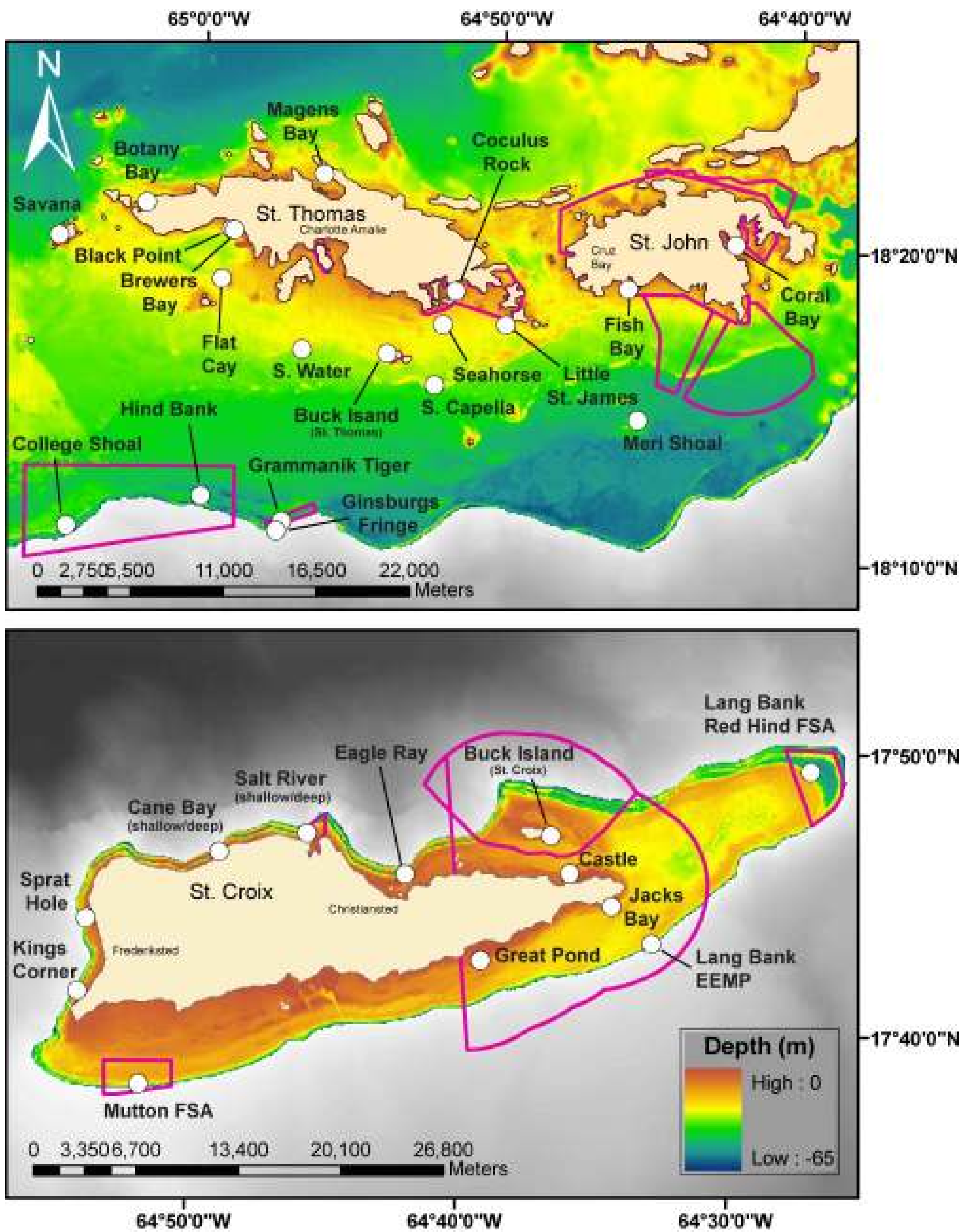

Figure 7. Locations of Territorial Coral Reef Monitoring Sites in the US Virgin Islands. Boundaries indicate federal and territorial marine protected areas.

METHODS

Photo: A research diver (V. Brandtneris) on closed circuit rebreather uses a high-definition video system to record coral cover at a deep (66m/220ft) mesophotic coral reef (Ginsburgs Fringe; Nov. 13, 2015; photo credit: T.B. Smith)

METHODS

Methods

BENTHIC ASSESSMENTS

The University of the Virgin Islands determined the benthic composition at 33 long-term monitoring sites between 2001 and 2015 (Fig. 7). All data is now available at the TCRMP website and updated annually after quality control:

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

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, Salt River Deep; sensu Ginsburg 2007) . Salt River Deep transects 1-4 established at 40 m depth in April 2009 sampling were relocated upslope 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). Because of its deep depth, Ginsburgs Fringe at 60-66m was only sampled for benthic cover and some fish transects.

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. 8). 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 randomly located dots on each image. The number of points varied with the evolution of the video camera systems and was 10 points from 2001-2011, 15 points from 2012-2013, and 20 points from 2014 onwards. 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 and are often an indicator of healthy grazing communities and high animal cover.

Figure 8. A screen grab of benthic video used for the determination of percent cover of coral reef organisms and non-living substrate.

Table 2. TCRMP site reef complex type, location coordinates (decimal degrees; WGS 1984), 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	Nearshore	17.78530	-64.75940	11
	Sprat Hole	Nearshore	17.73400	-64.89540	8
St. John	Coral Bay	Nearshore	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	18.35738	-65.03442	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 3. TCRMP site sampling data (benthic/health) and type of sampling.

Island	Site	Date Sampled	Benthic	Health	Fish/Urchin
St. Croix	Buck Island STX	10/01/15	x	x	x
	Cane Bay	10/02/15	x	x	x
	Cane Bay Deep	10/02/15	x	x	x
	Castle	10/03/15	x	x	x
	Eagle Ray	10/03/15	x	x	x
	Great Pond	09/29/15	x	x	x
	Jacks Bay	09/30/15	x	x	x
	Kings Corner	09/28/15	x	x	x
	Lang Bank EEMP	09/29/15	x	x	x
	Lang Bank Red Hind FSA	09/30/15	x	x	x
	Mutton Snapper FSA	10/02/15	x	x	x
	Salt River Deep	10/01/15	x	x	x
	Salt River West	10/01/15	x	x	x
	Sprat Hole	09/28/15	x	x	x
St. John	Coral Bay	10/16/15	x	x	x
	Fish Bay	10/16/15	x	x	x
	Meri Shoal	10/19/15	x	x	x
St. Thomas	Black Point	10/14/15	x	x	x
	Botany Bay	10/08/15	x	x	x
	Brewers Bay	11/05/15	x	x	x
	Buck Island STT	08/05/15	x	x	x
	Coculus Rock	10/13/15	x	x	x
	College Shoal East	11/13/15	x	x	x
	Flat Cay	10/14/15	x	x	x
	Ginsburgs Fringe	11/13/15	x		
	Grammanik Tiger FSA	11/04/15	x	x	x
	Hind Bank East FSA	11/12/15	x	x	x
	Magens Bay	10/08/15	x	x	x
	Savana	10/08/15	x	x	x
	Seahorse Cottage Shoal	10/13/15	x	x	x
	South Capella	10/15/15	x	x	x
	South Water	10/15/15	x	x	x
	St James	10/16/15	x	x	x

METHODS

Coral Health. Coral health assessments follow methodologies outlined in Calnan 2008, Smith et al. 2008, and Smith et al. 2013 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). Starting in 2008 all colonies were assessed, regardless of size, in contrast to previous years where only colonies greater than 10 cm in maximum linear dimension were assessed. 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 sites monitored that year, a mild bleaching event occurred September and October 2010 affecting only shallow sites, and a mild bleaching event occurred in October and November 2012 and affected only mesophotic sites (Smith et al. 2013; Smith et al. in press). 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 have been conducted at 14 sites around St. Croix and 18 sites around St. Thomas (Table 2). Ten replicate belt transects and three replicate roving dive surveys (RDS) were conducted at each site. Belt transects were 25m x 4m and conducted in 15 minutes per replicate. All transects were begun at a random location on the site, and were swum in a random direction. RDS replicates were 15 min in duration. 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 species 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 a transect. 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.

TCRMP MONITORING SUMMARY

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 2015. Benthic cover raw data is presented in electronic Appendix I. Coral health raw data is presented in electronic Appendix II. In addition, updated benthic cover for each site individually is presented in the "Site Summaries" section.

Coral Cover

The cover of hard corals decreased at most sites immediately after the 2005 coral bleaching event, but showed little or no change as the results of the 2010 and 2012 coral bleaching events (Fig. 9). 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 relative loss in coral cover of shallow *Orbicella* spp[2] dominated reefs ranged from 87% at the Mutton Snapper site to less than 20% at the Brewers Bay site. Mesophotic coral monitoring sites that were sampled before and after the 2005 coral bleaching event showed lower relative losses of coral cover compared with shallow site. Losses ranged from 5.4% (Grammanik Tiger) to 36.0% (Meri Shoal).

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 coral cover values near 0, these sites tend to be dominated by small massive species that are more resistant to bleaching and disease related mortality (Smith et al. 2013). A few sites showed no change, and included Buck Island STT, Coculus Rock, Jacks Bay, and South Water.

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[2] The genus for the species *Montastraea annularis*, *M. faveolata*, and *M. franksi* was changed to *Orbicella* Budd AF, Fukami H, Smith ND, Knowlton N (2012) Taxonomic reclassification of the coral reef coral family Mussidae (Cnidaria: Anthozoa: Scleractinia). Zoological Journal of the Linnean Society 166:465-529 and the TCRMP recognizes this change. Some figures still use "Montastraea" where they have not been converted from previous reports. Other genus revisions (e.g., *Pseudodiploria*) have not yet been incorporated.

However, the Buck Island STT site may be anomalous since transects were not permanently placed until 2007 and unprecedented prevalence of white disease was seen at this site in 2006.

Recovery since bleaching in 2005 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 and irregular upward trajectories are notable at some sites, including Black Point, Botany Bay, Cane Bay, Fish Bay, Lang Hind, Salt River West, Salt River Deep, Seahorse, and St. James. Generalities that might indicate why these sites are recovering are difficult, but the coral communities in these reefs are all diverse. This diversity may contribute to recovery as fast growing species, such as *Agaricites* spp. and *Porites porites* may lead increases in coral cover.

Some sites also showed degradation since 2007, when direct impacts of the 2005 bleaching abated. This was indicated by declines in coral cover and the sites include College Shoal, Ginsburgs Fringe, Grammanik Tiger, Magens Bay, Meri Shoal, and Savana. Four of six sites that were declining are mesophotic coral reefs, which may reflect the impact of generally higher prevalence of white diseases at high coral cover deep sites and a mild bleaching event that occurred in 2012.

In addition, the deep Ginsburgs Fringe site lost 25% coral cover between 2011 and 2015, in what appears to be a continuous decline. While lionfish are frequent at this site and there is high cover of the macroalgae *Lobophora variegata*, the most obvious cause of disturbance is anchoring. A recent derelict reef claw anchor with at least 30m of polypropylene line was seen embedded in the monitoring site in 2014. This anchor or repeated anchoring in the area has overturned portions of a large section of the large *Agaricia* spp. colonies that compose this reef. Ginsburgs Fringe is just along the border of the Grammanik Bank Federal Fisheries Managed Area and the site of a multi-species spawning aggregation, including Nassau grouper and yellowfin grouper (Kadison et al.

2006; Nemeth et al. 2006; Nemeth and Kadison 2013). Anchoring was likely for the purpose of fishing within the seasonal closed area, as there is little other obvious reason for anchoring at the shelf edge in deep water. Impacts to the corals and other essential fish habitat at this site may indirectly harm fishing in the US Virgin Islands.

Two nearshore shallow sites that are degrading since 2007 may be impacted for different reasons. Magens Bay is highly impacted by sedimentation since it is largely enclosed, is surrounded by steep hillsides under constant development (sediment run-off), and is susceptible to strong winter swells (Rothenberger et al. 2008). Degradation at this site may primarily be the result of sediment impacts. On the other hand, Savana is an offshore and uninhabited island next to the typically clear waters of the Virgin Passage. Degradation at this site can be largely attributed to encrusting alga (*Peyssonnelia* sp.), which has been competing for benthic space and slowly decreasing coral cover by overtopping colony margins.

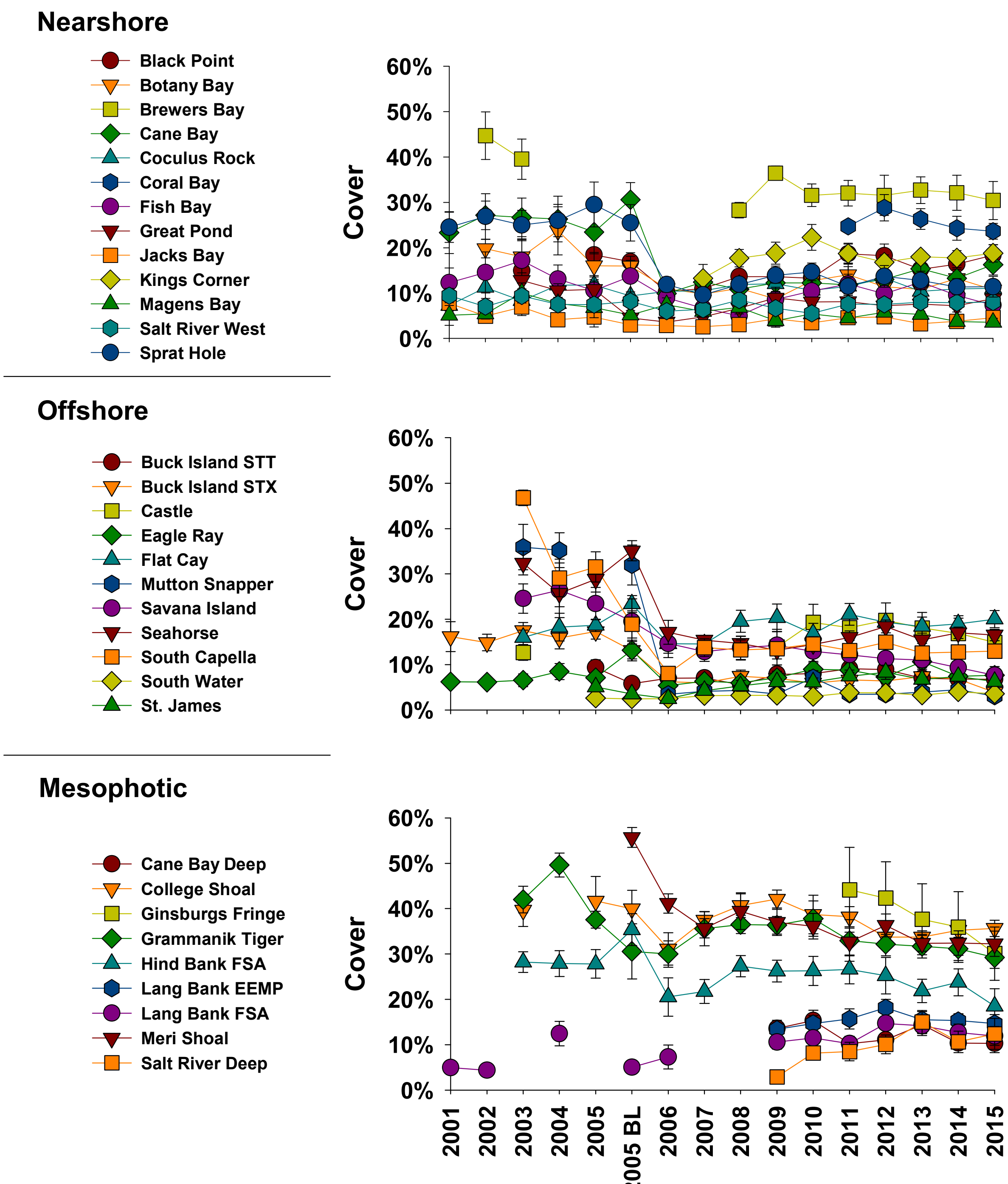


Figure 9. Coral cover (±SE) across TCRMP monitoring sites over time.

Epilithic Algal Community Cover

Algae show the highest inter-annual variability of any group of benthic organisms (Fig. 10). 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. Therefore, declines in the cover of epilithic algae (or increases in the cover of macroalgae and filamentous cyanobacteria) could be an early indication of declining herbivory at sites.

Some offshore sites, such as Eagle Ray, Buck Island-St. Croix, and Savana, appear to have a declining abundance of epilithic algae over the extent of the monitoring. Large recent declines in epilithic algae at Savana are due to increases in the "macroalgae" *Peyssonnelia* sp. in 2014 and 2015 (see next section). Nearshore and mesophotic sites typically showed little inter-annual trend in epilithic algal cover, although interannual variability was high at many nearshore monitoring sites.

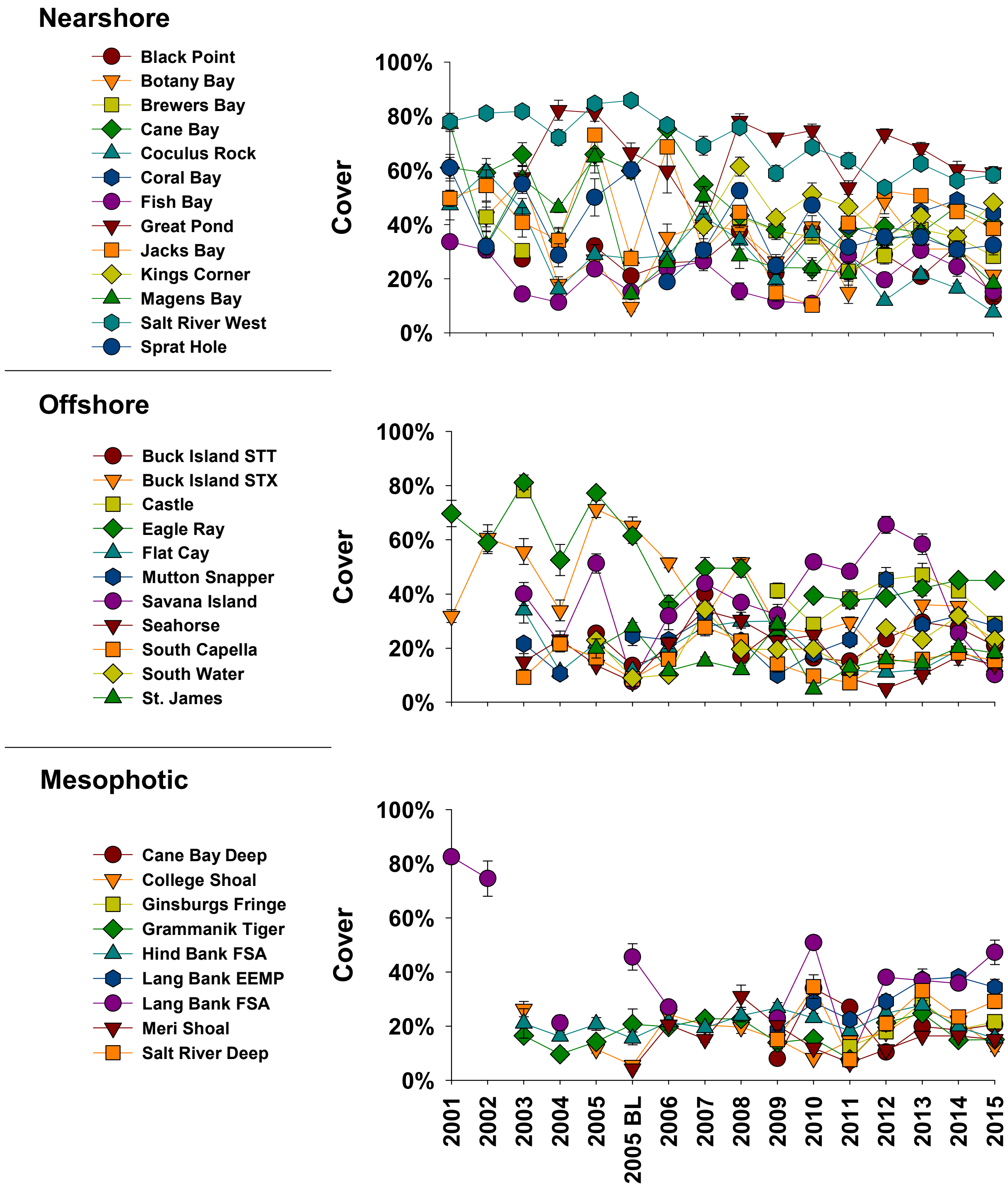


Figure 10. Epilithic Algal Community cover (±SE) across TCRMP monitoring sites over time.

Macroalgal Cover

Macroalgae have been increasing at many reefs, particularly after the 2005 bleaching event (Fig. 11). 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 have been taken by macroalgae. This might occur where resident herbivores communities are already at the threshold of maximum grazing rates (Williams et al. 2001). This process could be enhanced where herbivores numbers are falling due to fishing. 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). At Savana the large increase in macroalgae in 2014 and continuing to 2015 was due to a large increase in encrusting *Peyssonnelia* sp., which was mentioned above as a cause of declining coral cover (*Peyssonnelia* is classified with macroalgae in TCRMP data summaries despite its largely encrusting habitat). This increase in *Peyssonnelia* sp. was also at the expense of epilithic algae.

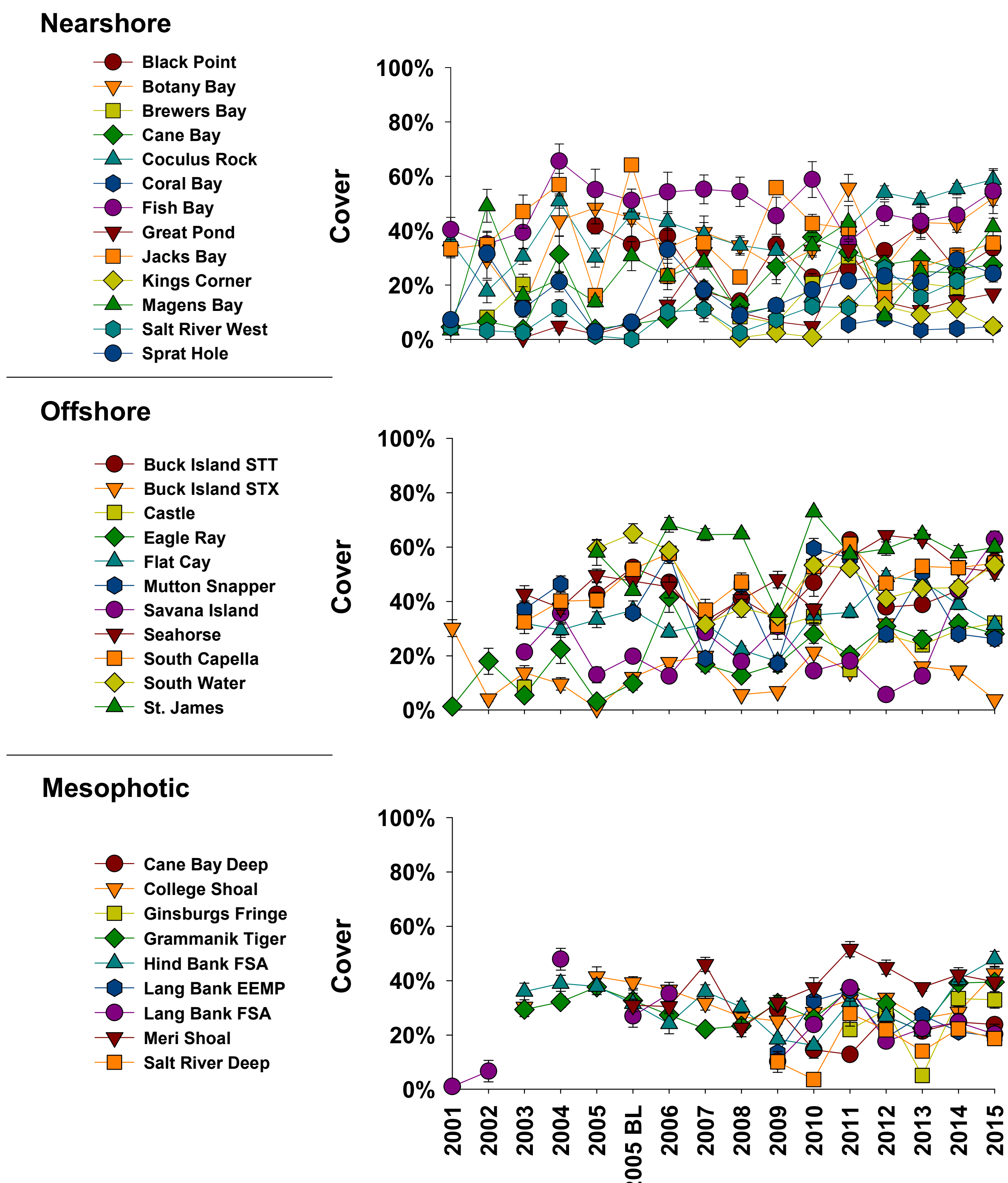


Figure 11. Macroalgae cover (±SE) across TCRMP monitoring sites over time.

Filamentous Cyanobacteria

Filamentous cyanobacteria cover has been increasing at many sites in the TCRMP since the 2005 coral bleaching event (Fig.12). In many cases this was a multi-year peak that has abated, but at some sites is has persisted until 2014. This is particularly true at many sites on St. Croix. 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. 2010a). Filamentous cyanobacteria can inhibit the recruitment of coral larvae (Kuffner et al. 2006) and have been observed interacting at the borders of adult coral (TCRMP, 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.

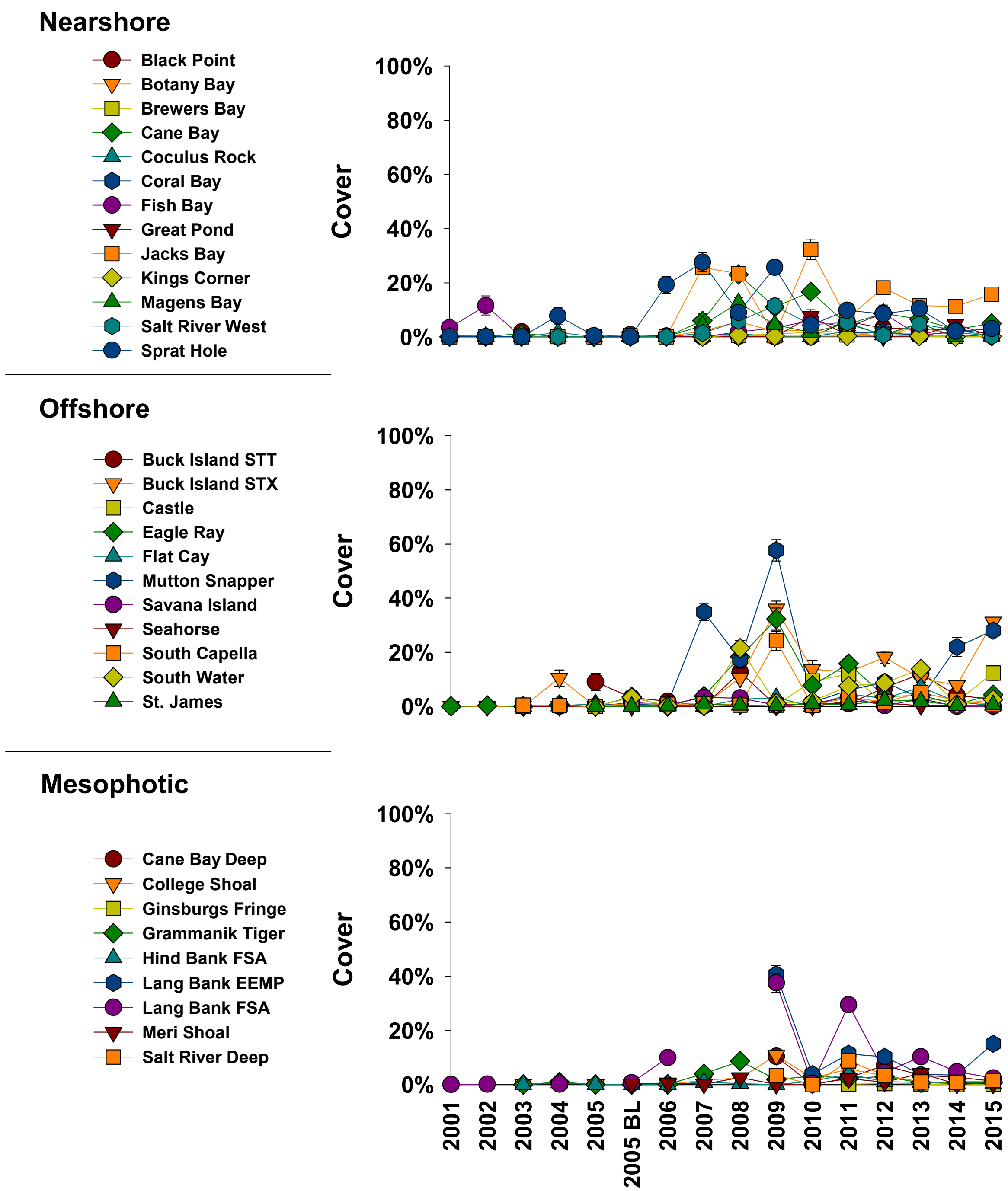


Figure 12. Filamentous cyanobacteria cover (±SE) across TCRMP monitoring sites over time.

Gorgonian and Antipatharian Cover

The cover of gorgonians and antipatharians has been fairly constant at most monitoring sites throughout the years of monitoring (Fig. 13). These groups did not seem sensitive to the thermal stress events in 2005, 2010, and 2012. In most cases they are a relatively minor component of cover because of their upright growth form and small branches. At Coral Bay, Fish Bay, and Magens Bay the cover of gorgonians has been increasing through the monitoring time series. These sites are known to have water quality issues and a high influx of terrestrial sediments. It is possible that inputs of nutrients from terrestrial run-off and poor sewage disposal are stimulating pelagic primary productivity (Furnas et al. 2005) and increasing the abundance of gorgonians that can feed heterotrophically on water column resources (De'ath and Fabricius 2010).

Note that Black Corals (antipatharians) are rare and when they occur tend to be more prominent in deep monitoring sites. For many gorgonians species their abundance tends to peak in shallow water where there is constant swell (benthic orbital turbulence).

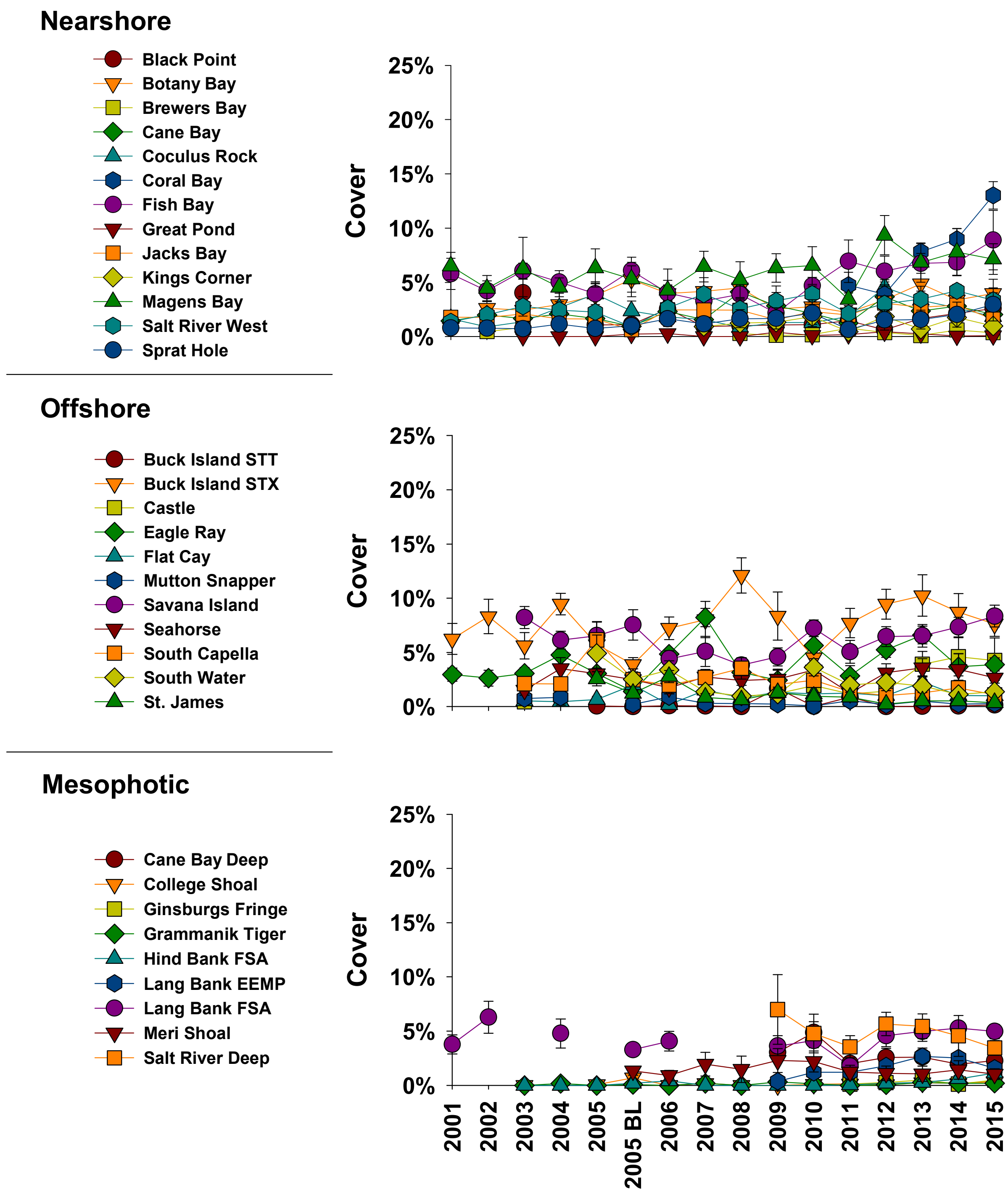


Figure 13. Gorgonian and Antipatharian cover (±SE) across TCRMP monitoring sites over time.

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. 14). Nearshore increases were most pronounced at Black Point, Coral Bay, and Magens Bay. 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.

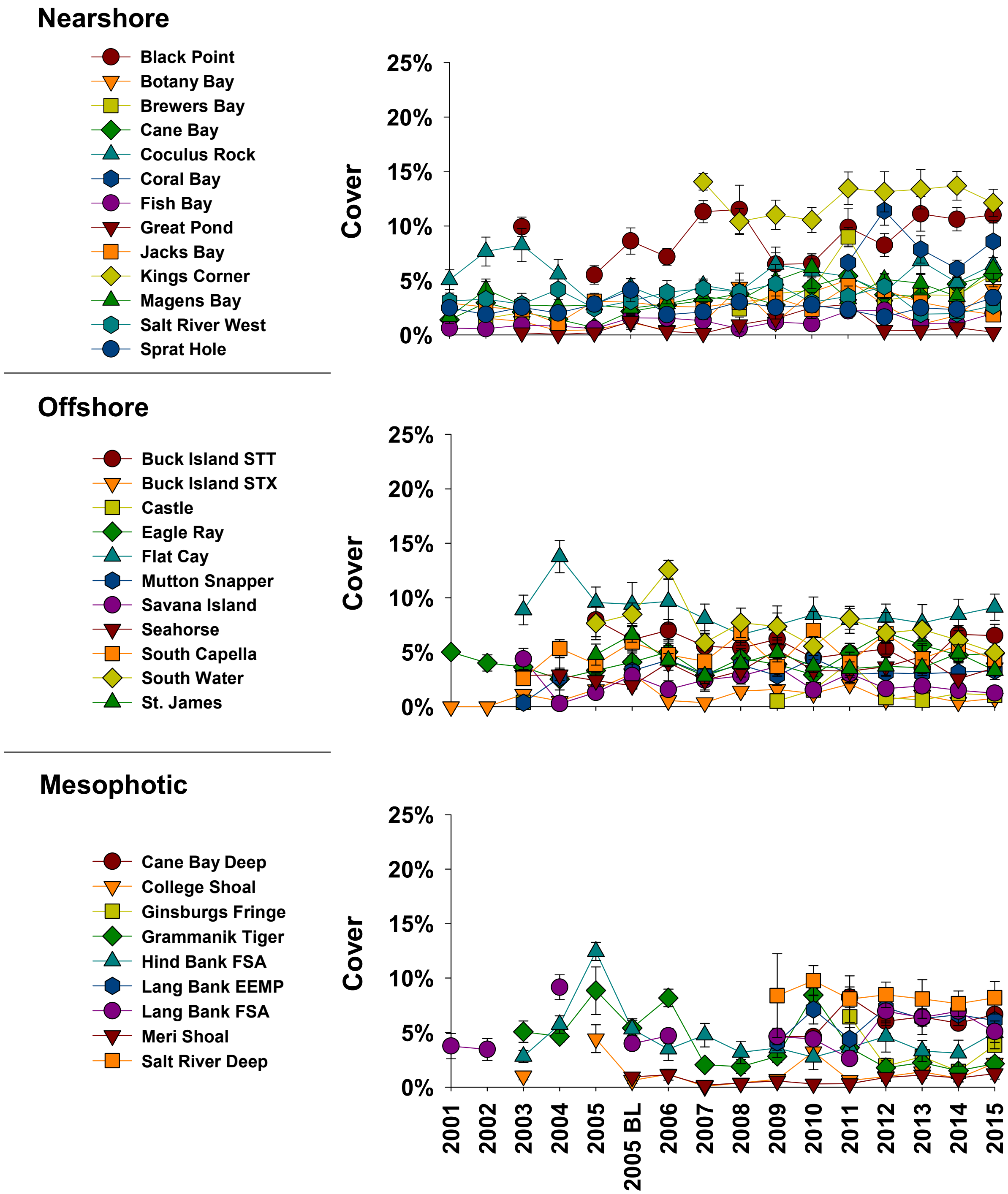


Figure 14. Sponge cover (±SE) across TCRMP monitoring sites over time.

FISH COMMUNITIES

FISH COMMUNITIES

In 2015, a total of 37,718 fish representing 132 species and 34 families were recorded over 139 belt transects across all 14 sites off St. Croix. Total calculated biomass on St. Croix sites was 1,465.97 kg. An additional 44,558 fish representing 134 species and 31 families were recorded over 183 transects across all 19 sites off the northern USVI. The calculated biomass was 3,537.17 kg. Using roving diver surveys (RDS) 106 species representing 32 families were observed in 2015 off St Croix and 126 species representing 31 families off the northern USVI (see https://sites.google.com/site/usvitcrmp/home). All of these numbers are higher than those reported for the same variables in 2014. Species richness did not differ significantly between survey methods or between nearshore, offshore, and mesophotic sites (Table 3); however, Ginsburgs Fringe had the lowest species diversity (16.2 ± 1.3 species transect^{-1}; data not shown in figures). Three nearshore sites, Great Pond off St. Croix, Fish Bay off St. John, and Magens Bay off St. Thomas, also had relatively low species diversity. Sites with notably high species diversity were Hind Bank East FSA and Seahorse Cottage Shoal off St. Thomas (29.0 ±1 .8 species transect^{-1} and 28.8 ± 1.2, respectively), and Mutton Snapper off St. Croix (28.7 ± 1.7 species transect^{-1}).

Overall fish size distribution on both St. Croix and the northern USVI followed trends seen in earlier years. Fish smaller than 10 cm total length (TL) predominated at all sites. Fifty percent of the individuals counted off St. Croix were less than 5 cm TL and 74% were less than 10 cm TL. Off the northern USVI, 41% were smaller than 5cm and 68% were under 10cm TL. Large fish (> 40cm TL) constituted 0.8% of the numeric total off the northern USVI (398 fish), and 0.1% off St. Croix (43 fish). Numerically the most dominant fish across northern USVI reefs were creole wrasse (*Clepticus parrae*), blue chromis (*Chromis cyanae*), striped parrotfish (*Scarus iserti*), bluehead wrasse (*Thalassoma bifaciatum*), and brown chromis (*Chromis multilineata*). These five species made up over 54% of the numeric total of fish observed on all northern USVI sites. The same five species made up 55% in 2014 surveys. The creole wrasse was again especially numerically dominant in the northern USVI (14% of all fish recorded in 2015). On St Croix reefs, blue chromis, bluehead wrasse, bicolor damselfish, creole wrasse, and brown chromis contributed 55% to the numeric total of all sites. All of these species were rather ubiquitous and were observed in relatively high numbers across all sites and across all years. The exception was the creole wrasse, which was only abundant on offshore and mesophotic sites and on nearshore sites adjacent to walls. Four of the six most common fish are planktivorous omnivores with the exception of the striped parrotfish and bicolor damselfish. Although herbivorous, these species are also opportunistic and are present on reef habitats with both high and low living coral cover.

Table 4. The 2015 species richness for 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	57	26.2±1.2	82
	Great Pond	41	17.7±0.9	57
	Jacks Bay	71	24.6±2.2	70
	Kings Corner	66	25.4±1.9	63
	Salt River West	51	21.2±1.1	48
	Sprat Hole	56	25.0±1.0	55
	Benner Bay	51	21.9±1.3	47
	Black Point	61	24.7±1.0	69
	Brewers Bay	54	20.9±1.0	54
	Botany Bay	53	24.6±0.9	58
	Buck Island, St. Thomas	61	27.7±1.3	69
	Coral Bay	44	18.2±0.9	30
	Fish Bay	52	17.8±1.6	53
	Magens Bay	42	17.9±0.7	43
Offshore	Eagle Ray	67	28.0±1.9	54
	Buck Island, St. Croix	55	24.2±1.5	56
	Castle	58	22.1±0.7	51
	Mutton Snapper	64	28.7±1.7	52
	Seahorse Cottage	65	28.1±1.6	57
	South Capella	61	26.1±1.4	59
	South Water Island	58	24.0±1.1	50
	Flat Cay	57	24.3±1.2	48
	Meri Shoal	52	22.7±1.6	42
	Savana Cay	65	28.8±1.2	52
	Little St. James	69	28.0±1.0	68
Mesophotic	Cane Bay Deep	50	18.6±1.5	41
	Lang EEMP	53	26.1±1.3	60
	Lang Bank	59	23.2±1.3	51
	Salt River Deep	39	26.4±4.8	45
	College Shoal East	63	25.2±1.4	47
	Grammanik Bank FSA	65	26.7±1.2	54
	Hind Bank East FSA	70	29.0±1.8	57
	Ginsburgs Fringe	36	16.2±1.3	36

Fish Abundance

Total fish abundances across nearshore, offshore, and mesophotic sites and years are shown in Fig.15. Fish abundance across all sites in 2015 was similar to data collected in previous years. Abundance was highly variable across sites and strata. No obvious patterns over time or space have been noted in overall fish abundance. Spikes in abundances of fish during some years represent schools of pelagic species, such as creole wrasse or blue chromis. No change has been detected in overall fish abundance since the coral bleaching of 2005 or the warm water events that have followed. Two of the nearshore sites added off the northern USVI in 2012, Coral Bay and Fish Bay, continue to have lower abundances of fish than other sites.

FISH COMMUNITIES

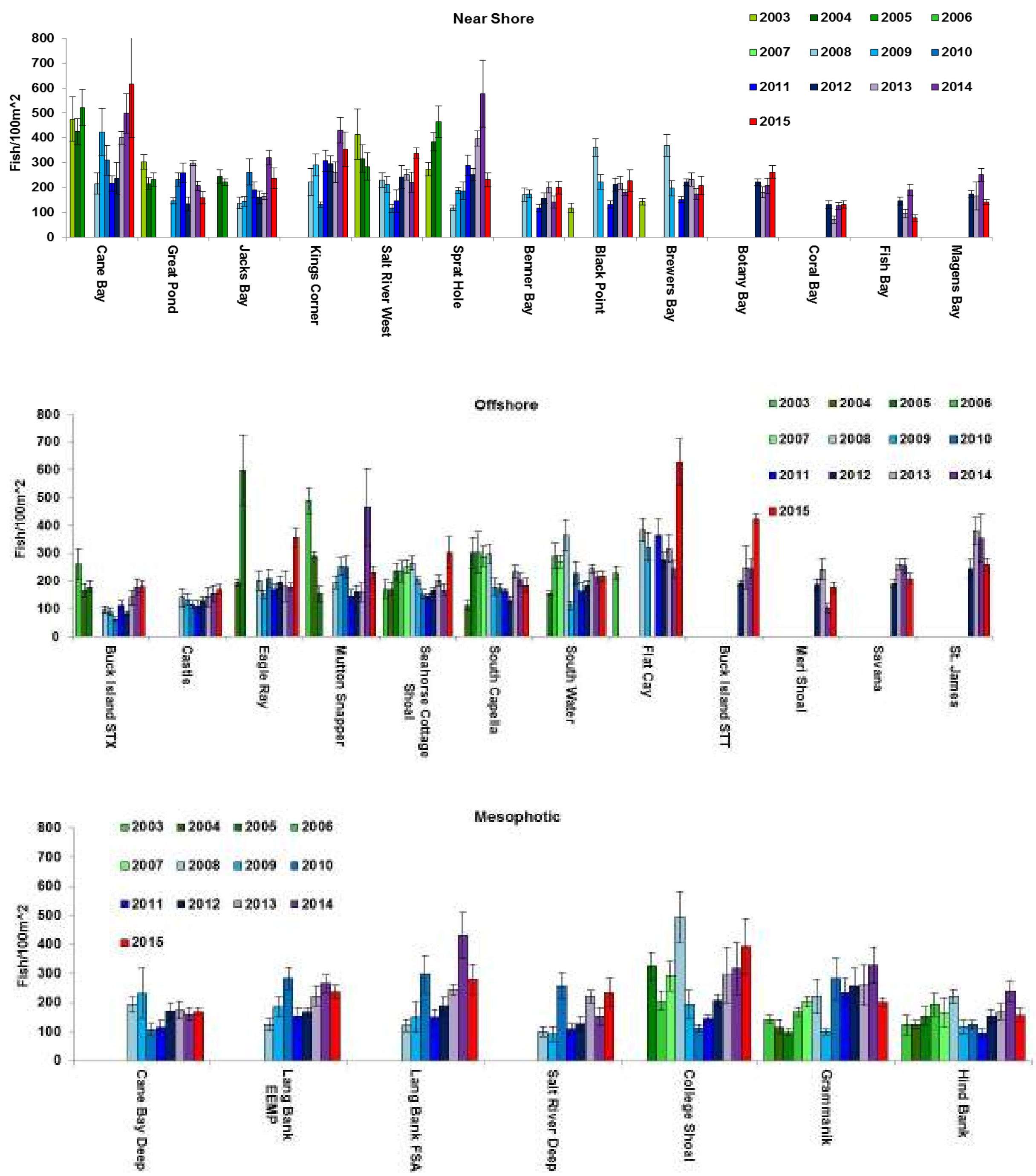


Figure 15. Fish abundance (±SE) across TCRMP monitoring sites over time. St. Croix sites are to the left and northern USVI to the right on the x-axis.

Fish Biomass

Fish biomass across sites is shown in Fig. 16. As with abundance, biomass is highly variable between sites and years. No temporal pattern is evident, and differences in time appear to be seasonal or natural variation. In general, the average biomass of fish at mesophotic sites off St. Thomas (Grammanik Bank FSA, Hind Bank FSA, and College Shoal) have been higher across the years throughout the sampling period when compared to the more shallow sites and the St. Croix mesophotic sites. An exception was 2014 when total fish biomass was also very high on Lang Bank EEMP and Lang Bang FSA (both mesophotic sites). These spikes were due to large numbers of adult creole wrasse in 2014 on those sites. In 2015, Lang Bank EEMP and Lang Bank FSA both had more typical biomass values. The Lang Bank mesophotic sites and the northern USVI mesophotic sites are in marine reserves and well offshore, away from land-based pollution. Biomass is notably higher on these sites than on Salt River and Cane Bay deep sites. The Grammanik, Hind Bank, and Lang Bank FSA are also multispecies spawning aggregation sites for groupers and snapper, and sampling periods sometimes overlap slightly with the aggregation periods for cubera snapper (*Lutjanus cyanopterus*) or schoolmaster snapper (*Lutjanus apodus*). In 2015 several Cubera snapper were observed on transects at Grammanik Bank FSA, which elevated the average biomass greatly. Northern USVI nearshore sites added in 2012 all had relatively low biomass of fish, especially Coral Bay. This site is a small patch reef with high turbidity, and supports only small species and juvenile fishes at very low abundances.

FISH COMMUNITIES

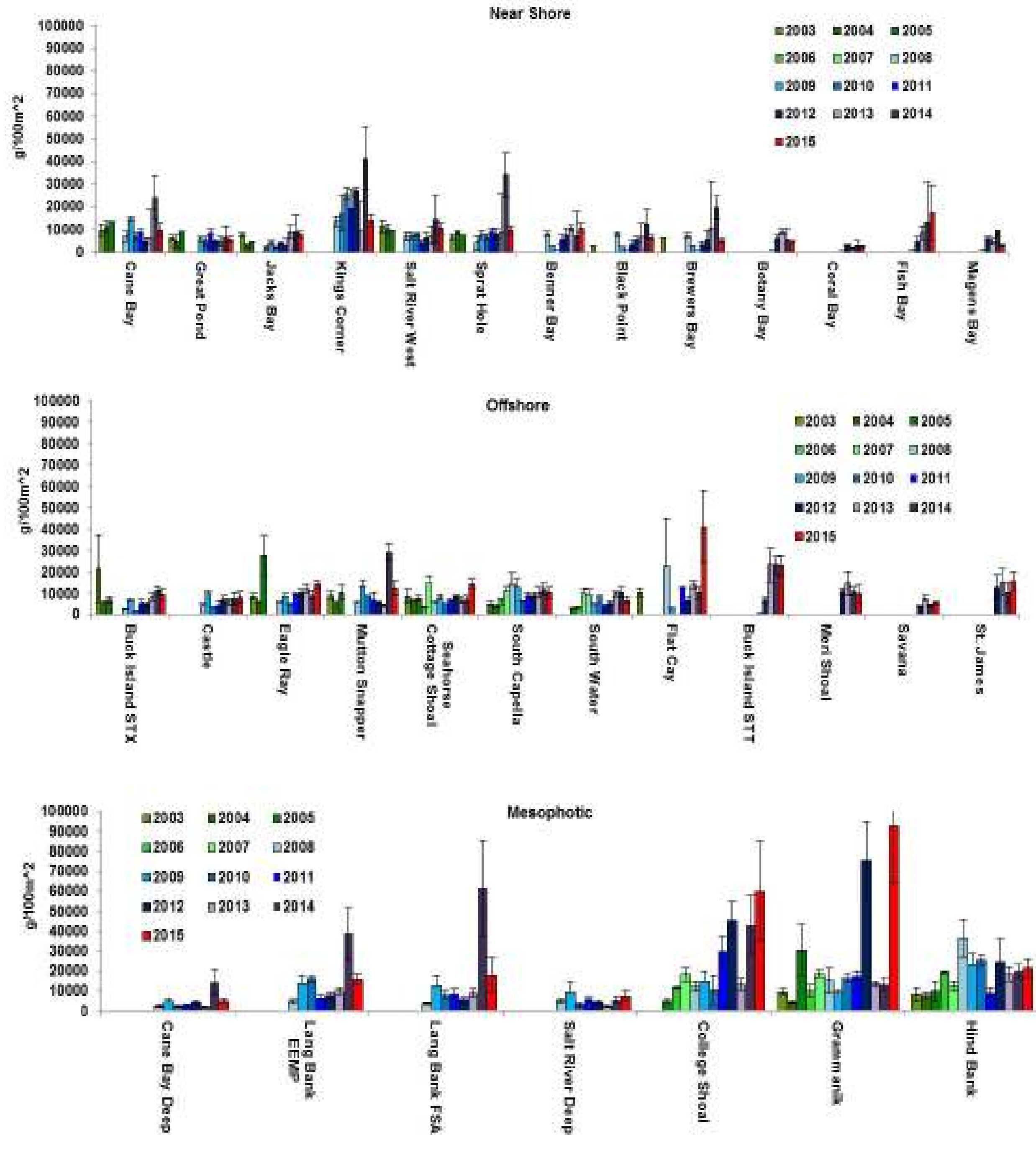


Figure 16. Mean fish biomass (±SE) across TCRMP monitoring sites over time. St. Croix sites are to the left and northern USVI to the right on the x-axis.

SEA URCHINS

BLACK SPINY SEA URCHIN *DIADEMA ANTILLARUM*

The abundance of the black spiny sea urchin *Diadema antillarum* shows tremendous site-to-site variability (Fig. 17). In general the shallowest sites, e.g., Great Pond, support the greatest abundance of *D. antillarum*. These sites also tend to have very low macroalgal cover. Trends are not presented here by year, as variability is generally low. At Coral Bay there is a high abundance of *Echinometra* spp. that has not been quantified. This species seems to be the dominant grazer and effectively removes most macroalgal cover, but also contributes apparently high bioerosion (gnawed coral bases). Future monitoring might considered targeted monitoring of these species at certain sites.

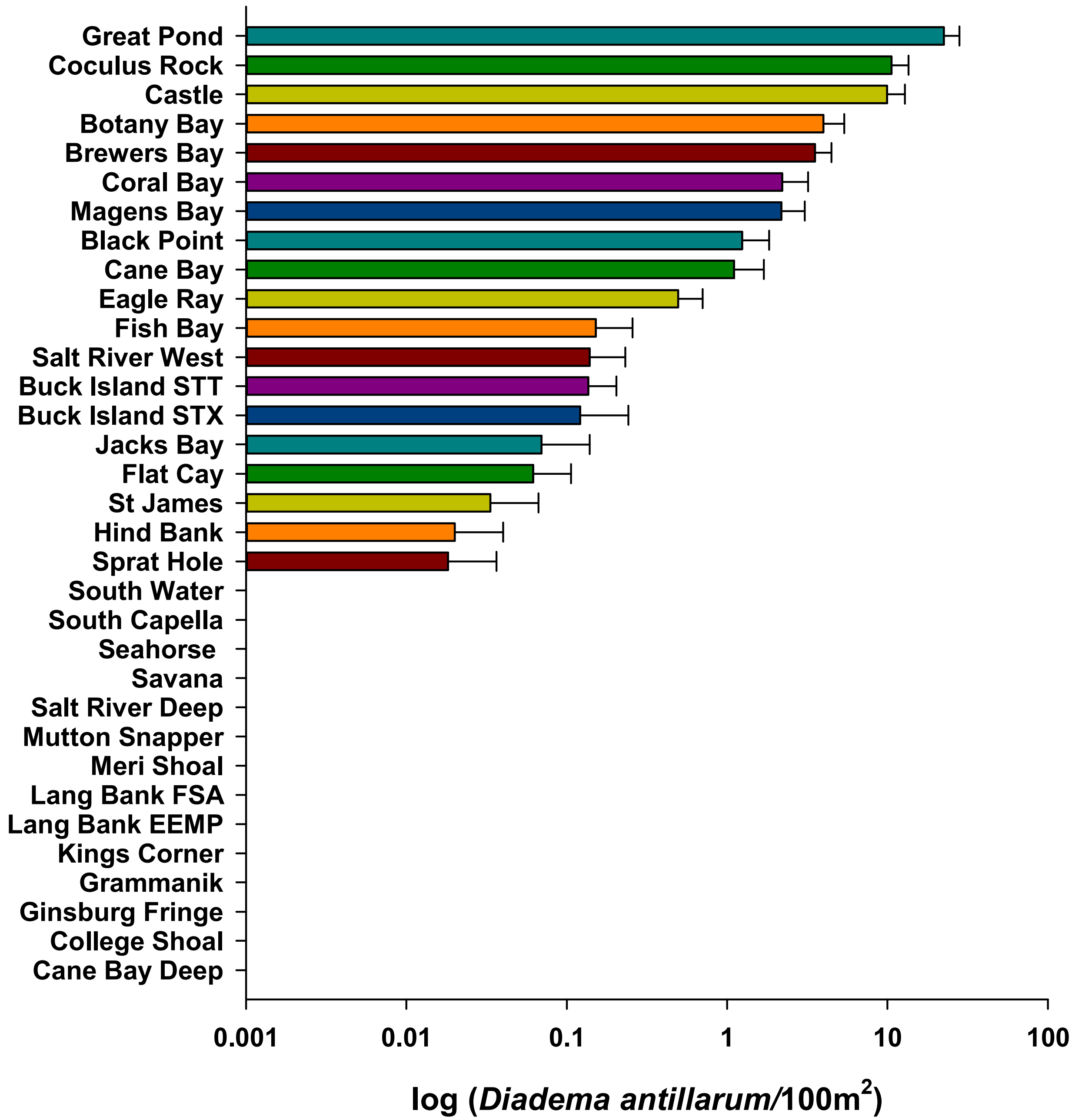


Figure 17. Abundance of the black spiny sea urchin (*Diadema antillarum*) at TCRMP monitoring sites. Note the log scale.

SITE SUMMARIES

Site Summaries

RATIONALE

The purpose of this section is to provide a more comprehensive survey of TCRMP site characteristics than can be achieved in the overall data compilations. Each TCRMP monitoring site is unique and has experienced distinctive responses to local and global stressors. Given the increase in sites included under this program and the inclusion of more information at each site, such as physical data, this section is designed to provide a summary that highlights each site's individual characteristics and serves as a quick reference guide for managers, policy makers, and academics. The duration of surveys at most sites also now provides sufficient data from which to draw conclusions about longer term site dynamics and the processes that might be contributing to recent trajectories of health, development, and degradation.

SITE SUMMMARY ELEMENTS

TCRMP site information is presented in six pages that provide a brief description of the setting and the potential susceptibility to local and global stressors and disturbances. Sub-sections include a description of (1) the physical environment, (2) the benthic community and (3) the fish community. The benthic data and coral health are updated in each annual report, whereas the fish summaries and physical data are updated periodically.

Benthic community structure is presented as the mean (±SE) cover of coral, macroalgae, cyanobacteria, and epilithic algae. Epilithic algal communities are diminutive turf and filamentous algae that cover hardbottom surfaces, whilst macroalgae have identifiable thallus differentiation and structure. Any open hardbottom space is assumed to host an epilithic algal community even if algae cannot be resolved in video images. The loss of coral cover due to the 2005 bleaching event was calculated as the relative change in coral cover from 2005 to 2007, unless otherwise noted for sites not sampled in these years. In addition, the percent recovery from the 2005 bleaching event was calculated as the amount of coral cover regained by 2011 $(Cover_{2011} - Cover_{2007})/(Cover_{2005} - Cover_{2007})$. Change calculations must be treated with caution for sites where transects where not made permanent until after the 2005 bleaching event or where percent cover is low, since the conditions introduce an unknown amount of error. Trends are shown for all available years of monitoring

Benthic community pie charts were constructed from all years of data. The sessile epibenthic animal community includes *Agaricia* spp., *Colpophyllia natans*, *Diploria strigosa*, *Orbicella annularis*[3], *Orbicella spp.* (*O. faveolata*, *O. fransksi*, + unidentified *Orbicella* spp.), *Montastraea cavernosa*, *Porites astreoides*, branching *Porites* species, *Siderastrea siderea*, other corals, sponges, and gorgonians. The algae/non-living substrata category includes cyanobacteria, epilithic algae ("DCA"), *Lobophora variegata*, *Dictyota* spp., *Halimeda* spp. crustose coralline algae, and sand/sediment. These figures not are updated every annual report, since relative composition tends to change slowly. Figures are changed every five years or after a major disturbance, such as a coral bleaching event.

Coral Health is presented as the mean (±SE) of coral bleaching prevalence (proportion of population affected) and extent (proportion of colony affected), disease prevalence, and partial mortality prevalence.

PHYSICAL CHARACTERISTICS.

Temperature. Benthic temperatures were recorded at each site with a HoboTemp™ thermistor data logger (Onset Computer Corporation, Bourne, Massachusetts). Thermistors were affixed within transects and set to record at intervals of 15 minutes. Records are presented as daily averages across months, February 29th excluded. Each temperature figure includes the climatological monthly maximum mean temperature (28.5°C), and the bleaching threshold temperature (29.5°C) established for the region (NOAA 2006). Data for 2005 was taken from current profilers or federal data sources.

[3] The genus *Orbicella* was formerly named *Montastraea*, but changed in 2012 reflecting an earlier precedence and dissimilarity with *Montastraea cavernosa* (Budd et al. 2012). Some figures in this report may still abbreviate the genus name as "*M*."

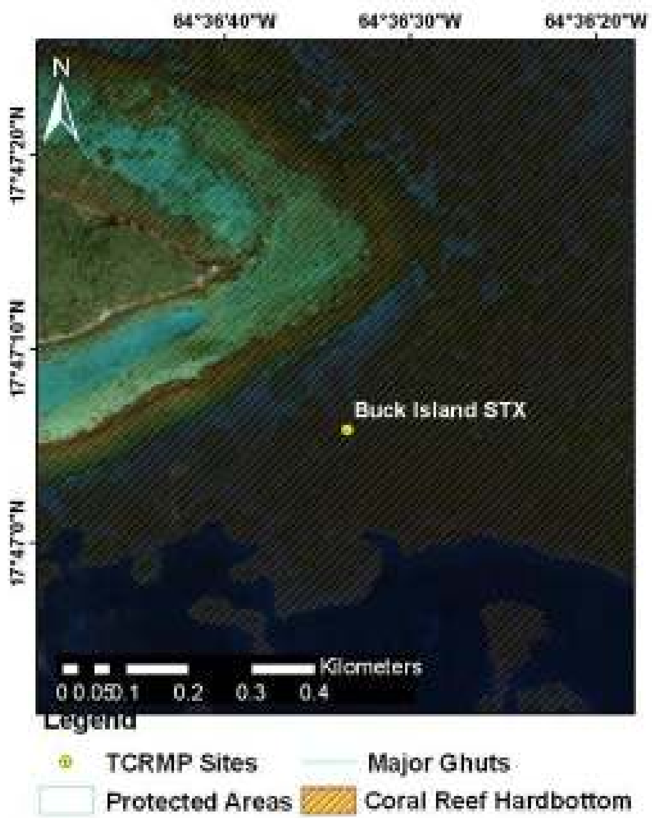
Currents. Water currents were recorded at a subset of sites and times with Nortek Aquadopp™ Acoustic Doppler Current Profilers (ADCPs). Profilers were set in bases on the seafloor and set to record current speed and direction within predefined depth bins above the substrate. The bin closest to the substrate and closest to the coral reef was selected for display. Compass rose figures were developed that show the frequency of current in magnetic directions 0, 22.5, 45, 67.5, 90, 112.5, 135, 157.5, 180, 202.5, 225, 247.5, 270, 292.5, 315, 337.5, 360°. Within each direction the frequency of current speed within bins of 0.1 m s^{-1} were plotted. For Flat Cay, current data was retrieved with an Aandaraa 2-D current meter that measured current speed and direction directly over the sensor head.

Chlorophyll and Turbidity. Continuous fluorometric measurements of chlorophyll and turbidity were conducted at some sites for short periods (Black Point, Grammanik, Magens Bay). Wetlabs ECOFLNT fluorometers with antifouling bio-wipers were deployed and set to record for one minute at hourly intervals. Water column chlorophyll measurements detect phytoplankton abundance. Fluorometric measurements of chlorophyll are proxies for true chlorophyll concentrations. Direct chlorophyll measurements to calibrate fluorometric measurements have not been conducted at the monitoring sites.

St. Croix

BUCK ISLAND, ST. CROIX

Description. The Buck Island, St. Croix site is a seaward extension of the southeast Buck Island barrier reef complex in water depth of 15 m. The reef is a low framework surrounded by a sand plain to the west and a rolling reef/hardbottom to the east. The Buck Island, St. Croix site is largely composed of large living and dead *O. annularis* heads surrounded by sand. The site has been monitored since 2001, with three permanent benthic transects installed in 2001, and three additional transects installed in 2003.



Outstanding Feature. The Buck Island, St. Croix site is within the expanded (2001) Buck Island Reef National Monument. The reef fish populations may show recovery due to the restriction of fishing.

Threats. Due to its protected area status and remoteness from land-based pollution Buck Island, St. Croix is primarily threatened by changing climate as its populations of *O. annularis* were shown to be susceptible during the 2005 bleaching event.

Figure 18. The Buck Island, St. Croix. (top) Position in the Buck Island Reef National Monument. (right)A representative photo.

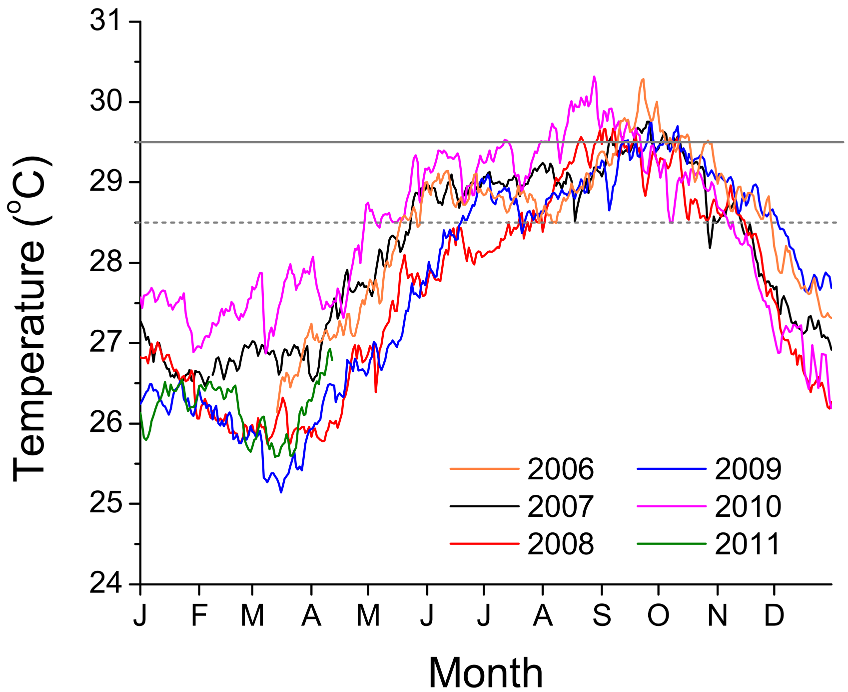


Figure 19. Buck Island, St. Croix benthic temperatures (14 m depth). Data provided by the National Park Service (site BUIS_SFR).

Physical Characteristics

Current. Currents have not been recorded at the Buck Island, St. Croix monitoring site. Unidirectional currents have always been light during monitoring. Oscillatory currents occasionally impact the site when swell is from the east.

Temperature. Temperatures at the Buck Island, St. Croix monitoring sites can get very warm and surpassed the bleaching threshold significantly in 2006 and 2010. There were no site records for the 2005 bleaching event.

Benthic Community. The Buck Island, St. Croix hard coral community is dominated by the boulder star coral *Orbicella annularis*; however, the most abundant sessile epibenthic animals are gorgonians. Epilithic algae dominate the algal community, with a low cover of macroalgae relative to other sites. There is a high proportion of sand.

This coral community lost 65.5% of its coral cover in the 2005 bleaching event and had only regained 6% of coral cover by 2011. Filamentous cyanobacteria showed very large increases in cover after the 2005 bleaching event.

Coral Health. Buck Island, St. Croix corals were likely severely affected during the 2005 bleaching event; however, bleaching health surveys were not completed until Jan. 13, 2006 when recovery had already commenced. Bleaching surveys were not conducted during the 2010 bleaching event. The prevalence of coral diseases was high on *O. annularis*, with frequent incidence of yellow band disease and white disease following the 2005 bleaching event. Old partial mortality was very prevalent after the 2005 coral bleaching event and then decreased to 2011.

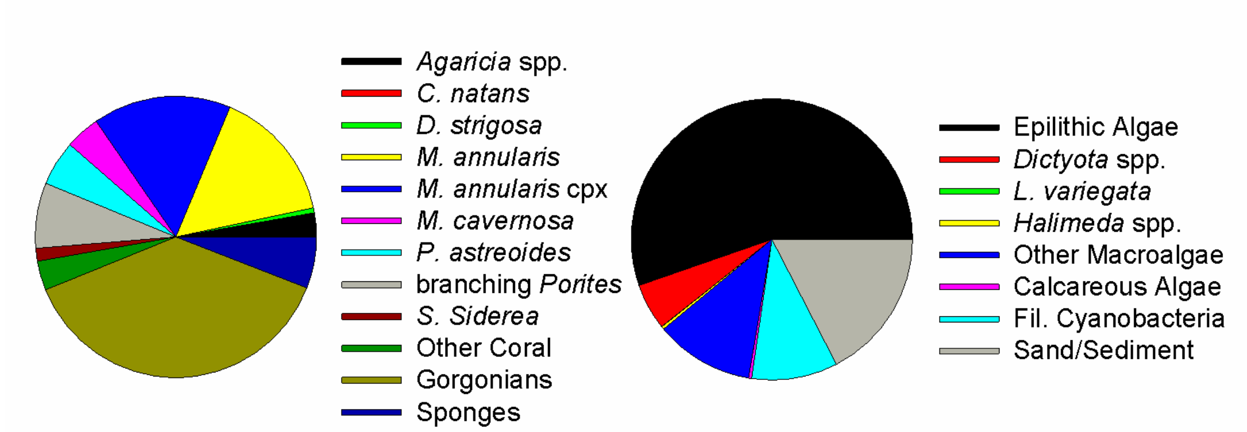


Figure 20. Buck Island, St. Croix. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

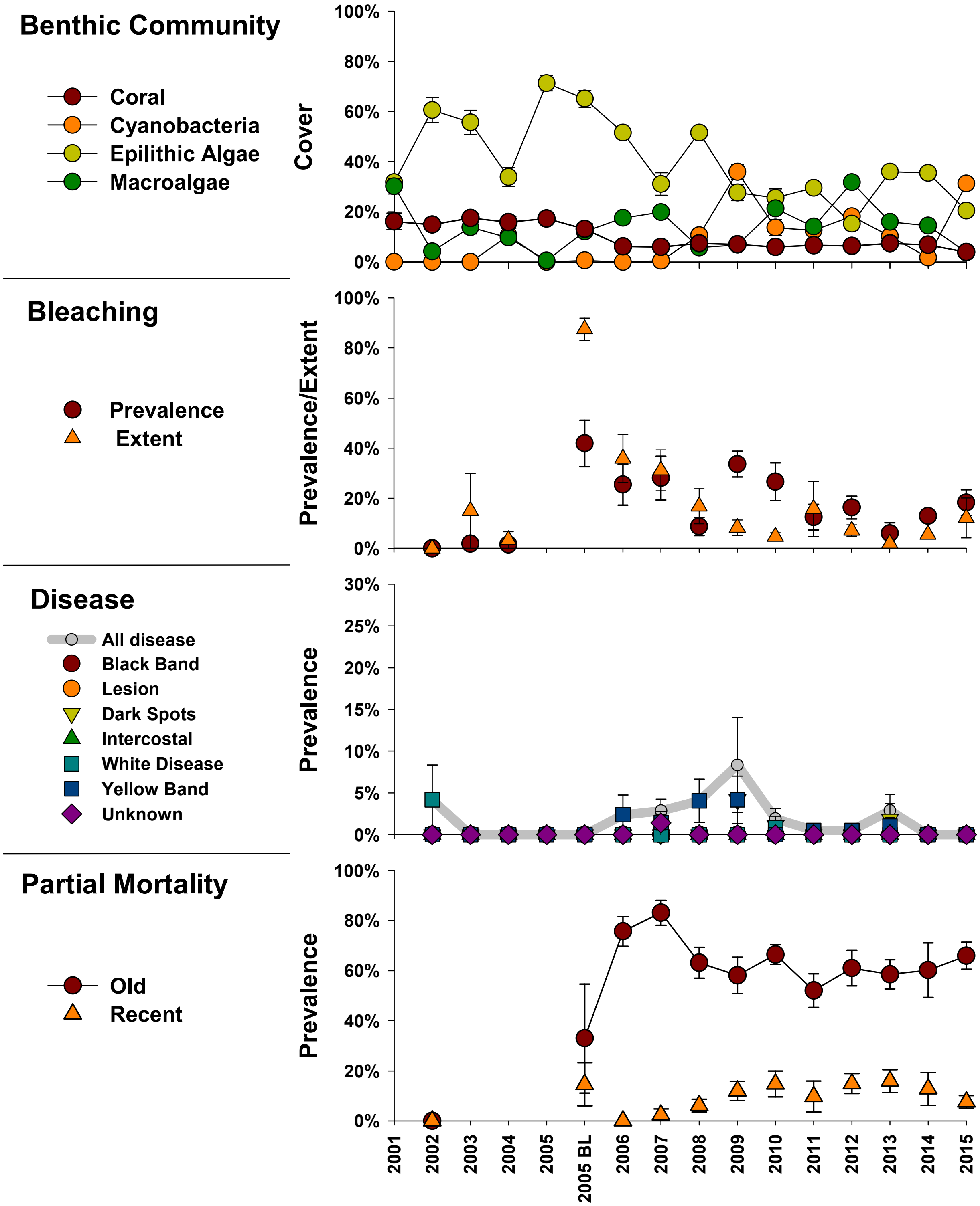


Figure 21. Buck Island, St. Croix benthic cover and coral health through time (mean ± SE).

Fish Community. Buck Island is a low patchy reef community surrounded by and interspersed with sand. The fish community is largely dominated in biomass by herbivores with a very high biomass of stoplight parrotfish. Close to the monitoring site are “the Haystacks”, large *Acropora palmata* skeletal remains that provide ample grazing area for the large parrotfish. In addition, the Buck Island site is within the National Monument and the fish inhabitants are theoretically protected from spearfishing and nets. There is also a high biomass of invertivore fishes, which are dominated by the yellowhead wrasse. Invertivores are diverse on the site and include several species of grunts (tomtate, French, Spanish, white, and bluestripe) as well as many wrasses (yellowhead, bluehead, clown, yellowcheek, slippery dick, and creole wrasse). Piscivores are uncommon, and the only serranids observed during transects in 2011 and 2012 were small red hind and graysby. Snapper were limited to schoolmaster and one mahogany snapper.

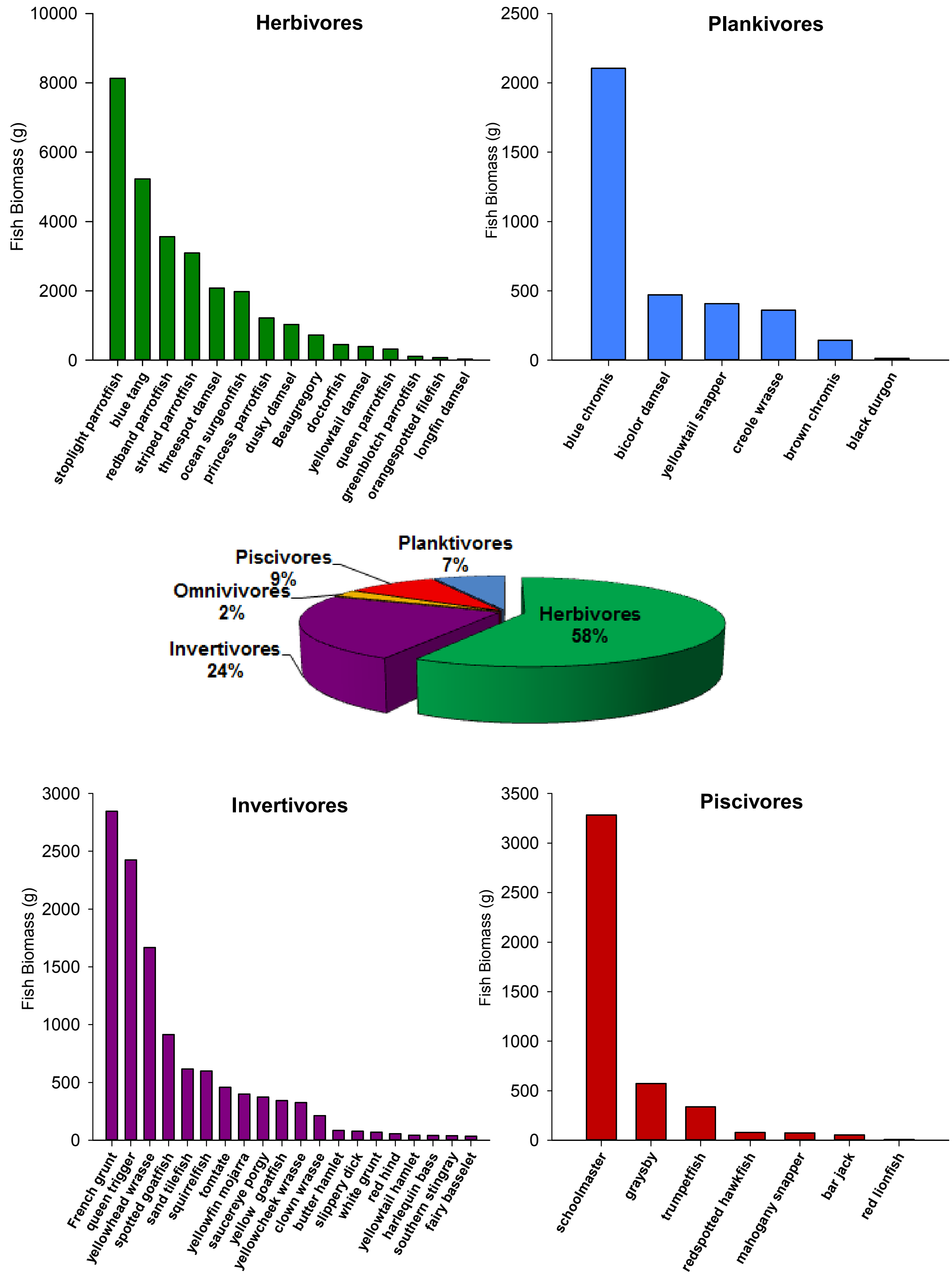


Figure 22. The Buck Island, St. Croix fish community by absolute and relative biomass.

CANE BAY

Description. The Cane Bay monitoring site is a nearshore/shelf edge fringing reef on the northwest coast of St. Croix. Transects follow the trend of the leeward spur and groove formations. Cane Bay has been monitored since 2001.

Outstanding Feature. Cane Bay is one of the most well developed nearshore reefs on St. Croix. It is also one of the most heavily visited dive sites by both tourists and residents in the Virgin Islands due to its proximity to the wall, considered by some to be the most precipitous submarine drop off in the world. The reef has been under scientific investigation since the 1970's.

Threats. Although the Cane Bay reef is a singular treasure for the Virgin Islands, it is threatened by pollution, fishing, climate change, and recreational overuse. The watershed above Cane Bay has been planned for residential development with potential for the influx of terrestrial sediment. The reef is also fished commercially, and teams of spearfishers on SCUBA have been observed. This reef also lost half its coral cover in the 2005 bleaching event, suggesting it is vulnerable to warming ocean temperatures.

Figure 23. Cane Bay. (top) Location. (right) A representative photo of the reef.

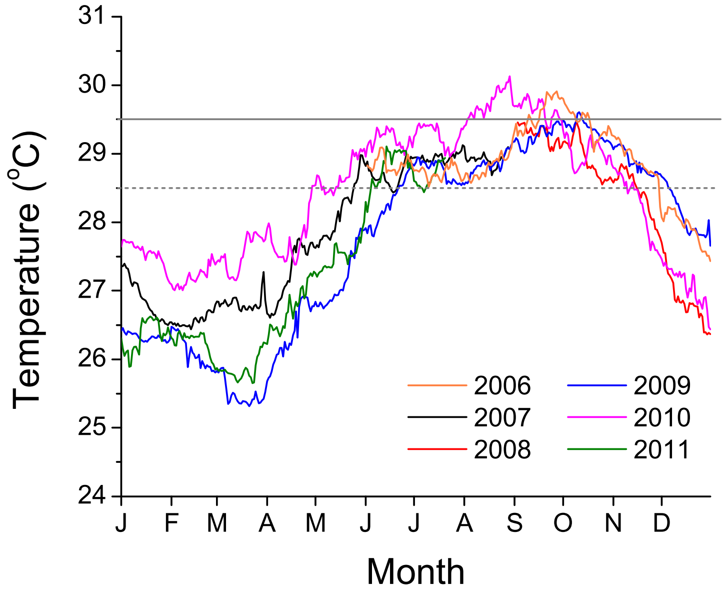


Figure 24. Cane Bay benthic temperatures (8 m depth)

Physical Characteristics

Current. Cane Bay currents have not been directly measured by the TCRMP. However, this site typically has moderate unidirectional currents with the occasional exposure to strong north swell. The current at the site may be part of an eddy formed by the dominant westward flowing current wrapping around the eastern point. Its downstream location from the entire north coast of St Croix may also make this site a recruitment sink for larvae, potentially adding to the diversity.

Temperature. Cane Bay is a relatively open and clear environment, and the temperatures tend to stay cooler, but the propensity for bleaching may be increased by the high light transmission.

Benthic Community. Cane Bay supports a very diverse coral community, with dominance by *Orbicella* spp. Open substrates were mostly epilithic algal community; however, epilithic algae cover has declined since the 2005 bleaching event with increases in the cover of macroalgae and filamentous cyanobacteria. This indicates that the resident herbivore community was not able to effectively graze substrates opened by coral mortality. This coral community lost 46.8% of coral cover in the 2005 bleaching event and lost 6% more as of 2011, a troubling sign.

Coral Health. Cane Bay corals were severely affected during the 2005 bleaching event with nearly all colonies bleached over 80% of the colony surface. The prevalence of bleaching was also high in 2010, yet at a low extent. The prevalence of coral diseases was low before 2005, but outbreaks of white, yellow band, and dark spots disease have occurred more recently, another indication of declining health at this reef. Old and recent partial mortality became very prevalent after the 2005 coral bleaching event and have remained nearly steady or increased since.

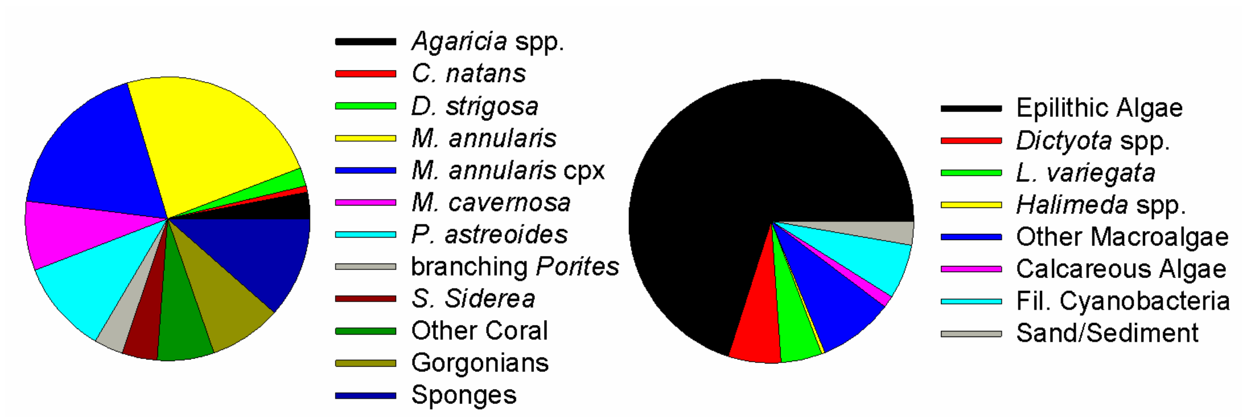


Figure 25. Cane Bay. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

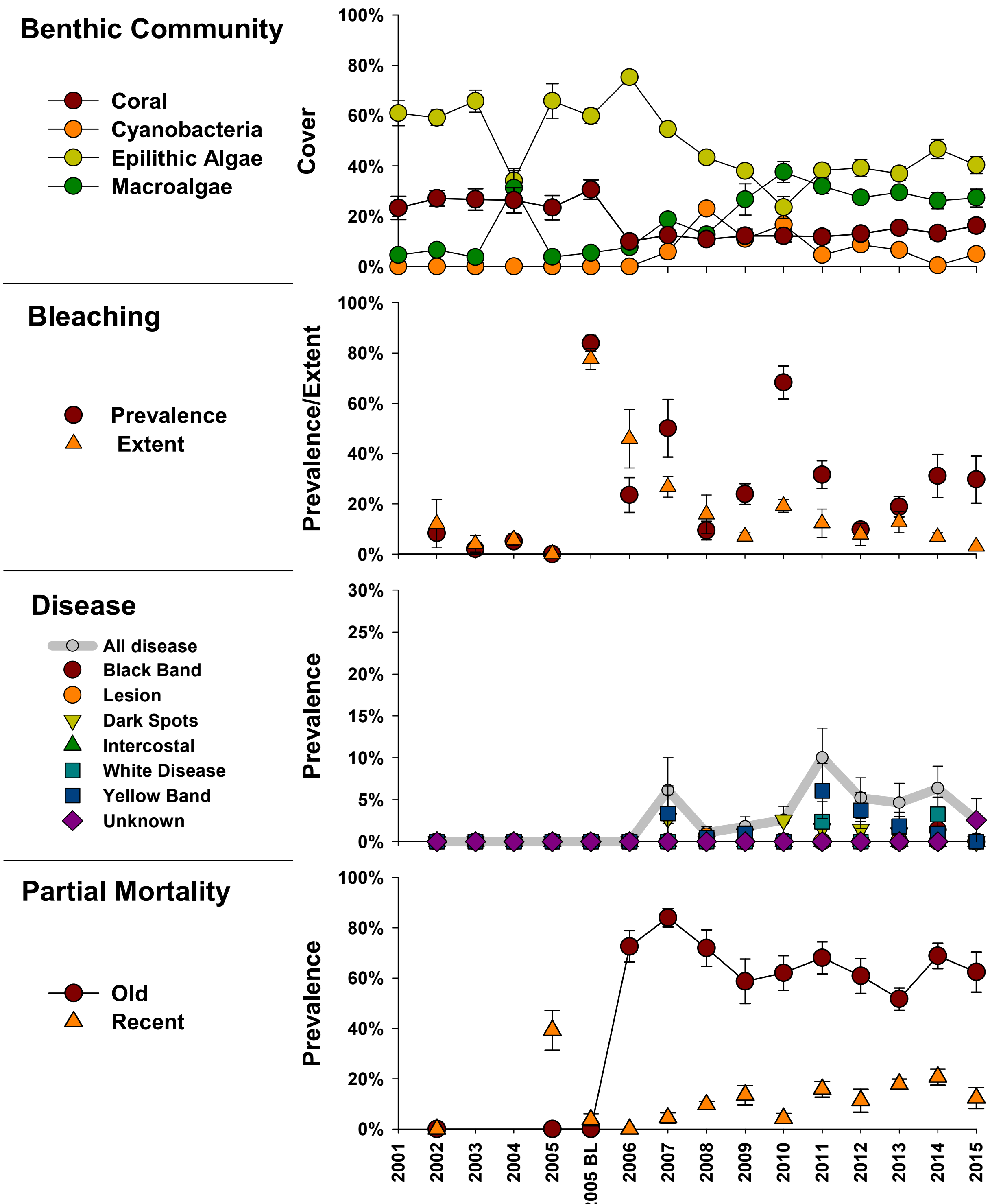


Figure 26. Cane Bay benthic cover and coral health through time (mean ± SE).

Fish Community. Cane Bay has a high diversity, abundance, and biomass of fish, reflecting the benthic diversity and high coral cover of the site. The most dominant fish species in terms of both abundance and biomass is the creole wrasse, zooplankton feeders. Also very common are other planktivorous fishes: the black durgeon, yellowtail snapper, and blue and brown chromis. Large parrotfishes can regularly be observed on the Cane Bay site, including adult queen and stoplight parrotfish. A variety of other herbivores are common, especially princess parrotfish, redband parrotfish, and blue tang. Mahogany snapper and graysby dominate the piscivores group. Other than these, no snapper or grouper were observed on the Cane Bay reef. Nonetheless the site has a high diversity of fish, with several butterflyfish and squirrelfish species present, as well as some deeper water species (sunshinefish, longsnout butterflyfish, and fairy basslet) due to the site's close proximity to the deep wall drop.

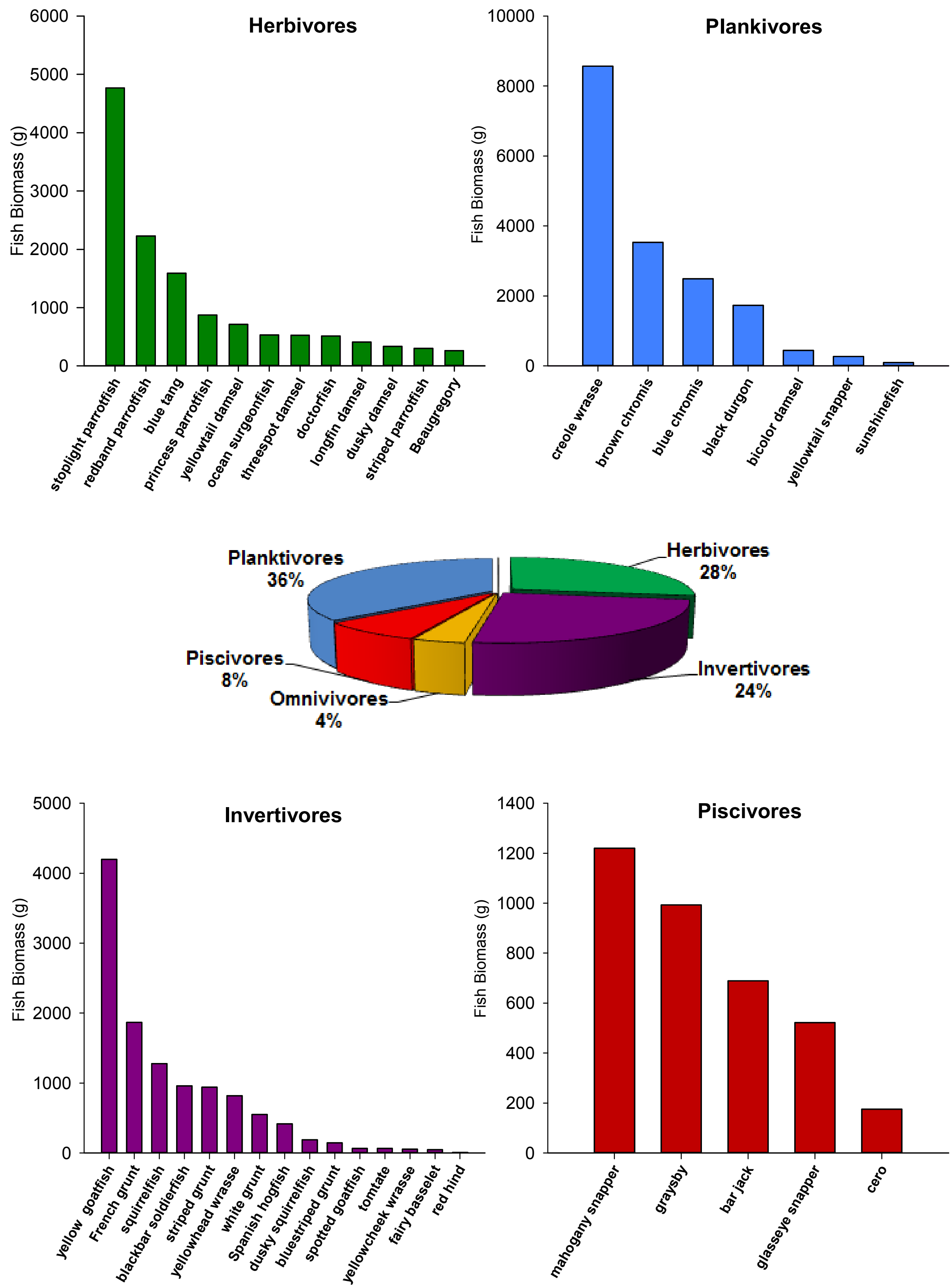


Figure 27. The Cane Bay fish community by absolute and relative biomass.

CANE BAY DEEP

Description. The Cane Bay Deep monitoring site is a mesophotic wall coral reef environment just downslope from the Cane Bay site. The reef is composed of deep spurs of coral interspersed with sediment. Cane Bay Deep was first surveyed during the 2005 coral bleaching event, but a permanent monitoring site was not established until 2009.

Outstanding Feature. Cane Bay Deep is one of the most impressive wall environments in the Caribbean and is the crown jewel for St. Croix dive tourism and biodiversity.

Threats. Although Cane Bay is economically important via dive tourism, it is under no special protection. Cane Bay Deep is threatened by sediment, fishing, climate change, and recreational overuse. Sediment cascades down from the shallow reef. Fishing occurs even at the deep reef evidenced by the presence of lost gear (monofilament and trap lines).

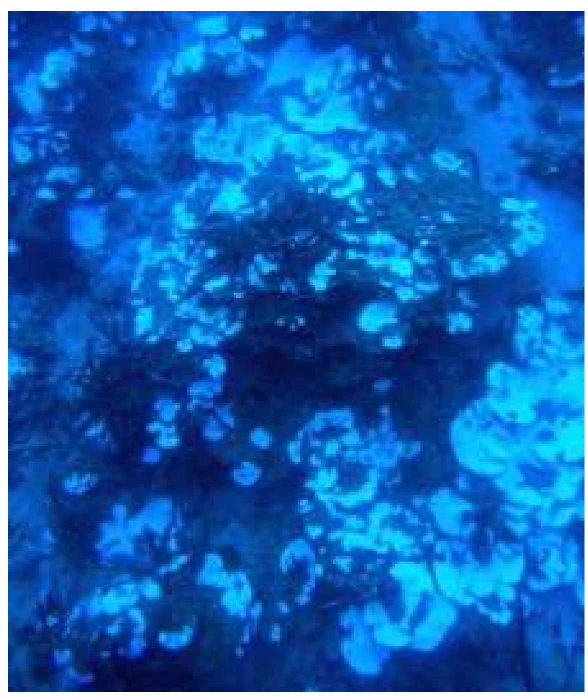


Figure 28. Cane Bay Deep. (top) Location. (right) A representative photo of the reef during the 2005 bleaching event. Bleached colonies are 0.5 – 3 m wide.

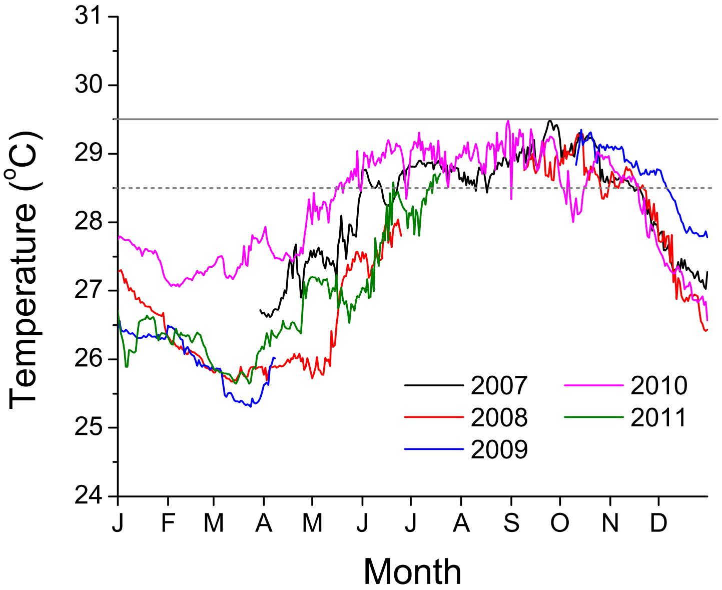


Figure 29. Cane Bay Deep temperature (39 m depth).

Physical Characteristics

Current. Cane Bay Deep is a calm wall environment that is buffered from water motion. However, it does receive sediment cascades from particles resuspended from the upper reef terrace. These flows are directed in the depressions between spurs.

Temperature. Cane Bay Deep temperatures are buffered in the warmest months by the presence of the thermocline. However, internal tide activity at this site is not as strong as in deep (~40 m) sites on the south shelf of St. Thomas, leading to less diurnal variability in temperatures. This may make the mesophotic wall environments more susceptible to bleaching than other mesophotic sites on the southern Puerto Rican shelf.

Benthic Community. Cane Bay Deep is a mesophotic plating coral community dominated by lettuce corals (*Agaricia* spp.), sponges, gorgonians, and black coral. The algal community is mostly epilithic algae, but there are also quantities of *Dictyota* spp. and *Lobophora variegata*. A high proportion of the substrate is soft sediment that flows from the upper shelf to deposit in grooves. Benthic cover was not measured until 2009.

Coral Health. Surprisingly for a dim and cooler mesophotic reef, Cane Bay Deep corals bleached heavily in the 2005 coral bleaching event by both prevalence and extent. Low-extent coral bleaching is very prevalent even in years without thermal stress, a likely result of sediment deposition. Unknown diseases and dark spots diseases are prevalent in some years. Old partial mortality increased after 2005, and remained high and steady from 2009-2011.

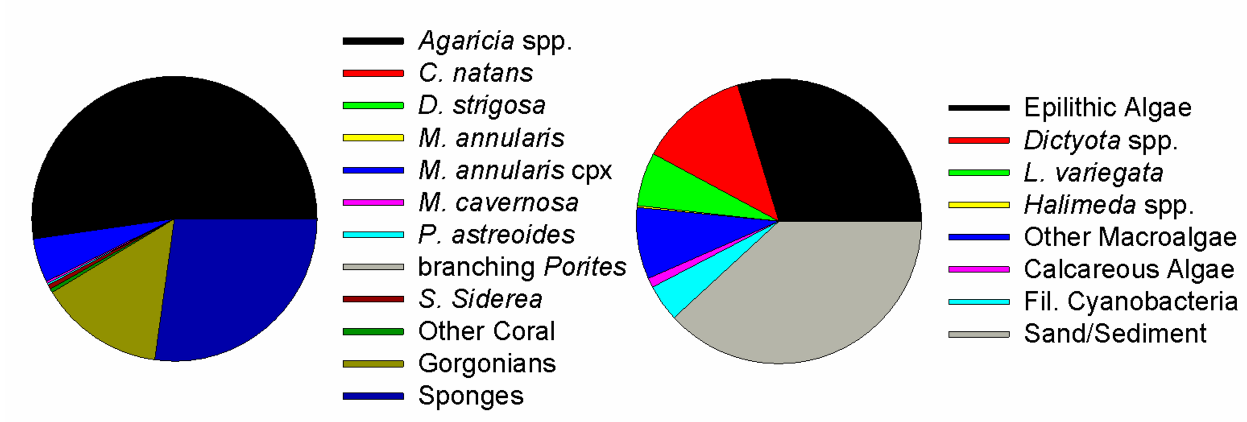


Figure 30. Cane Bay Deep. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

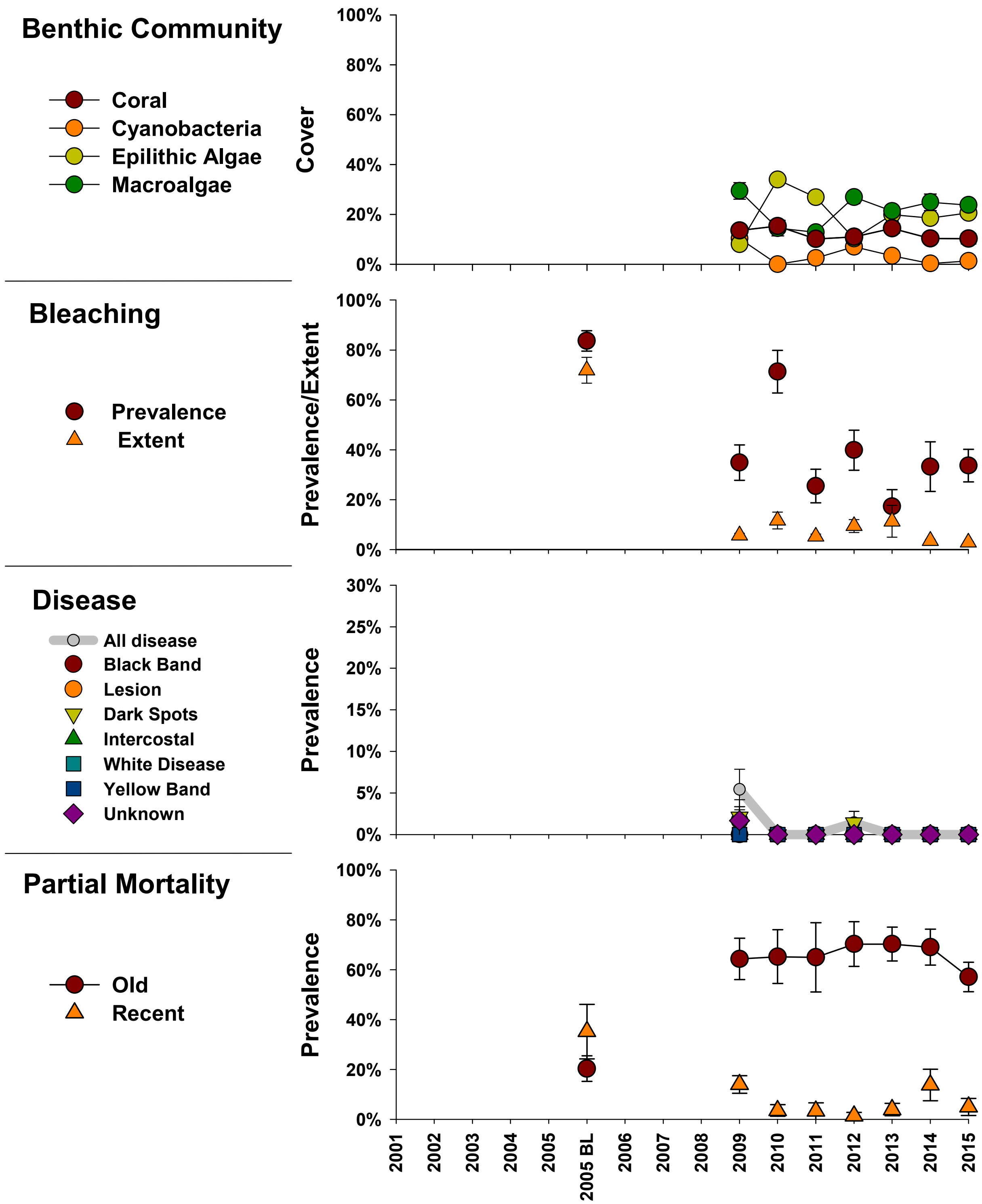


Figure 31. Cane Bay Deep benthic cover and coral health through time (mean ± SE).

Fish Community. Cane Bay Deep has maintained a very low fish biomass over the four year sampling period compared to both other mesophotic sites and shallow and midshelf sites of St. Croix. The site is dominated by invertivores, primarily planktivorous creole wrasse and blue chromis. This planktivorous community is depauperate compared to that of Salt River Deep, the reef wall site slightly east, probably due to less water movement and sediment deposition. Herbivores present are primarily benthic feeders: sub-adult princess parrotfish, redband parrotfish, and doctorfish. There is very low piscivorous biomass on the reef, generally made up of schoolmaster snapper, mahogany snapper, graysby, and an occasional barracuda. Deep water species such as the bantum bass, fairly basslet, cherubfish, and sunshine fish are common.

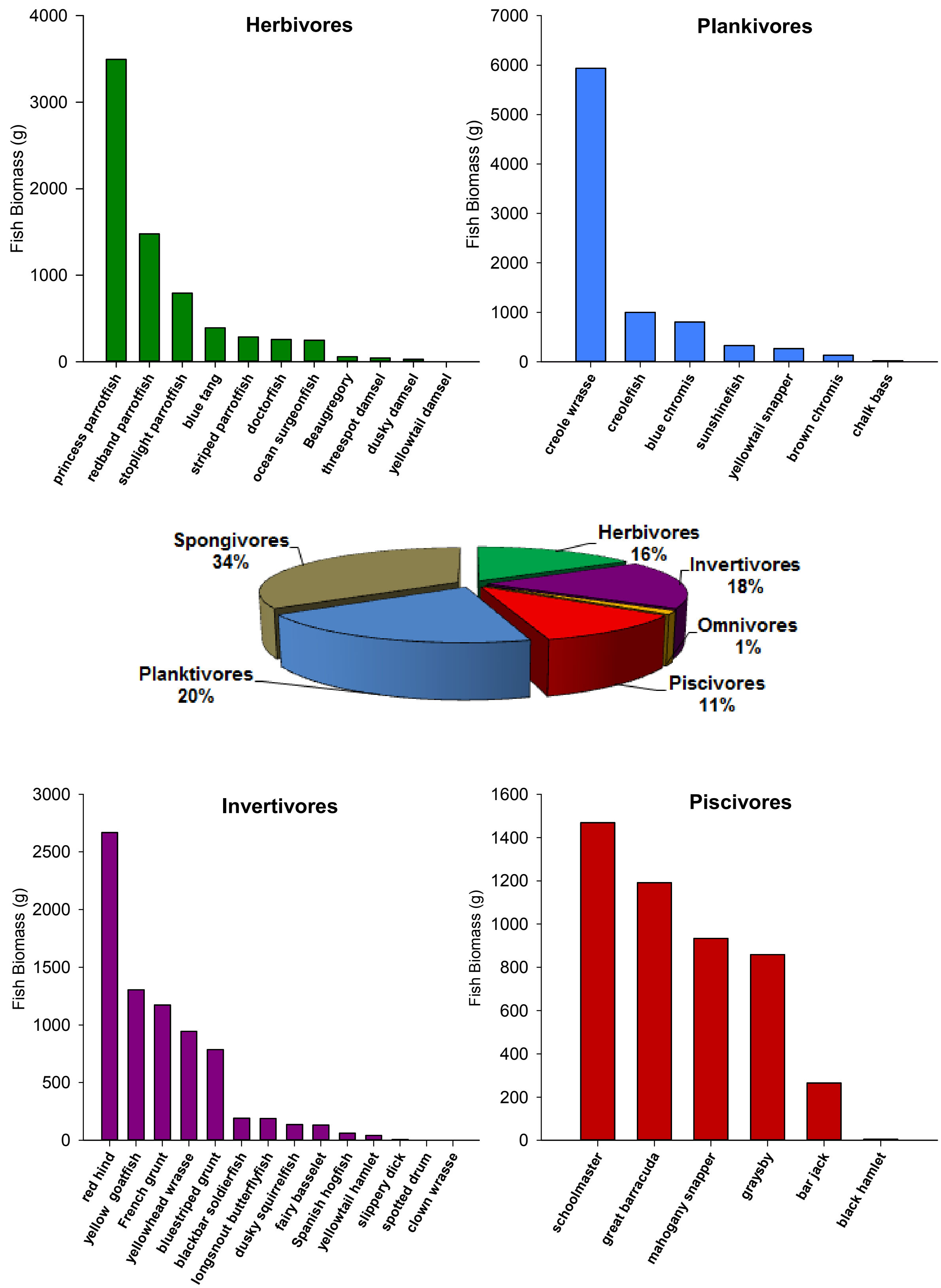
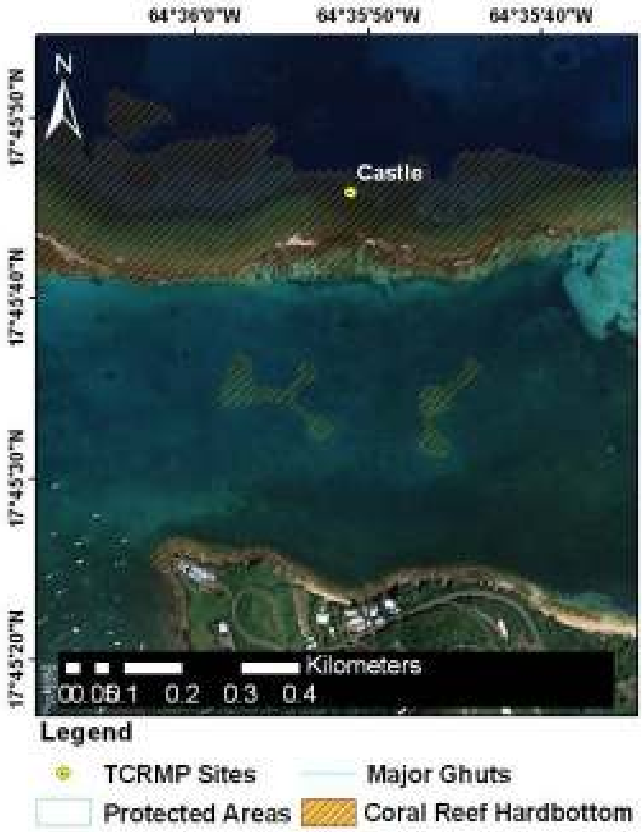


Figure 32. The Cane Bay Deep fish community by absolute and relative biomass.

CASTLE

Description. Castle (aka. West Indies Lab) is part of the seaward northeastern St. Croix barrier reef complex outside Teague Bay. The reef starts at sea level as a relict elkhorn coral reef and is dominated by boulder star corals along the seaward edge. The area around the Castle site was monitored initially in 2003, but permanent transect were not installed until 2008.



Outstanding Feature. Castle is part of the once luxurious living elkhorn coral barrier reef that protects the northeastern St. Croix shoreline. It was a research area of the former West Indies Laboratory of Farleigh Dickenson University, which was a seminal area for global coral reef research from the 1970's and 1980's.

Threats. The barrier reef outside Teague Bay is inside the St. Croix East End Marine Park, but is in the open fishing zone. There is relatively low potential for land-based sources of pollution due to the sites midshelf location in front of a lightly populated area. Clear water and warm temperatures make this an area of potential concern during bleaching events.

Figure 33. Castle. (top) Location. (right) A representative photo of the reef.

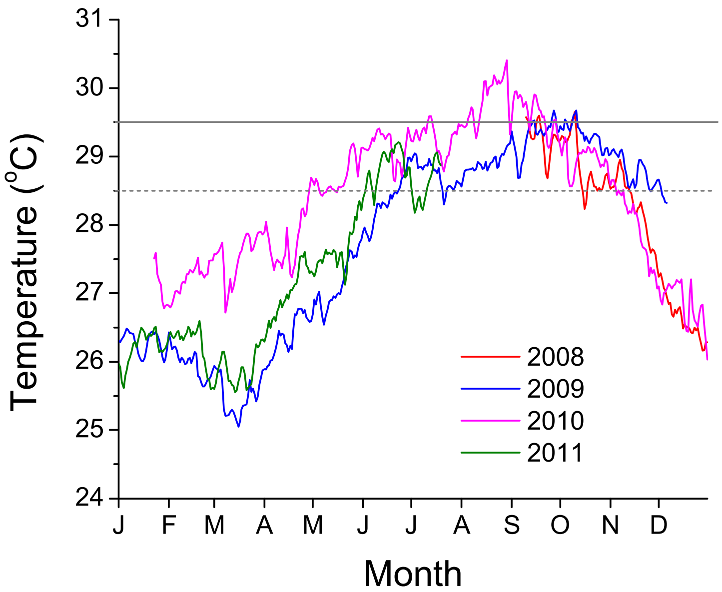


Figure 34. Castle benthic temperatures (9 m depth).

Physical Characteristics

Current. Little is known about the current at the Castle site. It is under the influence of wave-driven oscillatory flow in the shallows, but strong directional currents have not been experienced during monitoring activities.

Temperature. Castle has the potential to develop very warm temperatures and spent nearly a month above the bleaching threshold in 2010.

Benthic Community. The Castle site is unusual for its dominance of branching *Porites* corals along the slope and concentrations of *Orbicella* spp. corals at the outer fringe adjacent to sand. The algal community is dominated by epilithic algae, with lesser abundance of *Dictyota* spp.. Macroalgae and filamentous cyanobacteria are also common. The impacts of the 2005 bleaching event are not known since monitoring in 2003 was not necessarily in exactly the same spot and the site was not monitored in 2005.

Coral Health. Bleaching is mild at the site. Corals were assessed prior to but not during the 2010 coral bleaching event. Old partial mortality is high in prevalence and steady. Recent partial mortality is particularly high at the site, and this may be a consequence of numerous damselfish (*Stegastes* spp.) and predatory snails (*Coralliophila* spp.) on large *Orbicella* spp. colonies.

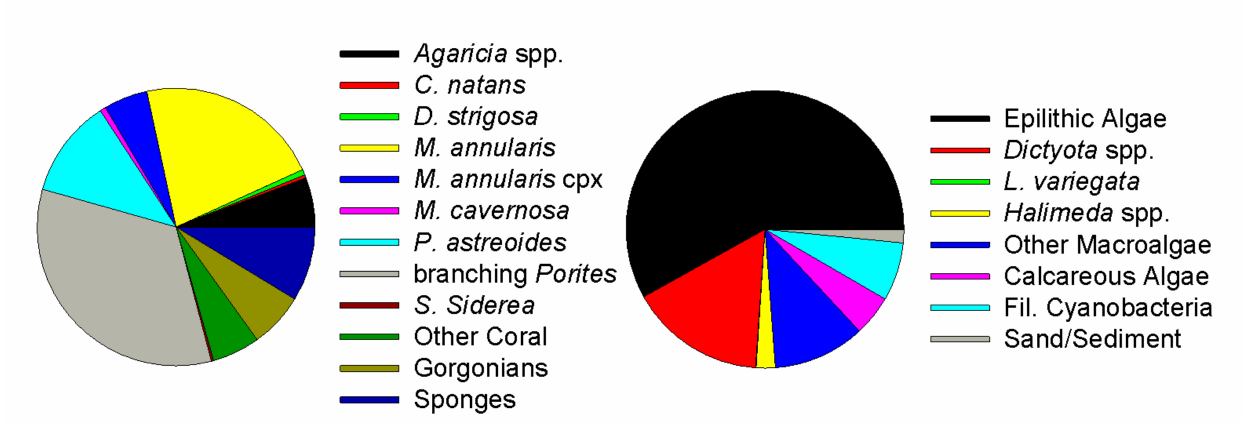


Figure 35. Castle. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

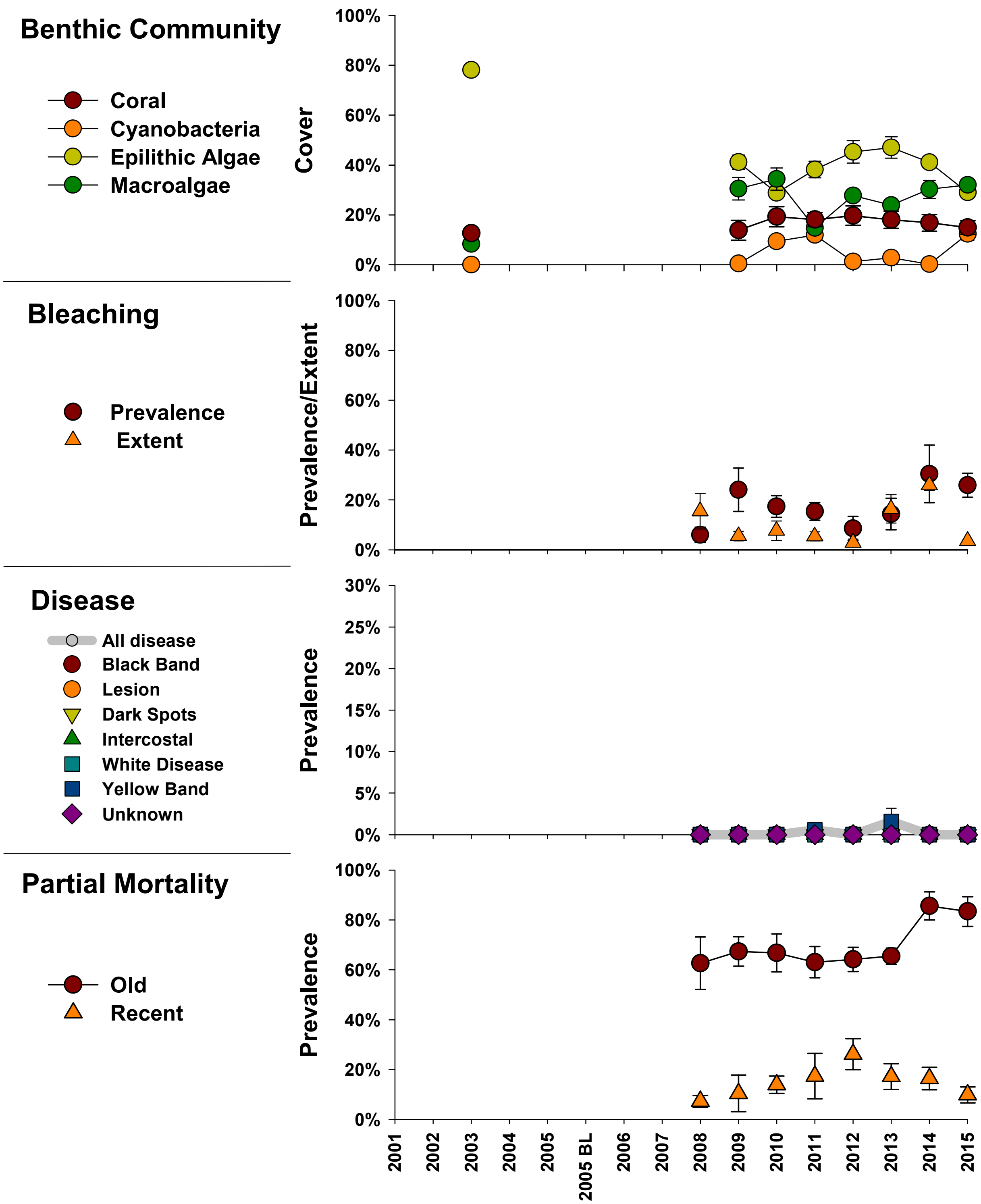


Figure 36. Castle benthic cover and coral health through time (mean ± SE).

Fish Community. The Castle fish community is typically lower in overall abundance and biomass than most of the St. Croix offshore sites. It is dominated by herbivores in biomass, driven by a few large stoplight parrotfish. However, sub-adult and juvenile redband, striped, and princess parrotfish are numerically much more common than stoplight. All three Acanthurids (ocean surgeonfish, blue tang, and doctorfish) are common, as are many species of damselfish. Invertivores are also fairly high in biomass and are a diverse group; dominated by benthic feeders such as yellow and spotted goatfishes, as well as blackbar soldierfish and squirrelfish. Piscivore biomass in recent years has been heavily dominated by the invasive lionfish. No serranids other than hamlets and tiny basslets are ever seen there.

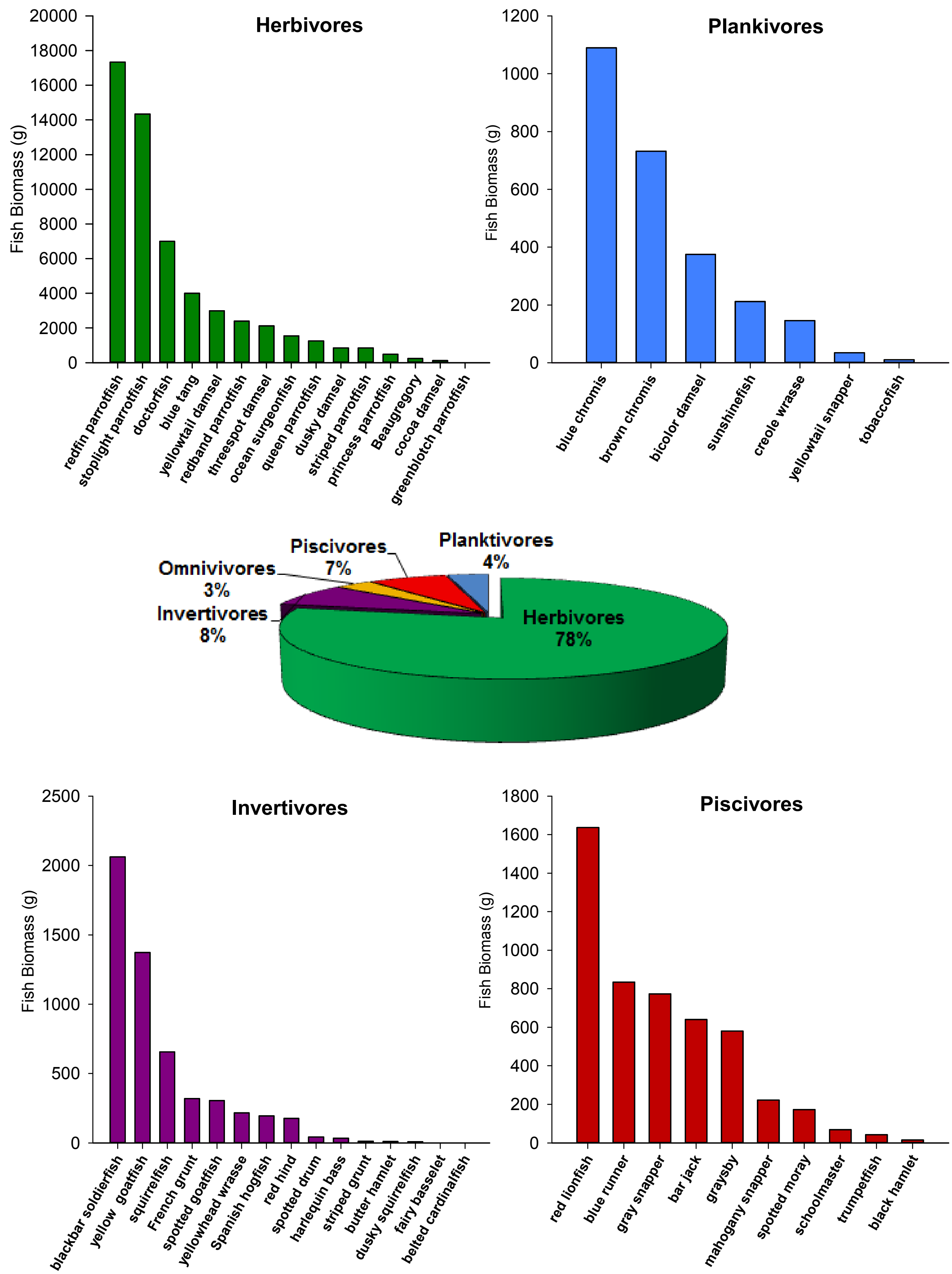
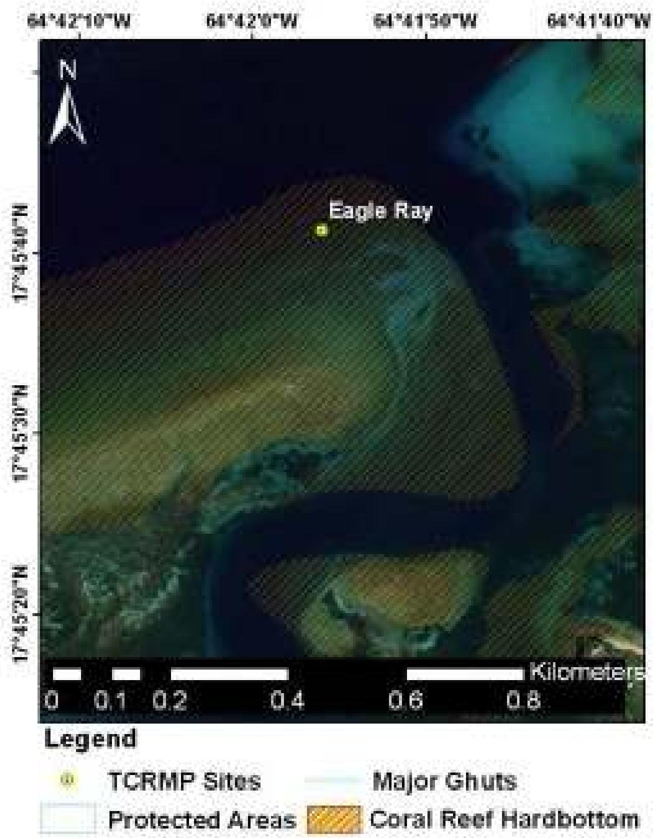


Figure 37. The Castle fish community by absolute and relative biomass.

EAGLE RAY



Description. The Eagle Ray site is a shallow seaward barrier reef located at west dive buoy 1 outside the main Christiansted access channel. The monitoring site is colonized hardbottom to coral reef, with more extensive development of reef at the seaward edge. Eagle Ray has been monitored since 2001.

Outstanding Feature. Eagle Ray is one of the most visited dive sites due to its proximity to Christiansted.

Threats. Proximity to Christiansted increases the potential for land-based sources of pollution, such as sewage, run-off, and marine debris. The site is frequented by small fishing craft that venture just out of port, likely increasing the fishing pressure.

Figure 38. Eagle Ray. (top) Location. (right) A representative photo of the reef.

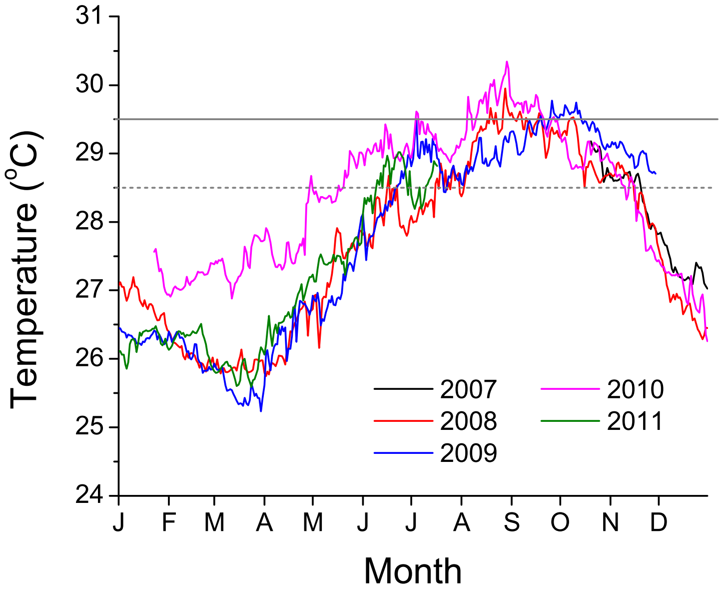


Figure 39. Eagle Ray benthic temperature at 9 m depth

Physical Characteristics

Current. Currents have not been measured at Eagle Ray; however, strong unidirectional currents seem rare. There are increased oscillatory currents near the shallow portion of the site.

Temperature. Eagle Ray is shallow but near deep water on two sides, which may potentially help to reduce thermal stress.

Benthic Community. Eagle Ray supports a diverse community of small coral colonies, but sponges and gorgonians compose half the sessile epibenthic animal community. Coral cover has been low (less than 10%) throughout the monitoring period. Coral cover decreased only slightly with the 2005 coral bleaching event, 11.7%, but cover has come back and actually increased above pre-bleaching values. The limited response may be partly due to the high relative abundance of more thermally resistant coral species. The site was dominated with epilithic algae; however, this has declined after the 2005 bleaching event with a concomitant increase in macroalgae and filamentous cyanobacteria.

Coral Health. Eagle Ray corals were severely affected during the 2005 bleaching event with nearly all colonies bleached over about 80% of the colony surface. Low-level bleaching is also common in years without thermal stress. The site was only monitored prior to the 2010 bleaching event. Diseases are a common feature of the site, with black band, yellow band, and dark spots disease having outbreaks in certain years. Lesions were also common during the 2005 coral bleaching event. Old partial mortality became very prevalent after the 2005 coral bleaching event and subsided in the following years.

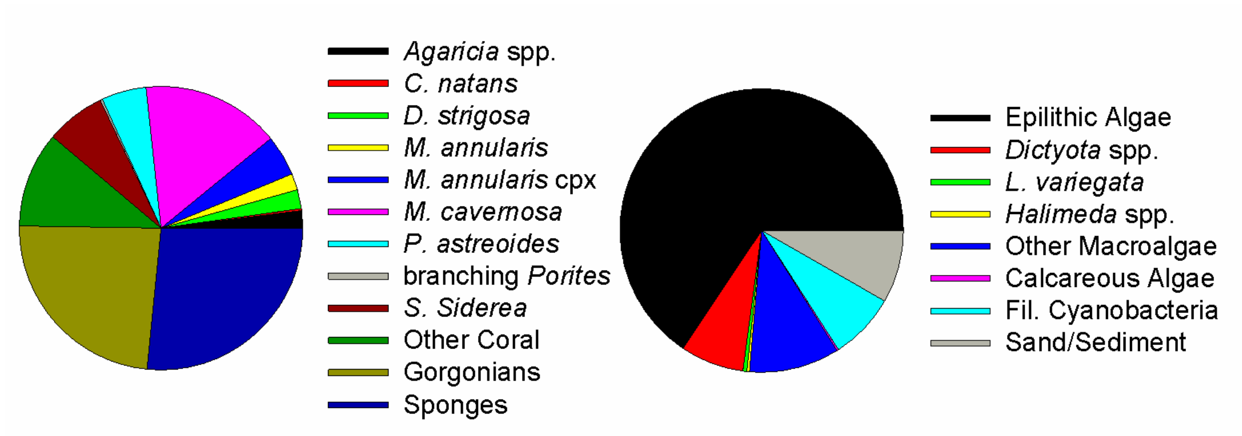


Figure 40. Eagle Ray. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

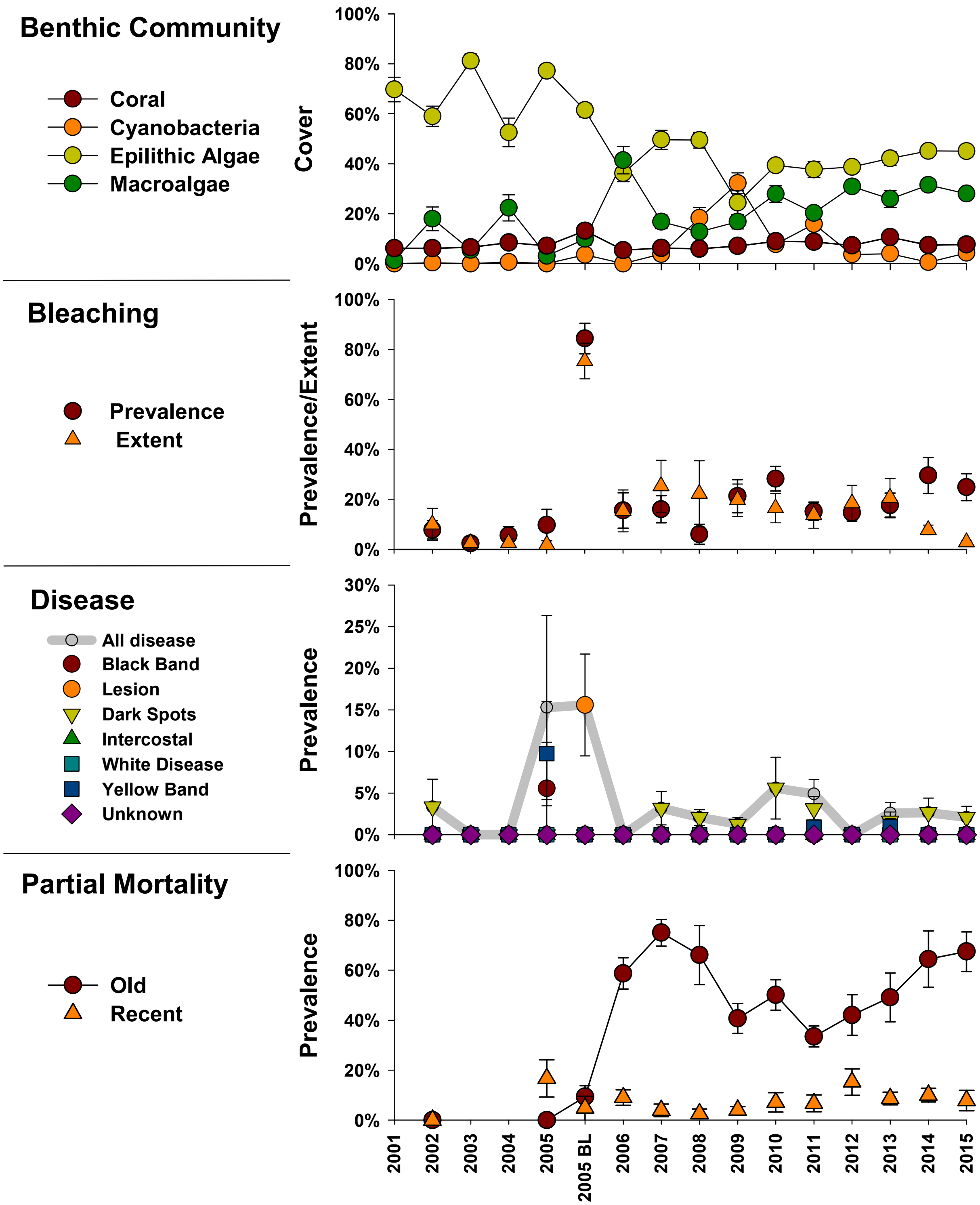


Figure 41. Eagle Ray benthic cover and coral health through time (mean ± SE).

Fish Community. Eagle Ray is a fairly diverse and rich site, especially considering the fishing and diving pressure it receives, as well as the proximity of Christiansted Harbor. It is dominated by herbivores and invertivores, with a large variety of parrotfishes and benthic feeders such as the blackbar soldierfish. Proximity to open deep water is evidenced by the occurrence of fairly high numbers of planktivorous creole wrasse and a few black durgeon. Yellowtail snapper are large and plentiful, probably due to the divers that frequent the site with fish food. Large jacks are common at the site and generally dominate the piscivores group. Graysbys are the most common serranid; no large serranids are ever observed on Eagle Ray. Overall the fish community, while lacking top predators, remains high in overall biomass and species richness.

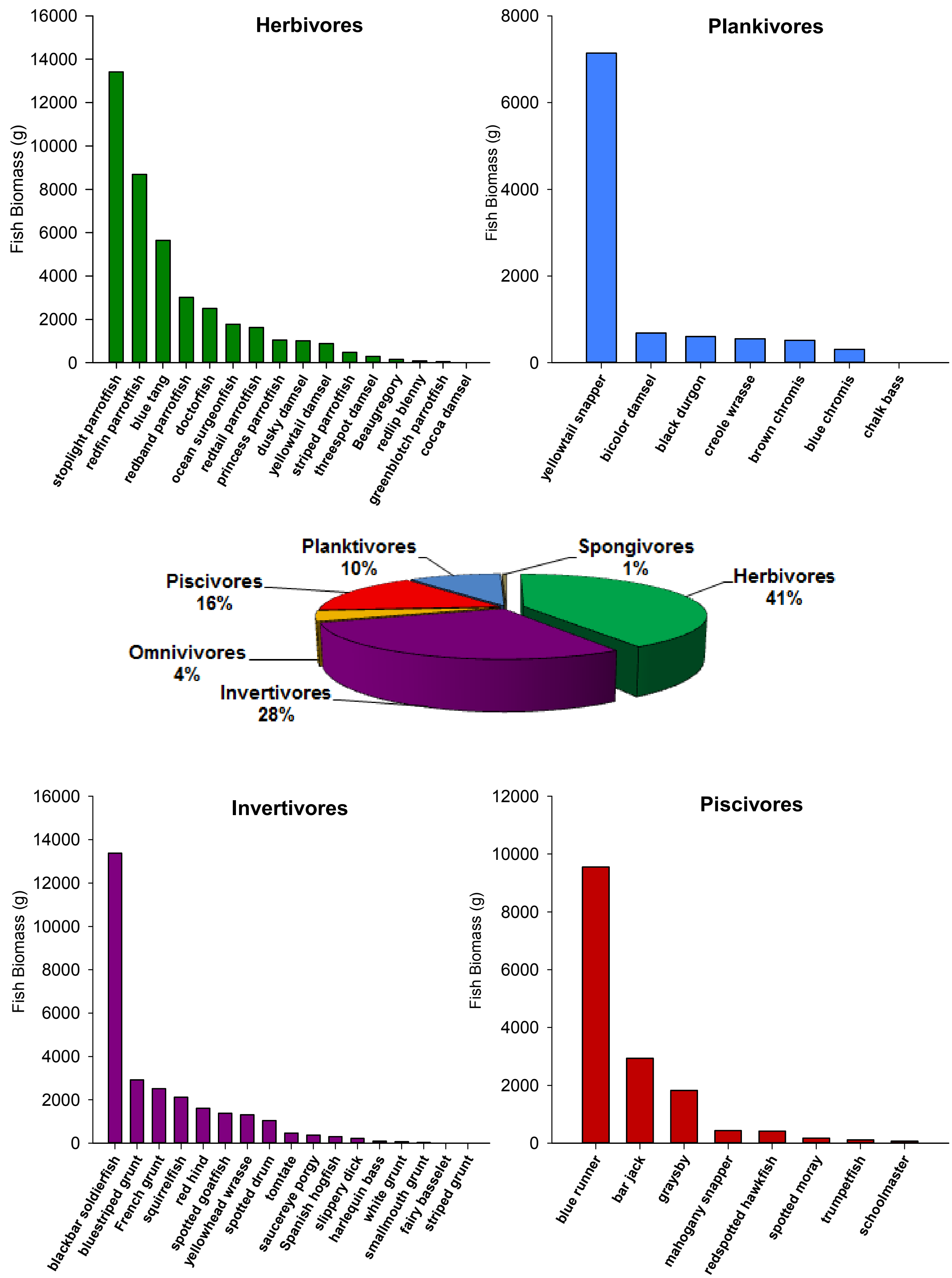
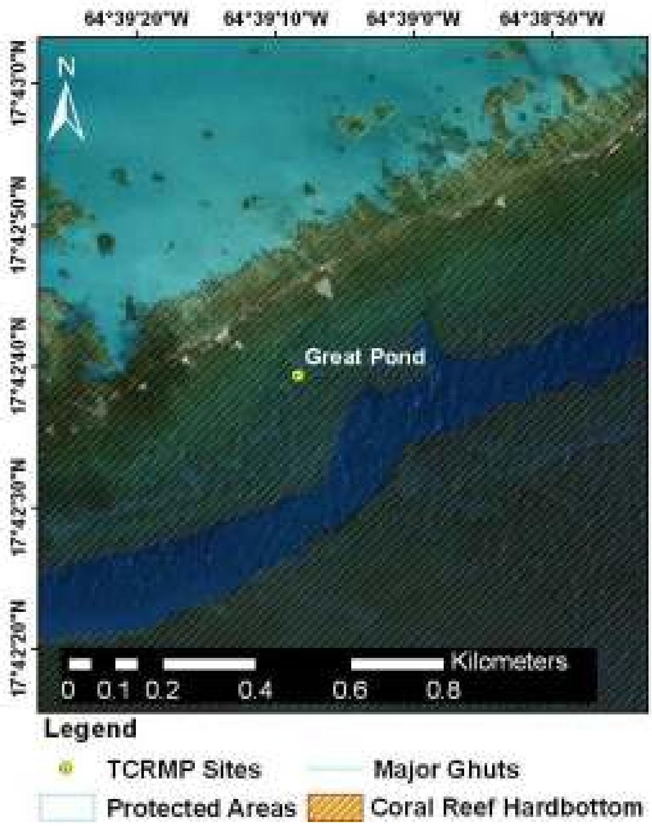


Figure 42. The Eagle Ray fish community by absolute and relative biomass.

GREAT POND

Description. The Great Pond monitoring site is a wave-washed shallow barrier reef that was formerly an elkhorn coral reef in depths of 5-7 m. The reef is part of the barrier reef front surrounded by patch reefs and sand. Great Pond has been monitored since 2003.



Outstanding Feature. Great Pond hosts the largest population of the black spiny urchin *Diadema antillarum* of any TCRMP monitoring site, likely because of its shallow depth. It also hosts an abundance of large-bodied stoplight (*Sparisoma virde*) and yellowfin parrotfish (*Sparisoma rubripinne*) that likely spawn near the site.

Threats. The Great Pond monitoring site is located in the St. Croix East End Marine Park but outside the no-take fishery zone. If park rules are enforced, this site could see a return of fisheries species by spillover from adjacent protected areas. Because of high turbulence and low watershed development, sediment is not considered a problem; however, large industrial sites operate within 10 km, including the Hovensa Refinery, and could contribute to pollution.

Figure 43. Great Pond. (top) Location. (right) A representative photo of the reef.

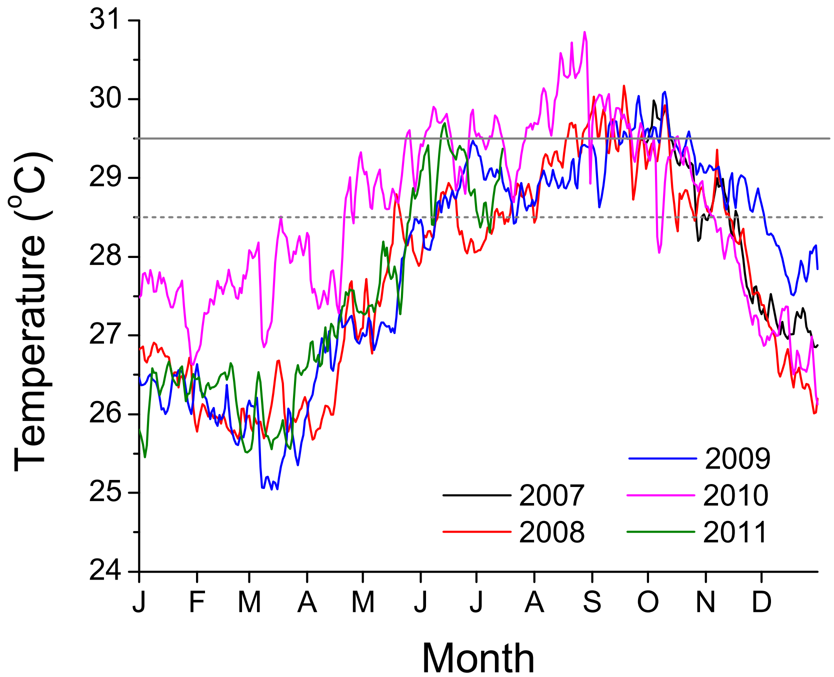


Figure 44. Great Pond benthic temperature (5 m depth).

Physical Characteristics

Current. Great Pond currents have not been measured directly. Wave-generated oscillatory currents dominate and this is the most regularly swell-influenced site in the TCRMP making work conditions difficult on all but the calmest day. Strong unidirectional currents have not been experienced.

Temperature. Great Pond typically experiences very high temperatures in August to October, with temperatures peaking at nearly 31°C in 2010.

Benthic Community. The Great Pond site is unusually dominated with the mustard hill coral (*Porites astreoides*) and *Diploria strigosa*. It is also the only site with a relatively high abundance of *Diploria clivosa.* The site lost 55.9% of its coral cover in the 2005 bleaching event, but has regained about half as of 2011. Macroalgal blooms occur occasionally (2007 and 2011), but the site is dominated by epilithic algae.

Coral Health. Great Pond corals were moderately affected during the 2005 coral bleaching event, which may be a reflection of the high composition of resistant coral species and the regular exposure to high temperatures. The site was not monitored during the height of the 2010 coral bleaching event. Patchy, low-level bleaching is common in some years. Diseases have been almost non-existent at the monitoring site. Partial mortality is variable and has not shown consistent trends over years.

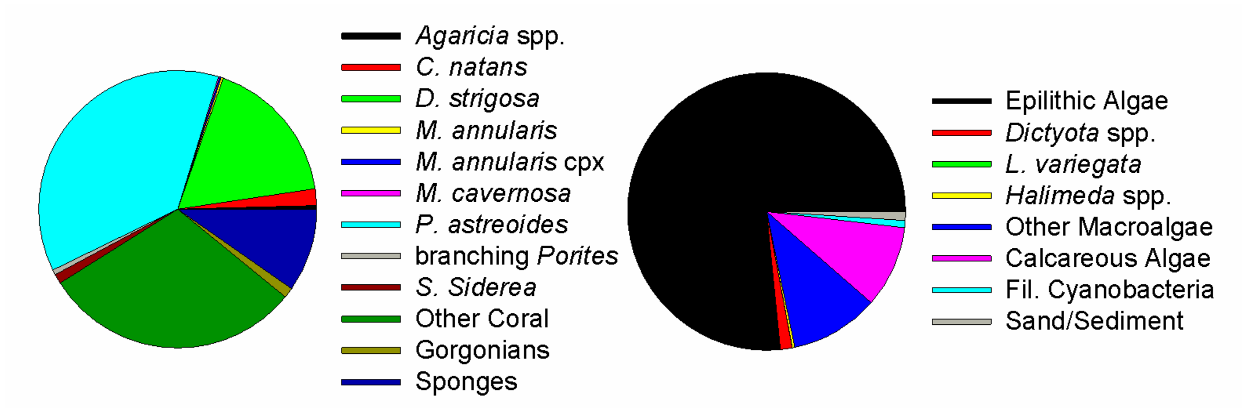


Figure 45. Great Pond (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

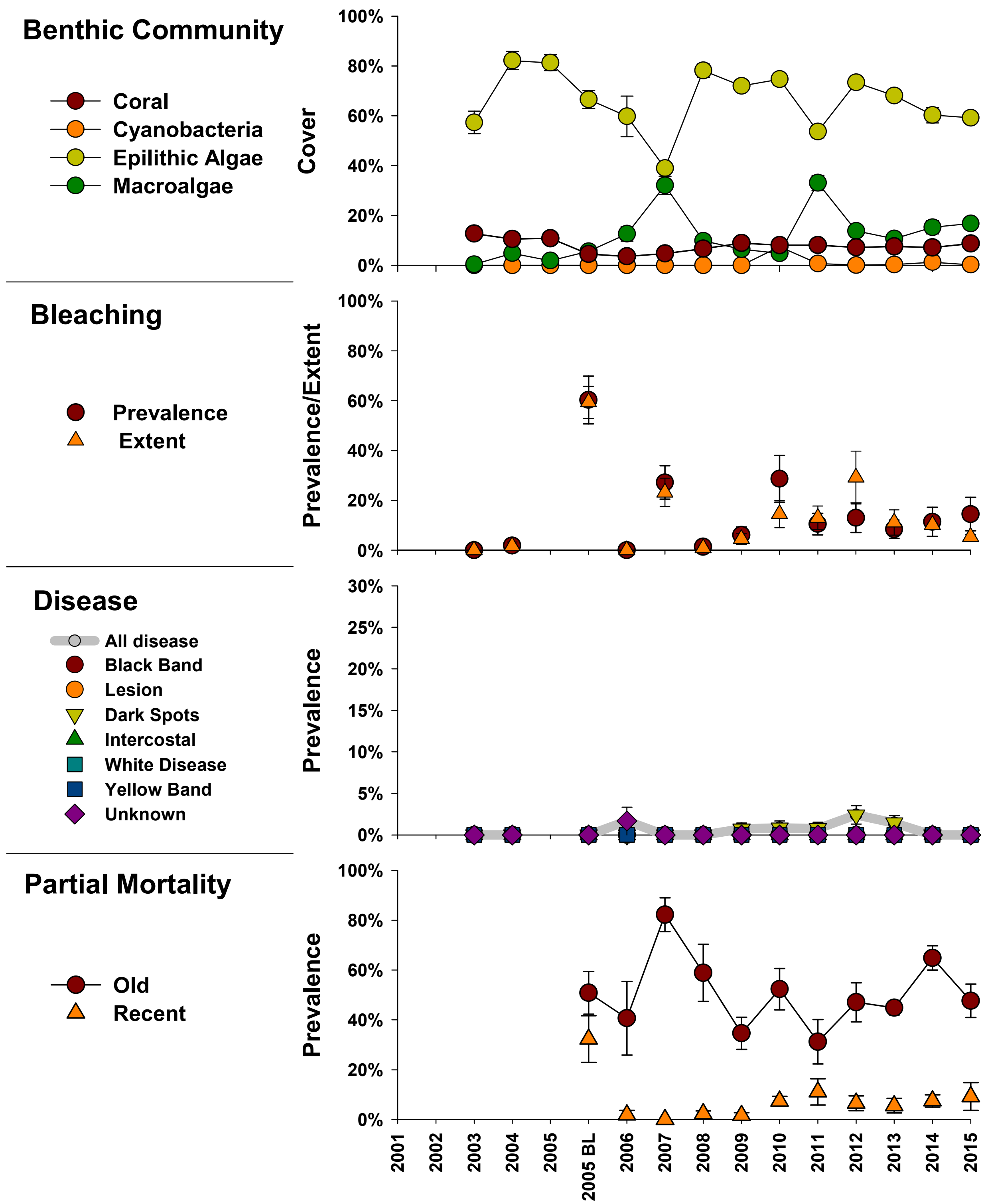


Figure 46. Great Pond benthic cover and coral health through time (mean ± SE).

Fish Community. The Great Pond fish community is dominated by herbivores. The primary herbivores at the site are the yellowtail damselfish and blue tang, which swim in foraging schools feeding on algae covering the relict elkhorn coral. Also present are large queen and stoplight parrotfish, which can also be seen foraging in large groups, and a probably spawning in the late afternoon and evening hours at or near the site. These fish concentrate around the "piles" of skeletal remains of *Acropora* across Great Pond. Between these areas, fish biomass is low and is primarily made up of yellow goatfish, wrasses, and juvenile parrotfish. Piscivores at Great Pond are limited almost entirely to mahogany snapper and bar jacks. Benthic invertivores are dominated in biomass by yellow goatfish and blackbar soldierfish, however the wrasse diversity is high on the site and includes slippery dicks, clown wrasse, yellowhead and bluehead wrasse, rainbow wrasse, puddingwife, and Spanish hogfish.

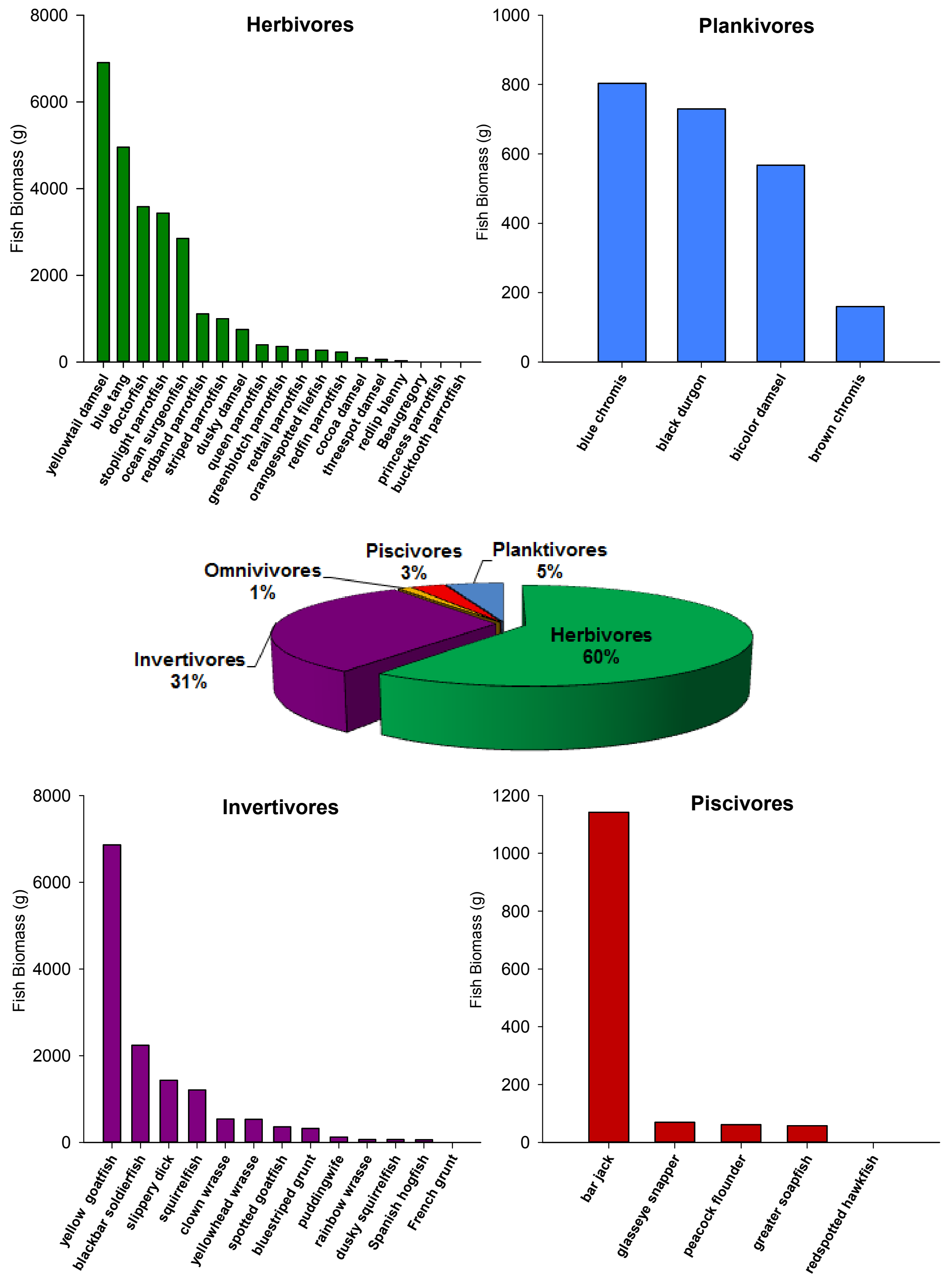


Figure 47. The Great Pond fish community by absolute and relative biomass.

JACKS BAY

Description. The Jacks Bay monitoring site (aka Jacks/Isaacs Bay) is part of fringing reef, colonized hardbottom on the southeast point of St. Croix in water depths of 13-16 m. The monitoring site is just inward from the shelf break and seaward reef slope, which terminates in a sand plain at about 20 m depth. Jacks Bay is largely a carbonate hardbottom with scattered hard coral, although there are some large coral heads seaward of the transects. Permanent transects were installed at Jacks Bay in 2001.

Outstanding Feature. Jacks Bay hosts a unique fish community with high abundance of small wrasses and the occasional occurrence of red hind (*Epinephelus guttatus*).

Threats. Jacks Bay is within the St. Croix East End Marine Park but lies just outside the restricted fisheries area and is open to fishing. High turbulence and no watershed development mean there is low threat of land-based sources of pollution at this nearshore site.

Figure 48. Jacks Bay. (top) Location. (right) A representative photo of the reef.

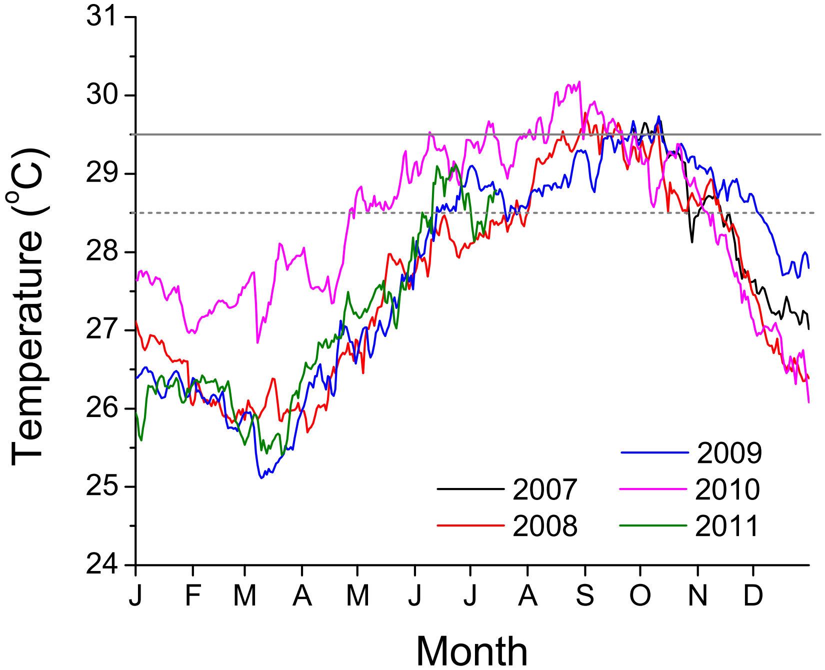


Figure 49. Jacks Bay benthic temperature at 12 m depth

Physical Characteristics

Current. Jacks Bay currents have not been measured directly. There are weak unidirectional currents, but there is a propensity for strong wave-generated oscillatory currents due the open coast southeast exposure.

Temperature. Jacks Bay can experience high temperatures during August to October.

Benthic Community. The Jacks Bay site has low coral cover (<10%) and is the only TCRMP site dominated by the great star coral *Montastraea cavernosa*. Jacks Bay lost 44.7% of its coral cover in the 2005 coral bleaching event, but had regained about 32% of the loss by 2011. Over half of the sessile epibenthic community is composed of gorgonians and sponges and the site might be considered more a colonized hardbottom than true coral reef. The algal community is composed of high proportions each of epilithic algae, macroalgae, and filamentous cyanobacteria. The site also shows a high degree of sand intermixed with filamentous algae, an important deterrent for coral larval settlement (Bellwood and Fulton 2008). This site is often colonized by fleshy upright brown algae, such as *Turbinaria turbinata* and *Sargassum hystrix* (species unconfirmed). Very large beach wrack of these brown algae can often accumulate on the windward beaches behind the site.

Coral Health. The Jacks Bay site was strongly affected during the 2005 bleaching event and was moderately affected during the 2010 bleaching event. Disease prevalence was low and only dark spots disease was present. Recent partial mortality was high during the 2005 bleaching event, likely reflecting the fact that surveys were conducted in November 2005 when mortality had begun. Old partial mortality increased greatly after the 2005 bleaching and then declined to stable levels in 2009-2011.

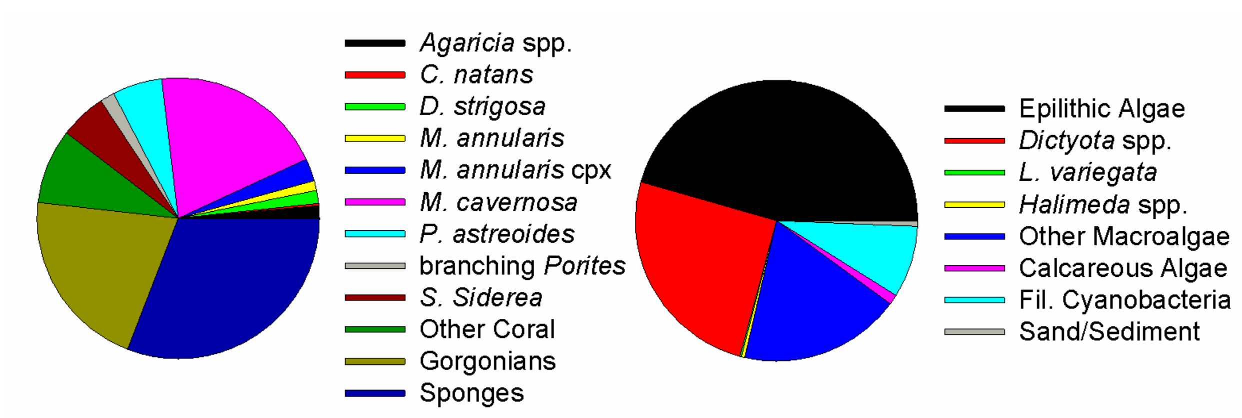


Figure 50. Jacks Bay (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

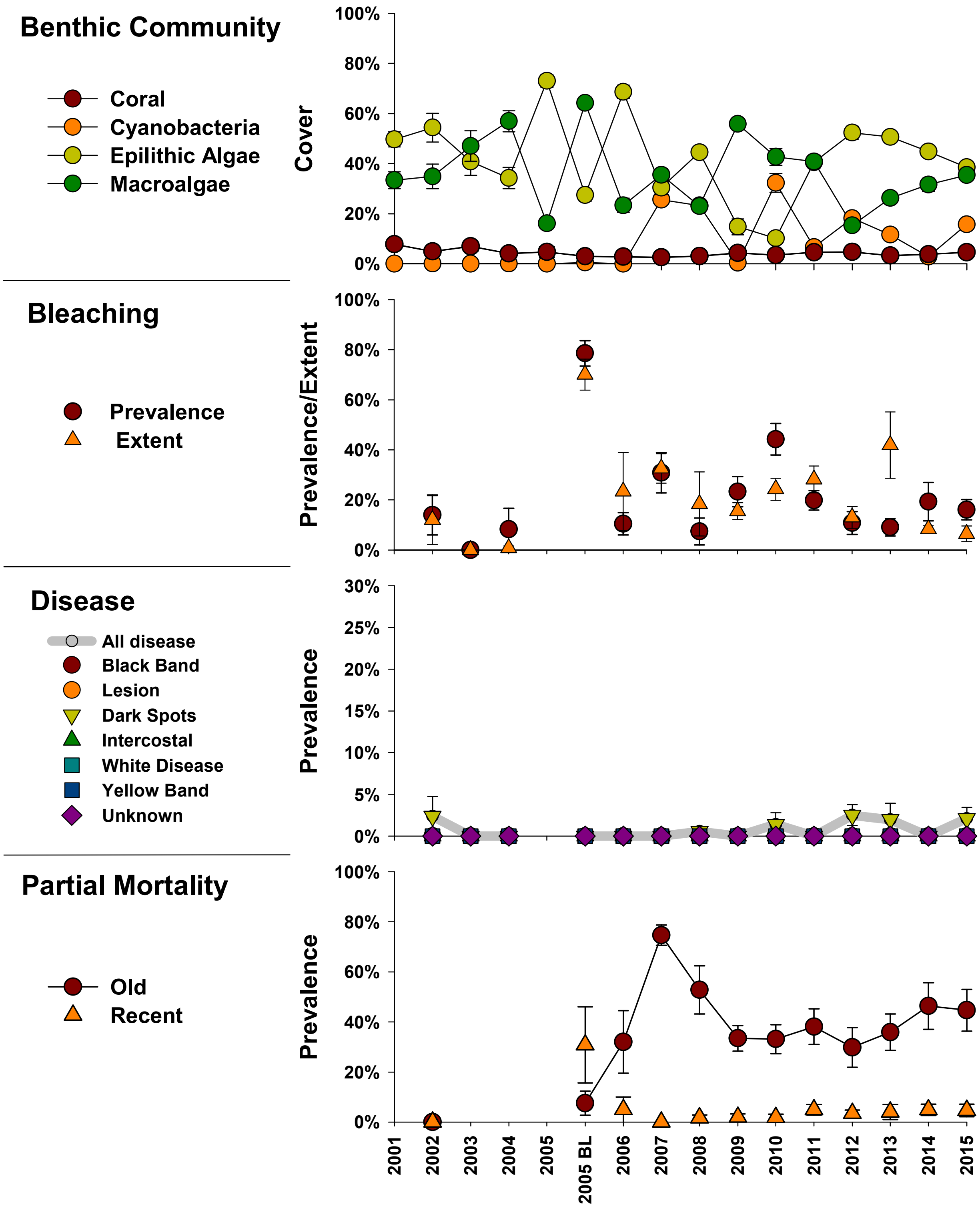


Figure 51. Jacks Bay benthic cover and coral health through time (mean ± SE).

Fish Community. The Jacks Bay fish community is characterized by very low fish biomass and abundance but relatively high diversity. The site is primarily hard bottom, adjacent to more developed coral reef on the seaward edge, over which larger fishes are observed. The hardbottom community is highly dominated numerically by blue chromis, yellowhead wrasse, and bicolor damselfish. Juvenile wrasses and parrotfish swim and hover in mixed schools among the rubble and gorgonians. Slippery dicks, clown wrasse, rainbow wrasse, and blackear wrasse are also fairly common. Angelfishes are common across the hardbottom. Piscivores are always rare and limited to schoolmaster, bar jack, glasseye snapper, and redspotted hawkfish. Medium to larger sized species are very rare, and nearly all of these species are seen at Jacks Bay in the juvenile life history stage.

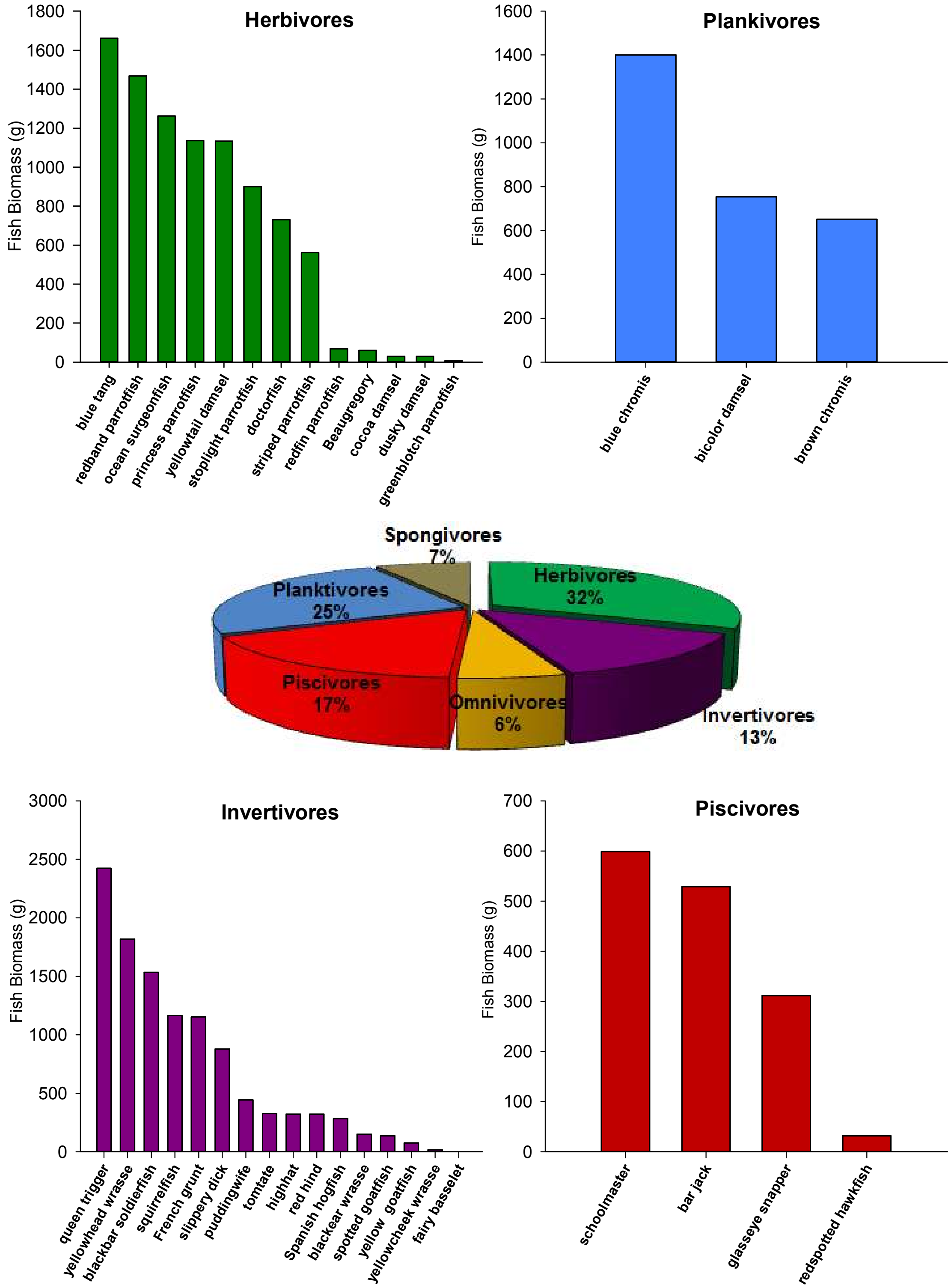
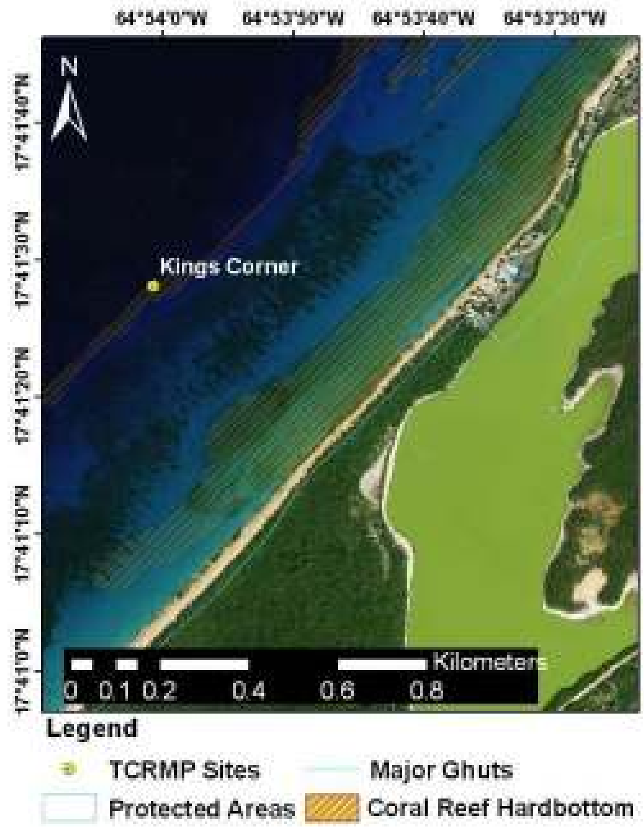


Figure 52. The Jacks Bay fish community by absolute and relative biomass.

KINGS CORNER

Description. The Kings Corner monitoring site is a part of a patchy reef complex along the steeply sloping west coast of St. Croix in depths of 15-25 m. The reef contains a high diversity of corals and sponges on mounds surrounded by sand. Kings Corner has been monitored since 2006, with permanent transects installed in 2007.



Outstanding Feature. Kings Corner is a commercially important recreational dive site. The site supports a high diversity and density of fishes. It is also a very aesthetically pleasing site with high topographic relief.

Threats. Kings Corner is open to fishing and is easily accessible as part of the calm lee of western St. Croix near Frederiksted. Derelict fishing lines, fish traps, fish weights, and other marine debris are in evidence in and around the site. Large plumes of sediment that wrap around Sandy Point from the south coast of St. Croix also periodically affect the site. Plumes can drop visibility to near zero and lead to high incidence of sediment on coral and spotty bleaching.

Figure 53. Kings Corner. (top) Location. (right) A representative photo of the reef with a school of lane snapper (*Lutjanus synagris*).

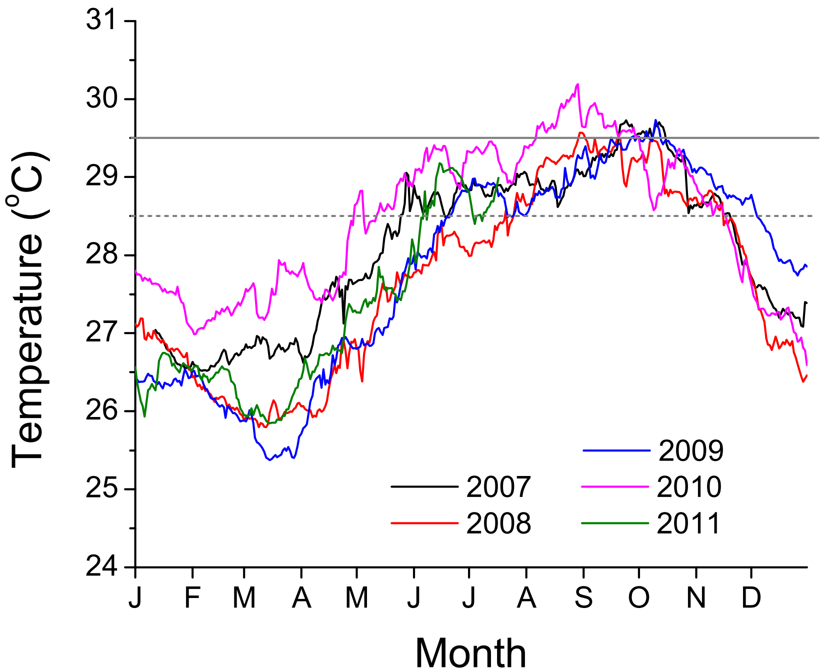


Figure 54. Kings Corner benthic temperature (17 m depth)

Physical Characteristics

Current. Kings Corner currents have not been measured directly. The site is protected from wave action, but can experience strong unidirectional currents at times, particularly at shallower depths.

Temperature. Kings Corner has moderately high temperatures.

Benthic Community. The Kings Corner site supports a diverse community of hard corals dominated by *Orbicella* spp. The site also has a very abundant population of sponges. This site was not monitored until after the 2005 bleaching event, so the impacts on coral cover are not known. Epilithic algae dominate the algal community at Kings Corner, with very low abundance of macroalgae and filamentous cyanobacteria. Sand is prominently interspersed among the coral banks.

Coral Health. Non-thermal bleaching with moderate prevalence but low extent on colonies is a common feature at this site, likely as the result of chronic sedimentation. The prevalence of coral diseases has been low with dark spots disease predominating. Old partial mortality has been very high at this site and may be an indication of impacts from the 2005 coral bleaching event. Old partial mortality has increased lately.

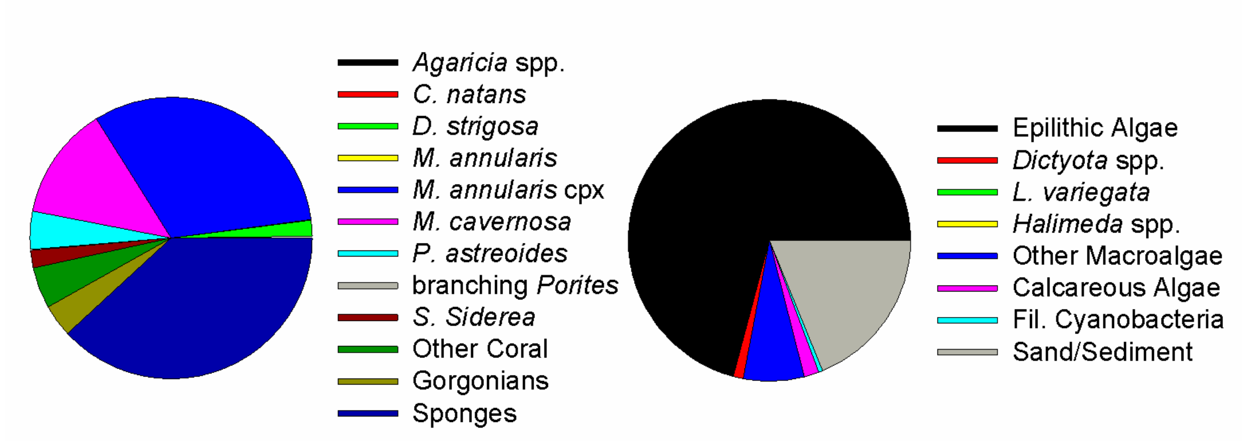


Figure 55. Kings Corner (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

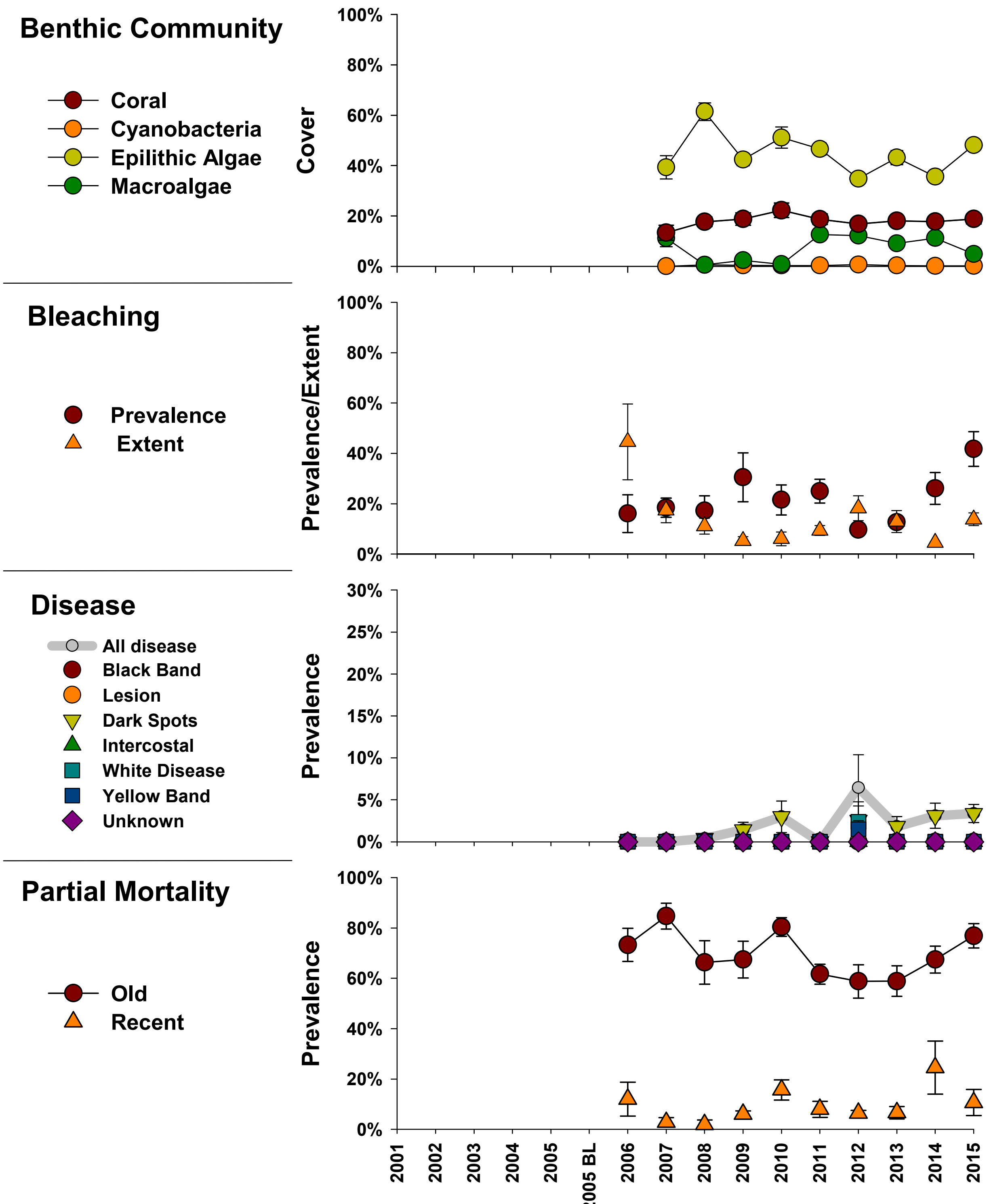


Figure 56. Kings Corner benthic cover and coral health through time (mean ± SE).

Fish Community. Kings Corner represents the most diverse fish community with the highest fish biomass in the St Croix monitoring program, with a huge variety of resources available for foraging and habitat. The site is dominated by invertivores, influenced highly by the large numbers of the nocturnal feeding blackbar soldierfish, a zooplanktivore, and the tomtate, a more opportunistic benthic feeder of invertebrates, zooplankton and benthic algae. Other common planktonic feeders include the black durgeon, creole wrasse, and yellowtail snapper. Common benthic herbivores include the blue tang and ocean surgeonfish as well as most of the parrotfishes (stoplight, princess, redband, redfin, queen, and striped). Grunts are common on the site and mutton snapper occasional. Piscivores as a group can be relatively high in biomass, primarily as a result of the great barracuda, which is generally observed in relatively high numbers at the site. Other common piscivores are represented by bar jacks (pelagic), glasseye snapper and bigeye (nocturnal feeders), and graysby, lionfish, and small snappers (diurnal bottom feeders).

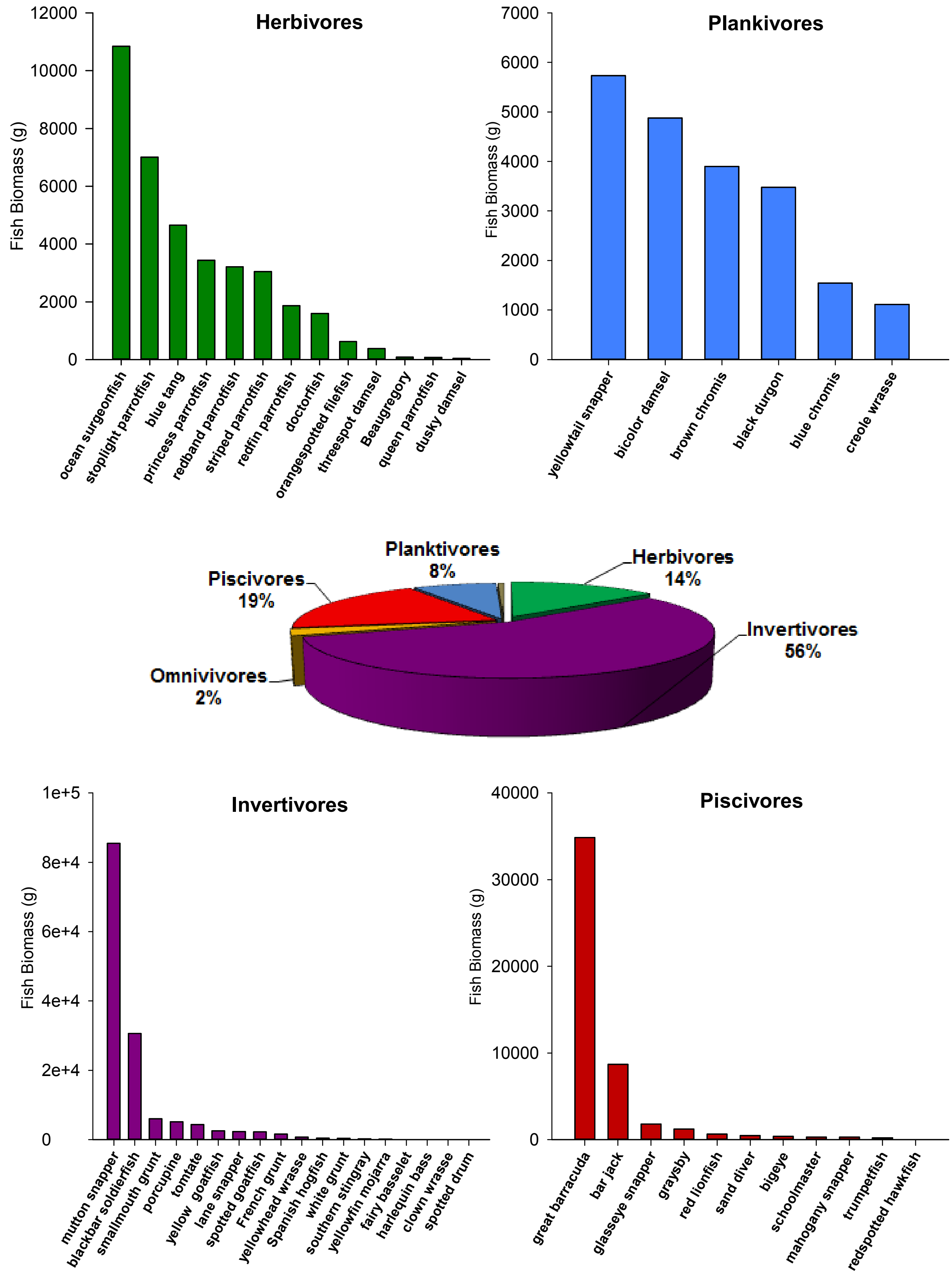
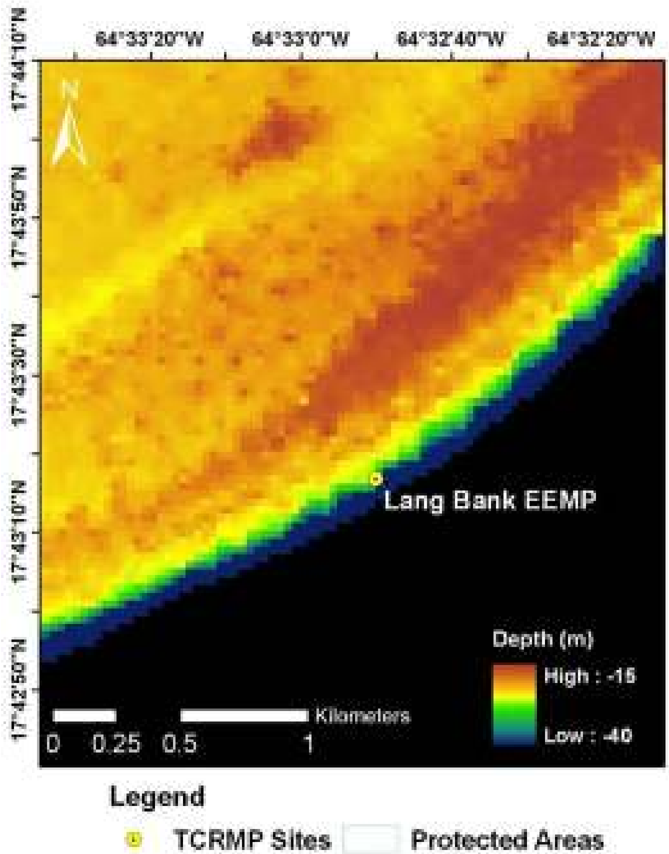


Figure 57. The Kings Corner fish community by absolute and relative biomass.

LANG BANK EAST END MARINE PARK

Description. The Lang Bank EEMP site is a shelf edge mesophotic coral reef located at a depth of 27 – 30 m. The monitoring site sits just above a steep shelf break and is composed of rolling coral knolls dominated by boulder star corals (*Orbicella* spp.). This site was established in 2009.

Outstanding Feature. The Lang Bank EEMP site appears to be a well-developed mesophotic boulder star coral reef on St. Croix, which may be relatively rare compared to St. Thomas. Large populations of fishes and spiny lobsters are often encountered



Threats. The Lang Bank EEMP is in the outer park area and is open to fishing year-round. Therefore fisheries pressure is present. Its offshore location protects it from land-based sources of pollution.

Figure 58. Lang Bank EEMP. (top) Location. (right) A representative photo of the reef.

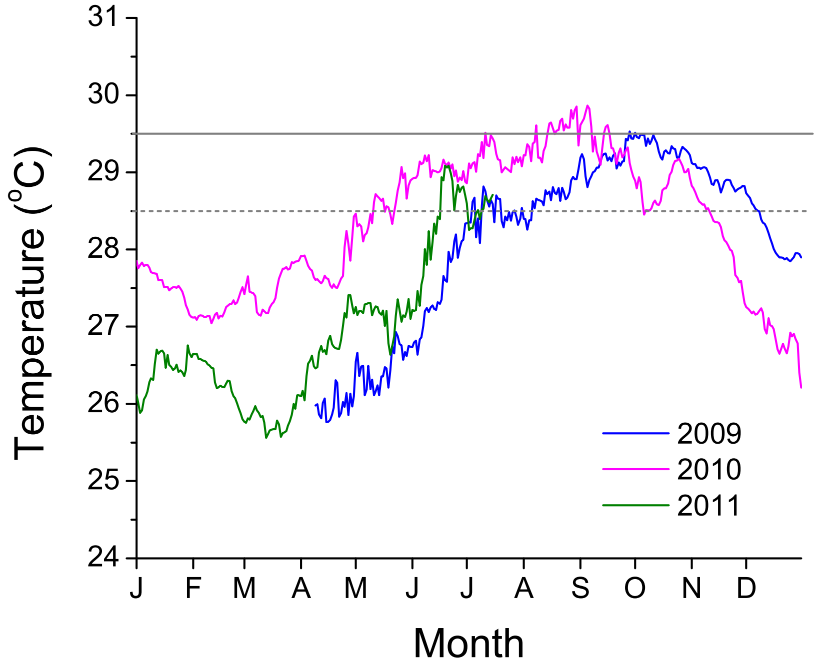


Figure 59. Lang Bank EEMP benthic temperature (28 m depth)

Physical Characteristics

Current. Direct current measurements have not been taken at Lang Bank EEMP. The depth buffers the site from wave-driven oscillatory currents. Only weak unidirectional benthic currents have been experienced at the site during monitoring; however, midwater and surface currents can be moderate to strong (>10cm s^{-1}).

Temperature. Lang Bank EEMP has temperature that is reduced relative to shallow water sites, as shown by the relatively mild temperatures experienced during the warm water event of August to September 2010. This may be protective during mass bleaching events, but temperatures are not as reduced as at other mesophotic sites.

Benthic Community. Lang Bank EEMP supports many coral species but is dominated by *Orbicella* spp.. Sponges are also quite prominent and make up a quarter of the sessile epibenthic animal community. Epilithic algae, *Lobophora variegata*, and filamentous cyanobacteria near equally represent the algal community. The prominence of filamentous cyanobacteria is quite striking and has reached almost 40% of the substrate in some years.

Coral Health. Background, non-thermal bleaching prevalence is quite high at Lang Bank EEMP. White disease showed an outbreak in 2011. Lang Bank EEMP was not initially monitored until well after the 2005 coral bleaching event; however, a high prevalence of old partial mortality suggests that corals were impacted. Many of the large faviids show lesion patterns that are consistent with the large lunate dead areas caused by white diseases following bleaching in 2005.

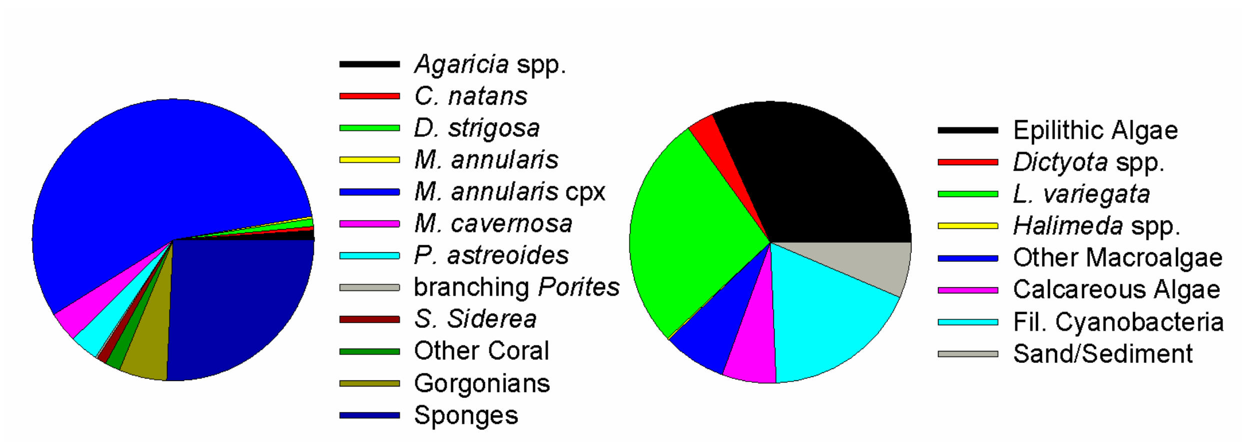


Figure 60. Lang Bank East End Marine Park (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

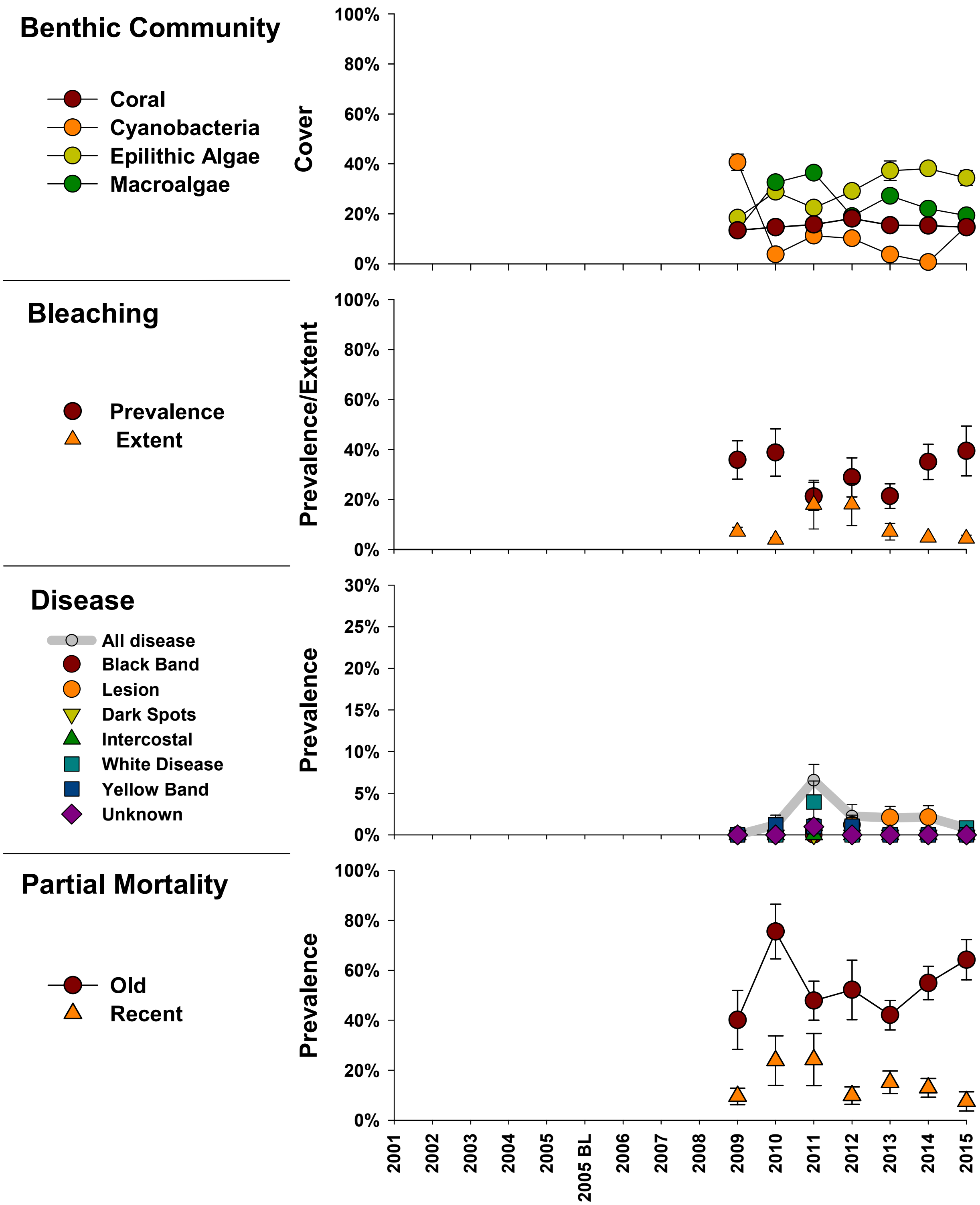


Figure 61. Lang Bank EEMP benthic cover and coral health through time (mean ± SE).

Fish Community. The Lang Bank East End Marine Park site represents a mesophotic reef community that is characterized by a high biomass of planktonic feeders. The high overall biomass of the group was influenced primarily by the black durgeon while numerically creole wrasse are dominant. Queen triggerfish are also common. Benthic herbivores are dominated both numerically and in biomass by the redband parrotfish. Large parrotfish are fairly uncommon, however small parrotfish (striped and princess) as well as the doctorfishes are very abundant. The benthic invertivores at the site are diverse and include nocturnally feeding blackbar soldierfish and squirrelfish, as well as several species of grunt (French, tomtate, white, bluestriped, Caesar, and smallmouth). Piscivores are generally dominated in biomass by barracuda; however, graysby were common numerically. Other piscivores on the site included the horse-eye jack and cero mackerel, indicators of a deep water community.

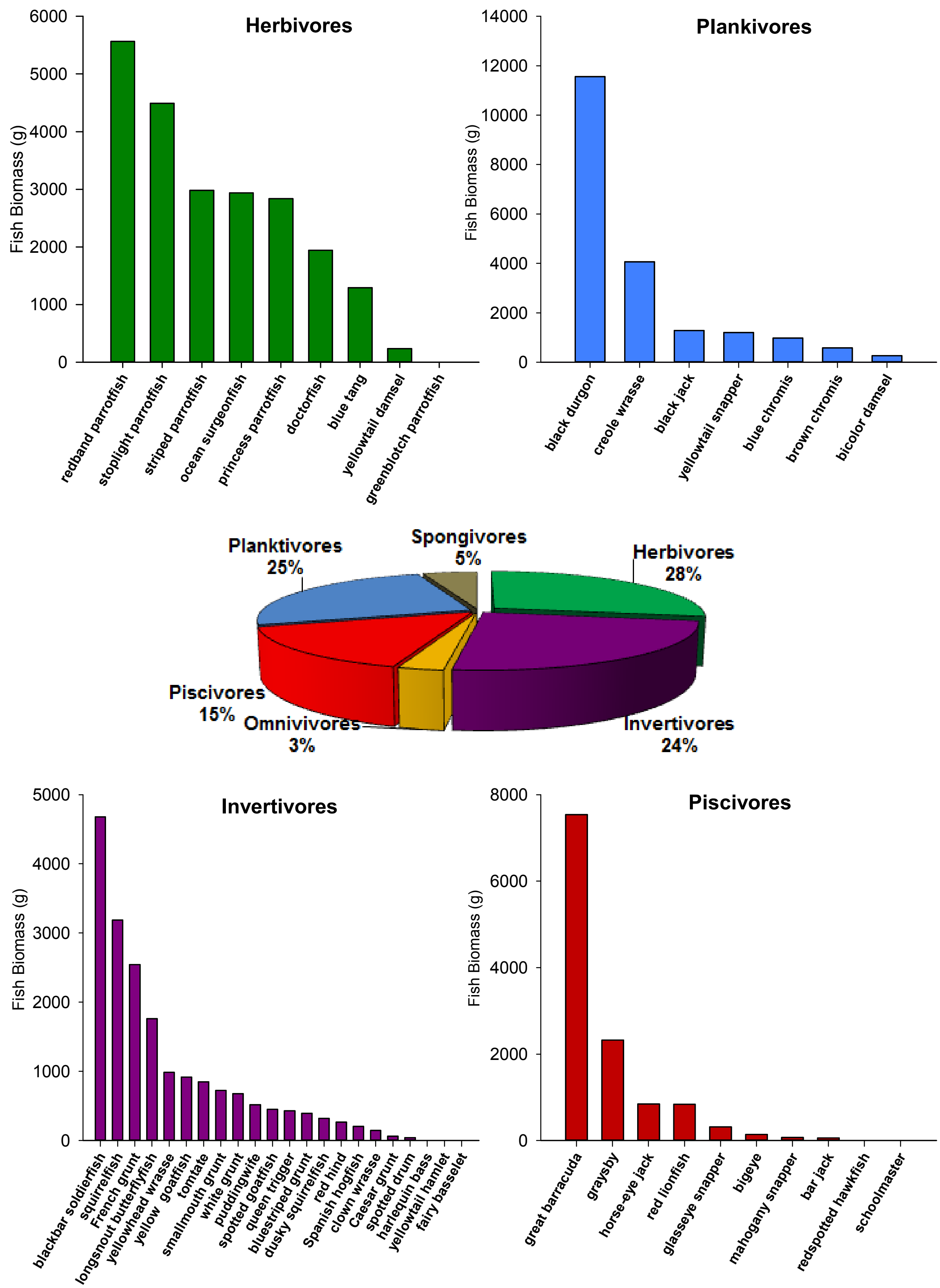
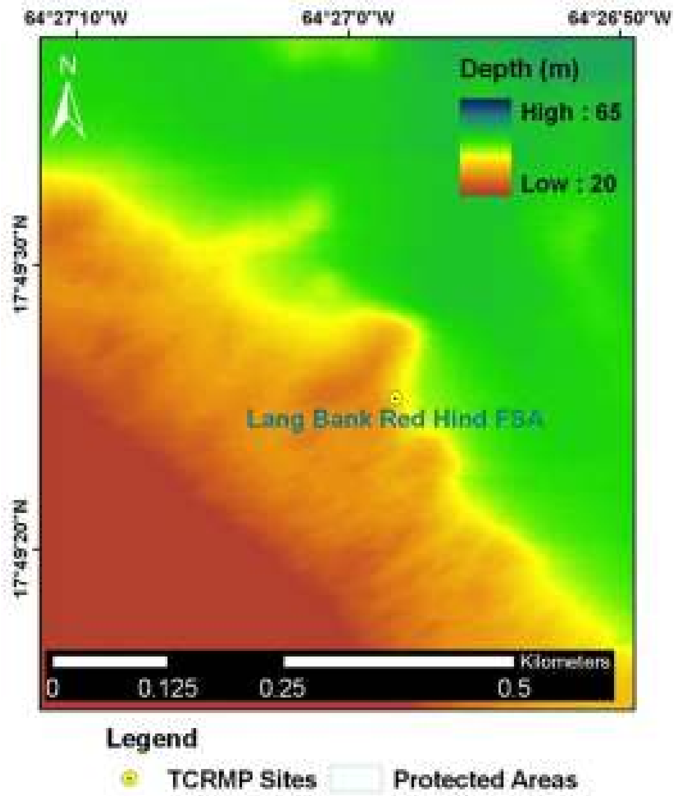


Figure 62. The Lang Bank EEMP fish community by absolute and relative biomass.



LANG BANK RED HIND FISH SPAWNING AGGREGATION

Description. The Lang Bank Red Hind Fish Spawning Aggregation (Lang Hind) monitoring site is a mesophotic reef of relict spur and groove structure at a depth of 30 – 35 m. The site is perched on the southeast side of the spur, which is a large finger that rises to 24 m to the west and drops on all other sides to a rhodolith/sand plain at about 50 m. Lang Hind was initially monitored in 2001 at a site on the shallower (24 m) portion of the bank to the west. Monitoring in 2004-2007 occurred along random transects in a deeper portion of the reef (~33 m depth) and benthic transects were made permanent in this area in 2009

Outstanding Feature. Lang Hind supports an annual fish spawning aggregation of the red hind (*Epinephelus guttatus*). This site also possesses high water clarity.

Threats. The Lang Hind site is removed from land-based stressors. Fishing of the red hind aggregation was common prior to closure of the area to fishing in 1993. However, the aggregation is near the closure boundary.

Figure 63. Lang Bank Red Hind FSA. (top) Location. (right) A representative photo of the reef.

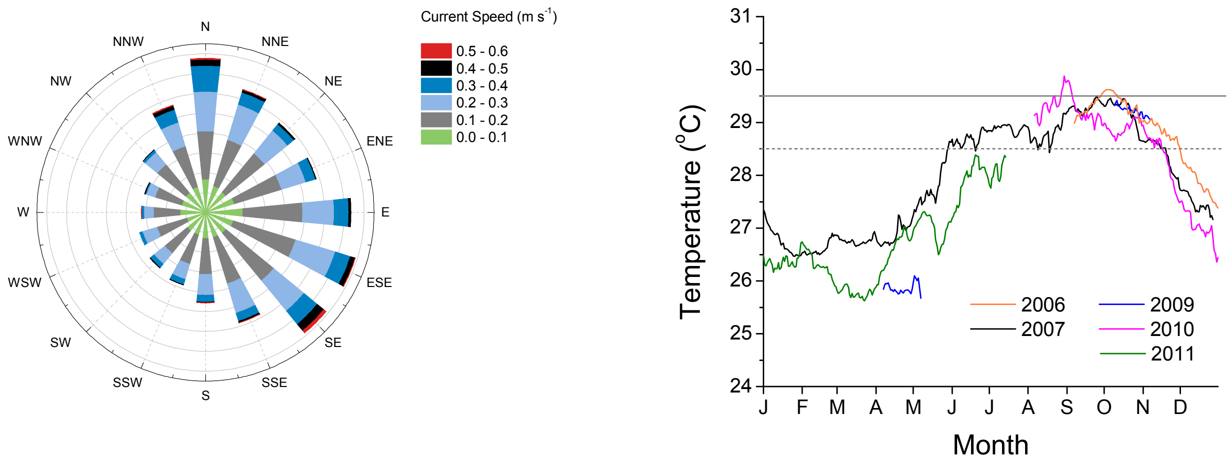


Figure 64. Lang Bank Hind current speed (left) and benthic temperature (right; 33 m depth)

Physical Characteristics

Current. Lang Hind had benthic currents recorded with ADCP every 30 minutes from 11/20/05 to 8/20/06, and 12/11/06 to 3/10/07. Bottom currents most typically alternate between north and southeast and can attain strong speeds periodically exceeding 0.4m s^{-1}.

Temperature. Lang Hind has temperatures that are reduced due to the depth and proximity of the warm season thermocline. However, temperatures are not as cool or variable as sites on the southern Puerto Rican shelf, indicating that this site may be more susceptible to warming ocean temperatures.

Benthic Community. Lang Hind has a diverse sessile epibenthic community dominated by hard corals, predominantly *Orbicella* spp., gorgonians, and sponges. Coral cover actually increased by 110% between the coral bleaching event and re-monitoring in 2006, but this may reflect the fact that transects were laid in random, rather than permanent, locations prior to 2009. The algal community is largely open epilithic algal communities, but also contains large proportions of *Lobophora variegata* and filamentous cyanobacteria. The algal community shows high inter-annual variability.

Coral Health. Lang Hind was heavily affected during the 2005 coral bleaching event, with a very high prevalence of corals that were 100% bleached over the colony surface. Non-thermal bleaching with moderate prevalence and low extent on colonies also occurred in later years. The site was heavily affected with white diseases after the coral bleaching event and has had high disease prevalence in all years of monitoring. Old partial mortality jumped after the 2005 bleaching event and was variable in later years. Recent partial mortality is unusually high at Lang Hind, largely as the result of fish bites and predation by the corallivorous snail *Coralliophila* spp.

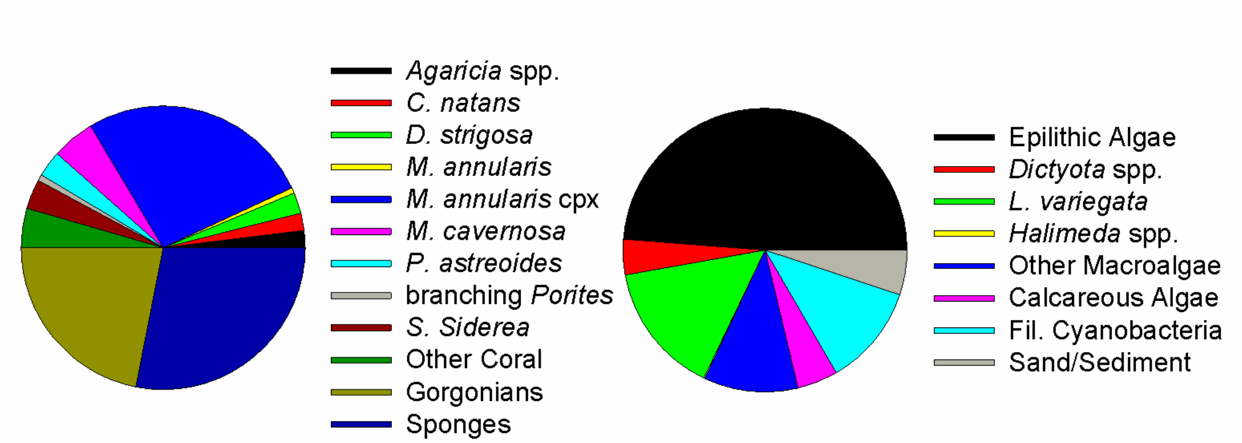


Figure 65. Lang Bank Red Hind FSA (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

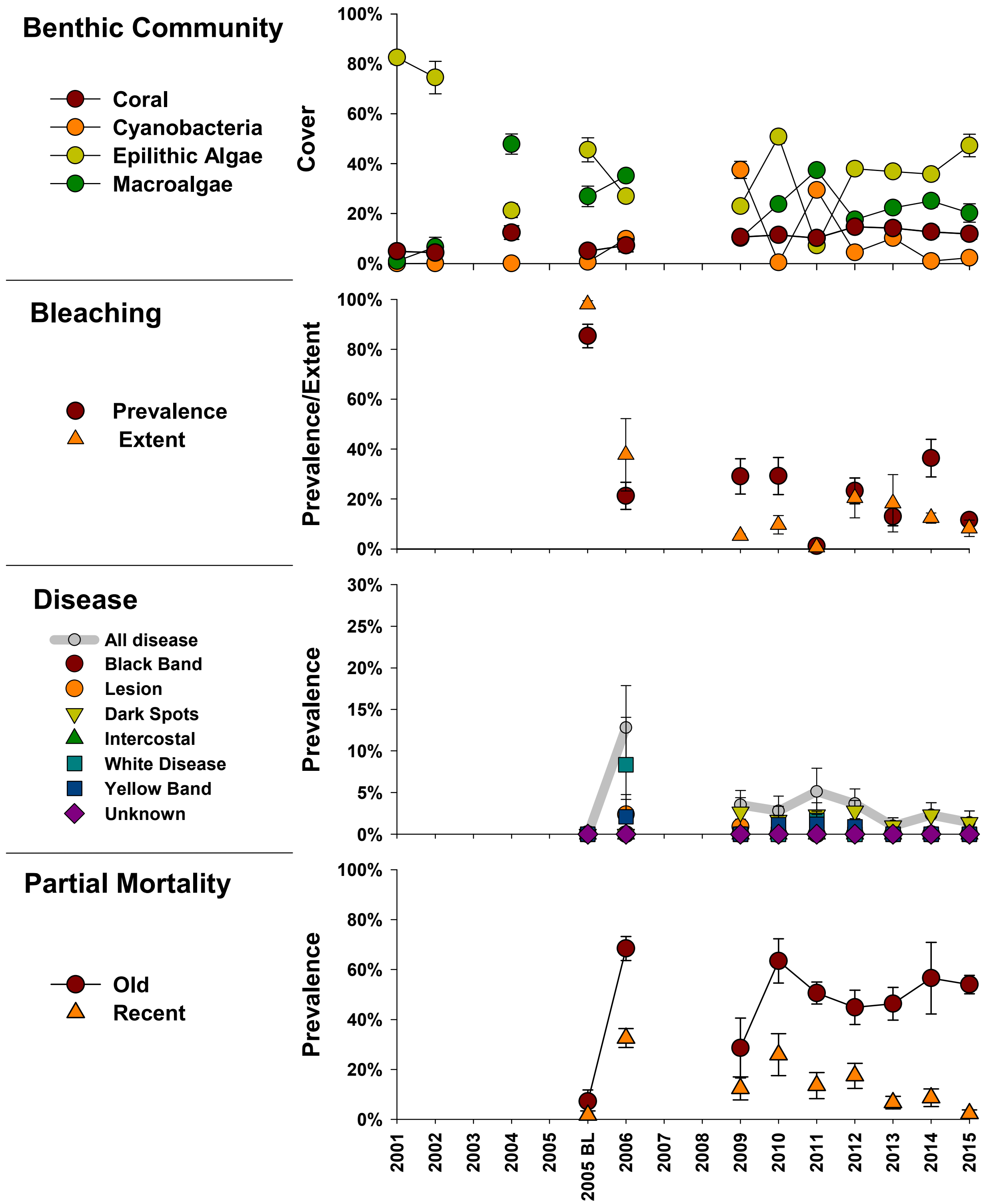


Figure 66. Lang Bank Red HindFSA benthic cover and coral health through time (mean ± SE).

Fish Community. The fish community at Lang Bank FSA is indicative of a mesophotic reef system. High water column planktonic feeders are abundant and include the black durgeon, creole wrasse, yellowtail snapper, and creolefish. Bicolor damselfish are numerous while herbivorous damselfishes are uncommon. Benthic herbivores are relatively low in diversity, abundance and biomass compared to nearshore sites. Invertivores are diverse and include many planktivores as well as benthic feeders, utilizing the varied resources of the bank. Four species of angelfish were observed on transects reflecting the high sponge cover. Lang Bank FSA supports a red hind spawning site, active during December through February each year, and red hind are occasionally seen on both roving dives and transects. One Nassau grouper was observed on the bank in 2011, a first observation across all St. Croix monitoring sites. There is reportedly a historic Nassau grouper spawning site near the Lang Hind monitoring site, and with the bank now closed to trap fishing there is hope of some re-establishment of the species on St. Croix. Mahogany snapper dominate piscivorous fish on Lang Bank FSA. No other large groupers or snappers are common although occasionally Caribbean reef sharks are observed.

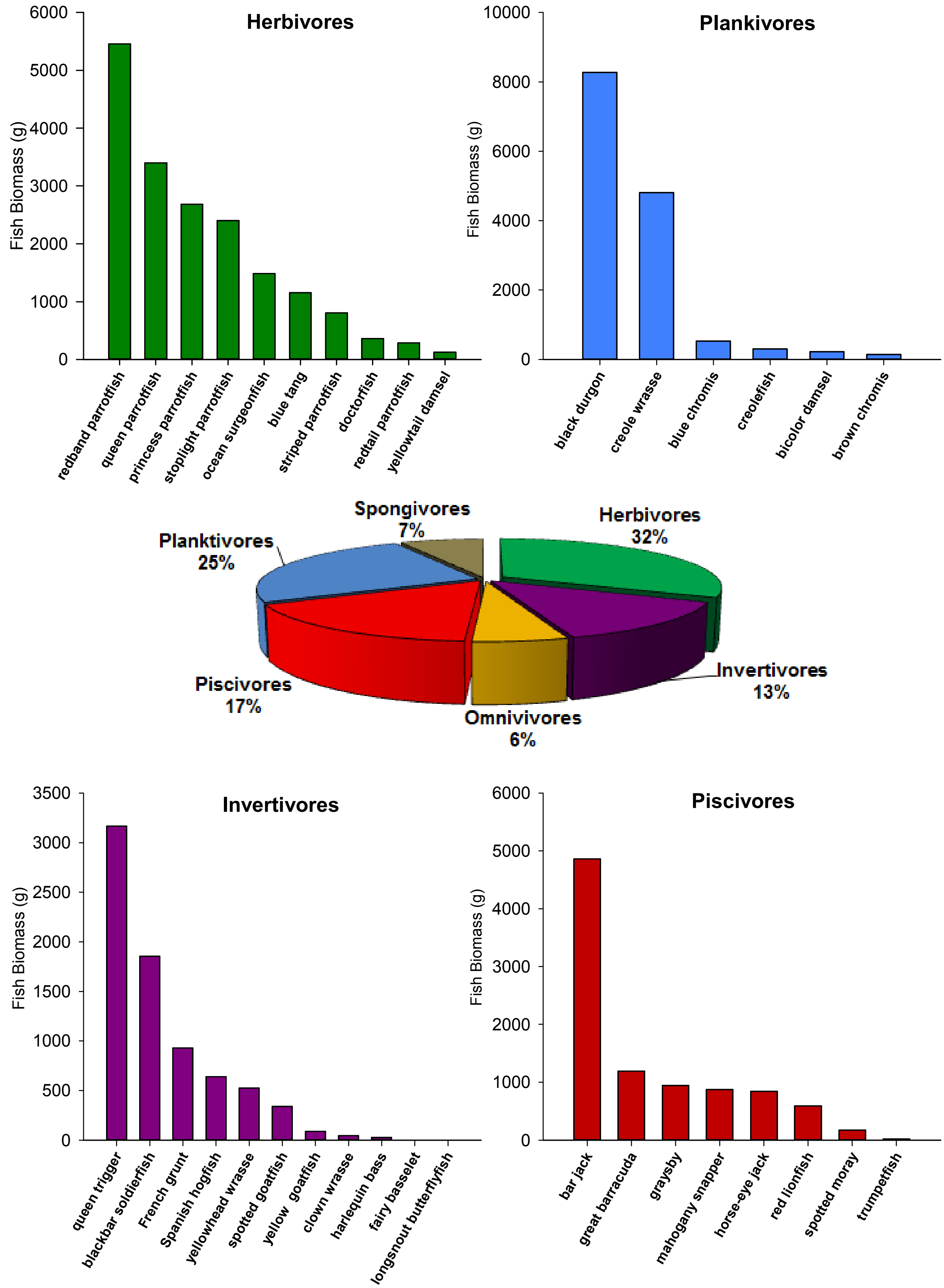
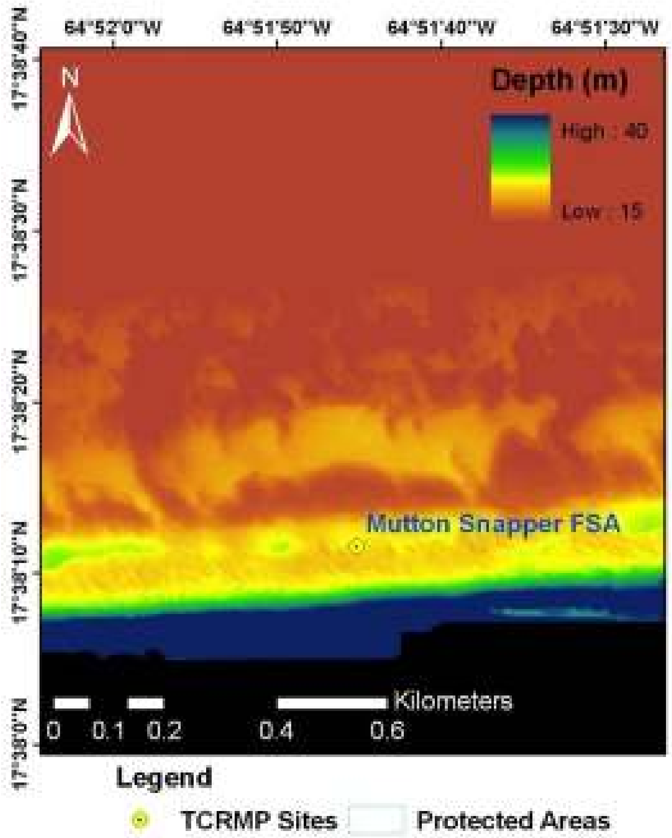


Figure 67. The Lang Bank Red Hind FSA fish community by absolute and relative biomass.

MUTTON SNAPPER

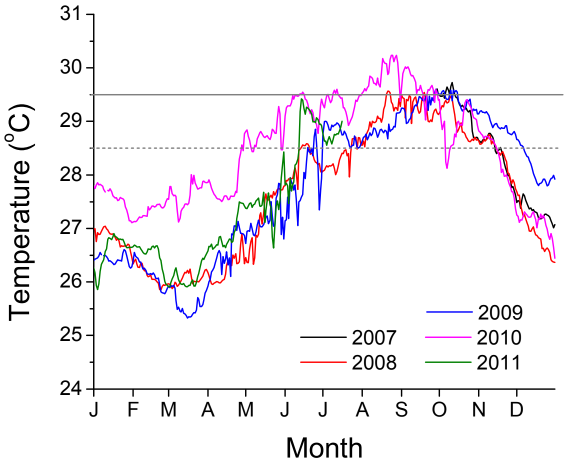


Description. The Mutton Snapper site is located on the landward side of a shelf edge spur and groove reef on the southwest shelf of St Croix in depths of 22-24 m. The reef was dominated by boulder star coral (primarily *Orbicella franksi*) until a mass coral die-off following the 2005 bleaching event. Mutton Snapper has been monitored since 2003.

Outstanding Feature. The Mutton Snapper site was located in conjunction with the possible proximity of a mutton snapper (*Lutjanus analis*) spawning aggregation. It is seasonally closed to fishing. The site was devastated by the 2005 coral bleaching event, with an 87% drop in coral cover and a concomitant increase in algae.

Threats. The Mutton Snapper site is threatened by fishing pressure as evidenced by the abundance of fishing line and fishing trap debris. This site is offshore and less likely threatened by land-based stressors. The clear waters and warm temperatures make this site vulnerable to long-term seawater warming.

Figure 68. Mutton Snapper. (top) Location. (right) A representative photo of the reef taken in 2014.



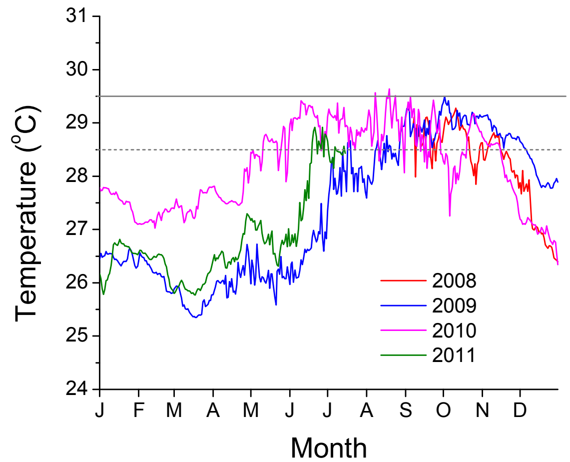


Figure 69. Mutton Snapper benthic temperature record at 23 m (left) and 39 m depth (right).

Physical Characteristics.

Current. Current records have not been taken at Mutton Snapper. There seems to be little wave-driven oscillatory flow. There are often strong unidirectional currents in a westward direction that penetrate to nearly the bottom.

Temperature. Benthic temperatures at the Mutton Snapper site (23 m) show warming above the regional bleaching threshold during the 2010 bleaching event, whereas benthic temperatures just off-shelf from the site (40 m) show few excursions above the bleaching threshold.

Benthic Community. The Mutton Snapper site's sessile epibenthic animal community is dominated the boulder star coral (*Orbicella* spp.), with sub-dominance of sponges. This site lost an extreme amount of coral cover (87.0%) in the 2005 coral bleaching event and has not regained any cover (-2.3%) as of 2011. *Lobophora variegata*, epilithic algae, and filamentous cyanobacteria dominate the algal community. Apparent is the rise in the abundance of macroalgae and filamentous cyanobacteria after 2005. Filamentous cyanobacteria reached extreme cover values (57.7%) in 2009. Current levels of herbivory no longer appear to be able to control algal abundance.

Coral Health. Mutton Snapper bleached heavily in the 2005, with 100% of corals bleaching over 90% of the colony surface. Bleaching prevalence has remained high for most years since 2005, but at low colony extent, indicating continued impairment of corals. White disease has been at consistently high values through many years of monitoring. Old partial mortality increased after 2005, and then subsided as whole colonies were lost from the system. Impairment of this site is puzzling as stressors besides fishing appear to be low. Clear water and low genetic diversity of corals may increase susceptibility to environmental stress and white disease.

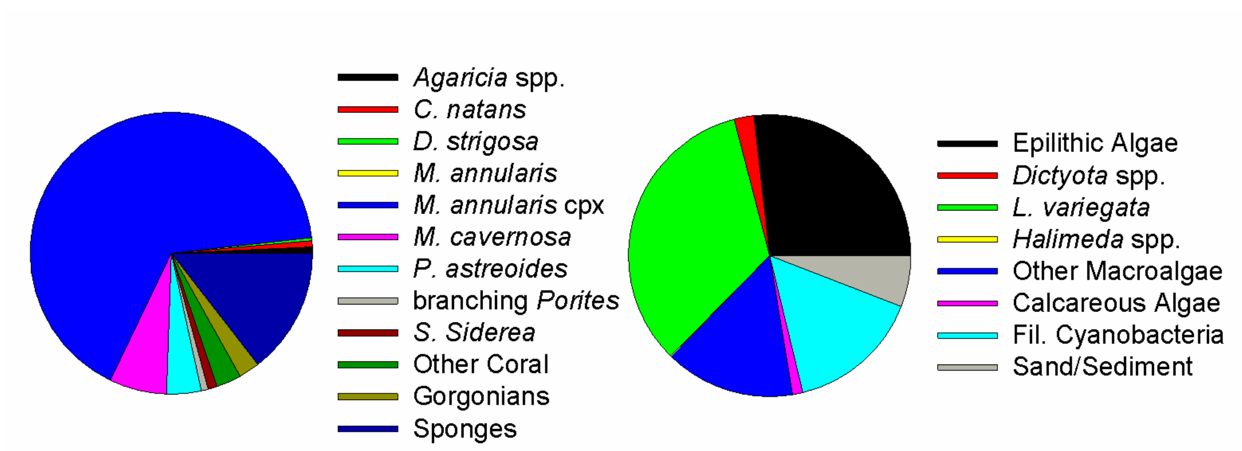


Figure 70. Mutton Snapper (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

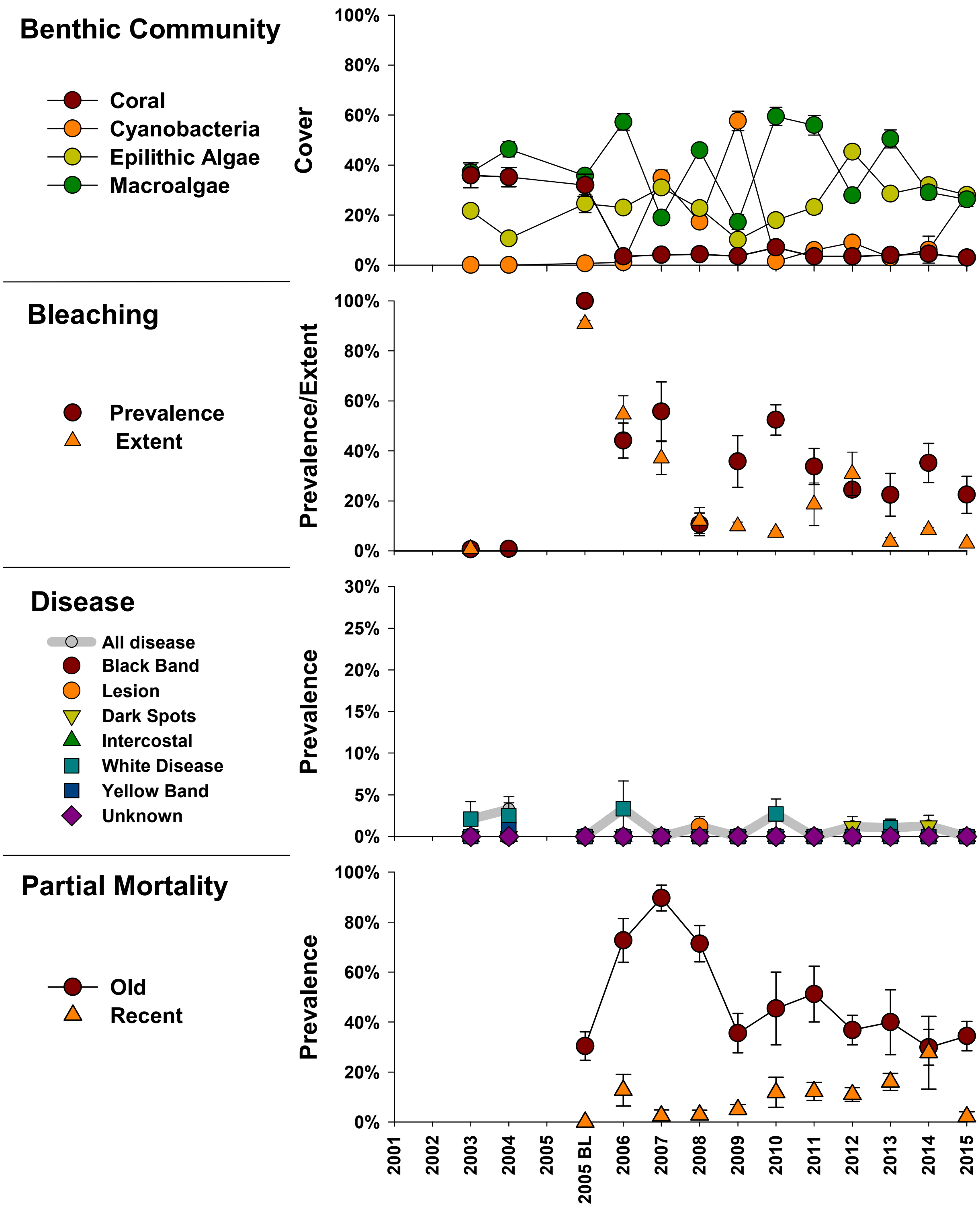


Figure 71. Mutton Snapper benthic cover and coral health through time (mean ± SE).

Fish Community. The Mutton Snapper site is an offshore, shelf edge site with a fairly diverse and rich fish community. Fish biomass is generally low on the site; however, in 2014 surveys biomass was much higher than in earlier years. Mutton Snapper is reportedly in an area that mutton snapper spawn, however mutton snapper have been very rare in surveys conducted at the site over the past 5 years. The Mutton Snapper site is very highly dominated in biomass by the black durgeon, a phytoplankton feeder, and numerically dominated by the creole wrasse, a zooplankton feeder. Stoplight parrotfish and doctorfish generally contribute the most biomass to the benthic herbivore group. Many parrotfish species can be found on the Mutton Snapper reef, however sub-adult and juveniles are by far the majority encountered. The invertivore group is also diverse, indicative of the variety of resources available on the reef. Piscivores are not common on Mutton Snapper and in general the biomass of this group was made up of primarily jacks and barracuda. Piscivorous serranids and lutjanids are usually limited to the graysby and mahogany snapper. Red lionfish are observed regularly on Mutton Snapper, probably because the reef is offshore and does not receive the diving and hunting pressure of nearshore sites.

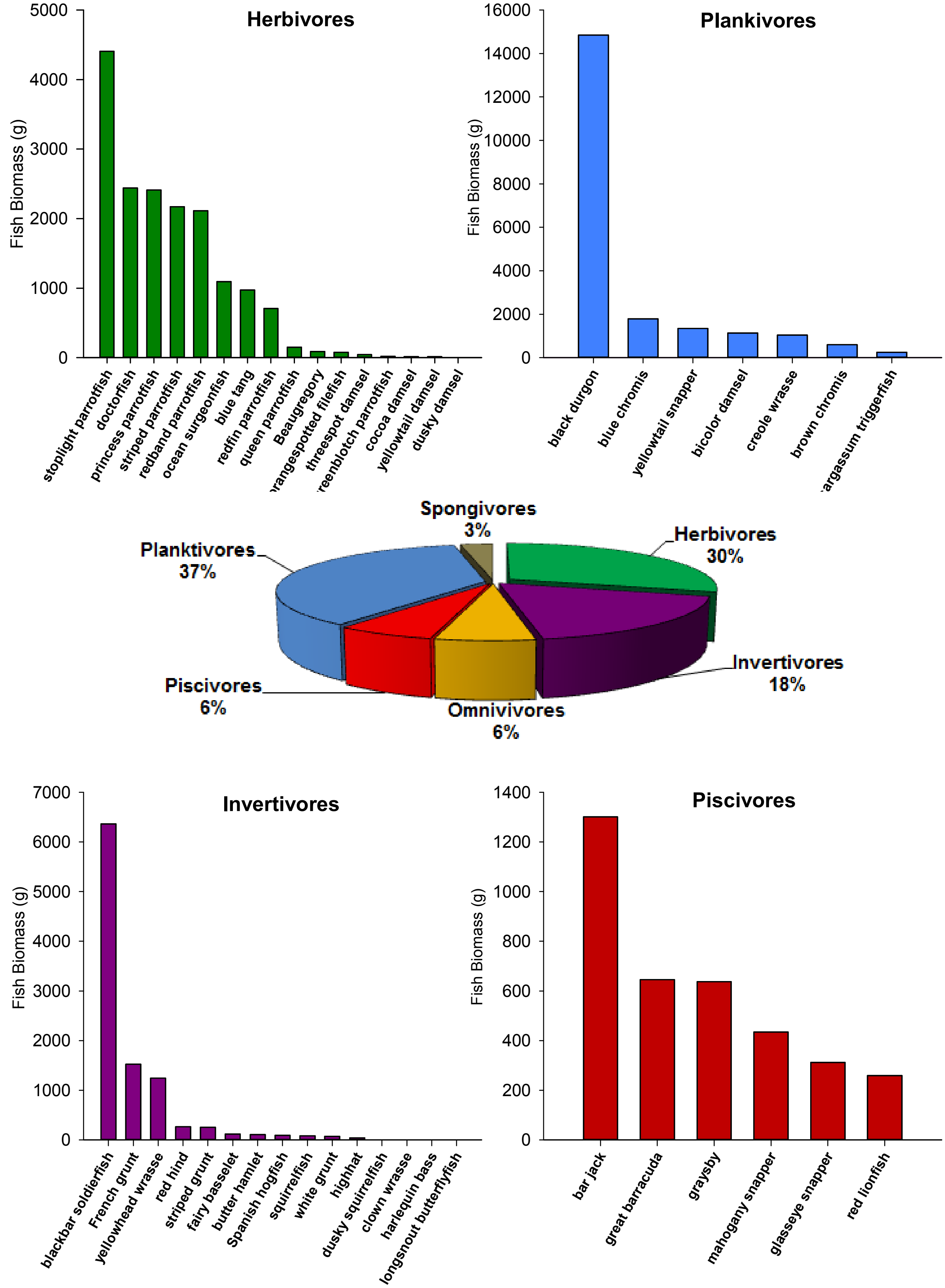
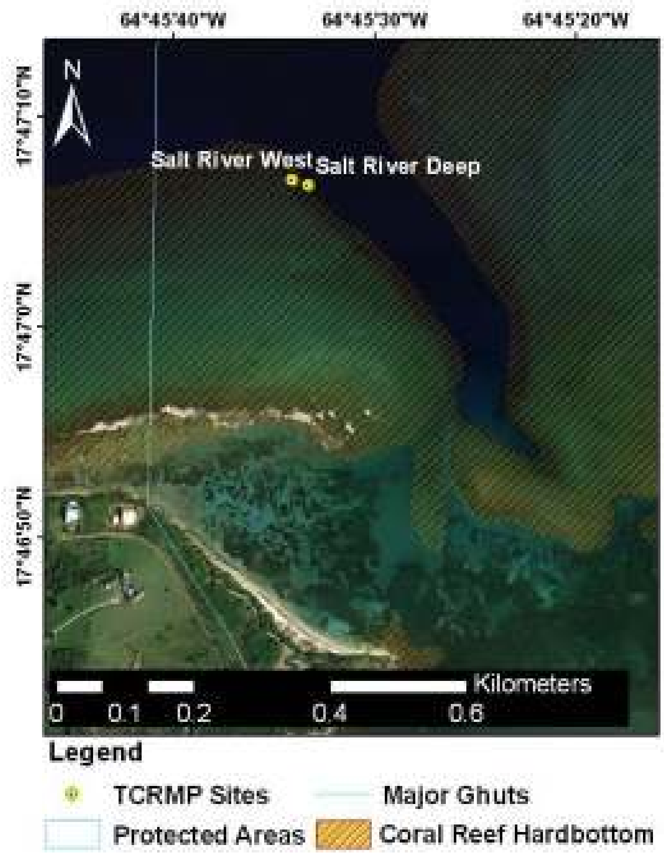


Figure 72. The Mutton Snapper fish community by absolute and relative biomass.

SALT RIVER WEST



Description. Salt River West lies just atop the Salt River Canyon west wall in a depth of 9 m. The reef is a flat colonized hardbottom/coral community atop ancient carbonates. Salt River West has been monitored since 2001.

Outstanding Feature. Salt River West is a popular tourist dive site with a unique sharp drop to the wall environment. This area has been under scientific investigation since the 1970s, beginning with the installation of the Hydrolab undersea habitat run by NOAA.

Threats. Salt River West is exposed to the outflow from the Salt River Canyon and resuspension of sediment from the Salt River eastern flats. The site is now within in the Salt River National Historic Park and Ecological Preserve. This protection will hopefully increase the fish populations within the reserve in the coming decades.

Figure 73. Salt River. (top) Location. (right) A representative photo of the reef with TCRMP researcher recording coral health data (Oct. 1, 2015).

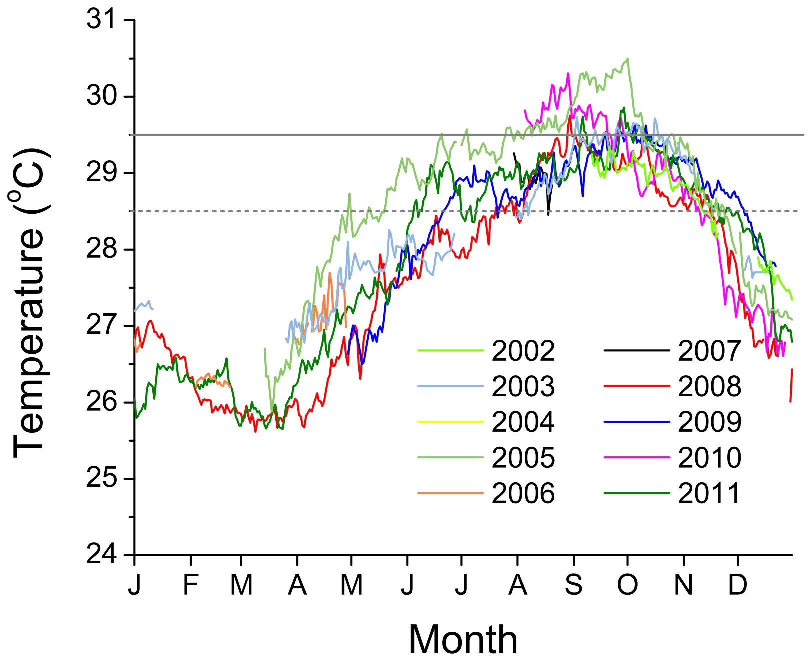


Figure 74. Salt River West surface-benthic temperature record (1 and 5m depths). Data provided by the NOAA ICON monitoring network.

Physical Characteristics.

Current. Currents have not been directly measured by the TCRMP. Due to the northern exposure and shallow depth, Salt River West experiences wave-driven oscillatory flow, which can be strong. Unidirectional benthic currents are typically weak to moderate (<15cm s^{-1}).

Temperature. The temperature at Salt River West can be very warm and in 2005 surpassed the bleaching threshold (29.5°C) for approximately 2.5 months between August and October. The record also shows how 2010 was actually warmer than 2005 until the passage of Hurricane Earl in late August dropped temperatures precipitously.

Benthic Community. The Salt River West epibenthic sessile animal community has a diverse hard coral community of small massive head corals and large proportions of sponges and gorgonians. The site lost an imperceptible amount of coral cover in the 2005 coral bleaching event (-13.6%) and had regained nearly half of that cover by 2011 (37.1%). The algal community shows extreme dominance by epilithic algae and low abundance of macroalgae and filamentous cyanobacteria. However, filamentous cyanobacteria have increased slightly since 2005.

Coral Health. Corals were severely bleached during the 2005 coral bleaching event, with over 90% of corals bleached over 80% of the colony surface. Corals were assessed just prior to the 2010 bleaching event in August, but were showing increased prevalence of low colony extent bleaching by then. Diseases are typically low, with the outstanding case of dark spots disease, which attains some of the highest values seen in TCRMP sites. Of note, is the fact that dark spots disease actually decreased following severe bleaching and recovery in 2005 and 2006. Old partial mortality increased rapidly after the 2005 bleaching and then subsided somewhat by 2011. Recent partial mortality can be high and is primarily caused by fish biting, such as from parrotfish. However, extent is quite low (data not shown).

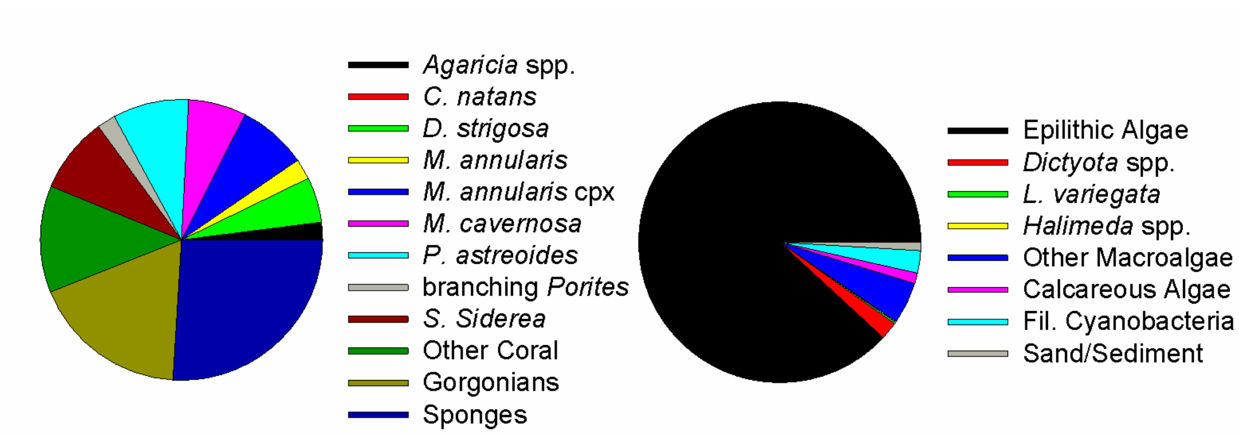


Figure 75. Salt River West (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

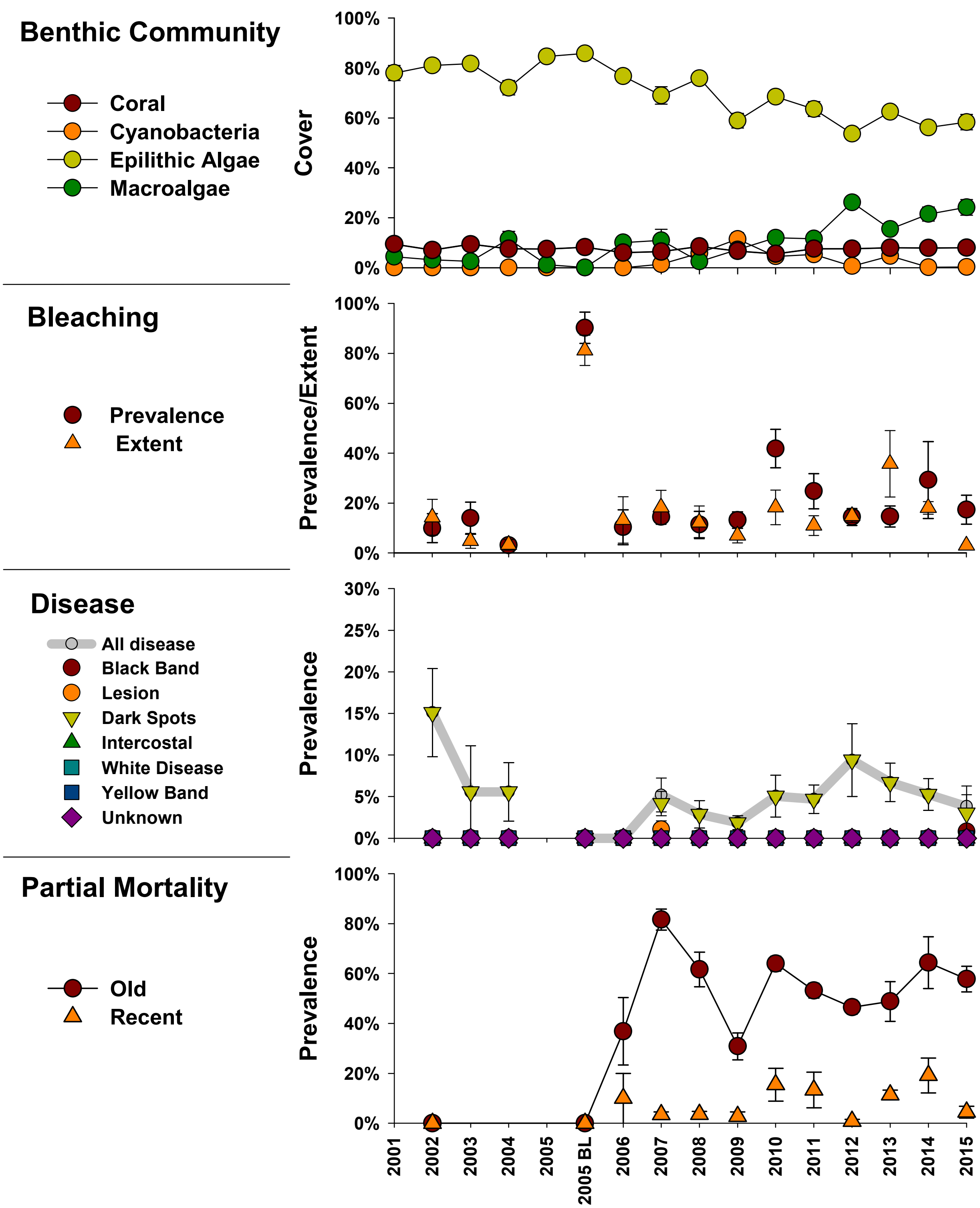


Figure 76. Salt River West benthic cover and coral health through time (mean ± SE).

Fish Community. Fish biomass is relatively low on the Salt River West site. More diversity and some larger fishes can be seen close to the edge of the site, near the Salt River wall; however, the top of the reef has little structure for larger fishes, with low lying coral heads, gorgonians, and sponges. Wrasses and damselfishes are both numerous and diverse; the most dominant species on the site is the bluehead wrasse followed closely by the bicolor damselfish. Black durgeon, an opportunistic planktivore that feeds on zooplankton, phytoplankton and algae, dominates the Salt River West site in biomass, followed by the stoplight parrotfish, ocean surgeonfish, and very numerous creole wrasse. Piscivores are nearly non-existent, and include primarily graysby. Occasional red lionfish are seen on a Salt River West. Yellowfin snapper are the only lutjanids regularly encountered on the site, and these are observed only near the shelf edge.

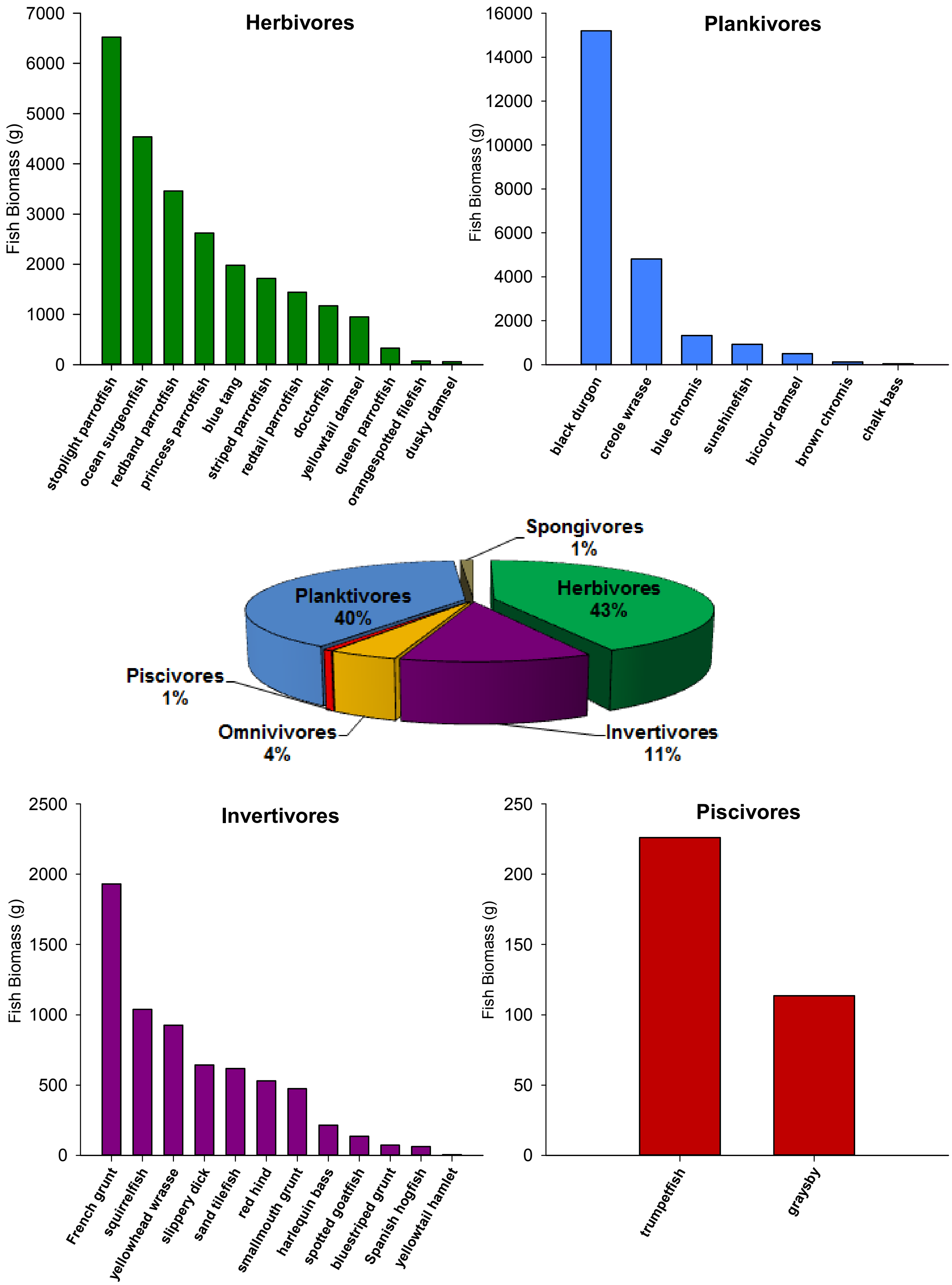


Figure 77. The Salt River West fish community by absolute and relative biomass.

SALT RIVER DEEP

Description. The Salt River Deep site is located on the steep canyon wall just below the Salt River West monitoring site. The reef consists of vertical buttresses surrounded by extensive sand deposits. The reef is largely formed of plating coral at these deep, mesophotic depths. The initial site was deployed in 2009 with two transects at 30 m depth and 4 transects at 40 m. Due to low coral cover at 40 m transects were moved to 30m in 2010.

Outstanding Feature. Salt River Deep is a heavily visited recreational dive site. The site has been under scientific investigation since the 1970's. The underwater HYDROLAB habitat was maintained near the site from 1977 to 1985 and the Aquarius habitat from 1986 to 1989.

Threats. Salt River Deep is threatened by land-based sources of pollution due to its proximity to the Salt River Canyon outflow. The site may also be susceptible to warming temperatures.

Figure 78. Salt River Deep. (top) Location. (right) A representative photo of the reef with TCRMP team (Oct. 1, 2015).

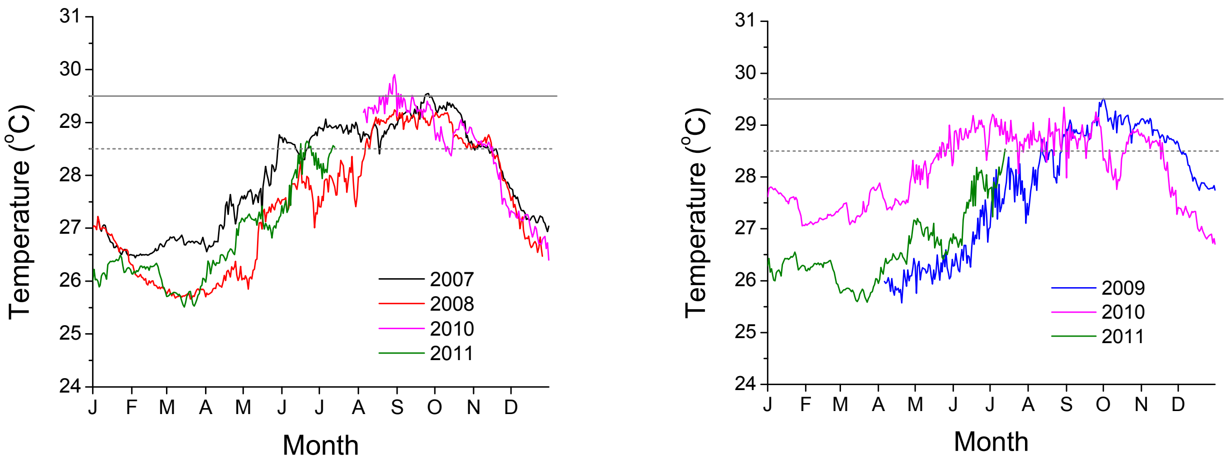


Figure 79. Salt River Deep benthic temperature at 30 m depth (left) and 40 m depth (right).

Physical Characteristics.

Current. Salt River deep currents have not been measured directly by the TCRMP. Only very weak oscillatory and unidirectional currents have been experienced at the site.

Temperature. Temperatures on the wall have been measured at two depth levels at 30 m and 40 m. Both sites have temperatures that are much cooler than the shallow site. The 40 m site experiences even greater cooling and experiences more diel variability (not shown) and day-to-day variability due to the influence of internal waves. Despite some interaction with the thermocline, cooling is not as great as at the mesophotic reefs at similar depths on the southern Puerto Rican Shelf.

Benthic Community. Hard coral community of the Salt River Deep monitoring site is dominated by plating lettuce corals (*Agaricia* spp.); however, sponges, gorgonians, and black corals dominate the overall sessile epibenthic animal community. The site was not monitored during the 2005 bleaching event, but as with the Cane Bay Deep site, severe bleaching was observed down to depths of 40m. The algal community is dominated by epilithic algae and unidentified diminutive macroalgae. The site is notable for the high composition of sediment, which cascades from the upper reef between spurs and buttresses.

Coral Health. Low extent coral bleaching is typically in moderate to high prevalence at the Salt River Deep site. Interaction data (not shown) indicates that sediment and *Lobophora variegata* overgrowth are responsible for much of the bleaching. Diseases have not been observed. Old partial mortality is high on corals, which may be a reflection of the 2005 bleaching event and cumulative impacts from interaction with sediment and algae.

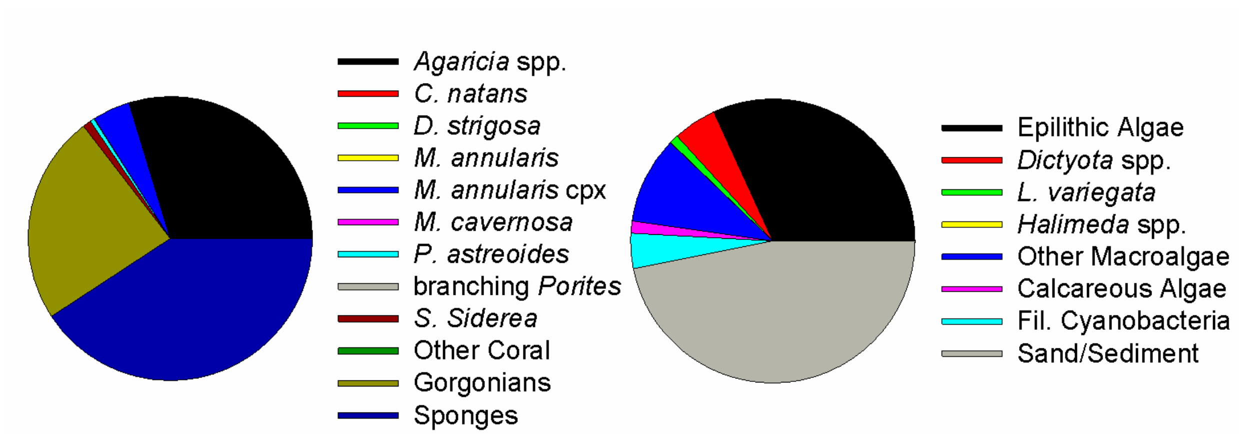


Figure 80. Salt River Deep (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

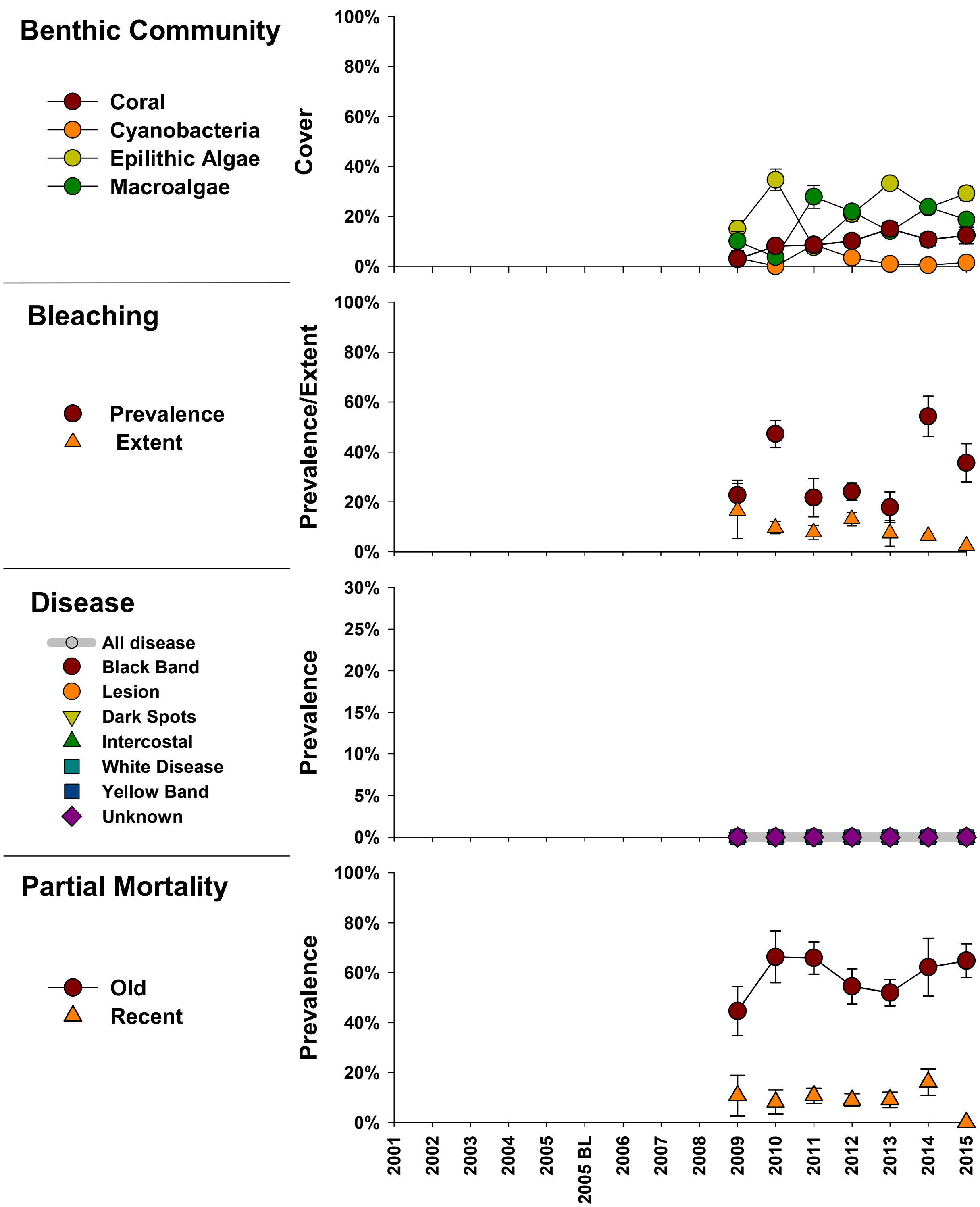


Figure 81. Salt River Deep benthic cover and coral health through time (mean ± SE).

Fish Community. The relatively high turbidity and high composition of sand and silt bottom, as a consequence of river discharge, influences the fish community of Salt River Deep. The mesophotic reef wall site is characterized by a primarily invertivore fish community, leading in both biomass and species richness. Invertivores are dominated numerically by the functionally planktivorous blue chromis and creole wrasse. The benthic feeding yellow goatfish dominates the invertivore group by biomass, swimming in small schools along the sandy wall. Mahogany snapper and graysby are common piscivores. Sub-adult princess and redband parrotfish are the prominent herbivores. Characteristic deep water fishes observed commonly on Salt Water Deep include the sunshinefish, bantum bass, fairy basslet, and longsnout butterflyfish. As on the Cane Bay Deep site, occasional cubera snapper (*Lutjanus cyanopterus*), mutton snapper (*L. analis*), or southern stingrays (*Dasyatis americana*) are observed during roving dives on the wall, and commonly one or two small, curious Caribbean reef sharks (*Carcharhinus perezi*) are present.

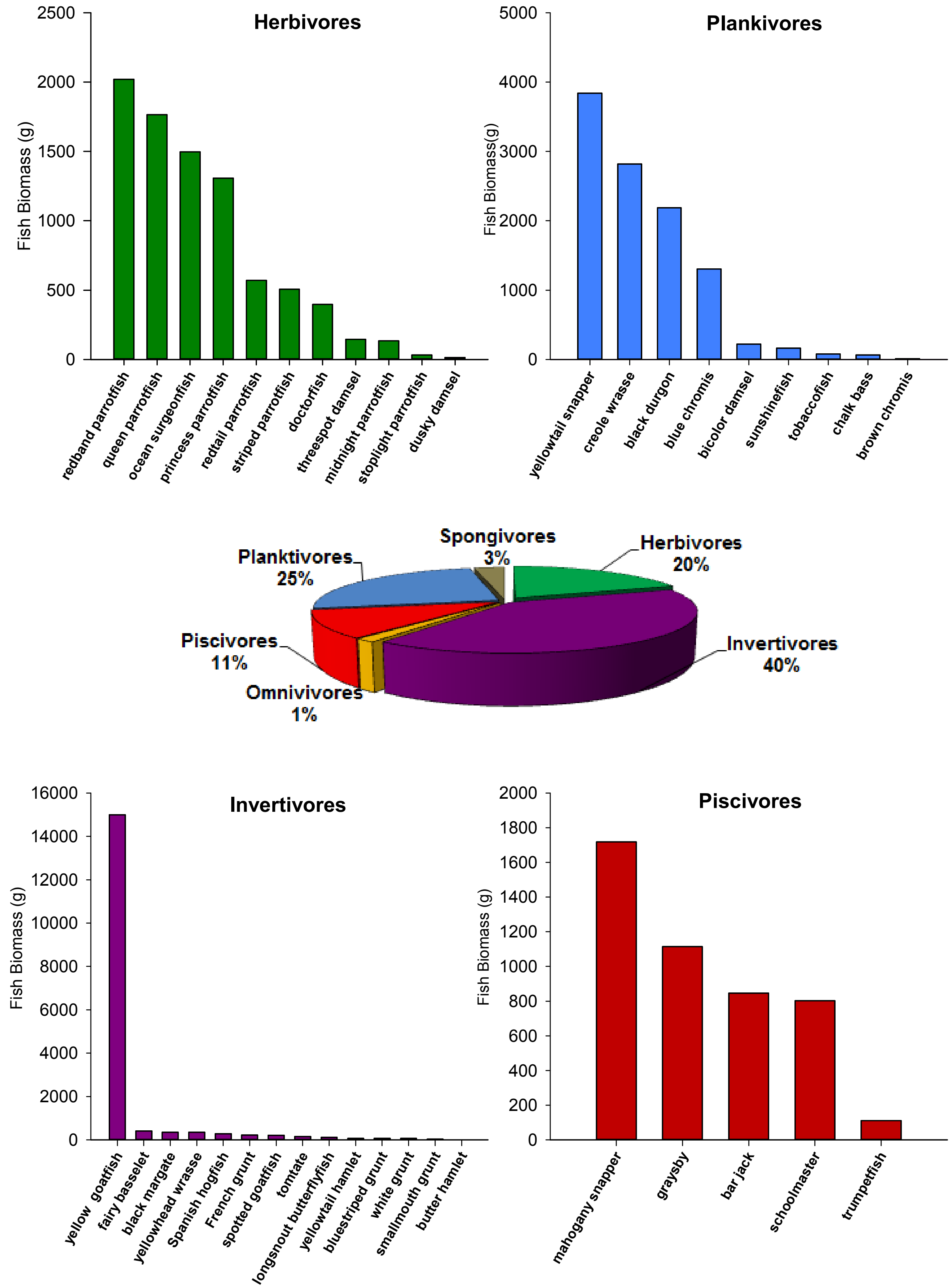
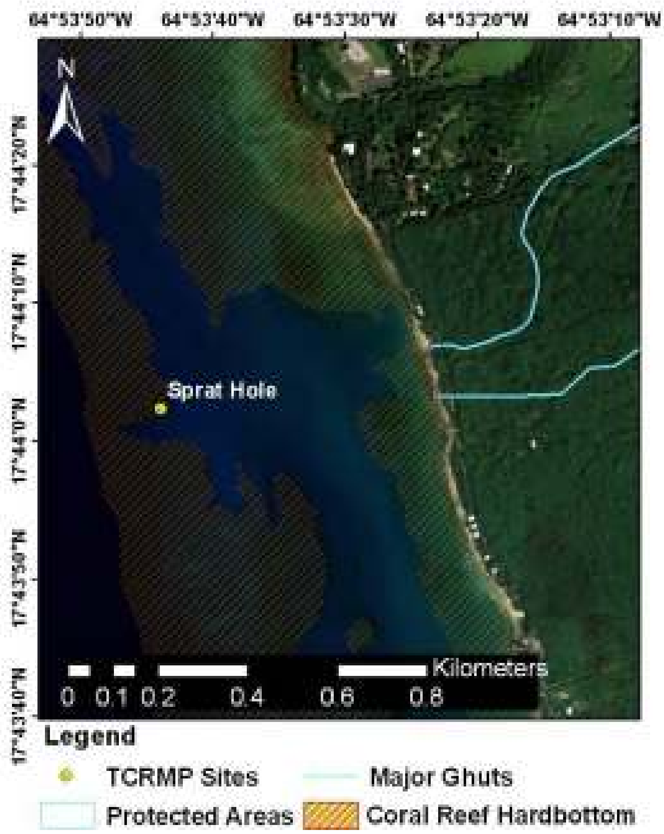


Figure 82. The Salt River Deep fish community by absolute and relative biomass.

SPRAT HOLE

Description. The Sprat Hole site is a nearshore/shelf-edge fringing reef in depths of 7 – 10 m. The site is a rolling boulder star coral (*Orbicella annularis*) reef. The slope to the west drops off to an attractive mixed coral community with abundant fish where it meets sand at about 25 m. Sprat Hole has been monitored since 2001.



Outstanding Feature. Sprat Hole is a heavily visited reef for snorkel and dive tours. It supports a very diverse fish community.

Threats. The Sprat Hole reef is vulnerable to land based sources of pollution if there is increased development of the watershed. Low wave action and light currents favor settling of small particles of terrestrial sediment that injure corals. The site is also frequently fished and there is derelict fishing gear in abundance. Recreational overuse may also be a threat.

Figure 83. Sprat Hole. (top) Location. (right) A representative photo of the reef.

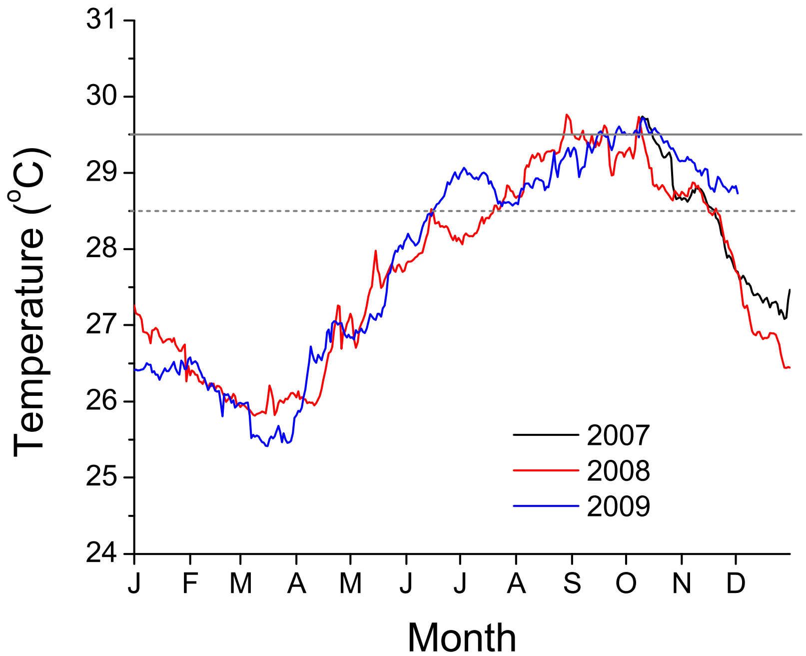


Figure 84. Sprat Hole benthic temperature (7 m depth).

Physical Characteristics.

Current. Currents have not been measured at Sprat Hole. Oscillatory currents are typically weak on the western lee of St. Croix. Unidirectional currents during monitoring have always been weak (<10cm s^{-1}).

Temperature. Sprat Hole temperature has not been monitored over many years due to loss of probes. This is likely due to the high exposure to recreational and commercial fishing divers. In general Sprat Hole appears to be a warm site.

Benthic Community. Sprat Hole is a fringing *Orbicella annularis* dominated reef, with a good diversity of other coral species. There was a 62.3% decline in coral cover due to the 2005 coral bleaching event, with a regain of 11.9% of cover by 2011. Epilithic algae dominate the algal community, with smaller amounts of a diverse group of macroalgae, including *Dictyota* spp. and *Halimeda* spp. There has been variable, but increasing cover of filamentous cyanobacteria since 2005.

Coral Health. The coral community at Sprat Hole was heavily affected during the 2005 coral bleaching event, with a high prevalence of bleaching at a very high extent. Bleaching prevalence has tended to be higher since the event. Disease prevalence can be quite high, particularly for white disease. Dark spots disease has also been in high prevalence in certain years. Old partial mortality was high on colonies from 2005 to 2011, and low when recorded in 2002. In this case, old partial mortality is a very common feature of *O. annularis* and it is likely that low values are due to observer bias and a different method for estimating partial mortality. Recent partial mortality is consistently very high at Sprat Hole, due in part to the high abundance of territorial damselfish (*Stegastes* spp.) forming algal lawns on *O. annularis.*

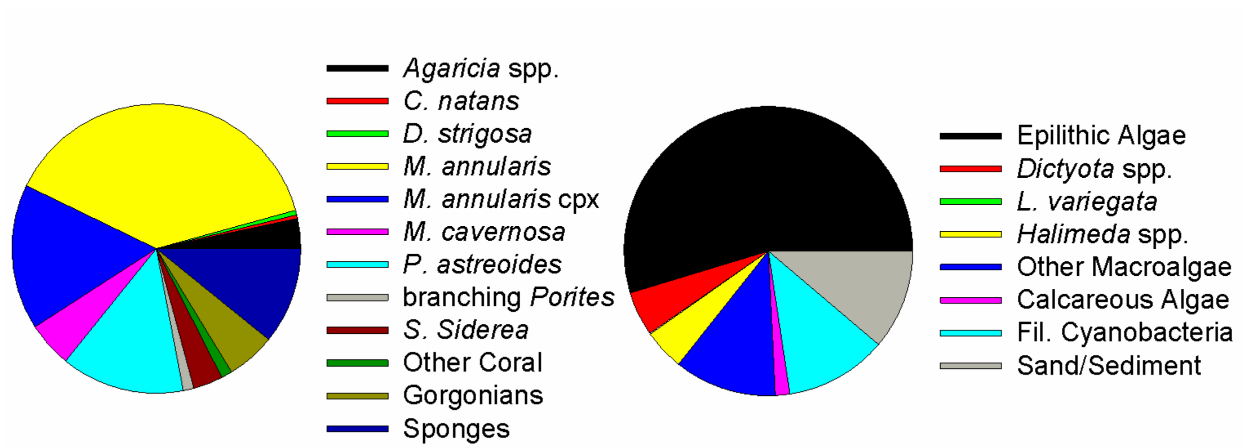


Figure 85. Sprat Hole (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

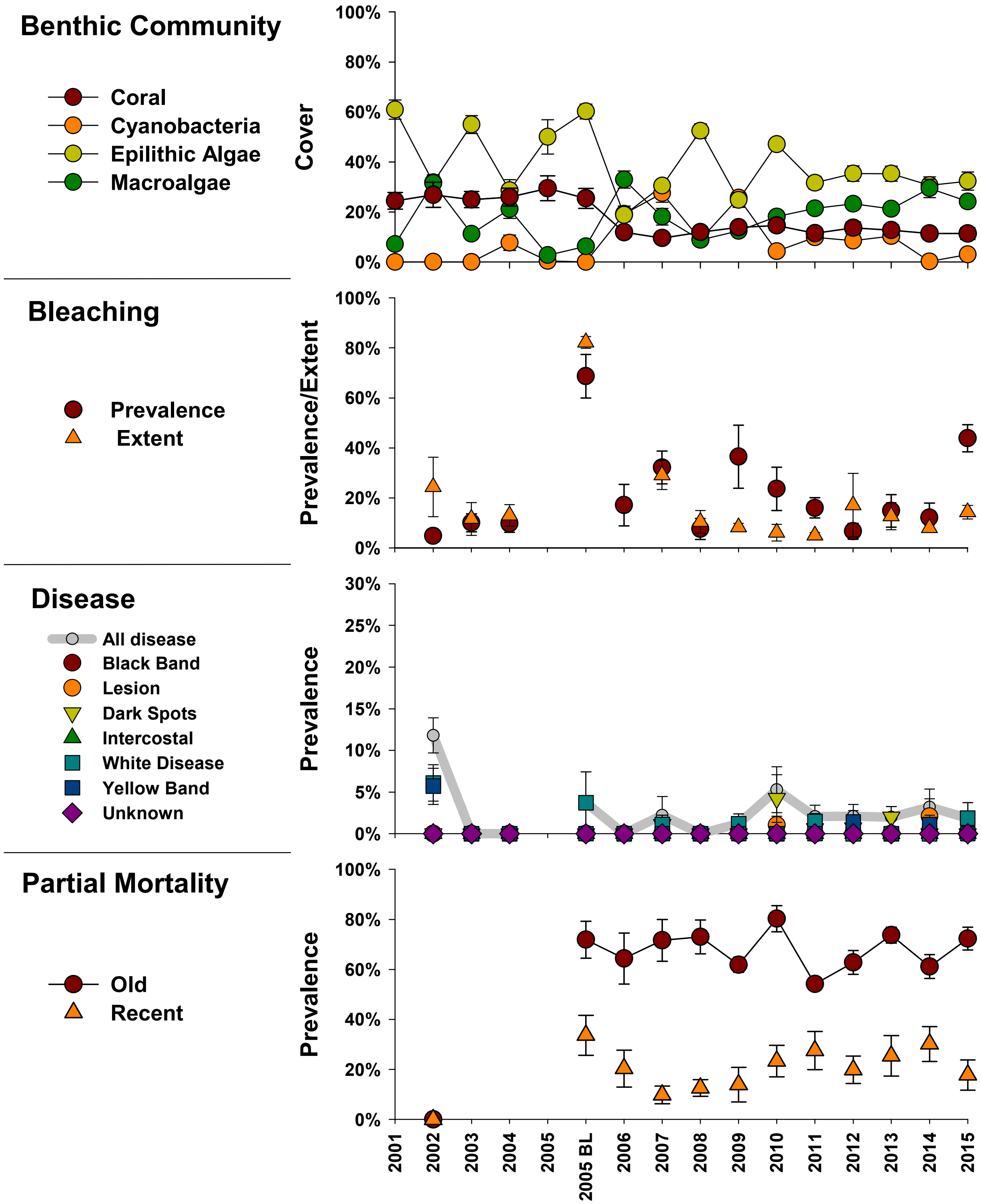


Figure 86. Sprat Hole benthic cover and coral health through time (mean ± SE).

Fish Community. Sprat Hole exhibits a fairly typical fish community structure for a nearshore coral reef ecosystem receiving some amount of terrestrial runoff from the watershed. Fish biomass is moderate, and the site is dominated numerically by the creole wrasse and blue chromis, planktivorous invertivores. Benthic herbivores are common and include small parrotfish and all three Caribbean acanthurid species. Invertivores are diverse and include both planktivores and benthic feeders; mostly small fish in small numbers. Mutton snapper have been recorded on the sight sporadically and a juvenile tiger grouper was spotted in 2013 and yellowfin grouper was seen in 2014. Numerically and by biomass the graysby dominate the piscivore group in. Lionfish have been observed on the Sprat Hole site every year since 2012.

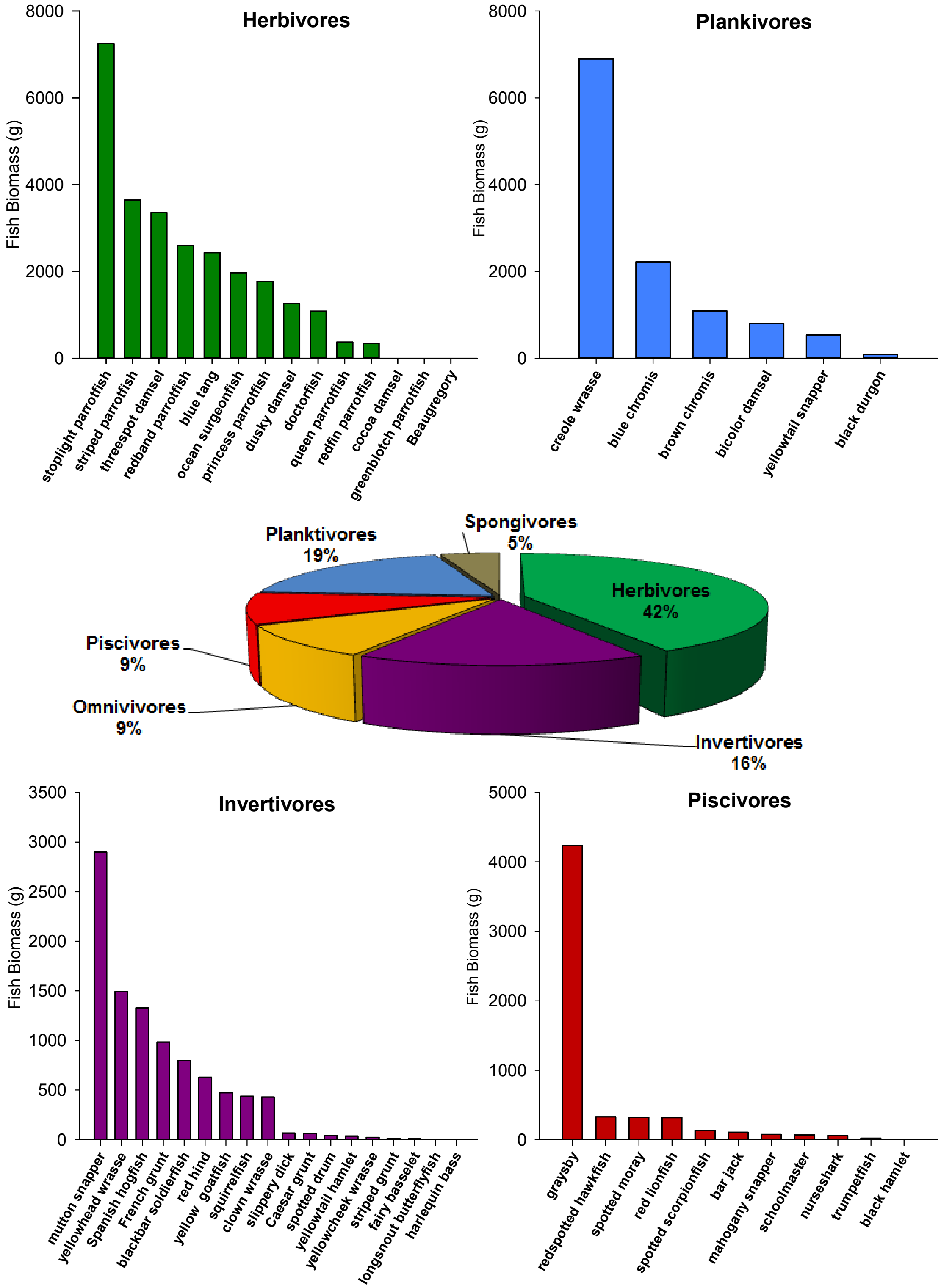


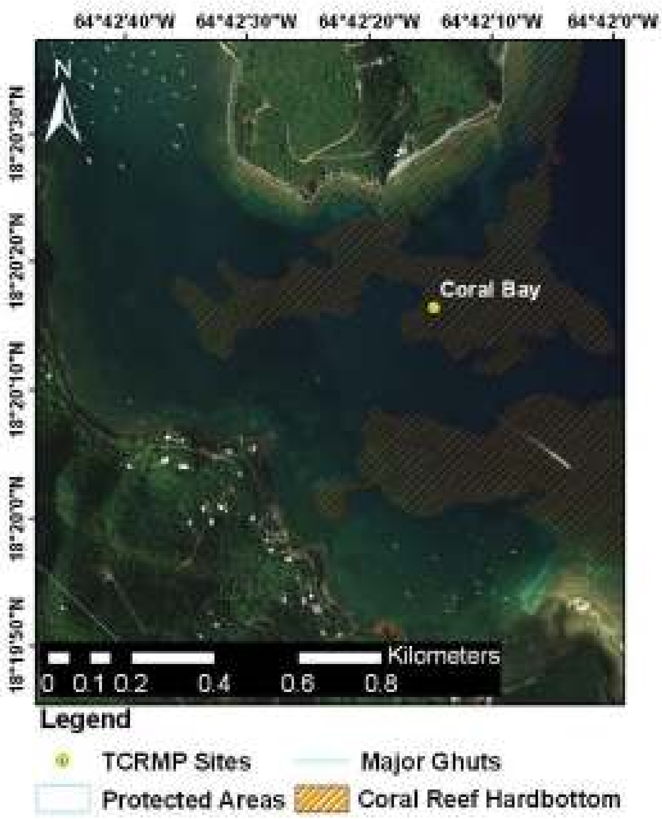
Figure 87. The Sprat Hole fish community by absolute and relative biomass.

St. John

160

CORAL BAY

Description. The Coral Bay site is atop a patch reef complex at the southeast mouth of Coral Harbor. The reef is a low carbonate build up with high coral diversity. Coral Bay appears to be a true reef with a well-developed carbonate framework over bedrock. Coral Bay monitoring was initiated in 2011.



Outstanding Feature. Coral Bay supports a high diversity of coral and an apparent high rate of coral recruitment.

Threats. Coral Bay is subject to land-based sources of pollution, primarily as sediment influx from the large and steep Coral Bay watershed. Recent restoration activities in the watershed are expected to decrease the sediment influx. Coral Bay may also be threatened by maritime activities within Coral Harbor. Proximity to land makes this site in territorial waters potentially vulnerable to fishing.

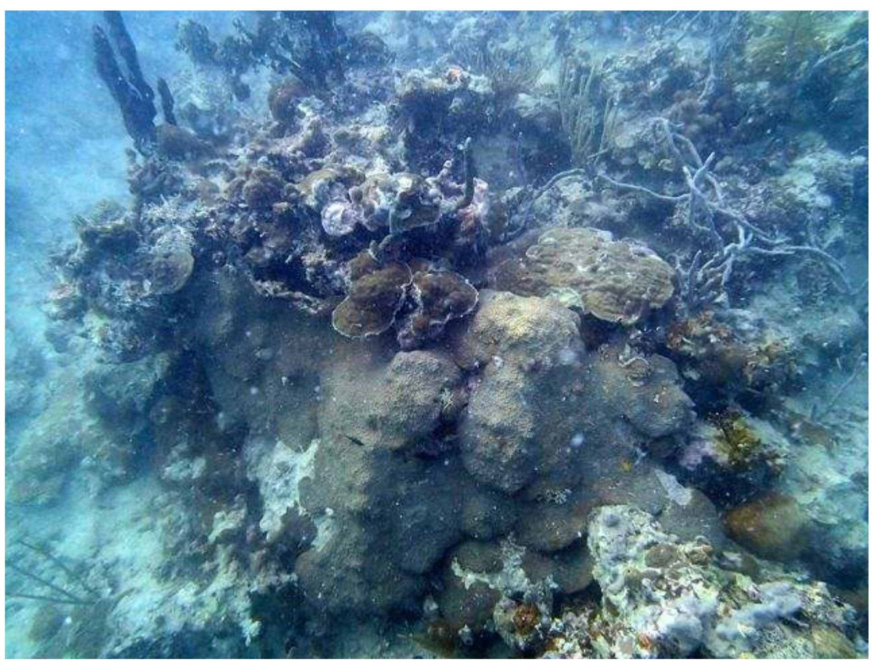


Figure 88. Coral Bay. (top) Location. (right) A representative photo of the reef.

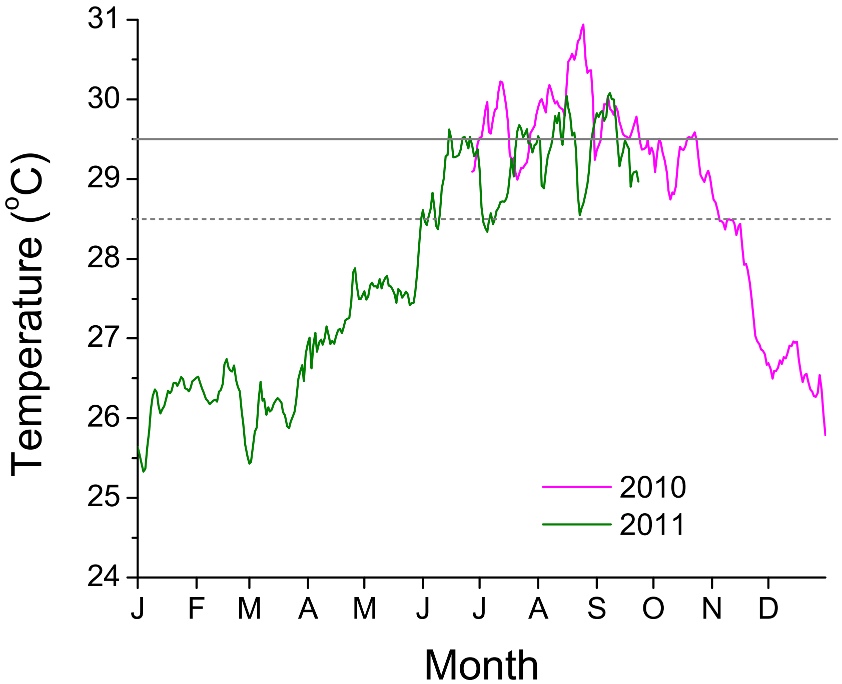


Figure 89. Coral Bay benthic temperature (9 m depth)

Physical Characteristics.

Current. Currents have not been measured by the TCRMP, however, Dr. Sarah Gray (University of San Diego) has measured 2-D near bottom measurements for some years between 2009-2011. Oscillatory currents are expected to be light and only weak unidirectional currents have been experienced.

Temperature. Coral Bay may have restricted water circulation and had very high temperatures during the 2010 bleaching event.

Other. This site and the wider Coral Bay area have been under investigation for land-based sources of pollution impacts since 2009. Projects have been involved terrestrial sediment measurement/modeling, marine sediment flux, coral demographic plots, and biological monitoring. The area has also been involved in water quality monitoring.

Benthic Community. Coral Bay has a very diverse coral community, with no clear dominance of cover. In contrast to most sites, the mustard hill coral *Porites astreoides* has the greatest cover among coral species. Sponges and gorgonians are also very common at this site. Epilithic algae and a high abundance of crustose coralline algae dominate the algal community, with very low abundance of macroalgae. This is surprising at this turbid reef site that likely receives high inputs of particulate and dissolved nutrient sources, and indicates that grazing is quite high. There is not a high abundance of herbivorous fish and only the occasional occurrence of *Diadema antillarum*. However, there is a great abundance of the rock boring urchin *Echinometra* spp. that appears to be the dominant grazer. This genus is not monitored in TCRMP protocols, but perhaps should be included in future years.

Coral Health. It is not known how corals were affected by bleaching in 2005. There was a low prevalence of low extent bleaching in 2011. Diseases were not recorded in 2011. Old partial mortality prevalence was low in 2011, but this may partly be explained by the high abundance of small coral colonies that are less prone old partial mortality. Recent mortality had low prevalence in 2011.

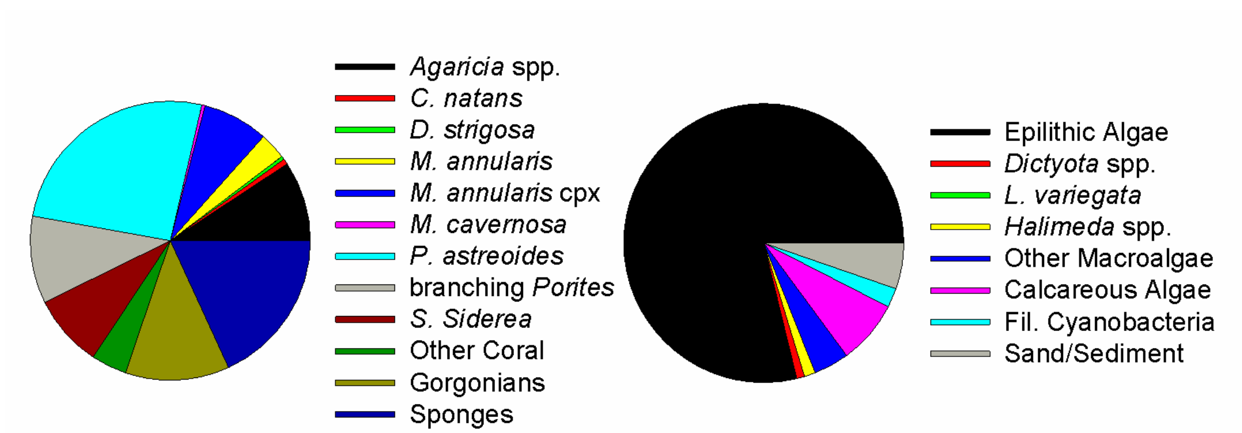


Figure 90. Coral Bay (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

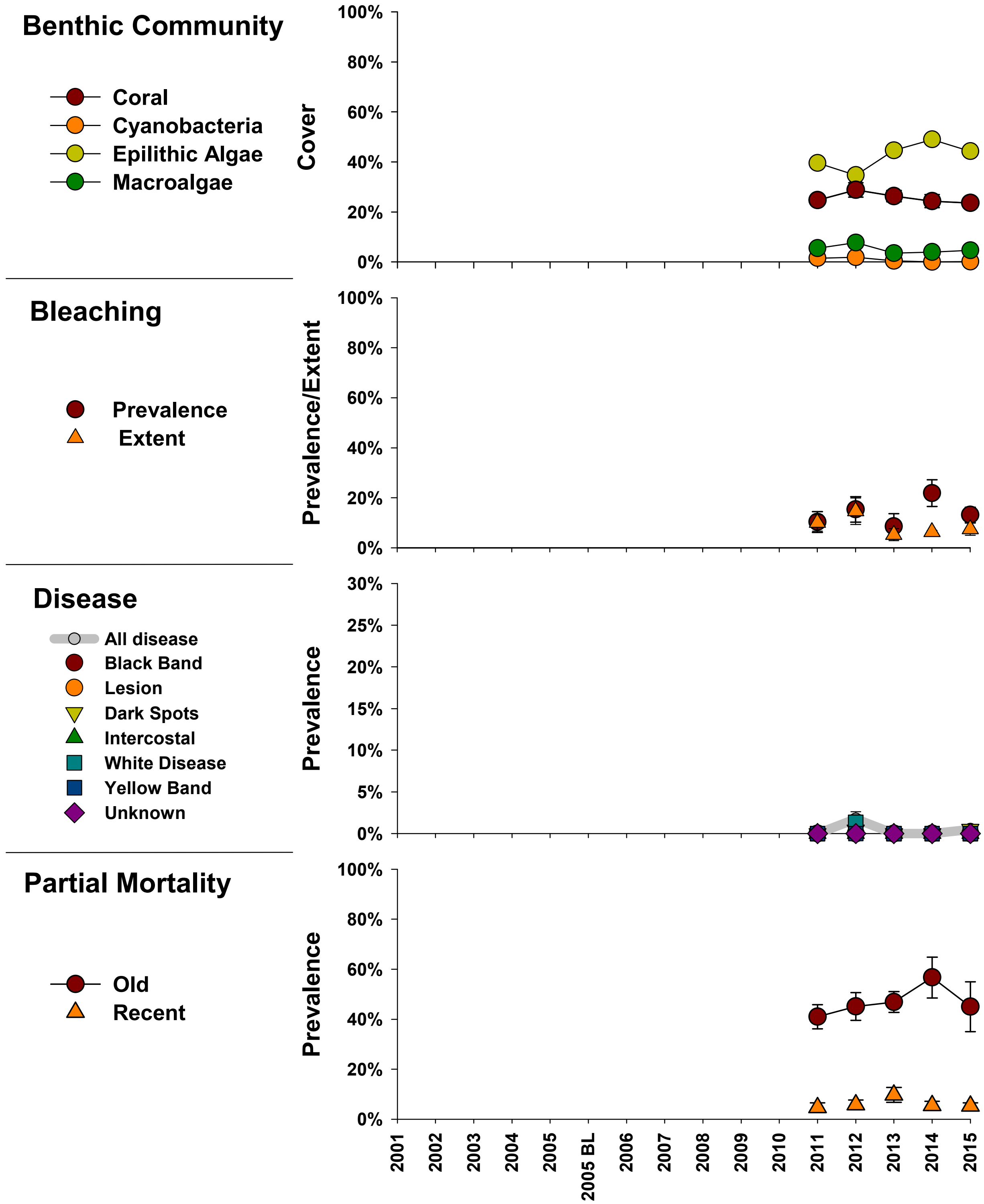


Figure 91. Coral Bay benthic cover and coral health through time (mean ± SE).

SITE SUMMARIES

Fish Community. The Coral Bay site is low in fish diversity, biomass and abundance. Although epilithic algae are prolific, large grazers are nearly absent. Three spot damselfish dominate the group in both abundance and biomass. Planktivores in the high turbidity habitat are limited to a few juvenile yellowtail snapper and pomocentrids. Although benthic invertivores were more prolific and diverse, only a few individuals comprise each species group. Likewise piscivores had a very low biomass and have been limited to a few individuals during monitoring surveys, most notably the schoolmaster snapper.

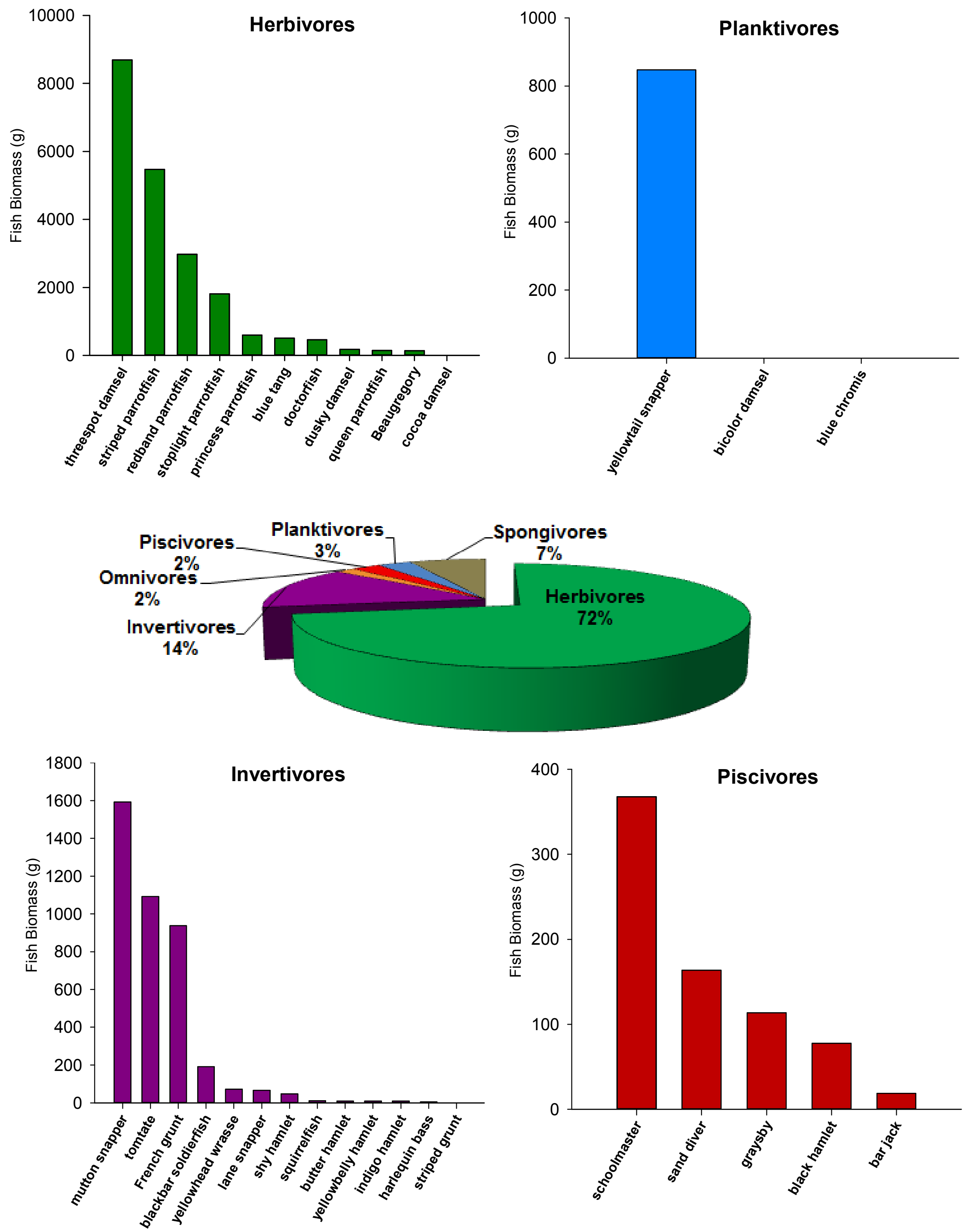


Figure 92. The Coral Bay fish community by absolute and relative biomass.

FISH BAY

Description. Fish Bay is a nearshore Fringing Reef in territorial waters. The monitoring site is a sharp edge of a shallow water coral community dropping to sand at 7 m depth. The site has been monitored since 2001.

Outstanding Feature. Fish Bay inner transects (1 – 3) are heavily sediment impacted, while outer transects (4-6) support large boulder star corals (*Orbicella faveolata*).

Threats. Fish Bay is subjected to land-based sources of pollution and tends to have turbid water and overgrowth by macroalgae on inner transects. This site may also be vulnerable to fishing impacts.

Figure 93. Fish Bay. (top) Location. (right) A representative photo of the reef.

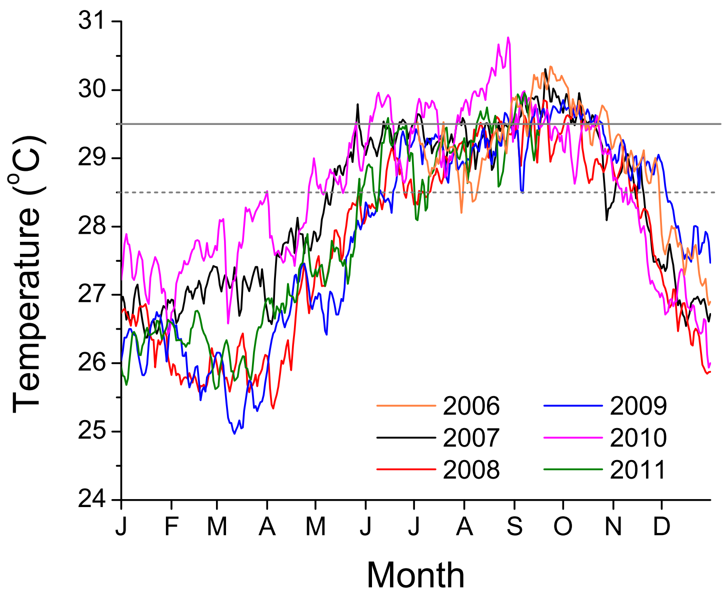


Figure 94. Fish Bay benthic temperature record (6 m depth).

Physical Characteristics.

Current. Fish Bay currents have not been measured directly by the TCRMP. Unidirectional currents are mild to slack. Because of the southeast exposure, wave driven oscillatory currents can be quite intense, particularly on the outer transects.

Temperature. Fish Bay has relatively high mean temperatures and was very far over the regoinal bleaching threshold in 2010.

Benthic Community. The coral community of Fish Bay is dominated by the boulder star coral *Orbicella* spp.. In particular, large (>2m wide) colonies of *O. faveolata* are common on the seaward transects (4-6). The inner transects (1-3) are mostly depauperate of coral (< 4% cover as of 2011). The site lost 37.1% of its cover due to the 2005 coral bleaching event, but had regained 136.1% of cover by 2011. Gorgonians are also very common on the wave-washed outer transects. Equal parts epilithic algae and the macroalgae *Dictyota* spp. dominate the algal community. The site also has a high abundance of *Halimeda opuntia*, which can be very abundant on inner transects closest to land-based sources of pollution.

Coral Health. Fish Bay corals were very severely affected in the 2005 with 100% of corals showing almost 100% bleaching. Bleaching is also normally high at this site even in years without thermal stress, a likely consequence of sediment and macroalgal interactions. Diseases, particularly dark spots disease and white disease, can have very high prevalence at Fish Bay. Old partial mortality did increase after the 2005 coral bleaching event, with a decline in 2010 and resurgence in 2011. Recent partial mortality can also be relatively high compared with other sites, largely as the results of bites from site-attached damselfish (*Stegastes* spp.).

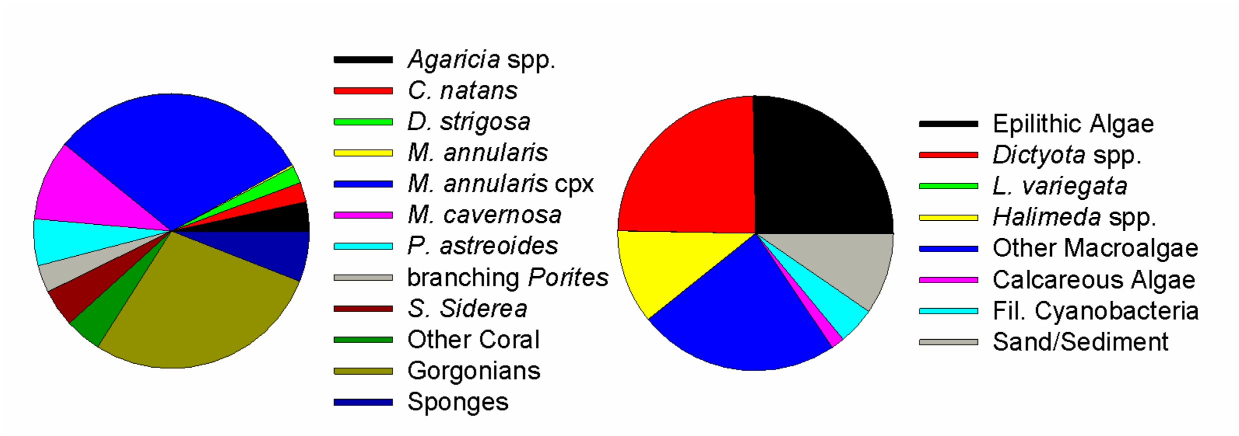


Figure 95. Fish Bay (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

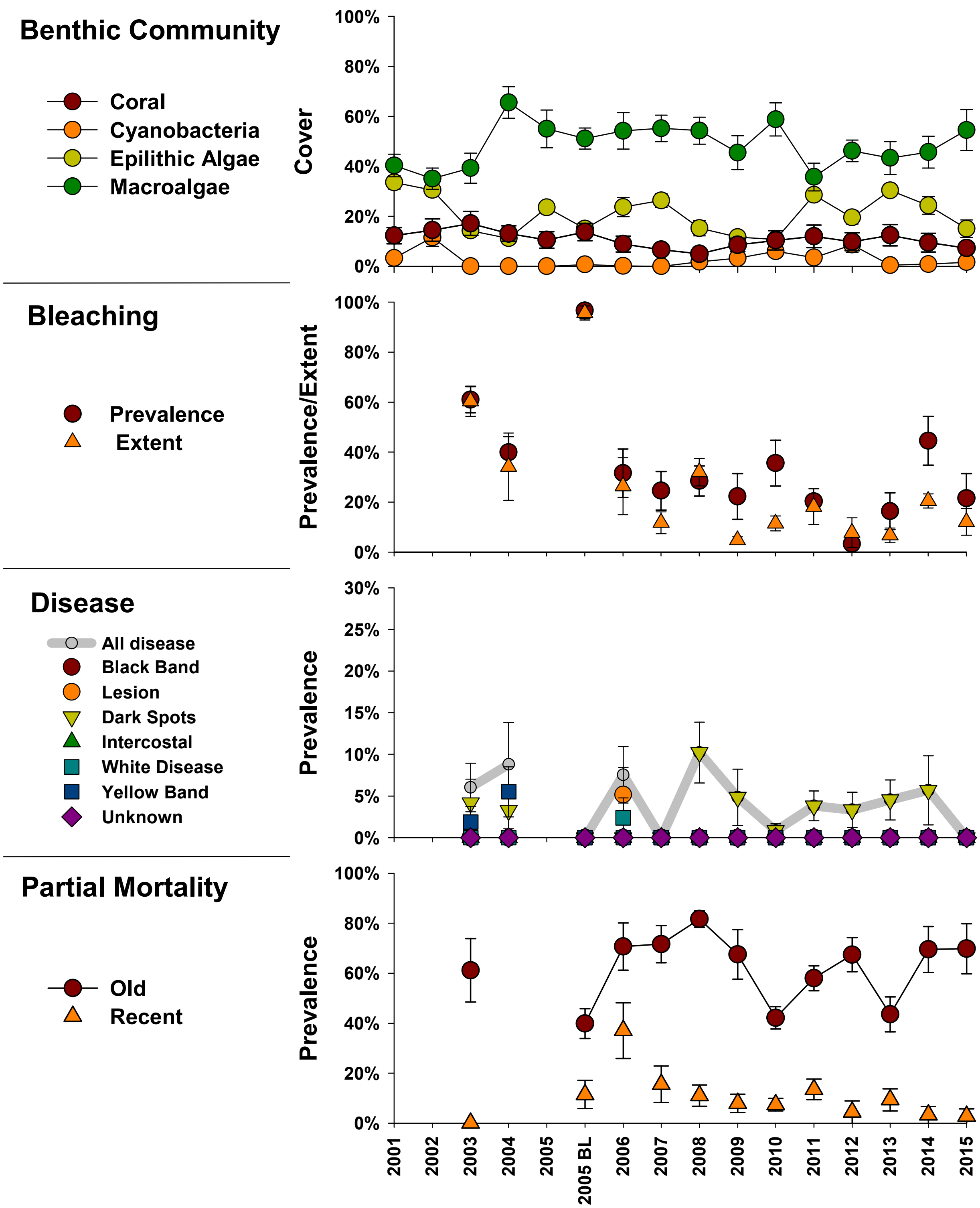


Figure 96. Fish Bay benthic cover and coral health through time (mean ± SE).

Fish Community. The Fish Bay fish community is typical of a nearshore reef habitat that receives moderate to heavy sedimentation. The site is dominated by herbivores that include all of the common Caribbean parrotfishes, large schools of mixed acanthurids, and herbivorous pomocentrids. Planktivores in the turbid water are limited to juvenile yellowtail snapper and a few small pomocentrids. Benthic invertivores and piscivores are more diverse and abundant but are dominated by wrasses and jacks, respectively. Large serranids and lutjanids are absent from Fish Bay although occasion juvenile lemon sharks are seen in the murky water, where adult females are known to pup.

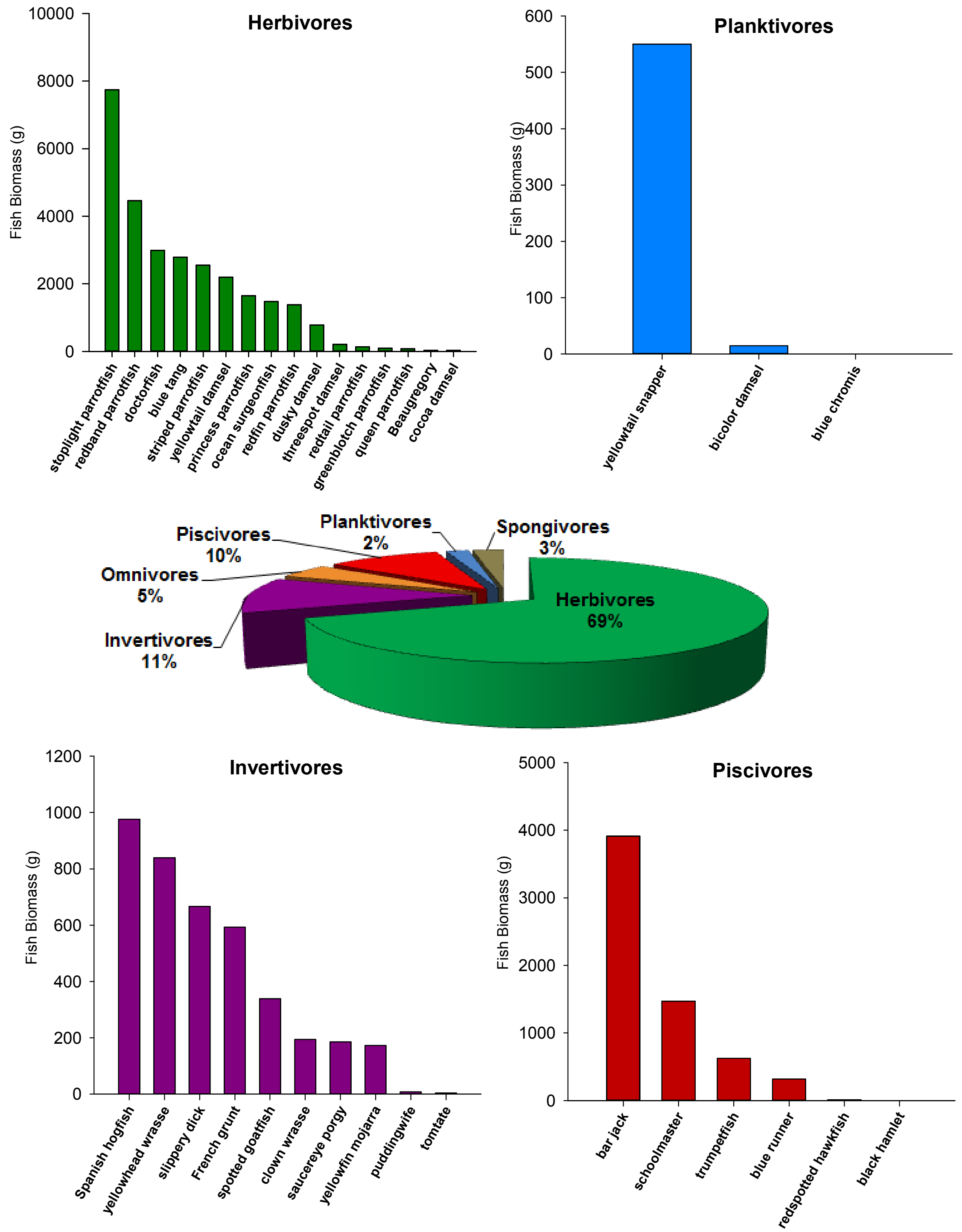
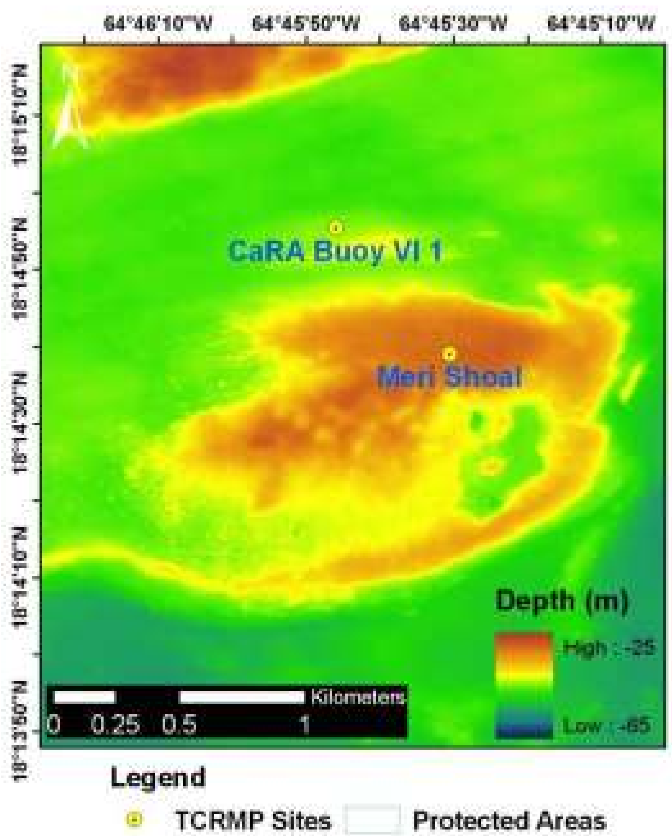


Figure 97. The Fish Bay fish community by absolute and relative biomass.

MERI SHOAL



Description. Meri Shoal is an offshore mesophotic coral bank 30 m depth. The reef is located four miles south of St. John and is on the southernmost of two impressive midshelf coral banks. The reef is dominated by interlocking colonies of boulder star corals (*Orbicella* spp.). The reef top is very flat coral plain. The site is named for Dr. Meri Whitaker, former director of the VI EPSCoR Program who passed away in 2009. Meri Shoal has been monitored since 2005.

Outstanding Feature. Meri Shoal has the highest star coral abundance of any site in the TCRMP and is bathed in clear, clean water.

Threats. Meri Shoal is vulnerable to fishing impacts, as it is outside any marine protected area. The high density of corals may also make this site vulnerable to disease impacts.

Figure 98. Meri Shoal. (top) Location. (right) A representative photo of the reef during the 2005 coral bleaching event (Oct. 6, 2005). The brain coral in the foreground is 1.8 m wide.

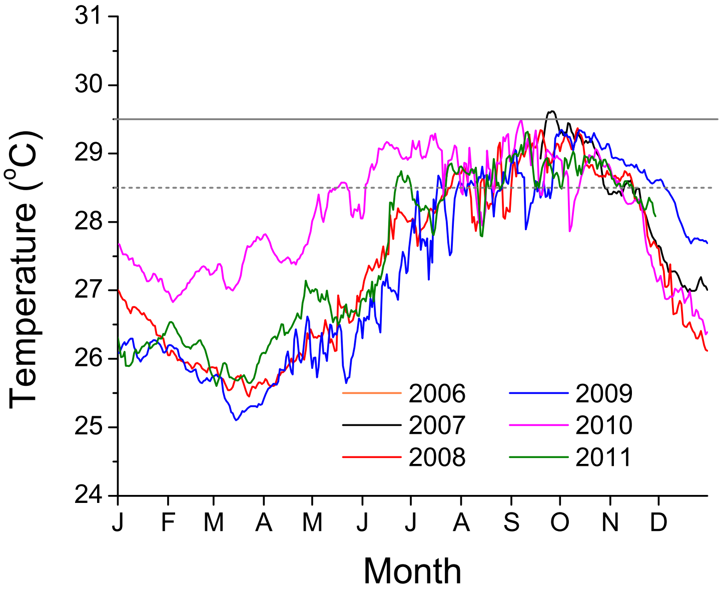


Figure 99. Meri Shoal benthic temperature record (30 m depth).

Physical Characteristics.

Current. Currents have not been measured directly at the Meri Shoal site, although the Caribbean Regional Association buoy VI 1 is located within 700 m and its downward focused ADCP has been recording data since April 2011.

Temperature. Meri Shoal has relatively low temperatures that are more similar to other mesophotic sites.

Benthic Community. The Meri Shoal site is exceptional for its domination by boulder star corals (*Orbicella* spp.). Cover of this and other coral species was exceptionally high when the site was first monitored during the 2005 coral bleaching event, but declined by 36.0% after bleaching and had not recovered any cover as of 2011 (-9.6%). Surprisingly, given the high coral cover, the algal community is dominated by *Lobophora variegata* and not epilithic algae and there has been a trend of increasing macroalgal cover since 2008.

Coral Health. Coral bleaching was relatively high for a mesophotic site during the coral bleaching event in 2005. Bleaching was again at high prevalence, but low extent in the thermal stress of 2010. However, low-extent bleaching at moderate prevalence is a persistent feature of Meri Shoal. Disease, particularly white disease and lesions that are likely the remnants of white disease, are highly prevalent, particularly in years following high thermal anomalies, such as 2006 and 2011. Old partial mortality climbed steeply from the 2005 coral bleaching event onwards and reached very high levels by 2006. Recent partial mortality has also been consistently high as the result of white disease and disease lesions.

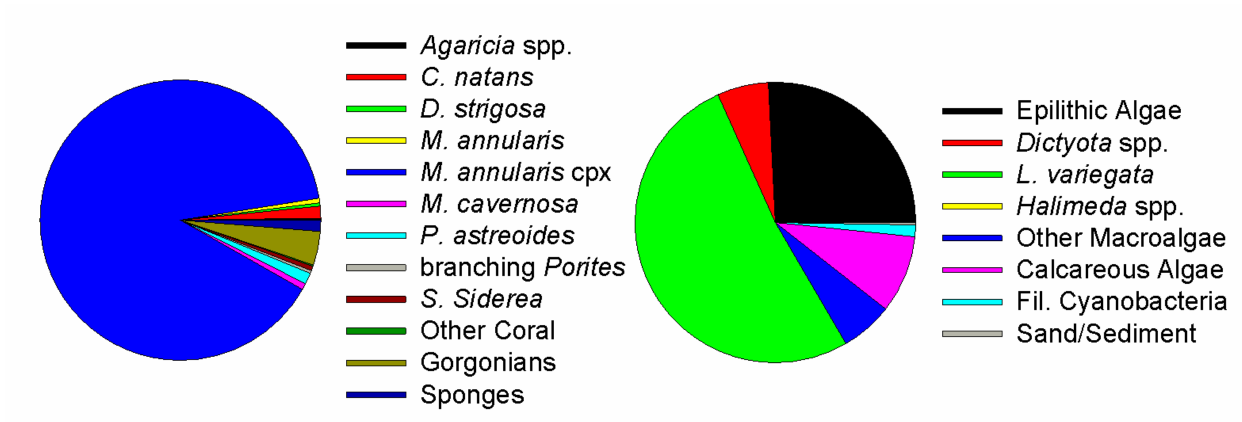


Figure 100. Meri Shoal (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

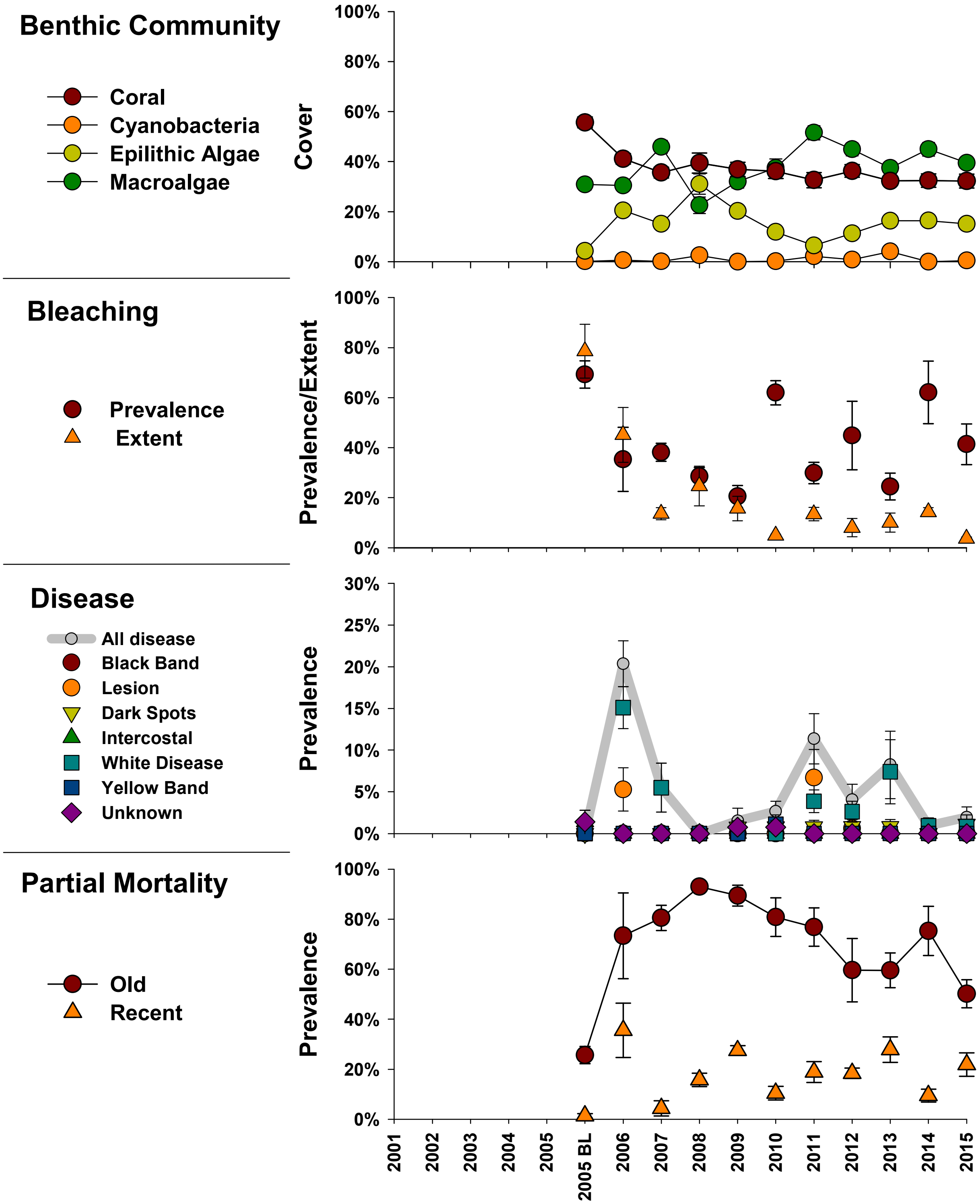


Figure 101. Meri Shoal benthic cover and coral health through time (mean ± SE).

Fish Community. Meri Shoal is a beautiful site in relatively deep water and holds a dynamic fish community of high biomass. Important planktivores include the very prolific creole wrasse, feeding on tiny jellyfish, invertivore larvae and phytoplankton, and the black durgeon, primarily a zooplankton feeder. Herbivores observed on the site include large stoplight parrotfish, all of the common smaller parrotfish, and all three acanthurids in fairly large numbers. Queen triggerfish and red hind are both common. In 2012 a tiger grouper was observed on a belt transect and another on a roving dive. A Nassau grouper was also observed on a roving dive in 2013. These are exciting encounters as the site is not near a spawning aggregation area and is not protected from traps or any type of fishing. Jacks, mackerels, and barracuda are also regularly observed in the water column at Meri Shoal.

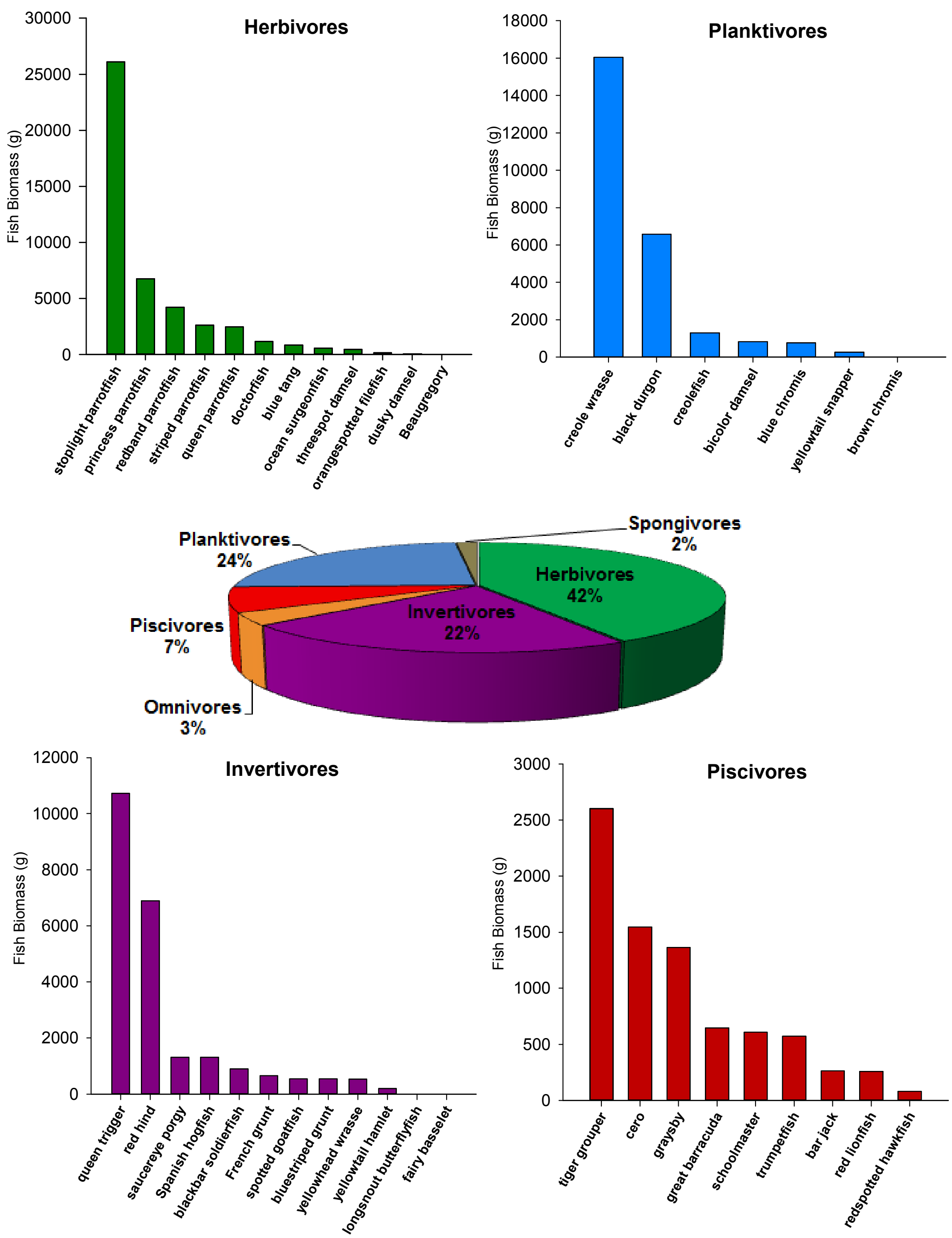


Figure 102. The Meri Shoal fish community by absolute and relative biomass.

St. Thomas

BLACK POINT

Description. Black Point is a nearshore fringing reef located at the mouth of Brewers Bay along the southwest coast of St. Thomas in water depths of 7 – 17 m. The reef has a sharp break in slope leading to a steep escarpment that terminates in a sediment plain at the reef base. Black Point appears to be a true reef with a well-developed carbonate framework over bedrock. Black Point has been monitored since 2003, with permanent benthic transects installed in 2007. A ciguatera fish poisoning study with monthly sampling has been ongoing since 2009.

Outstanding Feature. Black Point supports a fish spawning aggregation of striped parrotfish (*Scarus iserti*) with daily afternoon mating at the edge of the upper reef break.

Threats. Black Point is subjected to land-based sources of pollution and tends to have turbid water and overgrowth by heterotrophic organisms, such as sponges. Recreational/artisanal fishers with handline and spear frequently fish this site.

Figure 103. Black Point. (top) Location. (right) A representative photo of the reef.

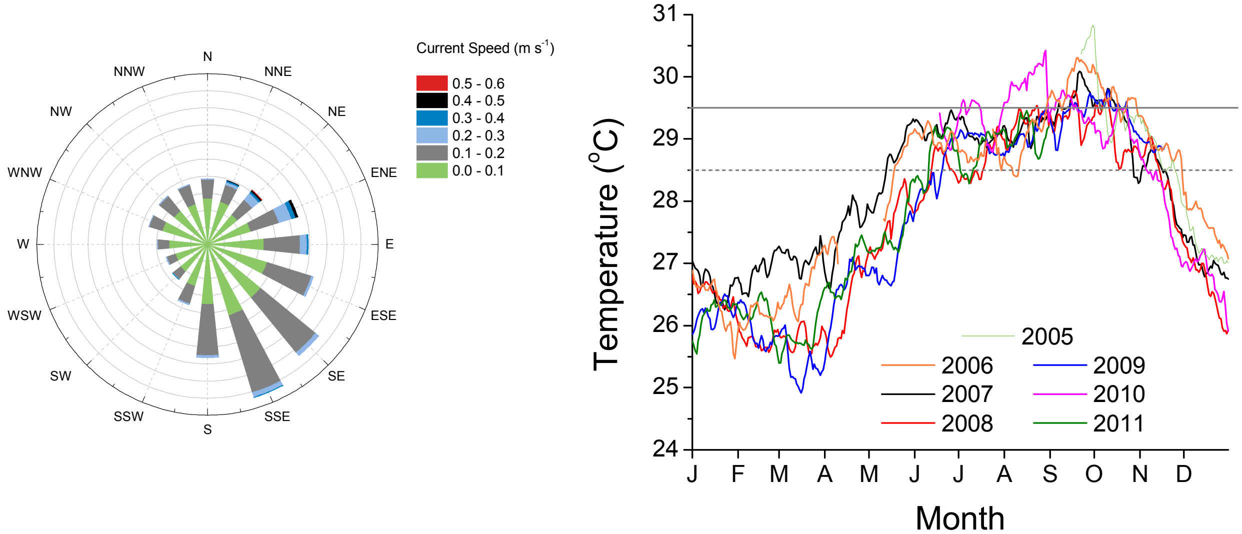


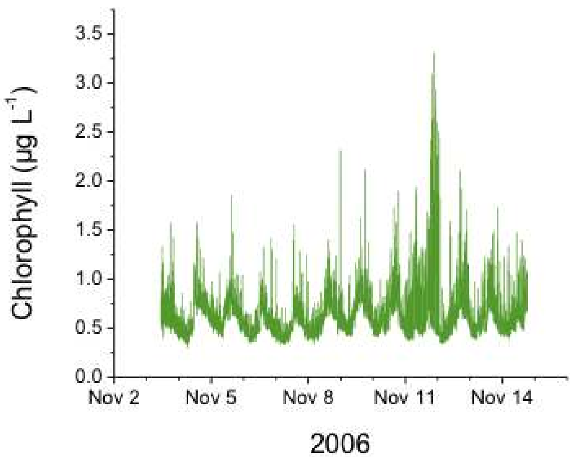
Figure 104. Black point current speed and benthic temperature record (8 m depth).

Physical Characteristics.

Current. Black Point has restricted water flow dominated by weak currents running counter or orthogonally to the left of the dominant wind direction. This may indicate that there is a counter flowing eddy from Perseverance Bay to the west that impinges on the headland. Current data are based on average data taken every 30 min. (11/29/06 to 3/1/2007) and hourly (4/19/07 to 9/5/07).

Temperature. Black Point has low circulation and relatively high mean temperatures with very low day-to-day variability.

Chlorophyll & Turbidity. Chlorophyll tends to be high at Black Point, likely due to inputs of land-based nutrients that fuel pelagic productivity. There are also exists a very prominent tidal signature that reflects switching source currents at the reef.



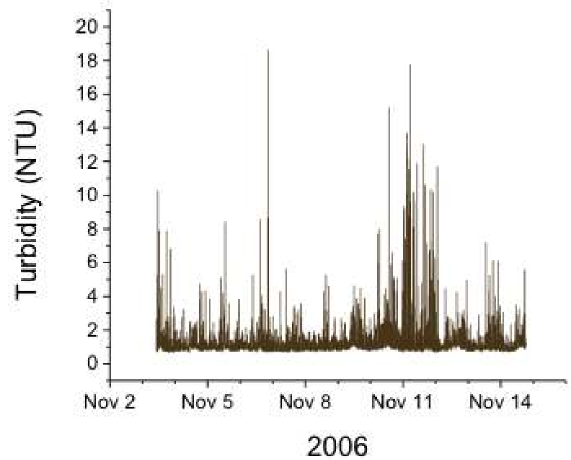


Figure 105. Black Point chlorophyll (left) and turbidity (right) record (16 m depth).

Benthic Community. Black Point supports a very diverse coral community with very equal representation by many coral species. However, large colonies (> 100 cm diameter) of *Orbicella annularis* and *Orbicella faveolata* occur on the eastern edge of the site, with a few occurring within transects. This coral community lost 40.5% of its coral cover in the 2005 bleaching event; however, by 2011 it had regained 103.5% of its coral cover. The algal community at Black Point is co-dominated by epilithic algae and the macroalga *Dictyota* spp..

Coral Health. Black Point corals were severely affected during the 2005 bleaching event with nearly all colonies bleached over 100% of the colony surface. The prevalence of coral diseases was moderate with dark spots disease predominating. However, white disease outbreaks occurred at least twice over the sampling period. Old partial mortality became very prevalent after the 2005 coral bleaching event and subsided in the following two years.

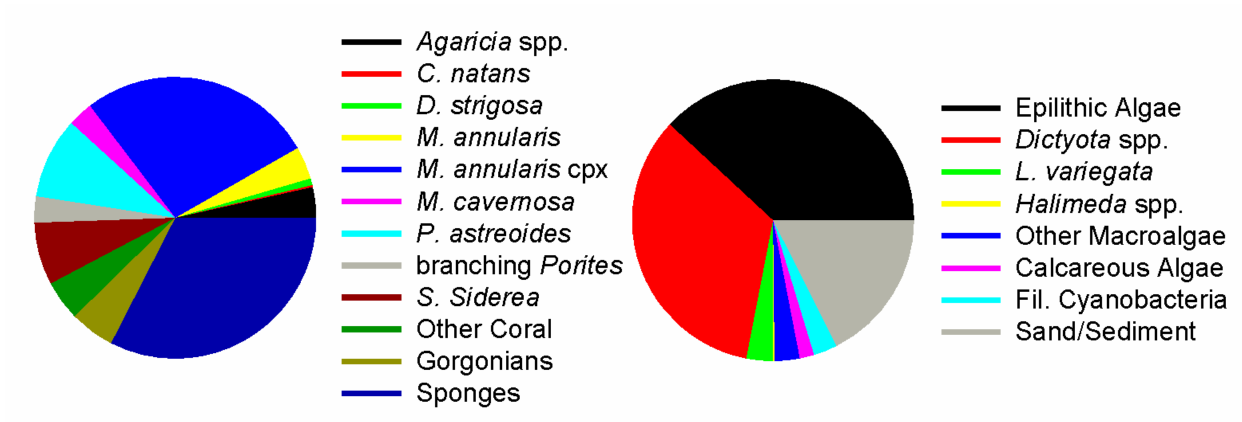


Figure 106. Black Point. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

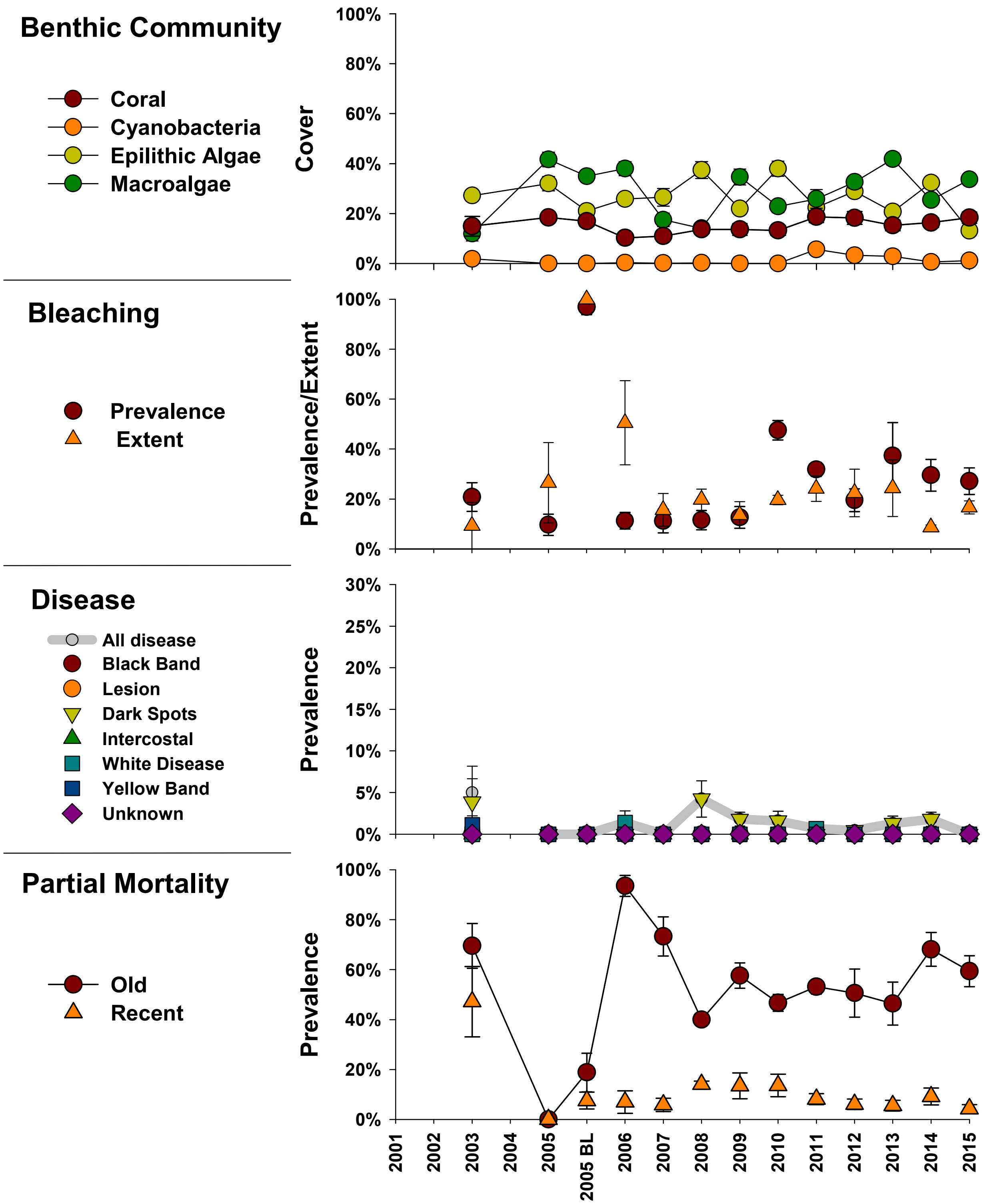


Figure 107. Black Point benthic cover and coral health through time (mean ± SE).

BLACK POINT

Fish Community. Black Point is highly dominated by herbivores. Juvenile parrotfish and damselfish are numerous. Brown chromis are equally abundant. The site is turbid and holds very few large fish, although the very occasional cubera snapper, Nassau grouper, or yellowfin grouper can be spotted, a rarity for nearshore areas of the USVI. These individuals are always observed near the eastern edge of the site where the reef is undercut and caves have formed. A resident mutton snapper (or two) is regularly observed cruising the sand line at the bottom of the reef. Hamlets are diverse and common. The black hamlet is especially abundant. In the mid to late afternoon, striped parrotfish (*Scarus iserti*) spawn at Black Point. They can be seen swimming along the reef edge in large groups beginning in the early afternoon. Spawning goes in to the late afternoon and involves tens of fish. Black Point is close to shore and is not trapped often; however, divers can swim to the reef from the beach to spearfish. It is notably lacking of resident large edible fish.

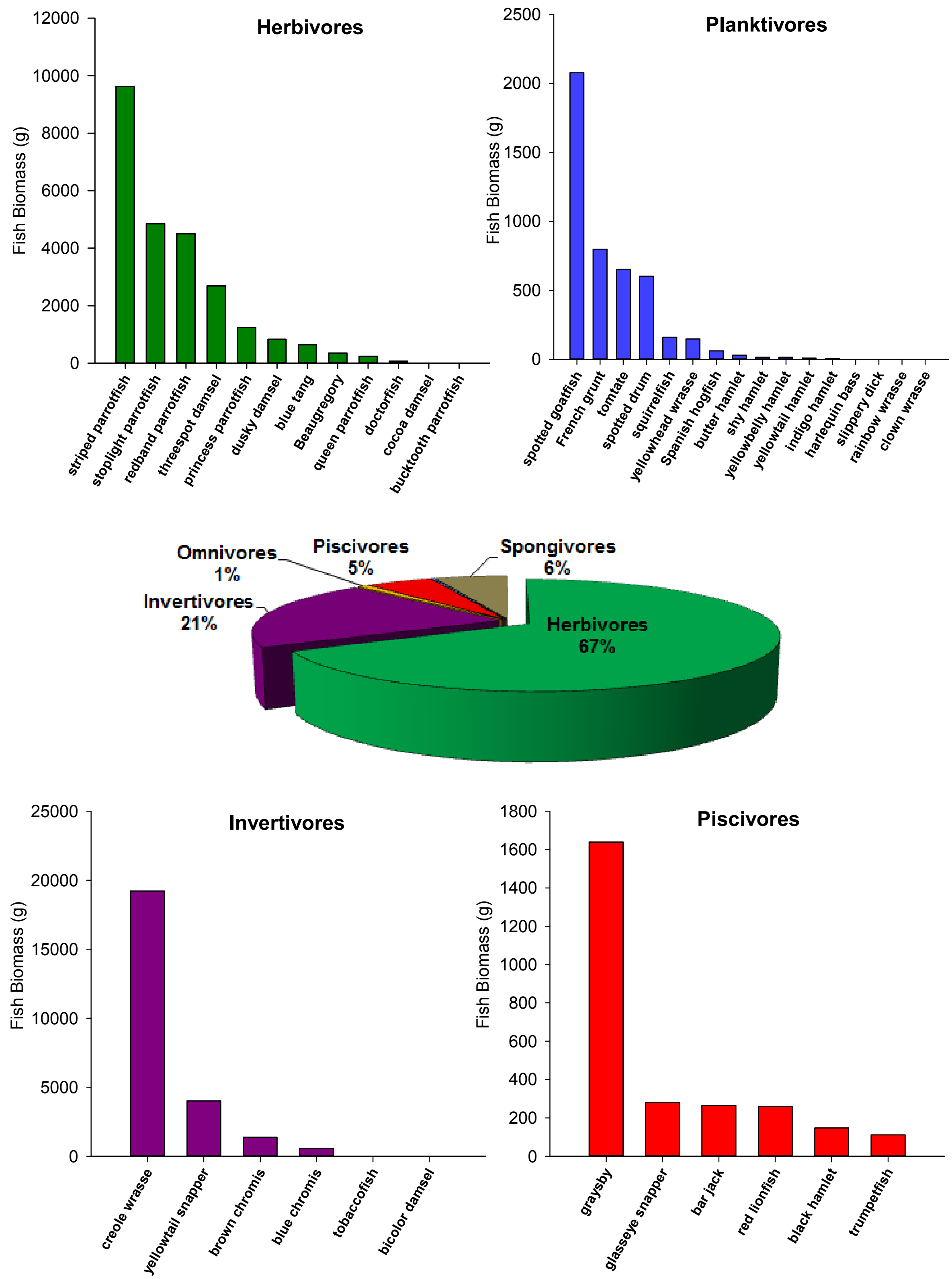
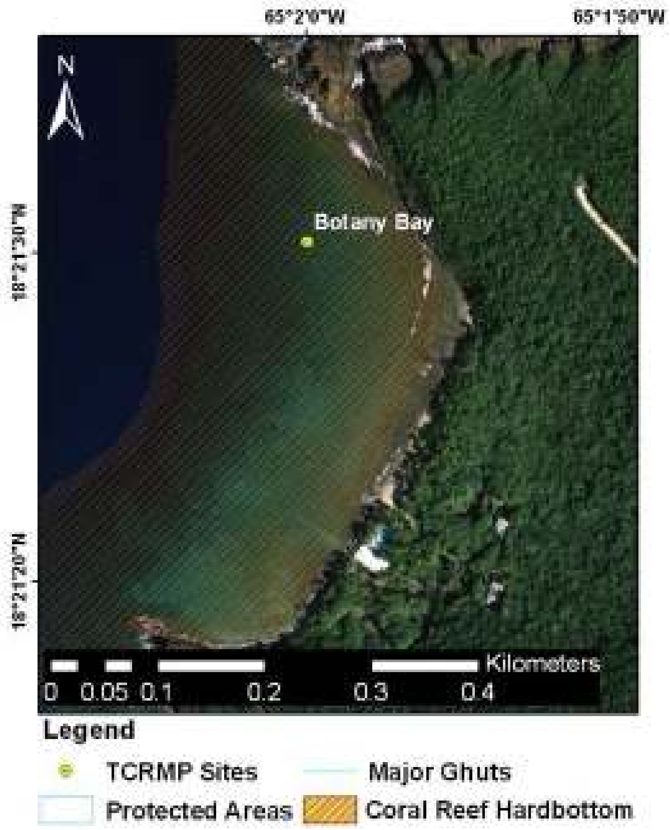


Figure 108. The Black Point fish community by absolute and relative biomass.

BOTANY BAY

BOTANY BAY

Description. The Botany Bay site is located on the fore slope of a nearshore fringing reef in water depths of 5 – 17 m. The reef crest is a distinct spur-and-groove, with a sharp break in slope leading to an escarpment that terminates in a sand/sediment plain at the reef base. Botany Bay has been monitored since 2002.



Outstanding Feature. Botany Bay supports a diverse and productive reef that is one of the prettiest nearshore reefs in the Virgin Islands and is surrounded by one of the most aesthetically pleasing locales on St. Thomas.

Threats. Botany Bay is threatened by development of the previously fully vegetated watershed and increased land-based sources of pollution. The area is open to fishing. Increased residential development in the watershed may lead to increased recreational use of the reef, including fishing and collecting. The area is also occasionally impacted by large Atlantic swells, causing breakage of corals.

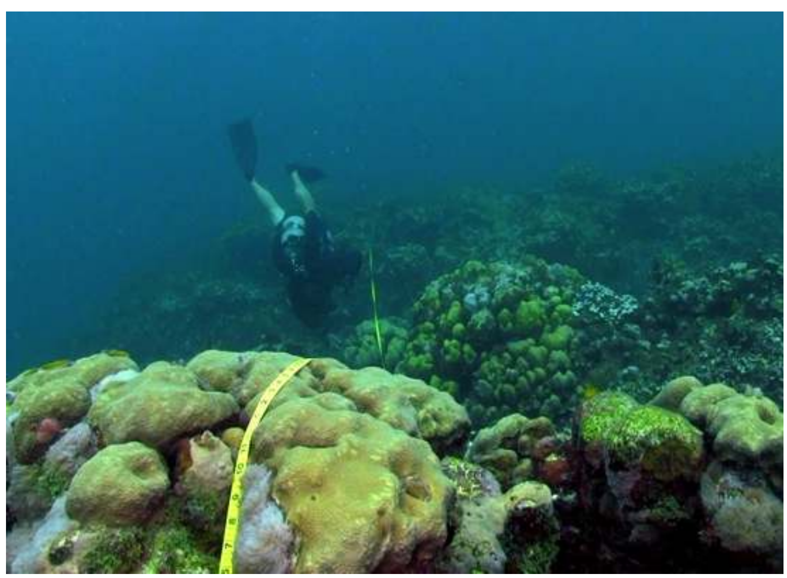


Figure 109. Botany Bay. (top) Location. (right) A representative photo of the reef.

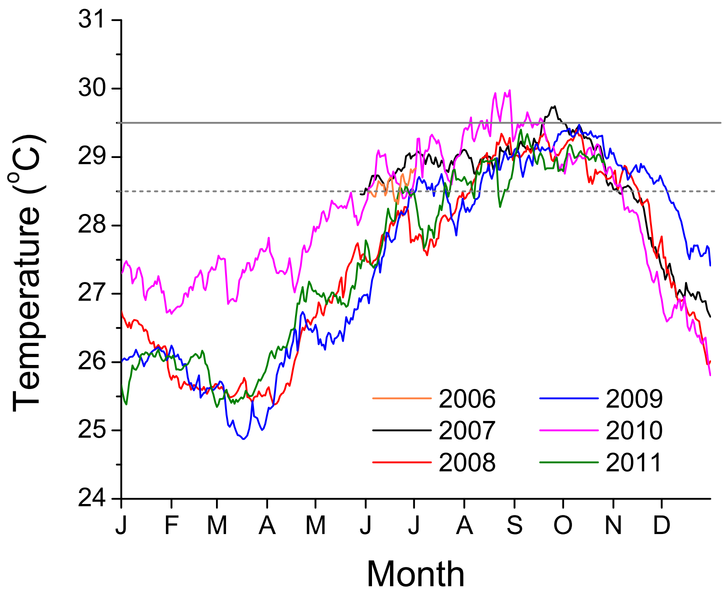


Figure 110. Botany Bay benthic temperature record (11 m depth).

Physical Characteristics. **Current**. Currents have not been measured at directly at Botany Bay. Unidirectional currents do not tend to be strong. Wave-driven oscillatory currents can impact the reef crest and fore reef. The site is vulnerable to impacts from large Atlantic swells. Many corals were broken and toppled during the 2009 March swell event when offshore swells reached heights to 4 m. **Temperature**. Botany Bay tends to have slightly cooler temperatures than other nearshore sites, likely owing to its open position facing the Atlantic.

Figure 111. A large colony of pillar coral (*Dendrogyra cylindricus*) dislodge, toppled, and diseased after the 2009 swell event (Botany Bay, June 25, 2009).

BOTANY BAY

Benthic Community. The Botany Bay site coral community is unique for the dominance of branching *Porites* spp., particularly *Porites porites*. The site lost 38.9% of its coral cover in the 2005 bleaching event and had regained 10.6% by 2011. There is a high abundance of gorgonians on the seaward slope exposed to wave swell. The Botany Bay algal community is co-dominated by epilithic algae and the macroalga *Dictyota* spp., which tend to negatively covary.

Coral Health. Bleaching was extremely severe during 2005, with nearly 100% of corals bleached or pale over 100% of their surface. There was also a high prevalence of bleaching in 2002 at an unknown extent and in 2010 at a low extent. Non-thermal stress years have seen variable bleaching. Coral diseases can be high at Botany Bay, with a preponderance of white and dark spots diseases, and lesions that are likely related to white disease. Old partial mortality shows a pattern that is difficult to explain before 2005. During bleaching and afterwards consistent observers have done partial mortality assessments and this data is valid. There was a large increase in old partial mortality after the 2005 bleaching event, then some subsidence and leveling off after 2008. Recent partial mortality was high through most years of monitoring, largely due to biting by territorial damselfish (*Stegastes* spp.; data not shown).

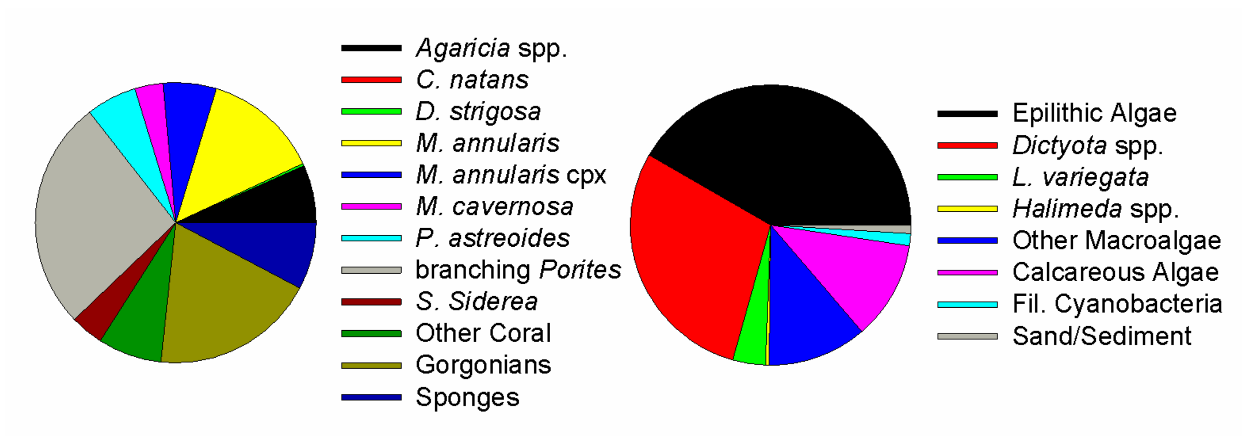


Figure 112. Botany Bay. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

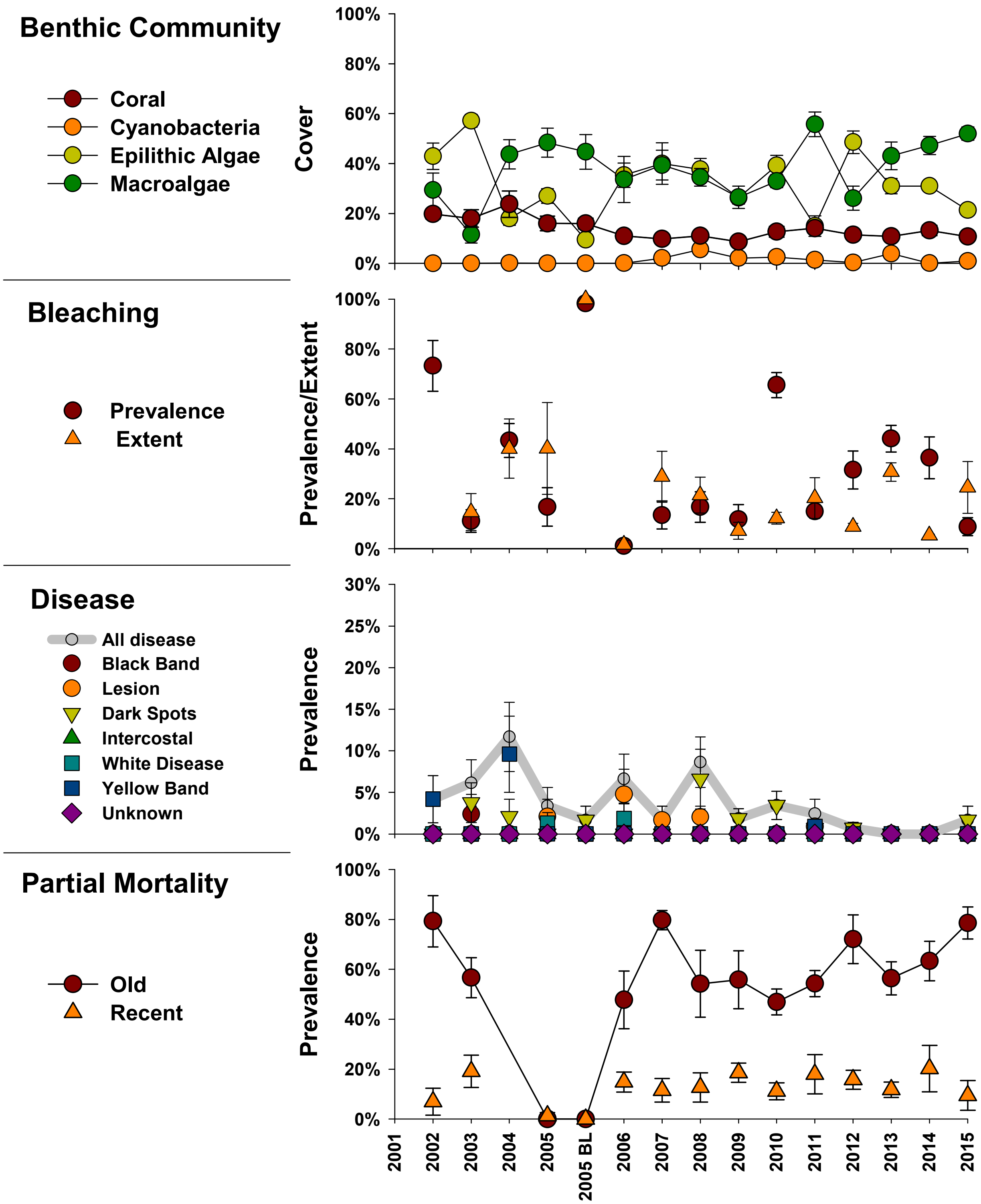


Figure 113. Botany Bay benthic cover and coral health through time (mean ± SE).

BOTANY BAY

Fish Community. The fish community at Botany Bay is typical of well developed nearshore reefs around St. Thomas. The site is dominated by herbivores, primarily large stoplight parrotfish. Large habitat diversity at the site supports fish species richness and all trophic groups are well represented. Botany has a highly diverse fish community, similarly to Cane Bay, St. Croix. These sites may each be recruitment sinks owing to their position on the northwest sides of the islands where eddies tend to circulate. Generally, red hind, dog snapper, and yellowtail snapper are recorded in fish transects. In 2014, a rainbow parrotfish was observed. On roving dives, spiny lobsters are nearly always encountered. Grunts and wrasses are especially numerous and diverse at the site. Like most nearshore reefs, large jacks and balistids are nearly absent, and the planktivore community is comprised mainly of blue and brown chromis.

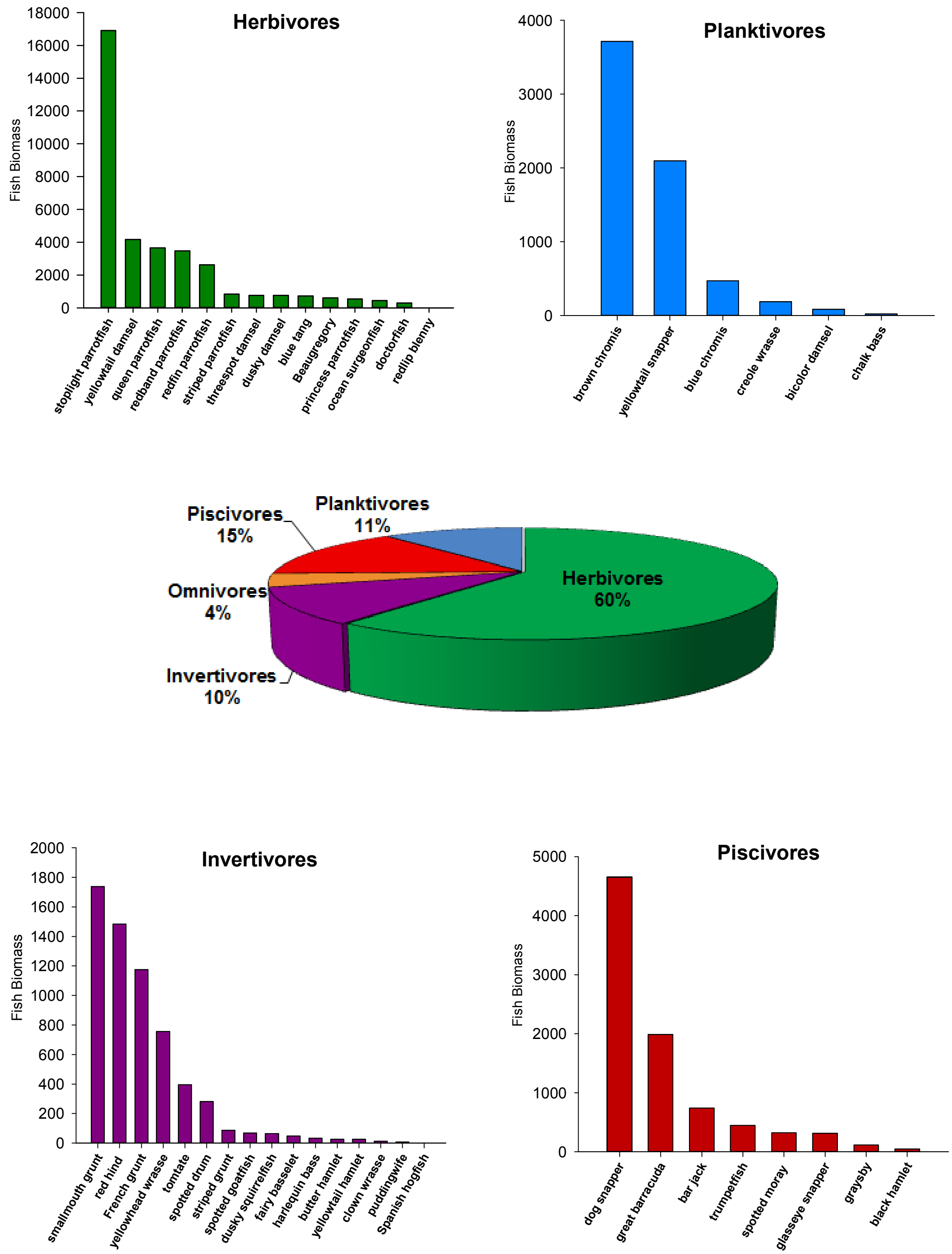


Figure 114. The Botany Bay fish community by absolute and relative biomass.

BREWERS BAY

Description. Brewers Bay is a nearshore fringing reef located along the southwest coast of St. Thomas in water depths of 7 – 17 m. Brewers Bay is a very well develop boulder star coral (*Orbicella annularis*) dominated reef. Brewers Bay was initially monitored in 2002/2003, but was abandoned due to its proximity to the Black Point site. It was picked-up again in 2008 due to? the excellent coral development and resistance to bleaching impacts.

Outstanding Feature. Brewers Bay is very good example of a nearshore boulder star coral fringing reef and has fared better than other reefs of this type over the 2005 mass coral bleaching event.

Threats. Brewers Bay is subjected to land-based sources of pollution and tends to have turbid water and overgrowth by heterotrophic organisms, such as sponges. Recreational/artisanal fishers frequently fish Brewers Bay with hand line and spear. The site has a great deal of marine debris, including boat hulls, rope, and metal pieces.

Figure 115. Brewers Bay. (top) Location. (right) A representative photo of the reef.

Physical Characteristics.

Current. Brewers Bay currents have not been measured directly, but both unidirectional and oscillatory currents are usually very low in magnitude. See also the Black Point physical data, which was taken within 500 m distance.

Temperature. Brewers Bay temperatures have not been recorded directly, but see the Black Point temperature data from less than 300 m horizontal distance. The site has restricted flow and should develop high warm season temperatures.

Benthic Community. The Brewers Bay site is highly dominated by the boulder coral *Orbicella annularis* and exhibits the highest coral cover of any nearshore site in the TCRMP, with a coral cover of 32% in 2013. Coral cover was not monitored between 2003 and 2008; however there was a 28.4% decline in cover that could largely be attributed to the 2005 coral bleaching event. The algal community at Brewers Bay is dominated by epilithic algae, with lesser amounts of the macroalga *Dictyota* spp..

Coral Health. Corals at the Brewers Bay site were not monitored for health over the 2005 bleaching event. However, corals exhibited some of the highest prevalence of bleaching during the 2010 coral bleaching event, albeit at a low extent. In other years, bleaching prevalence remained high, with a low extent. Yellow band disease outbreaks were severe and affected the *O. annularis* community in 2002 and 2003. Old partial mortality is a prominent and persistent feature of the large *O. annularis* colonies. Recent mortality is very high and largely attributable to the biting of large populations of the territorial three-spot damselfish (*Stegastes planifrons*; data not shown).

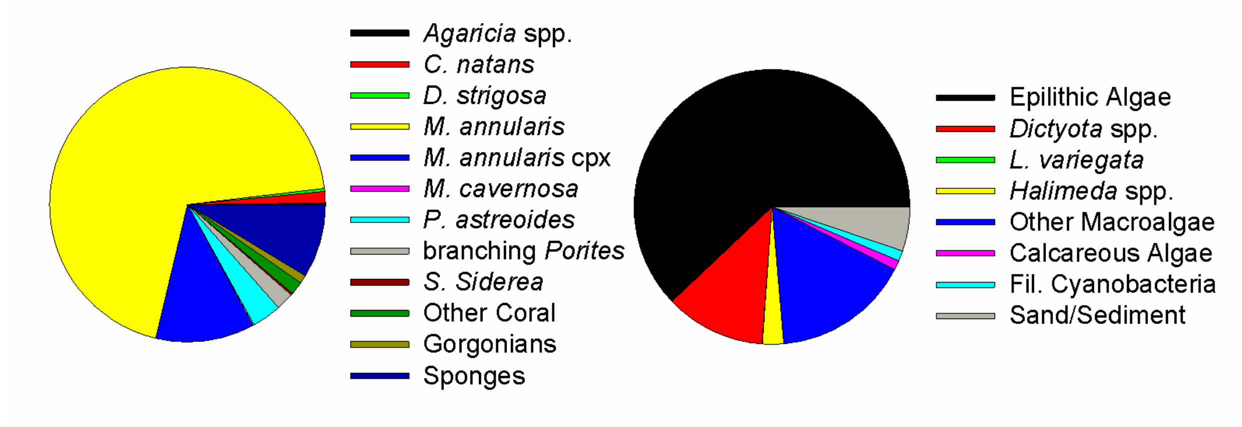


Figure 116. Brewers Bay. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

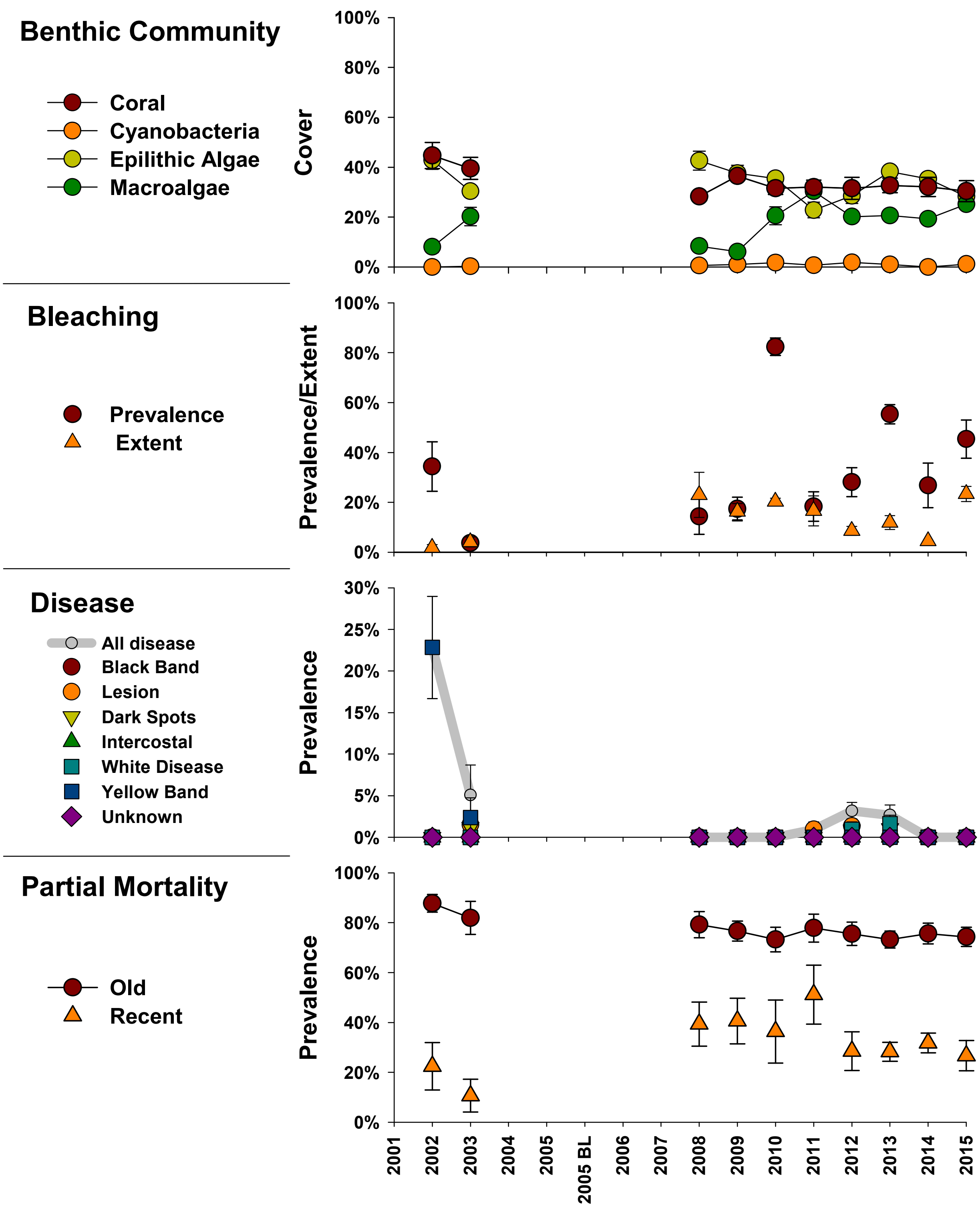


Figure 117. Brewers Bay benthic cover and coral health through time (mean ± SE)

Fish Community. Brewers Bay is characterized by a high fish abundance dominated by herbivores. The site holds large numbers of parrotfish. Numerically, the herbivores are dominated by juvenile striped parrotfish that swim over the reef in groups of mixed parrotfish and wrasse. Both yellowhead and bluehead wrasse are prolific and school with the juvenile parrotfish. There are also larger stoplights and queen parrotfish grazing the reef. Piscivores are limited in biomass but are fairly diverse and generally include inshore pelagics such as cero mackerel and bar jacks or yellow jacks. Hamlets (*Hypoplectrus*) are very common and diverse, represented by 6 to 7 species in each annual survey. The occasional large snapper (schoolmaster, dog, mutton, and cubera) are sighted on the reef periphery or around large coral heads. The reef is spearfished regularly, so these sighting are becoming more rare. Nassau and yellowfin grouper inhabited Brewers Bay reef during the early years of monitoring and were common forty years ago (Rogers 1982); however, large groupers have not been observed on the reef in several years.

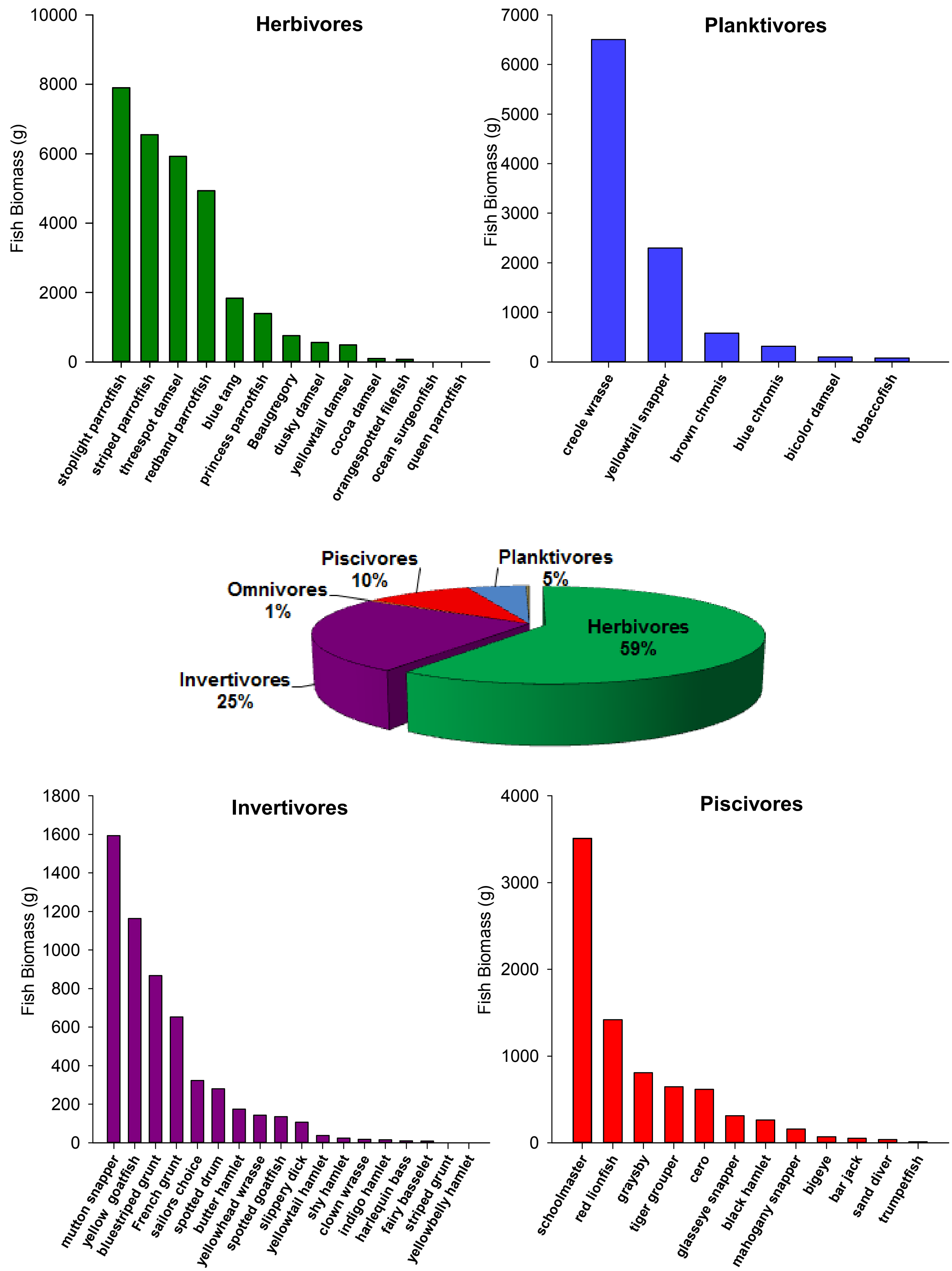


Figure 118. The Brewers Bay fish community by absolute and relative biomass.

BUCK ISLAND, ST. THOMAS

BUCK ISLAND, ST. THOMAS

Description. Buck Island, St. Thomas is a midshelf reef fringing the northwest coast of an uninhabited offshore island in water depths of 7 – 20 m. The reef has a sharp break in slope leading to a steep escarpment that terminates in a sand/sediment plain at the reef base. The monitoring site is located on that slope. Buck Island, St. Thomas has been monitored since 2005, with permanent benthic transects installed in 2007.

Outstanding Feature. Buck Island, St. Thomas is one of the most important tourist sites in the Virgin Islands, with frequent visitation by cruise ship passengers on day boats.

Threats. Buck Island, St. Thomas is very heavily used as a recreational dive site with the potential for cumulative impacts. The water surrounding Buck Island, St. Thomas is open to fishing. Commercial trap fishermen frequently target this site, and trap strings have been laid over the monitoring transects. Federally protected Nassau Grouper (*Epinephelus striatus*) have been observed within traps at the monitoring site. In addition, derelict traps are common around the site.

Figure 119. Buck Island, St. Thomas. (top) Location. (right) A representative photo of the reef.

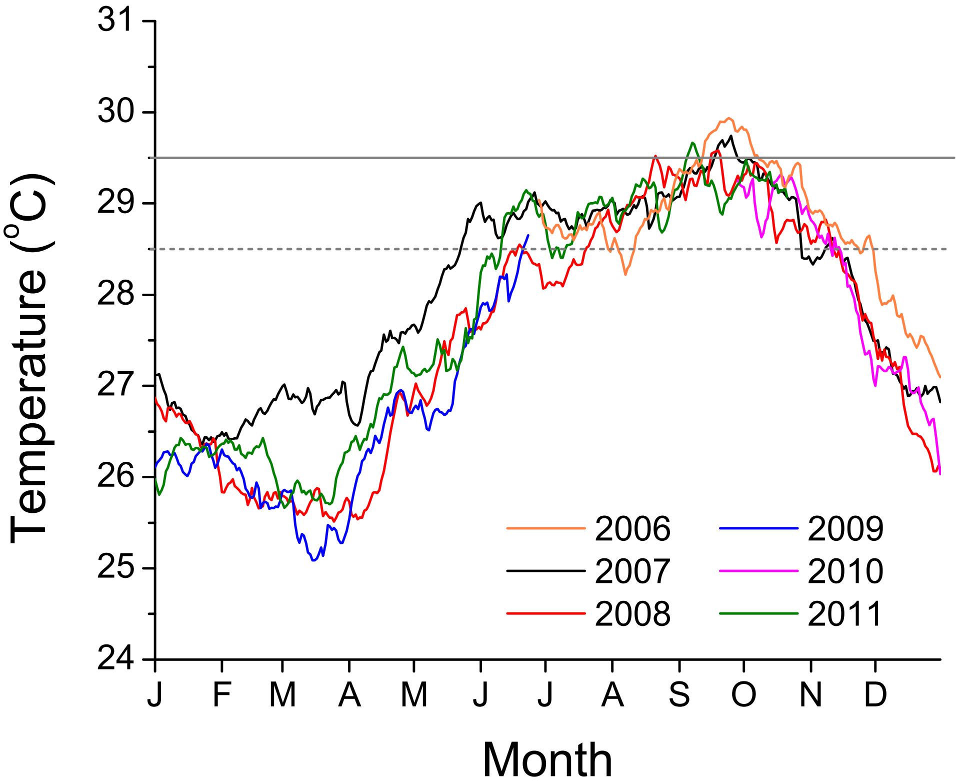


Figure 120. Buck Island, St. Thomas benthic temperature record (12 m depth).

Physical Characteristics.

Current. Buck Island, St. Thomas currents have not been measured directly. Moderately strong unidirectional currents occasionally influence the site; however, in general currents are very weak.

Temperature. Buck Island, St. Thomas may develop high temperatures. Unfortunately, the temperature probe placed during the 2010 coral bleaching event was lost.

BUCK ISLAND, ST. THOMAS

Benthic Community. The Buck Island, St. Thomas site coral community is dominated by the boulder star coral (*Orbicella* spp.), but shows high and even representation of other species. Coral cover declined by 23.4% due to the 2005 coral bleaching event and the site had regained 13.4% of this cover by 2011. Among sessile epibenthic animals a high proportion of the community is composed of sponges. The algal community is co-dominated by epilithic algae and the macroalgae *Dictyota* spp. and *Lobophora variegata*. Filamentous cyanobacteria were also abundant in 2008.

Coral Health. The Buck Island, St. Thomas site was severely bleached in the 2005 coral bleaching event, with over 80% of colonies bleached over 100% of the colony surface. Bleaching was also high during the 2010 bleaching event, but at a low extent on colonies. Low prevalence of low-extent bleaching was common in other years of study. Coral diseases were usually low, in prevalence with the striking exception of 2006, when white diseases and lesions consistent with recent white disease reached extremely high prevalence. Old partial mortality increased rapidly after the 2005 bleaching event and then declined steadily in following years.

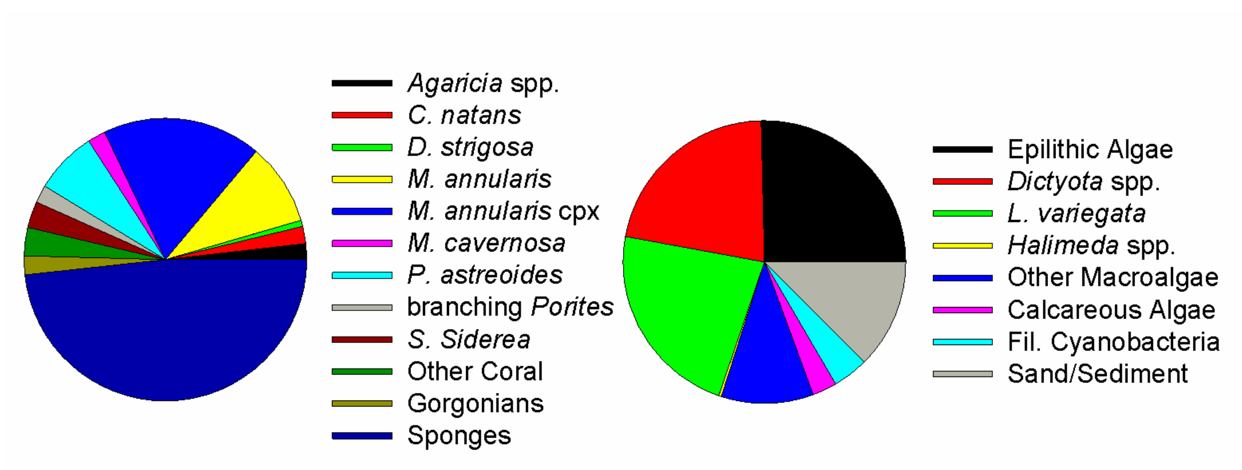


Figure 121. Buck Island, St. Thomas. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

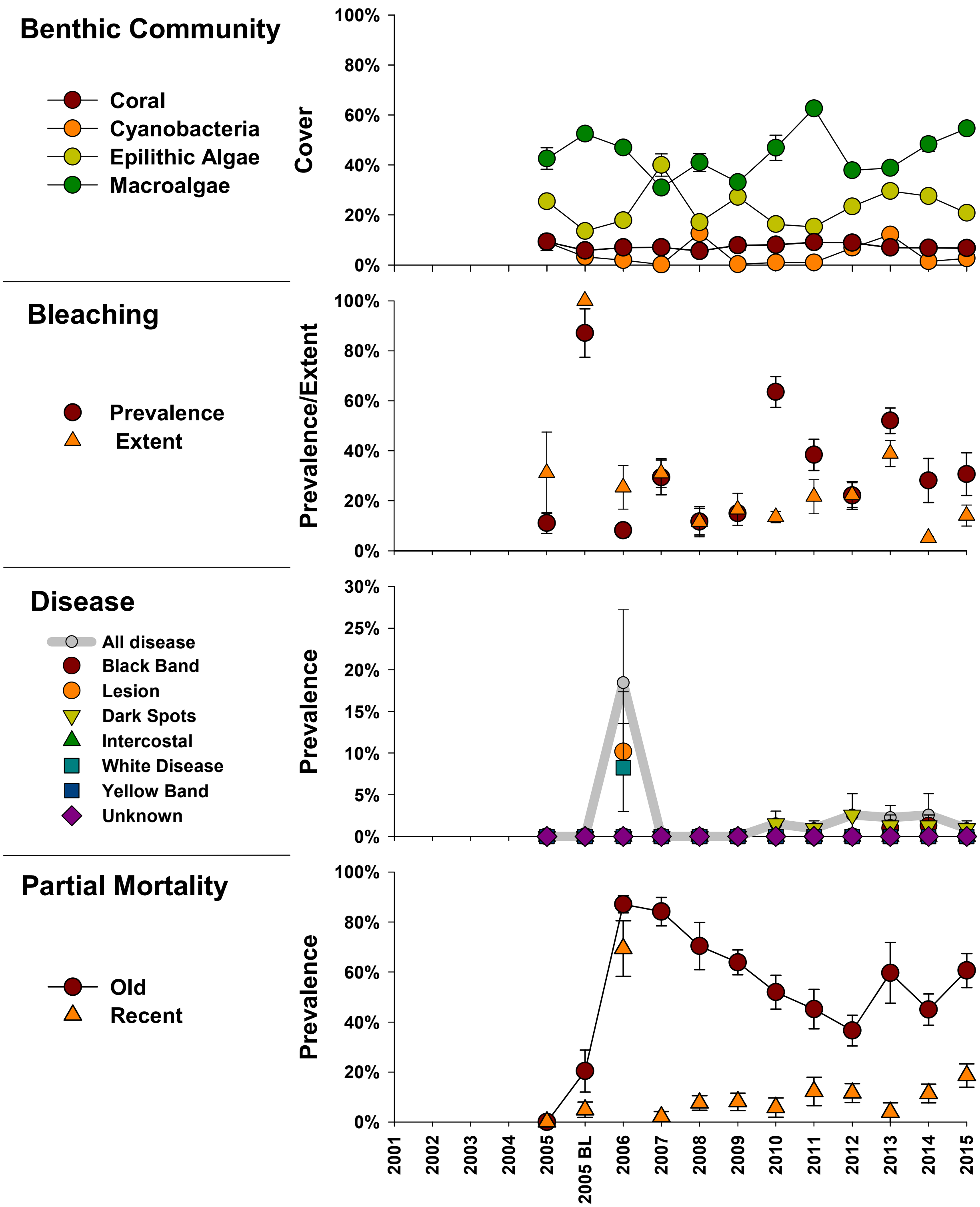


Figure 122. Buck Island, St. Thomas benthic cover and coral health through time (mean ± SE).

BUCK ISLAND, ST. THOMAS

Fish Community. The fish community at Buck Island, St. Thomas is very diverse and represents the utilization of many habitats and resources. Herbivores, especially parrotfishes, dominate the site. Invertivores, however, are also diverse and very common. Both spotted and yellow goatfish roam the top of the reef and large wrasses, including the Spanish hogfish and puddingwife, are prolific. In addition to goatfish and wrasses, a variety of grunts inhabit the Buck Island Reef, and large schools of both jolthead and saucereye porgies are observed there. Tourists and commercial dive operators are known to feed fish at Buck Island and gregarious yellowtail snapper are large and numerous. Mutton snapper are occasionally observed. Schoolmaster snapper dominate the piscivores community on the site. No large grouper or snapper have been observed in belt transects or roving dives; however, small Caribbean reef sharks are generally sighted. Although a Territorial Park on land, the area is fished with hook and line, traps, and speargun. It is also a very heavily dove SCUBA and snorkel site.

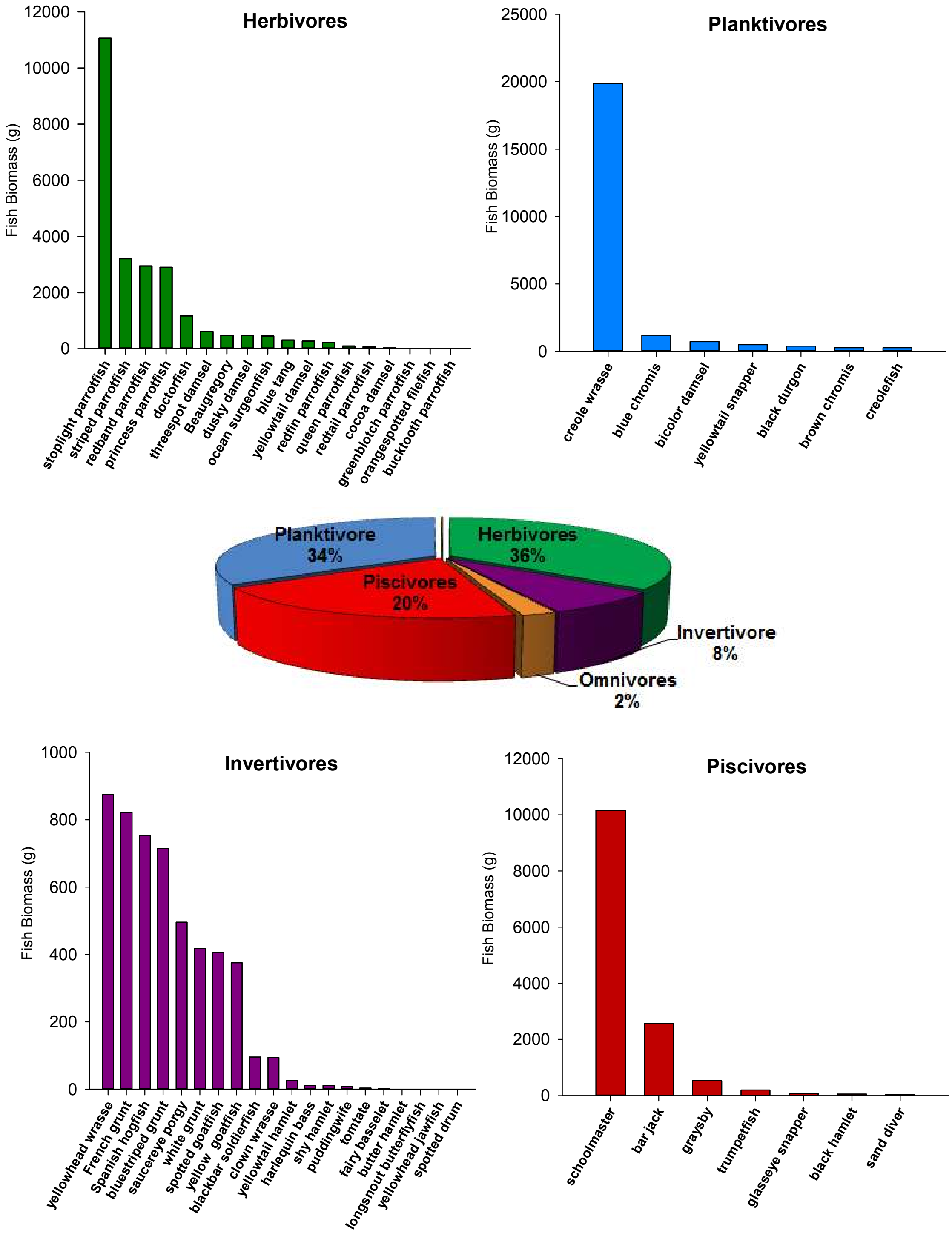
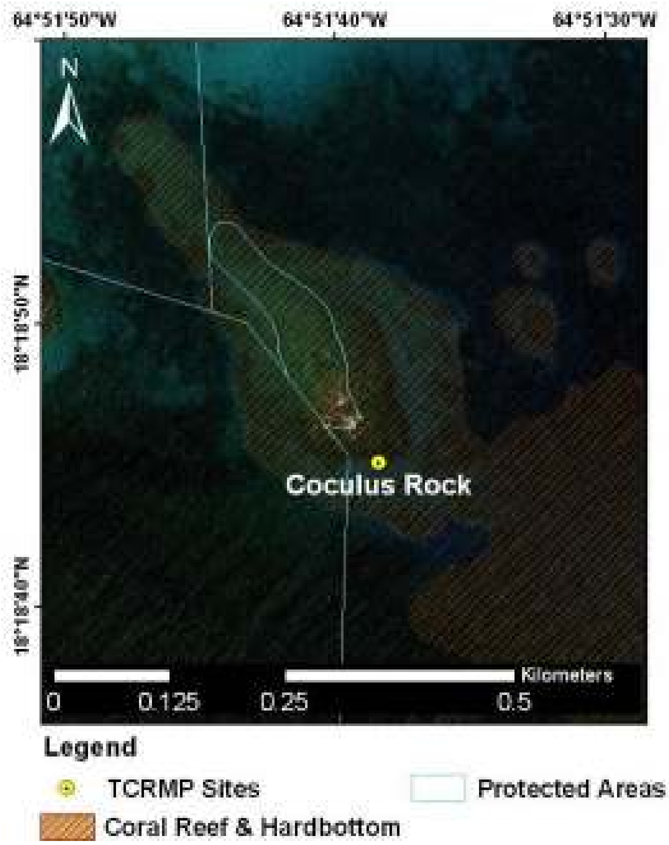


Figure 123. The Buck Island, St. Thomas fish community by absolute and relative biomass.

COCULUS ROCK

COCULUS ROCK



Description. The Coculus Rock site is a coral community on bedrock and pavement in depths of 4 – 7 m. The reef is formed between emergent rocks and a sand plain at 7m. Coculus Rock has been monitored since 2001, with fish community assessment starting in 2009. A ciguatera fish poisoning study with monthly sampling has been ongoing since 2009.

Outstanding Feature. Coculus Rock is located in the St. Thomas East End Reserve and is closed to taking of reef fishes. The site supports a fish spawning aggregation of redfin parrotfish (*Sparisoma rubripinne*). These 100+ fish engage in daily afternoon mating at southeast reef corner. A ciguatera study with monthly sampling has been ongoing since 2009.

Threats. Coculus Rock is subject to land-based sources of pollution from the large Turpentine Gut drainage of the Tutu watershed and the numerous industrial maritime activities in Benner Bay.

Figure 124. Coculus Rock. (top) Location. (right) A representative photo of the reef showing the aggregation of redfin parrotfish.

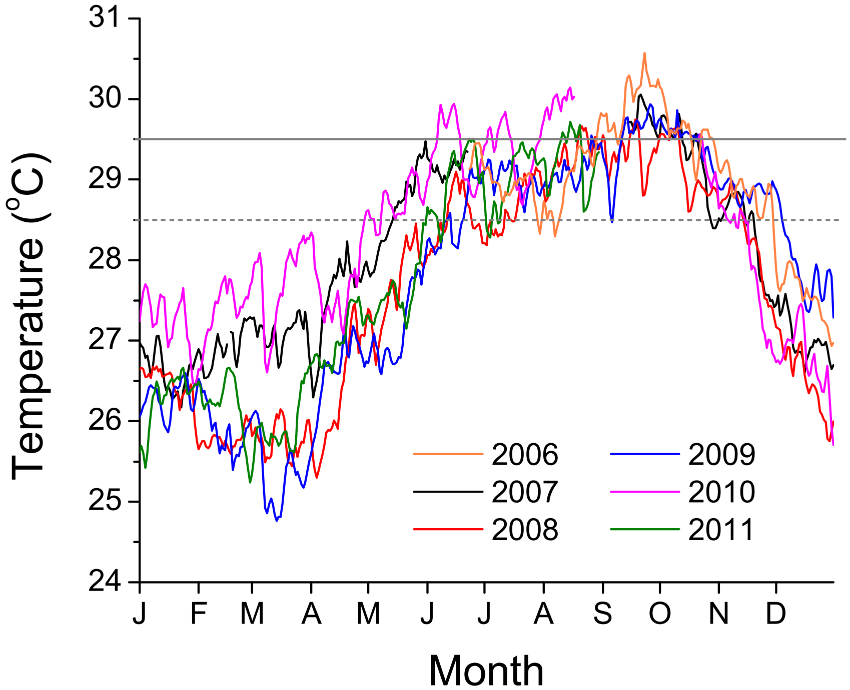


Figure 125. Coculus Rock benthic temperature record (7 m depth).

Physical Characteristics.

Current. Coculus Rock currents have not been measured directly. Only weak unidirectional currents have been experienced. Wave-driven oscillatory currents can be intense from swells coming from the southeast.

Temperature. Coculus Rock can experience very high temperatures during the peak warm season.

COCULUS ROCK

Benthic Community. The Coculus Rock site is a coral community on bedrock and thin carbonate pavement that supports a very diverse coral community with no dominance by any species. The site lost 10.7% of its coral cover in the 2005 bleaching event, but had regained 76.0% of this lost cover by 2011. Sponges are a very prominent component of the sessile epibenthic animal community. The algal community is co-dominated by epilithic algae and the macroalga *Dictyota* spp., which tend to covary.

Coral Health. Corals at Coculus Rock were relatively moderately impacted by the 2005 coral bleaching event in both prevalence and extent on colonies. This may be due to a coral species assemblage composed of small massive species that tend to be less susceptible to bleaching (Smith et al., unpublished manuscript). A modest prevalence of low extent bleaching was also evident in the 2010 coral bleaching event. In years without high thermal stress, there tends to be a relatively high prevalence of bleaching relative to other sites, and prior to 2004 this was at high extent over colonies. Coral diseases, represented almost exclusively by dark spots disease, can be quite high in some years. Old partial mortality has been fairly high and consistent over time, with a slight increase after the 2005 and 2010 bleaching events. Recent partial mortality tends to be quite low in prevalence.

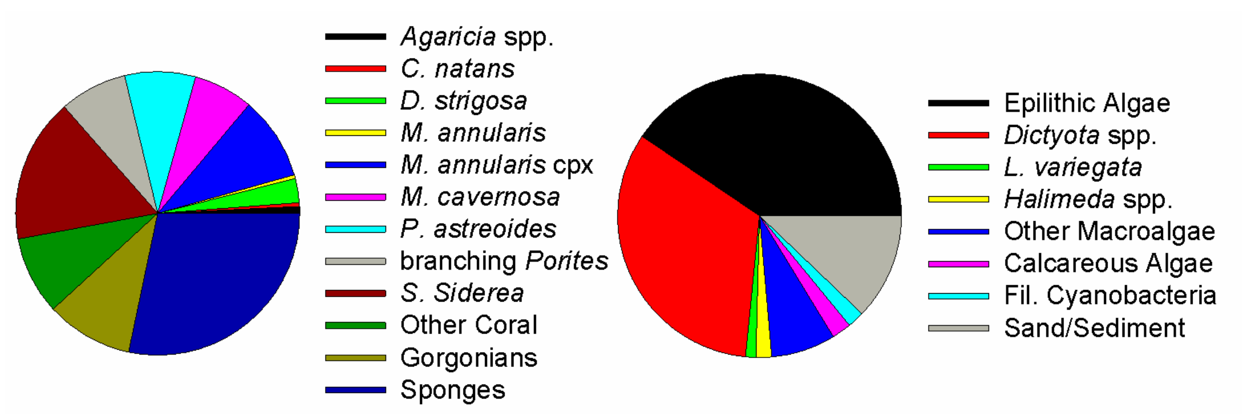


Figure 126. Coculus Rock. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

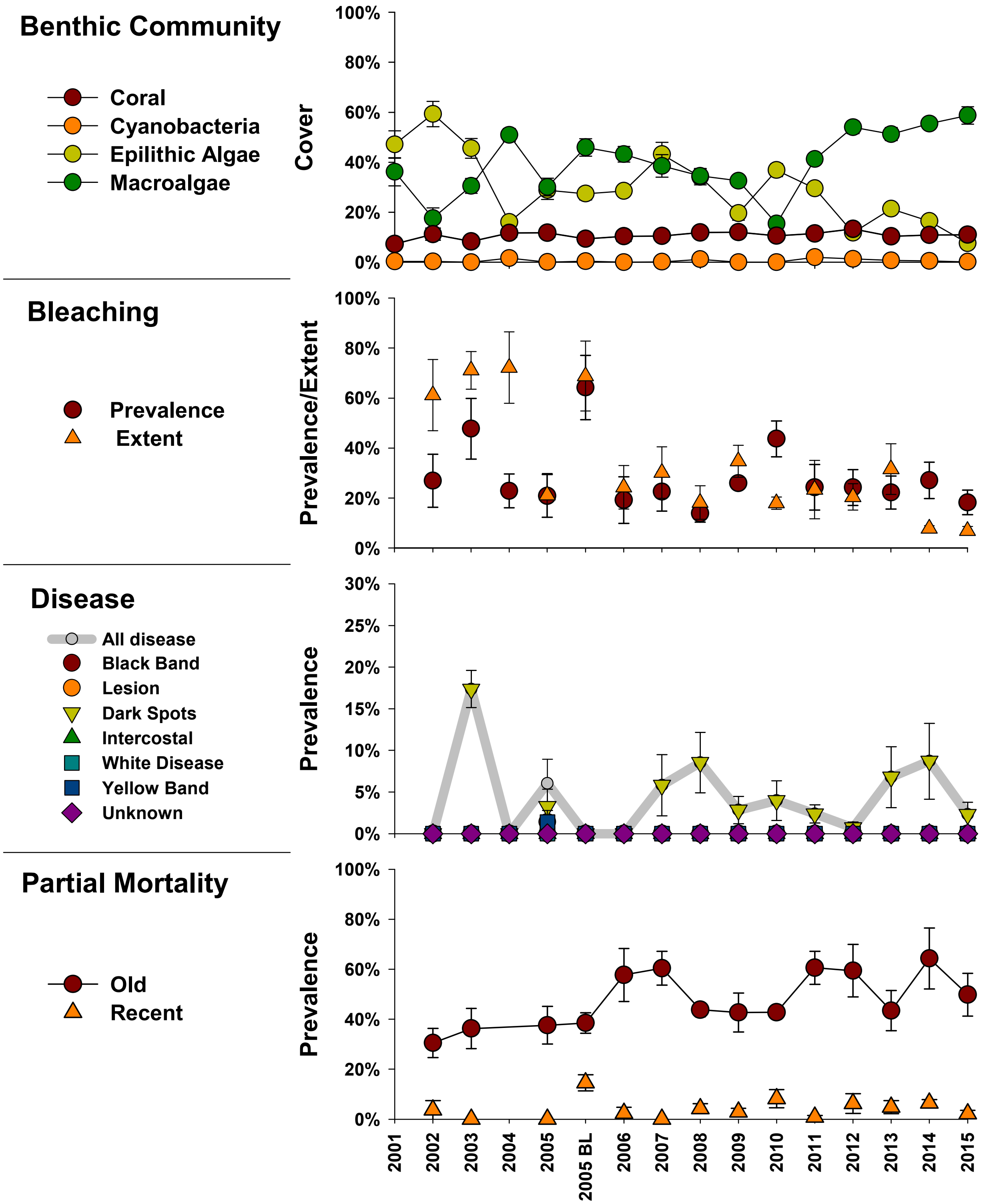


Figure 127. Coculus Rock benthic cover and coral health through time (mean ± SE).

COCULUS ROCK

Fish Community. The Coculus Rock fish community is interesting in several ways and it represents an inshore promontory that aggregates redfin parrotfish (*Sparisoma rubripinne*) to spawn every afternoon. For that reason, redfin highly dominate the site in biomass. The top of the reef, emergent at points, is turbid and rough with breaking waves, but large parrotfish, jacks, snappers, doctorfish, and damselfishes swim in this area. At the bottom of the reef, where coral and rock meet the sand, a small ledge runs along the southeast edge. Red hind and an occasional Nassau grouper have been observed hiding in the ledge here. There are generally a dozen or more juvenile lobster using the ledge as well. Juvenile grunts can be particularly common at Coculus Rock, schooling on large limestone rocks on the western side of the site. Otherwise the fish community inhabiting the steep walled rock and algae covered limestone site is primarily wrasses, small parrotfishes, and acanthurids. Coculus Rock is part of the Territorial East End Reserve (STEER) and fishes are protected from all harvest year-round.

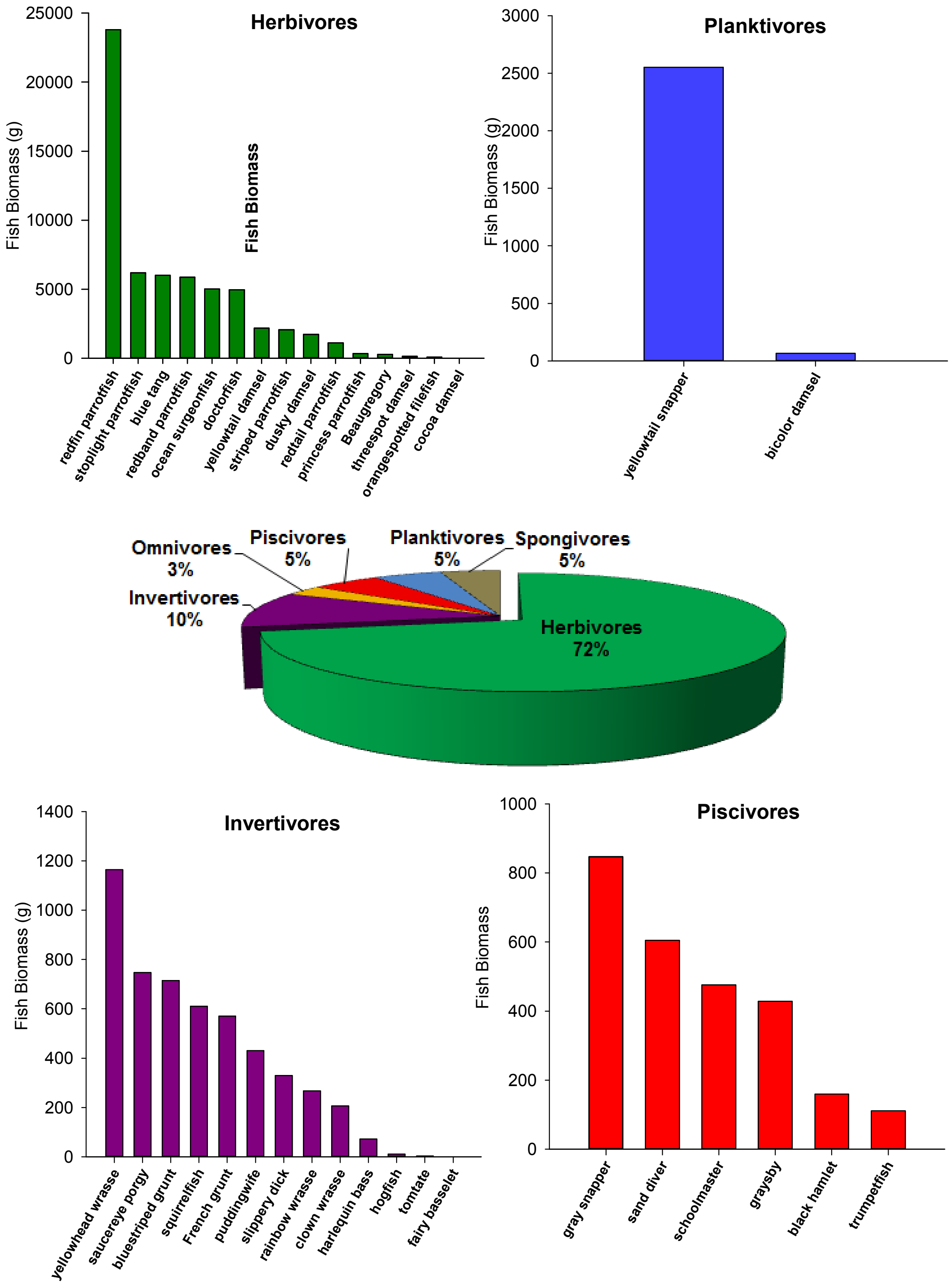
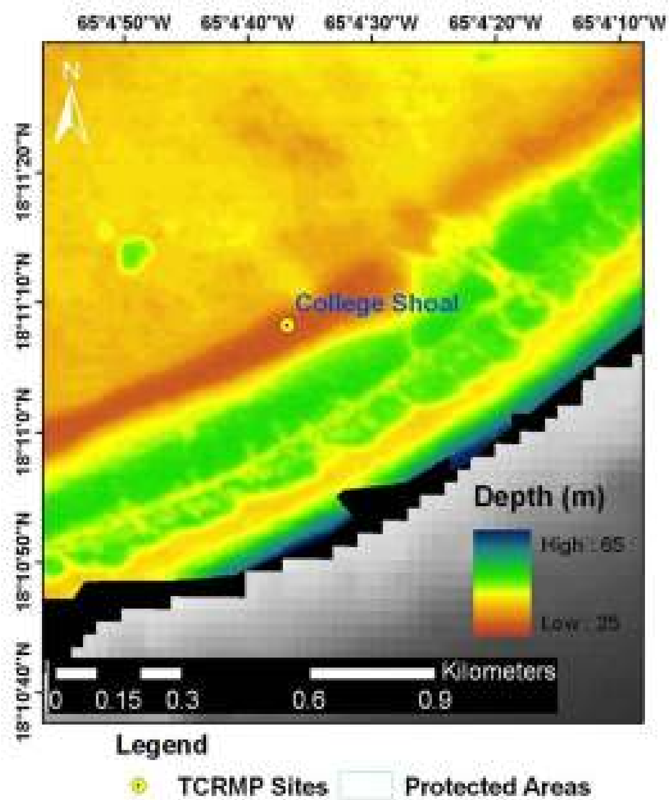


Figure 128. The Coculus Rock fish community by absolute and relative biomass.

COLLEGE SHOAL



Description. College Shoal is part of a mesophotic bank located in the Red Hind Marine Conservation District (est. 1999) in depths of 28 – 33 m. The densely populated coral reef is surrounded by continuous reef structure dominated by star corals (*Orbicella* spp.). College Shoal has been monitored since 2003, with permanent benthic transects installed in 2007.

Outstanding Feature. College Shoal is notable for possessing high water clarity, relatively strong currents, a high density of corals (>30% coral cover), and a great abundance of fishes, including commercially important groupers and snappers. College Shoal is one of the most aesthetically pleasing reefs for diving due to its relatively pristine condition, high coral abundance, and high fish abundance.

Threats. College Shoal has experienced coral white diseases at chronically high levels (> 1% prevalence). This reef also supports a high abundance of the invasive Indo-Pacific Lionfish (*Pterois volitans*).

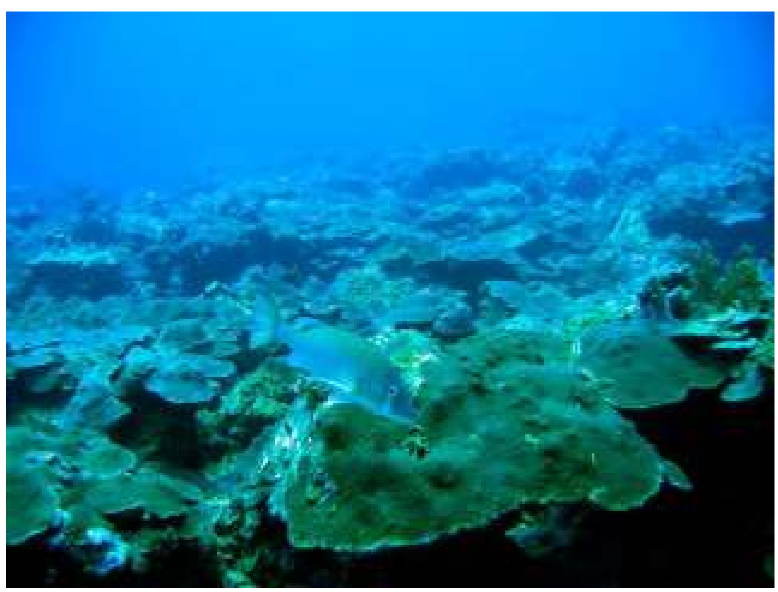


Figure 129. College Shoal. (top) Location. (right) A representative photo of the reef.

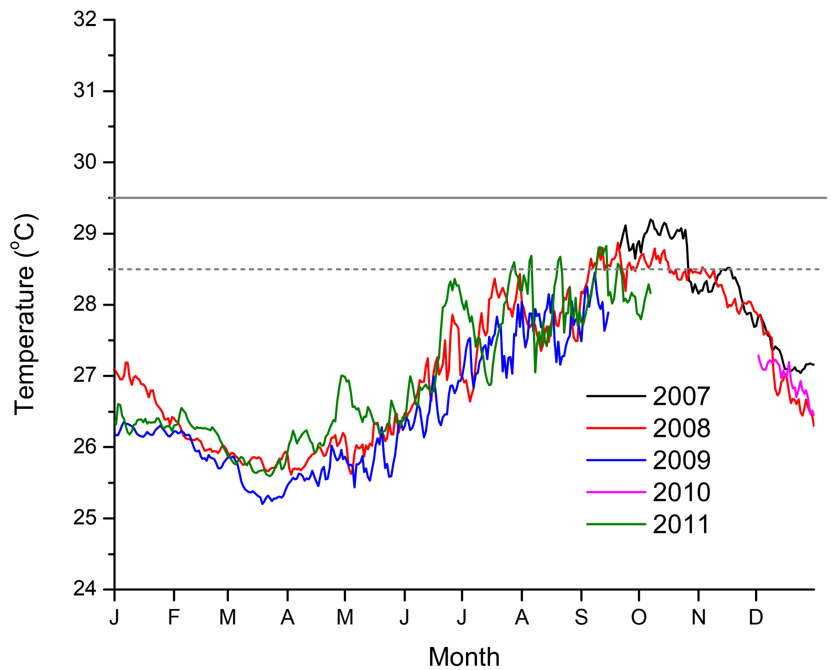


Figure 130. College Shoal benthic temperature record (29 m depth).

Physical Characteristics.

Currents. Although not measured directly, College Shoal has strong unidirectional driven currents that seem to be tidally driven and follow a pattern of increasing strength during spring tides. Current data has been collected and will be presented in a future report.

Temperature. Benthic temperatures are ameliorated in the warm season by the proximity of the thermocline. The presence of the thermocline causes temperatures that are cool and diurnally variable from May to October. Unfortunately, the thermistor re-initialized improperly in 2009 and the 2010 coral bleaching event temperatures where missed at this site.

Benthic Community. College Shoal is among the TCRMP sites with the highest coral cover (38.2% in 2011) and, similar to other bank mesophotic sites south of the St. Thomas, is dominated by the boulder star coral (*Orbicella* spp.). This site lost only 10.1% of its coral cover in the 2005 bleaching event, but had not regained cover since then (-1.3%); however, these estimates have some additional error since transects were not made permanent until 2007. Sponges and gorgonians are in very low relative abundance. The algal community is dominated by the macroalga *Lobophora variegata* and lesser representation by epilithic algae. There is also a relatively high proportion of crustose coralline algae.

Coral Health. College Shoal bleached at a relatively low prevalence during the 2005 mass coral bleaching event, although corals that were bleached tended to lose color over their entire surface. The 2010 coral bleaching event had no apparent effect above background bleaching levels. Bleaching in years without thermal stress tends to be moderate. Diseases were dominated by white disease, which reached very high prevalence after the 2005 bleaching event, with an outbreak that lasted for two years in 2006 and 2007. This disease was again very prevalent in 2011 after the 2010 bleaching event, even without apparent thermal bleaching. Old partial mortality was elevated on corals after the mortality from the 2005 bleaching event, and this level has remained stable through 2011. Recent partial mortality is always relatively high, much of it attributable to fish bites.

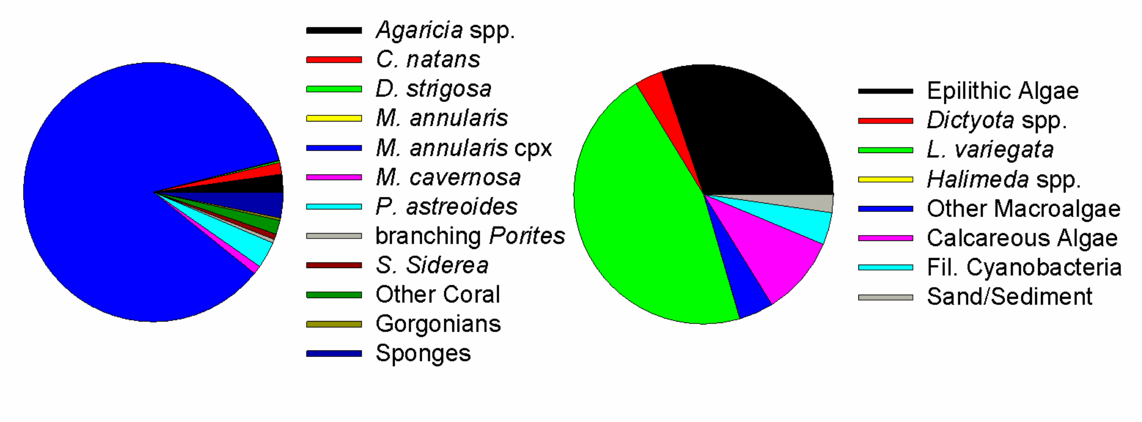


Figure 131. College Shoal (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

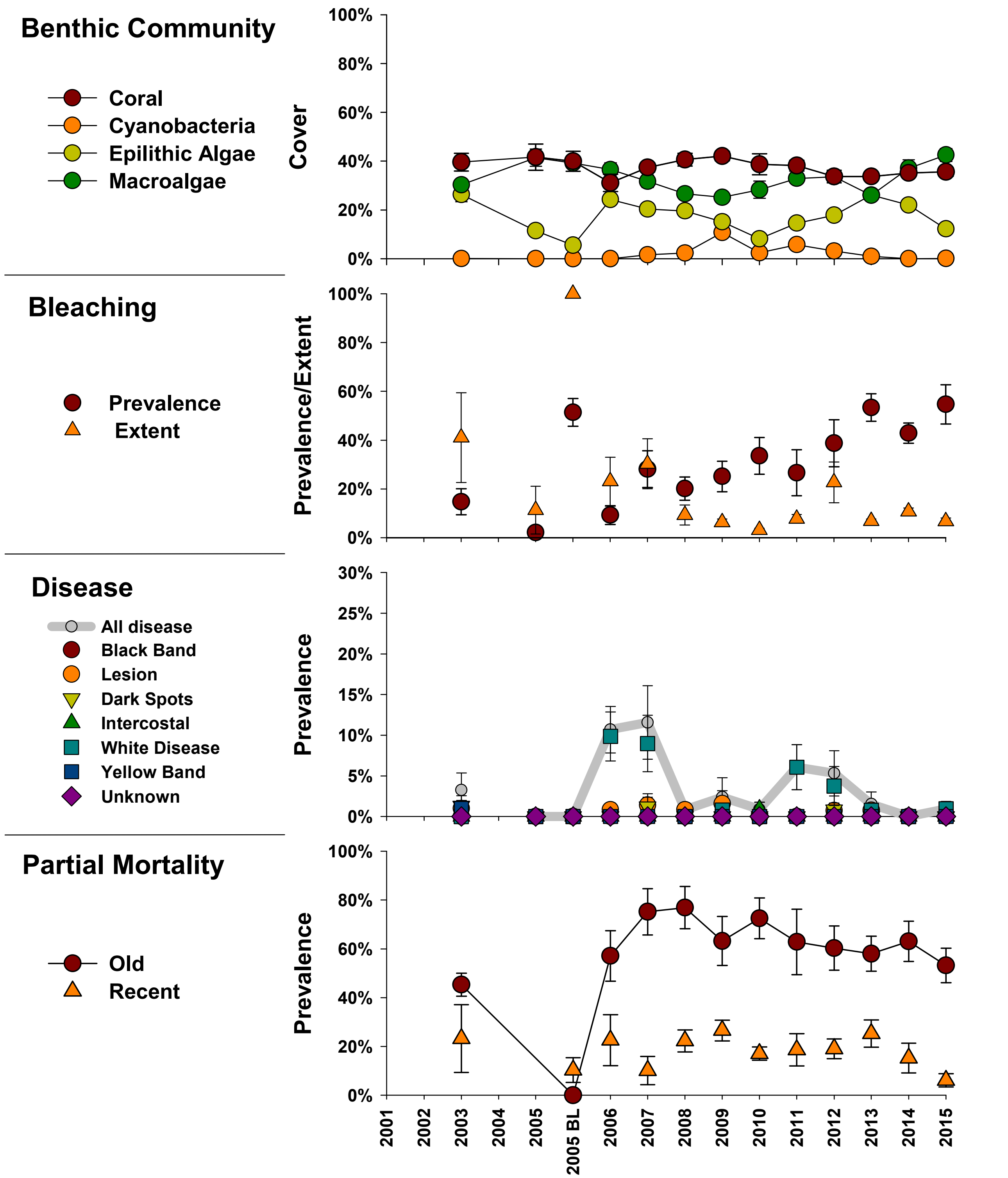


Figure 132. College Shoal benthic cover and coral health through time (mean ±SE).

Fish Community. College Shoal is characterized by a high fish biomass and high species diversity. Large planktivores are also characteristic of College Shoal, including ocean triggerfish, Atlantic spadefish, black jacks, and yellowtail snapper. Numerically, the site is dominated by creole wrasse; however, large jacks, ocean triggerfish, and black durgeon are very common. College Shoal lies within the Marine Conservation District (MCD) and is protected year round from all fishing. Nassau, yellowfin, and yellowmouth grouper are occasionally observed on the site. Tiger grouper are seen there regularly. The mesophotic, high coral cover reef supports less herbivores than the more shallow nearshore and offshore sites; however, more herbivores (ocean surgeonfish) are present than on the significantly deeper Hind Bank FSA and Grammanik Bank FSA sites. Diversity is high in all trophic guilds indicating a high variety of niches available for fishes.

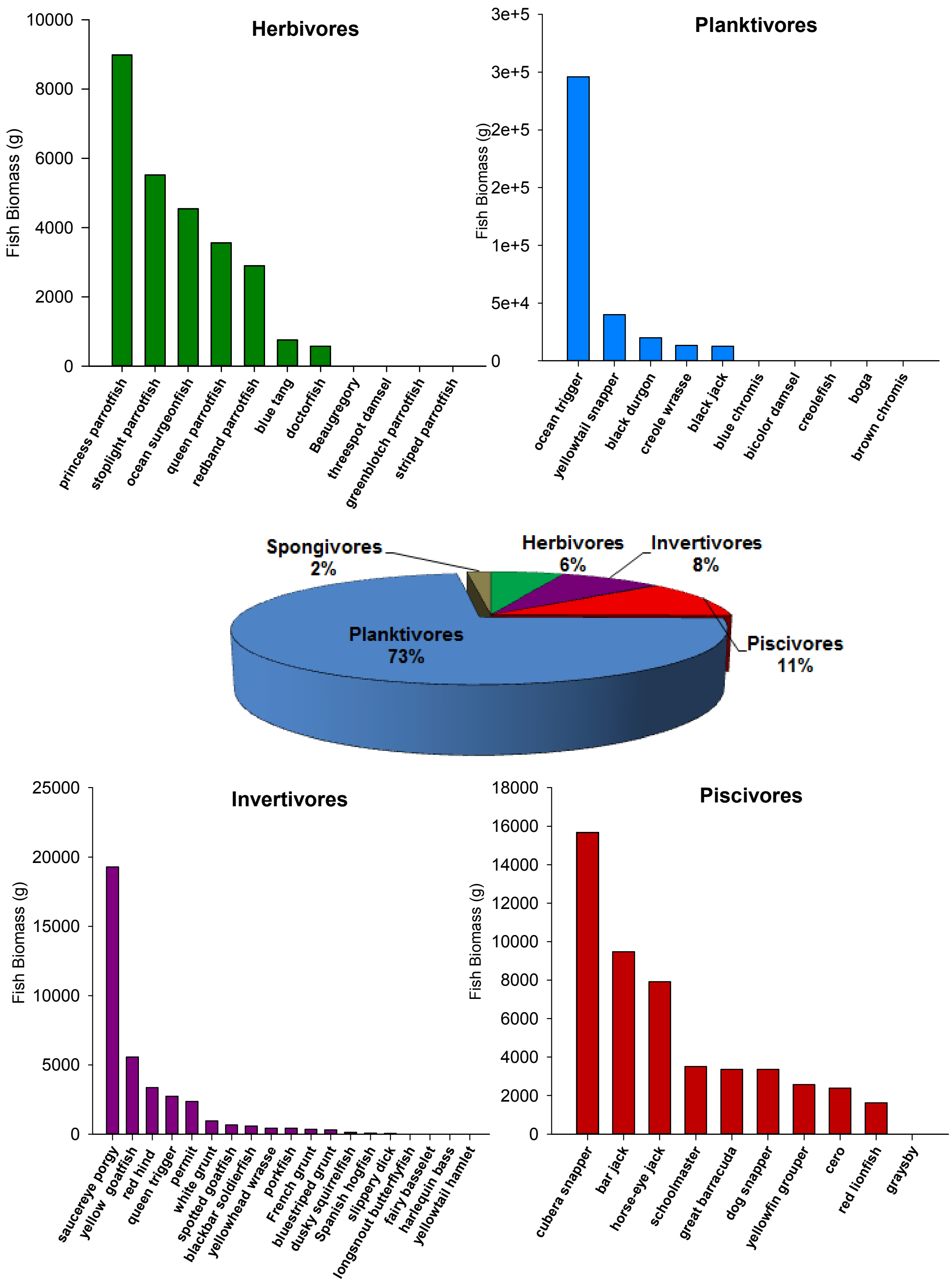


Figure 133. The College Shoal fish community by absolute and relative biomass.

FLAT CAY

Description. This monitoring site wraps around the northwest corner depths of Flat Cay in depths of 10 – 17 m. Flat Cay has been monitored since 2003, with permanent benthic transects installed in 2007. A ciguatera fish poisoning study with monthly sampling has been ongoing since 2009.

Outstanding Feature. Flat Cay supports a lush coral community, including dense populations of the endangered elkhorn and staghorn corals (*Acropora* spp.) outside the TCRMP monitoring site. The site is a popular tourist dive site and is an important site for research by local and international investigators.

Threats. Flat Cay is down current of industrial port activities and a major sewage outfall. Mollusks, including the commercially important queen conch (*Strombus gigas*) show sterility (imposex) as a likely result of exposure to hormone mimics released from boat hulls coated with marine antifouling paint containing Tributyltin (Strand et al. 2009). The area experiences heavy fishing and damage from anchoring within the reef.

Figure 134. Flat Cay. (top) Location. (right) A representative photo of the reef.

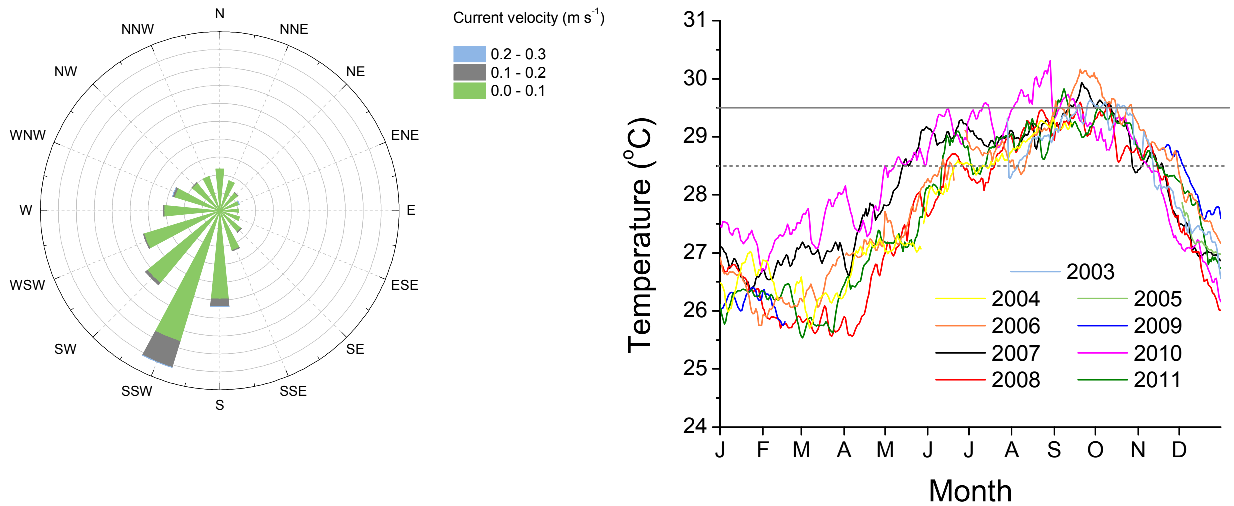


Figure 135. Flat Cay benthic current speed (left) and temperature record (right) (14 m depth).

Physical Characteristics.

Current. The benthic current at the Flat Cay site is weak and dominated by a south-southwesterly flow. This may be an effect of the wrapping of the generally westward and occasionally strong surface current. Currents were measured with an Aandaraa 2-D current meter measuring 1m above the seafloor.

Temperature. Flat Cay experiences moderate warming for a shallow water site and rapid cooling with the passage of tropical storms.

Benthic Community. Flat Cay supports a diverse coral community with dominance of boulder star corals (*Orbicella* spp.). The sessile epibenthic animal community also shows a high abundance of sponges. The site lost a moderate 21.9% of cover in the 2005 bleaching event and had regained 159.3% of this cover by 2011. A caveat is that transects were not made permanent until 2007. Epilithic algae and the macroalga *Dictyota* spp., with lesser amounts of *Lobophora variegata*, dominate the algal community. Sand in pockets between coral also makes up a fair amount of the non-living substrate.

Coral Health. Corals were severely affected during the 2005 coral bleaching event, with over 90% of corals bleached at 100% extent of the colony surface. Bleaching was also moderately prevalent in the 2010 bleaching event, but at low extent. Coral diseases, particularly dark spots disease can be very prevalent at Flat Cay. There was an unusual outbreak of black band disease in 2004. This disease is rare at the depths of Flat Cay. White disease was somewhat prevalent after the 2005 bleaching. Old partial mortality increased rapidly after the 2005 bleaching event and has not decreased in the intervening years. Recent mortality can be moderate and is due to a variety of causes.

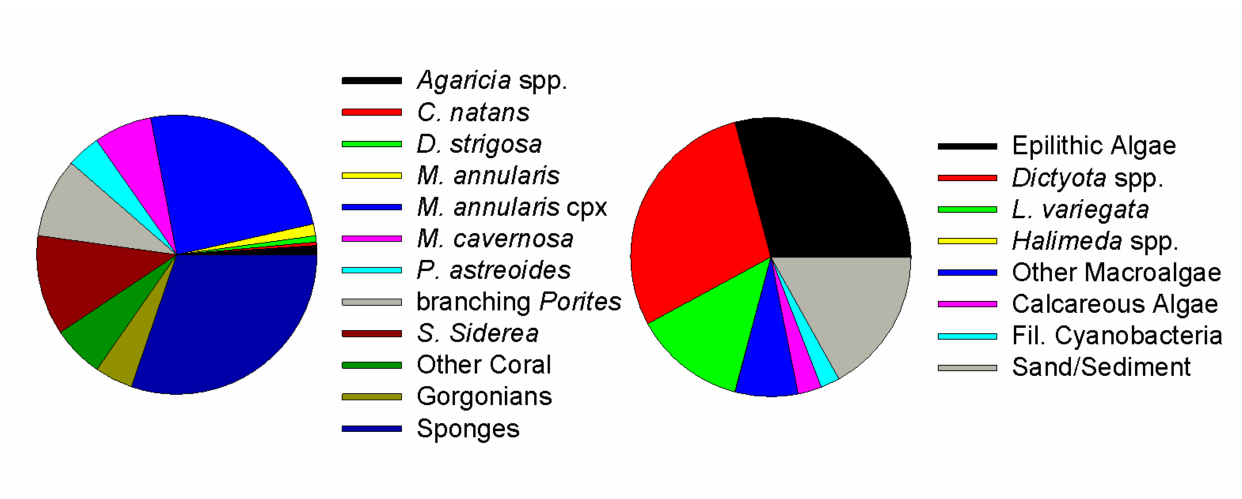


Figure 136. Flat Cay (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

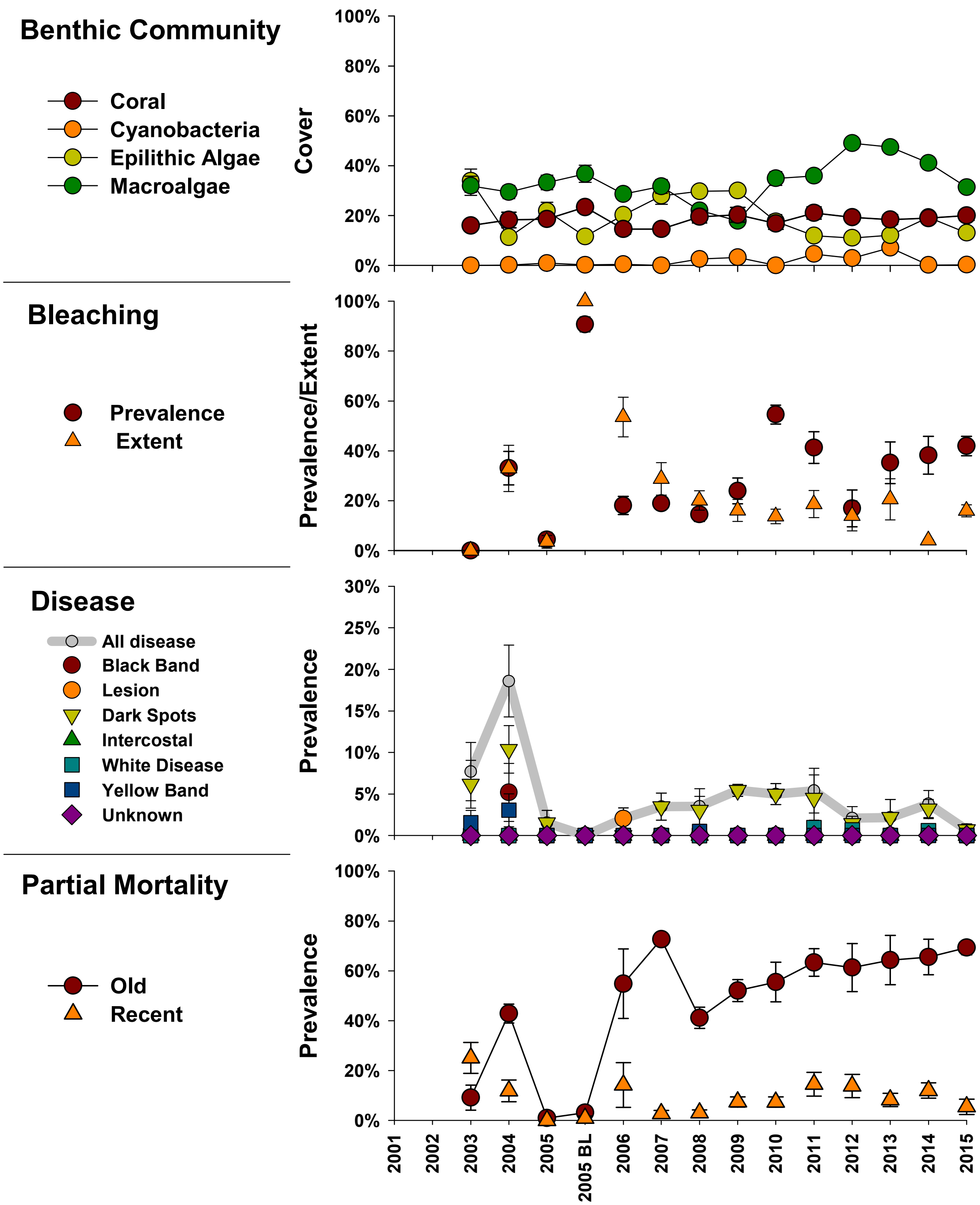


Figure 137. Flat Cay benthic cover and coral health through time (mean ± SE).

Fish Community. Flat Cay is characterized by a large diversity of fish evenly distributed across trophic guilds. There is a higher biomass of invertivores than other groups due to the regular occurrence of large schools of creole wrasse. Herbivores are dominated by redband and striped parrotfish; however, there is a diversity of parrotfish species. Juvenile parrotfish are most prevalent. Carangids frequent the reef and dominate the piscivore trophic group. Very occasional large groupers (Nassau, yellowfin, black) have been observed on Flat Cay over the past eight years. The occurrence of black grouper is notable, since this species is absent throughout the majority of monitoring sites. Generally, the serranids are highly dominated by the coney. The Flat Cay reef is highly used as a recreational dive site and spearfishing occurs regularly. Where the reef meets the sand offshore, large schools of grunts, gray snapper, squirrelfish, and goatfish occur. Small reef sharks are seen out over the sand regularly.

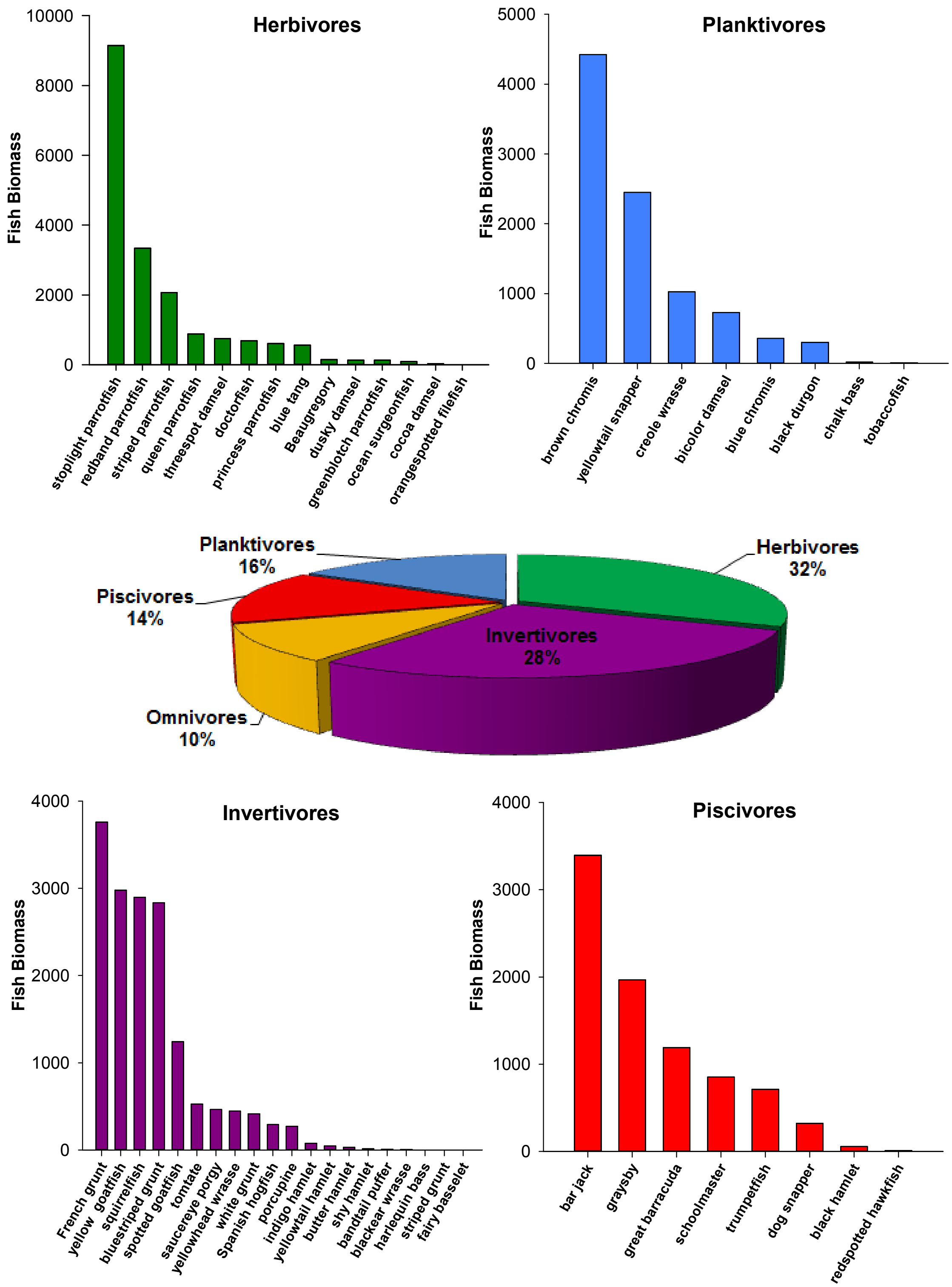
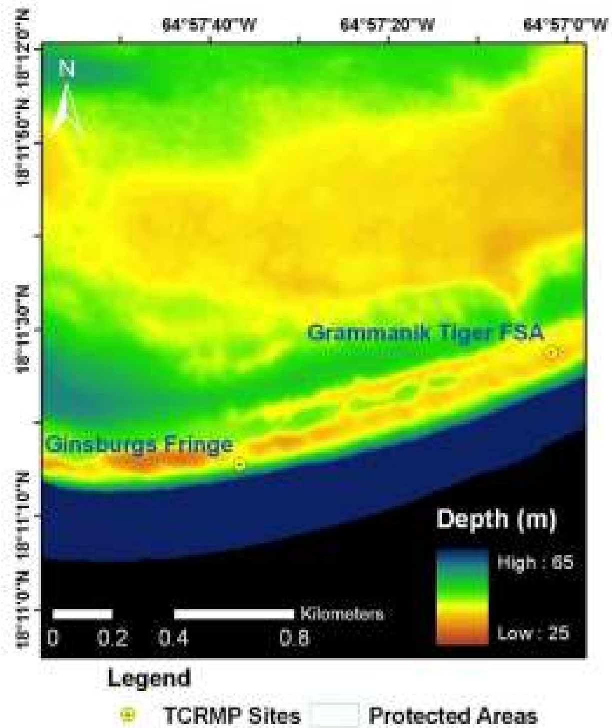


Figure 138. The Flat Cay fish community by absolute and relative biomass.

GINSBURGS FRINGE



Description. Ginsburgs Fringe is a lower mesophotic lettuce coral (*Agaricia undata*.) reef at depths of 60-75 m (established in 2011). The reef is on a steep escarpment dropping into the abyssal Virgin Islands trough.

Outstanding Feature. Ginsburgs Fringe had the highest 2011 coral cover among all TCRMP monitoring sites (44%), with living colonies of lettuce corals over 6m (20') wide. This site is the epicenter of a multispecies fish spawning aggregation, including the threatened Nassau grouper (*Epinephelus striatus*). The site name honors the father of comparative sedimentology and mesophotic coral studies, Dr. Robert N. Ginsburg.

Threats. Although little is known about conditions in deep mesophotic lettuce coral reefs, Lettuce corals at these depths are potato chip thin at edges and fragile. Reef claw-type anchors appear to be responsible for a 10% drop in coral cover in the last few years. The site is being heavily invaded by red lionfish (*Pterois volitans*).

Figure 139. Ginsburgs Fringe. (top) Location. (right) A representative photo of the reef showing whorled lettuce coral colonies up to 7m in width and research diver filming permanent transect in background (Nov. 13, 2015).

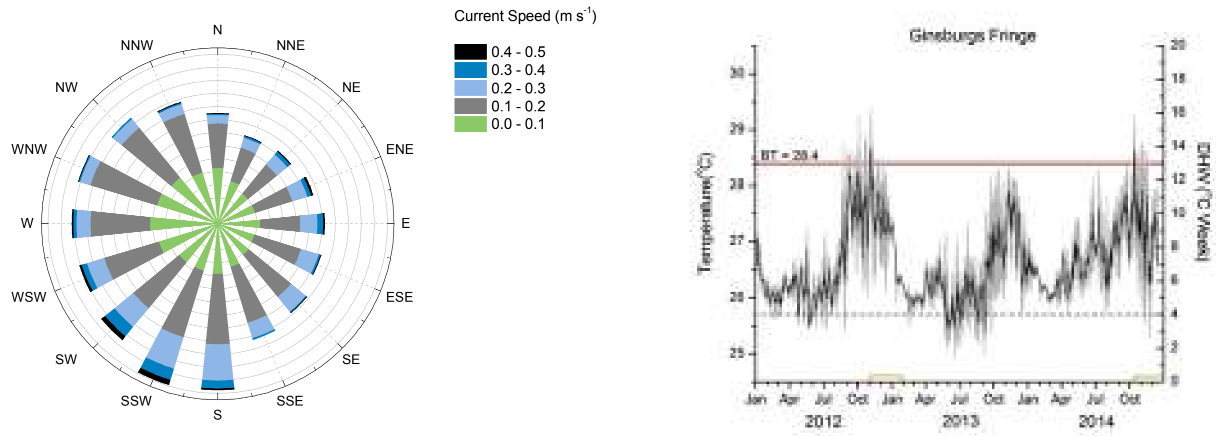


Figure 140. Ginsburgs Fringe current speed (50 m depth) and benthic temperature (63 m depth). BT = bleaching threshold ; DHW = degree heating weeks .

Physical Characteristics.

Current. Currents have been measured above the site in 50 m depth. There is a strong offshelf-downwelling (southward) that occurs just above the site, potentially carrying larvae and heterotrophic food supplies to the site.

Temperature. Temperatures are much cooler at Ginsburgs Fringe than any other TCRMP site, but still quite suitable for healthy Caribbean stony corals. The cooler temperatures lead to a lower bleaching threshold temperature.

Benthic Community. The coral community at Ginsburgs Fringe is almost exclusively lettuce corals of the genus *Agaricia*. Among the agariciid genus, the rank abundance of species is *A. undata* (30.8% absolute cover), *A. grahamae* (8.2%), and *A. lamarcki* (2.3%), with no colonies of *A. agaricites* and *A. fragilis* occurring in transects. However, no specimens have been collecting, making species identification of agariciids preliminary. These species identifications are tentative as voucher specimens have not been collected. Although not well represented in cover, individual colonies of *Montastraea cavernosa* and *Siderastrea siderea* also occur at the site. The algal community is dominated by the macroalga *Lobophora variegata*, which is surprising for these depths, and epilithic algae. Crustose coralline algae are also in high abundance, as well as a variety of unidentified algal species.

Coral Health. Coral health is not directly monitored at Ginsburgs Fringe due to the depth and difficulties assessing colonies greater than 3m width. However, some observations have been made. What appears to be warm season bleaching has been observed. Colonies have a fair degree of partial mortality and recent mortality is very common. In some cases it appears that shaded colony portions die back due to lack of light. The corallivorous snail, *Coralliophila abbreviata*, has been observed feeding on lettuce corals. Anchor damage from reef claw type anchors used in fishing appears to be causing recent losses of coral cover (a 20% decrease between 2011 and 2014).

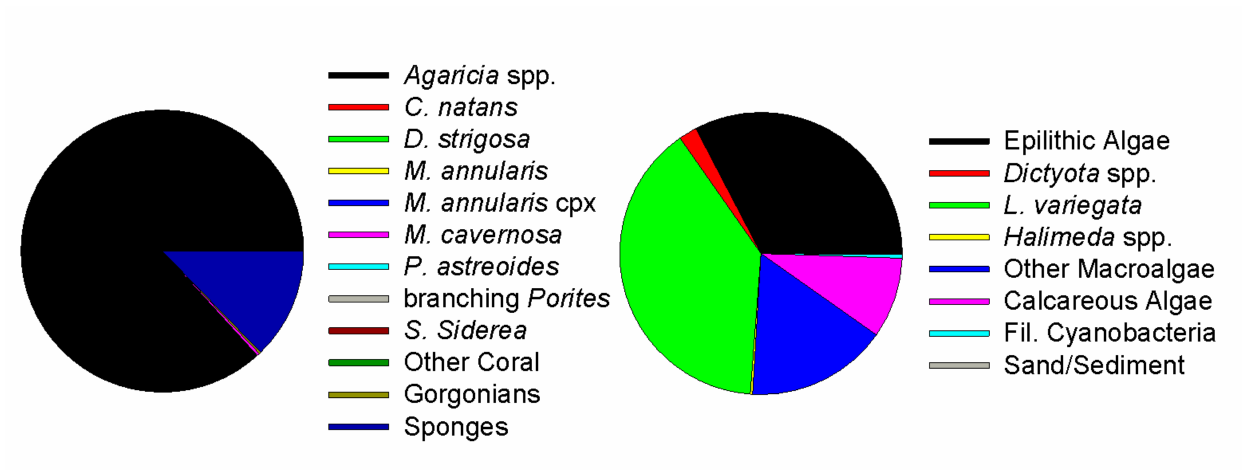


Figure 141. Ginsburgs Fringe. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

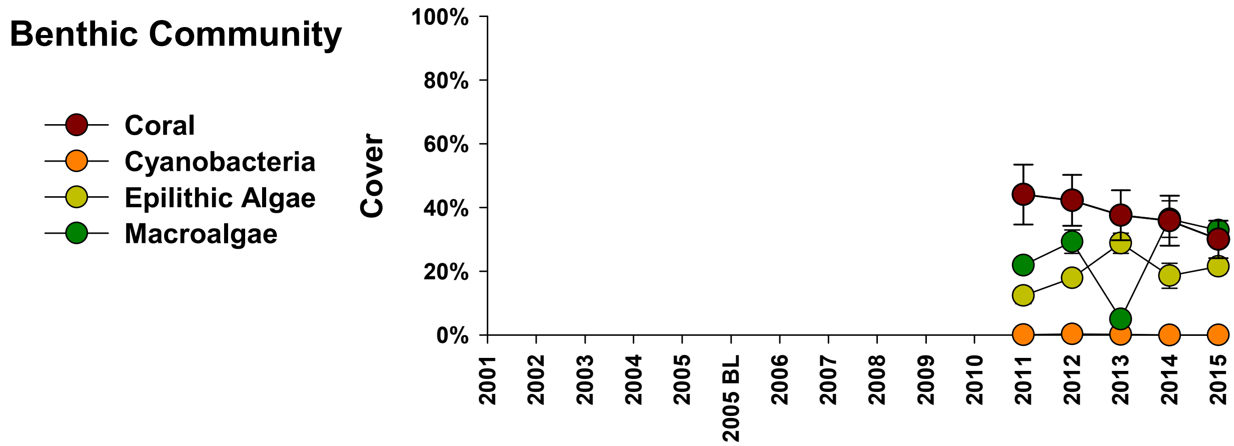


Figure 142. Ginsburgs Fringe benthic cover through time (mean ± SE).

Fish Community. Both abundance and biomass of fish are low on this lower mesophotic scroll coral reef. Herbivores are in notably low abundance. Piscivores make up the bulk in biomass of fishes encountered, include dog snapper and blackfin snapper. Lionfish are also very abundant and make up much of the biomass within the piscivore group. During the grouper spawning aggregation period in the winter and spring months, large groups of Nassau and yellowfin grouper have been observed spawning over the reef at depths between 46-65 m. Historically, black grouper were caught off this reef in the spawning season, but they have not been observed spawning here in the last 10 years (Edmond Bryan, commercial fishermen). Deep-water fishes, such as blackfin snapper and small cherubfish, are commonly found on Ginsburgs Fringe, but are rare in upper mesophotic and shallow sites.

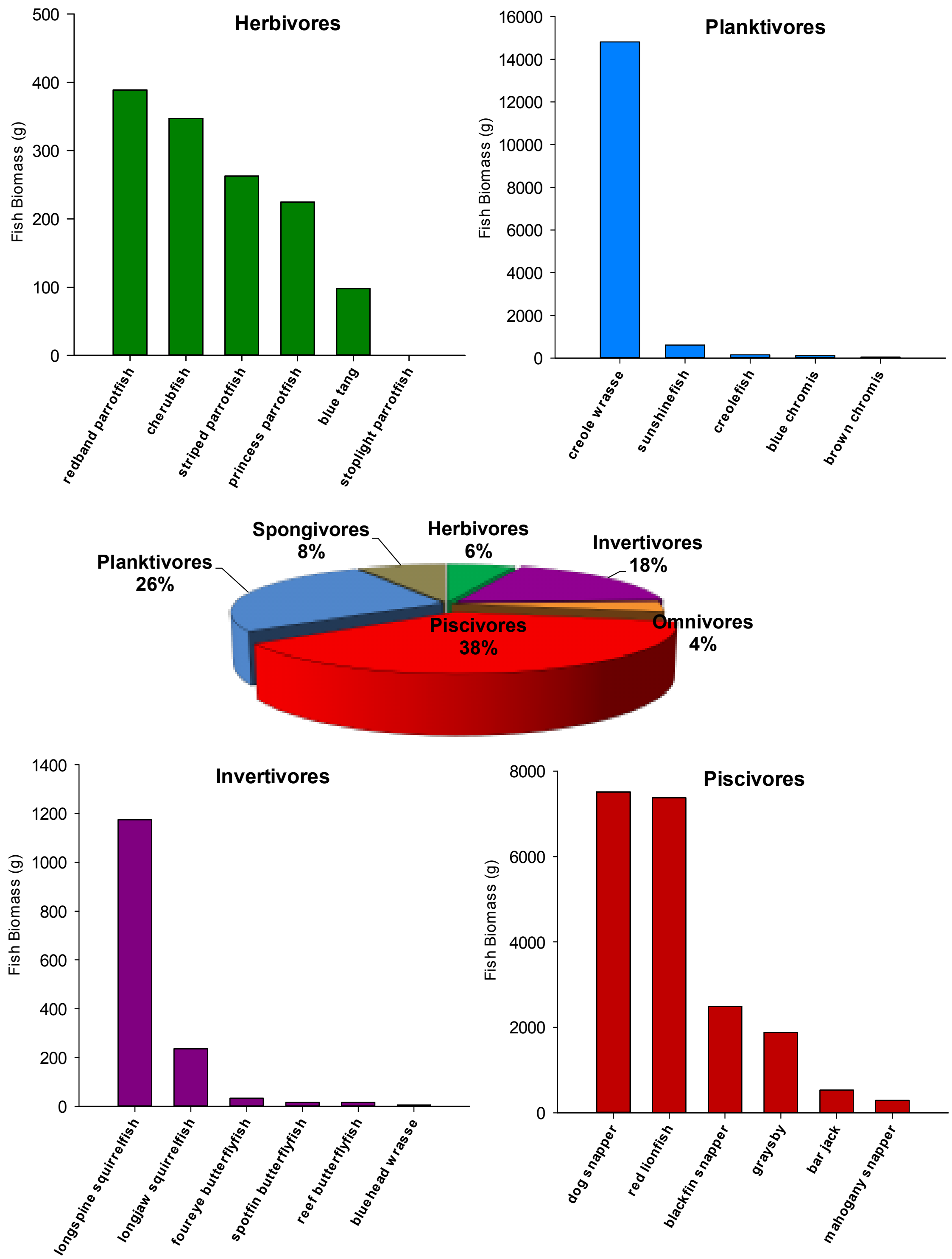
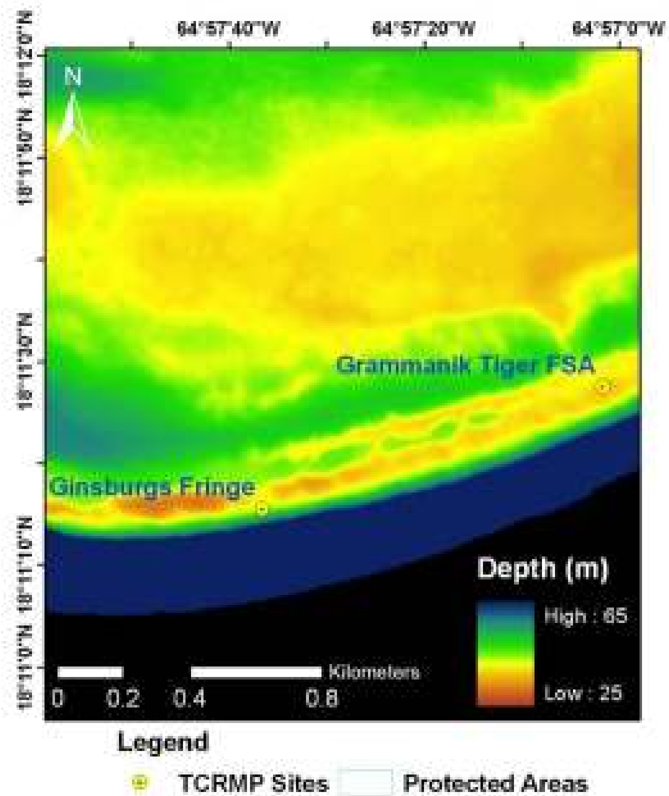


Figure 143. The Ginsburgs Fringe fish community by absolute and relative biomass.

SITE SUMMARIES

GRAMMANIK TIGER



Description. The Grammanik Tiger monitoring site is a primary bank mesophotic reef in depths of 37 – 41m. Star corals (*Orbicella* spp.) dominate the reef structure. Grammanik Tiger has been monitored since 2003, with permanent transects installed in 2007.

Outstanding Feature. The Grammanik Tiger monitoring site supports a dense coral community that is a staging area for annual multi-species fish spawning events, including the threatened Nassau grouper (*Epinephelus striatus*).

Threats. Although the Grammanik Tiger site and surrounding dense reefs are somewhat buffered from high thermal stress, but they are susceptible to chronic coral white diseases. Periodic disease outbreaks follow coral bleaching events. The Indo-Pacific lionfish (*Pterois volitans*) has formed dense populations within the study area and may be affecting native fish populations.

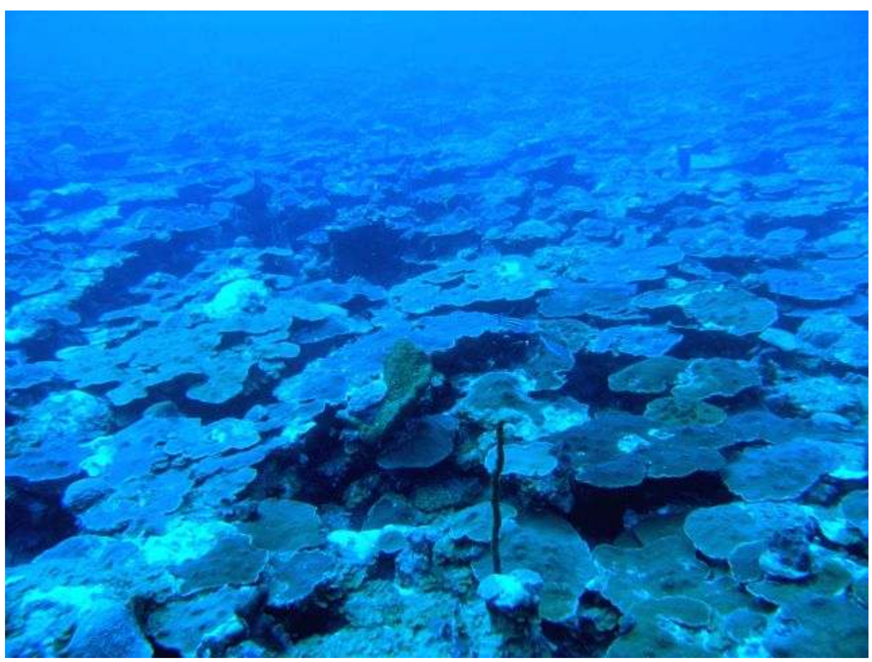


Figure 144. Grammanik Tiger (top) Location. (right) A representative photo of the reef.

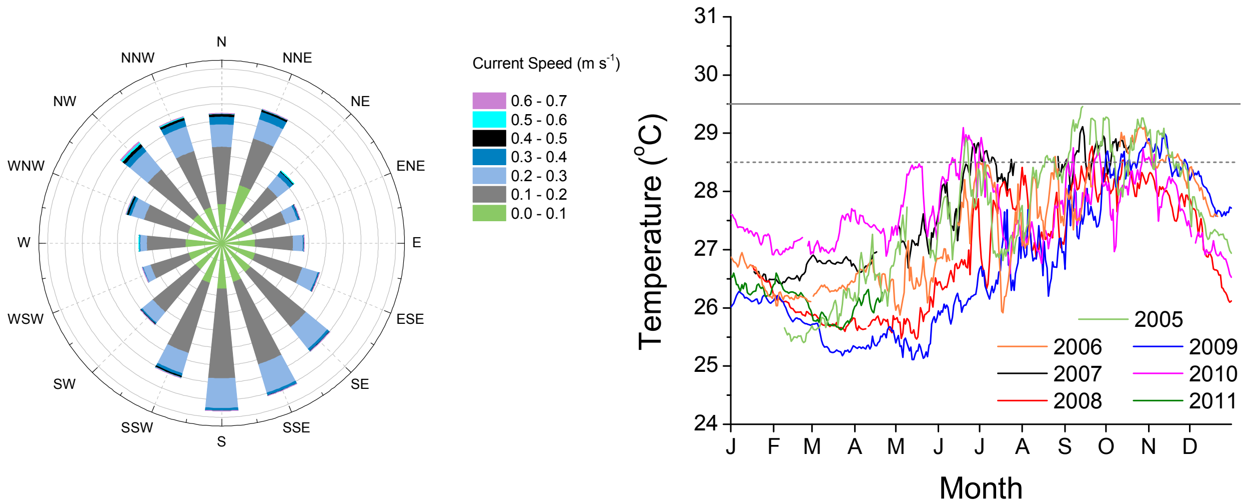


Figure 145. Grammanik Tiger benthic currents speed and temperature record (38 m depth).

Physical Characteristics.

Current. Unidirectional benthic currents at the Grammanik Tiger site are generally north-south, with the strongest current from the north-northeast to the northwest. Currents are typically weak to moderate, but occasionally reach strengths greater than 30cm s^{-1}. Current speeds are based on near-continuous ADCP deployments from February 2005 to April 2009, with measurements at 30 or 60 minute intervals. Oscillatory currents are nil at this depth, with the possible exception of long period swells generated by tropical storms, although this has not been measured.

Temperature. Benthic temperatures at Grammanik Tiger are ameliorated by the passage of tidally driven internal tides in the warm season (May-November). Even in 2005 and 2010 when shallow waters were there warmest during monitoring, temperatures at this site were less than the shallow water bleaching threshold. However, the monthly maximum mean of surface waters established for the region is routinely surpassed. Inter-annual variability creates temperatures that can be up to 2°C different for the same Julian Day.

Benthic Community. Boulder star corals (*Orbicella* spp.) dominate the coral community of the Grammanik Tiger site; however, there is representation by a high number of other species that are also present in shallow water reefs. Grammanik Tiger lost only 5.4% of its coral cover in the 2005 bleaching event, but had not regained any cover (-129.6%) by 2011. A caveat is that transects were not made permanent until 2007. Other prominent members of the sessile epibenthic animal community are sponges. The macroalga *Lobophora variegata* and epilithic algae dominate the algal community. There are also a relatively high proportion of crustose coralline algae and various other macroalgae species.

Coral Health. Corals at Grammanik Tiger were very weakly affected by bleaching in 2005, with only about 10% of corals exhibiting bleaching; however, those that bleached had nearly 70% of the colony surface affected. The 2010 bleaching event was not detectible above background bleaching levels. The prevalence of bleaching in normal years is quite high, but at low extent. This and other mesophotic reefs dominated by *Orbicella* spp. exhibit a type of granular bleaching, whereby pigmented spots are surrounded by bleached areas. Coral diseases are very prevalent with high representation of white disease. Yellow band disease was reported at high prevalence in the first years of monitoring. Old partial mortality was low, but increased rapidly after the 2005 coral bleaching event. Recent partial mortality is very high and is caused by disease lesions, predations, and fish bites.

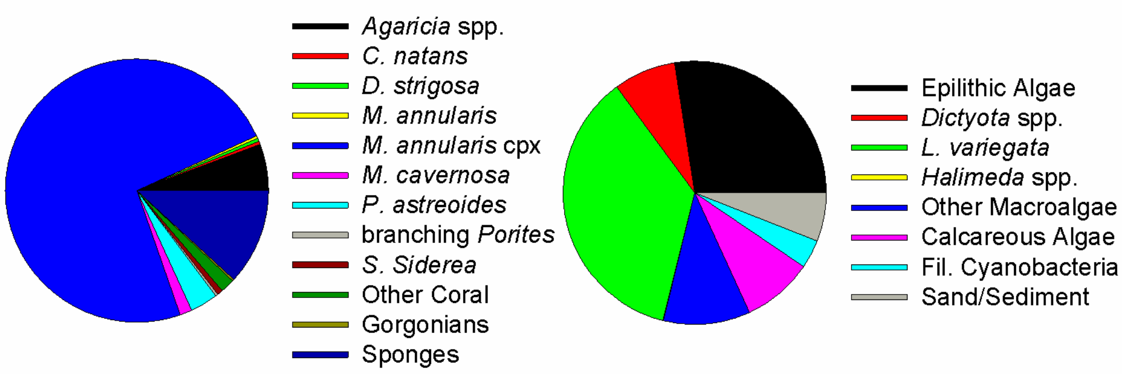


Figure 146. Grammanik Tiger FSA. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

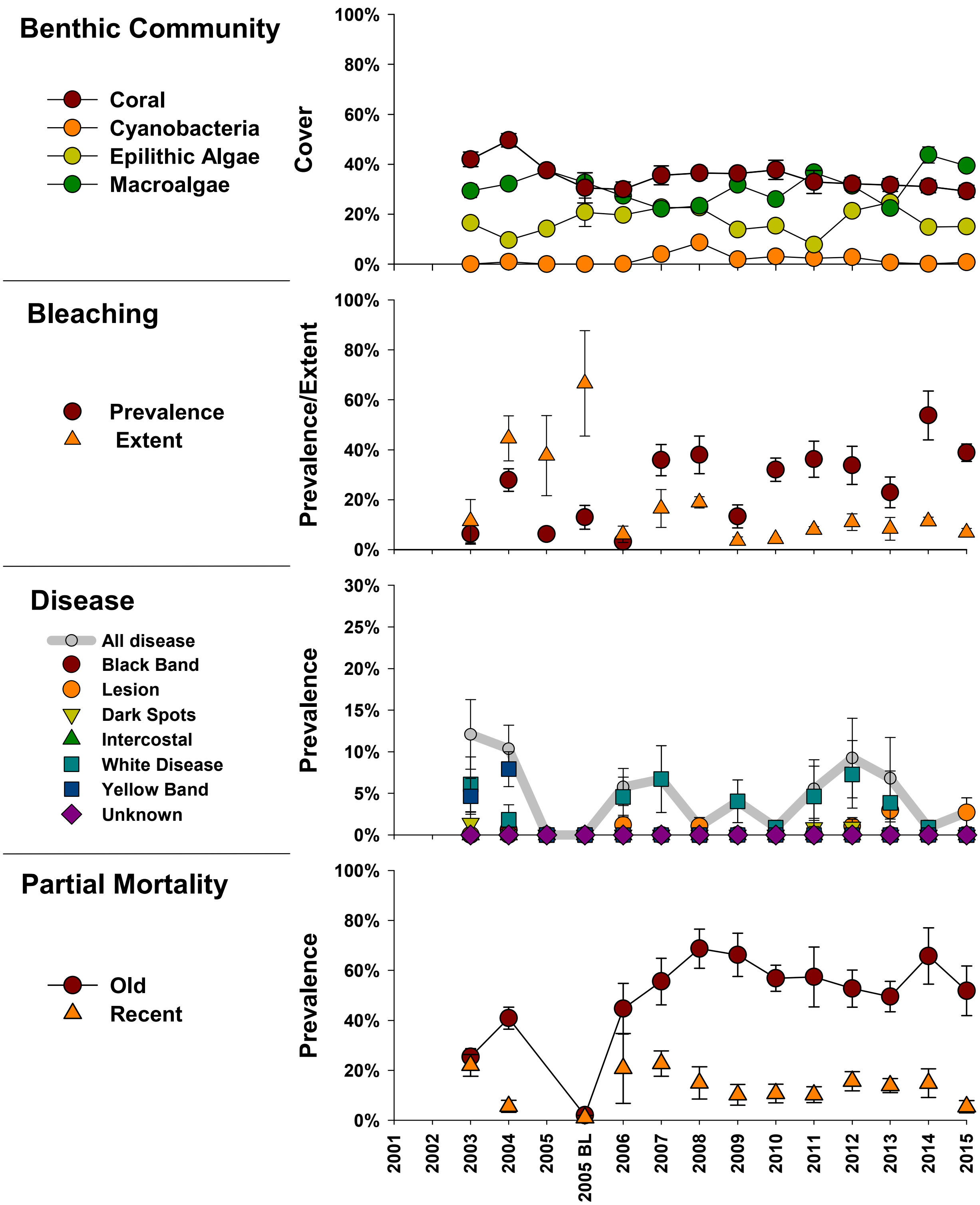


Figure 147. Grammanik Tiger benthic cover and coral health through time (mean ± SE).

Fish Community. The Grammanik Tiger site supports less herbivores and a greater number of piscivores than the more shallow sites in the TCRMP. It is within the staging area and near the spawning site of an aggregation of several species of grouper and snapper. Given the range of spawning species encountered, surveys often coincide with the occurrence of aggregations, particularly in those species with protracted spawning seasons (e.g., cubera and schoolmaster snapper). This drives up the relative piscivore biomass; however, on the Grammanik Bank there also commonly occur members of the pelagic jack family (Carangidae) as well as occasional other large non-spawning grouper and snapper that are rarely or never found on other near and offshore reefs. Nassau, yellowfin, yellowmouth, and tiger grouper are present during non-spawning periods. This reef is protected from traps year round, and from all fishing gear from February through April. Creole wrasse highly dominate the invertivores and adult stoplight parrotfish dominate the herbivores. Juvenile parrotfish and doctorfish are relatively uncommon on this and all mesophotic sites. Yellowhead and bluehead wrasse are also notably much less common on the Grammanik Bank than other sites. In recent years the invasive Indo-Pacific lionfish (*Pterois volitans*) has become very common, with tens of individual commonly observed on any given dive. This is bothersome because, although fishing pressure is low, potential lionfish predators are in relatively high abundance. As well as large groupers and snappers, lemon and bull sharks are seen frequently on the Grammanik Bank reef.

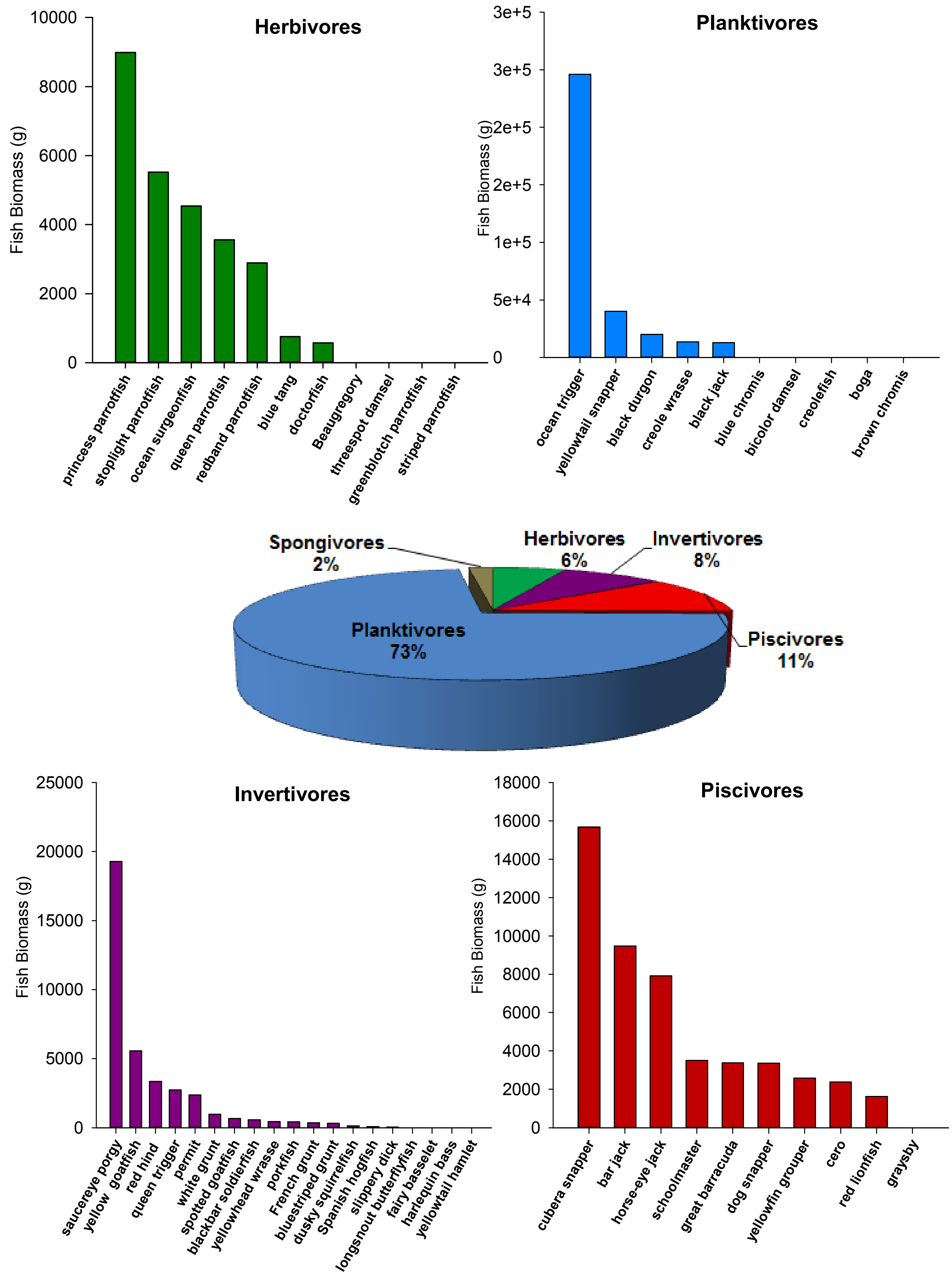
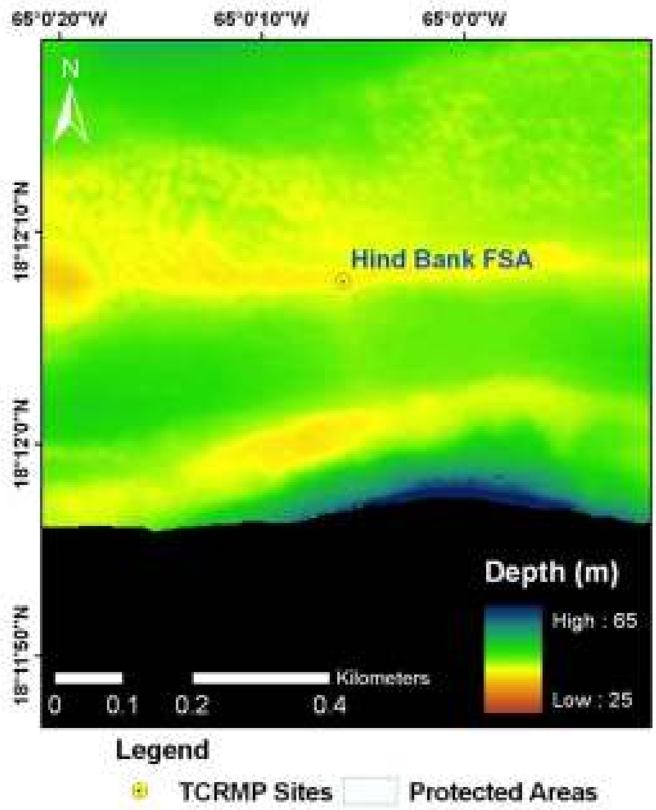


Figure 148. The Grammanik Tiger fish community by absolute and relative biomass.

HIND BANK

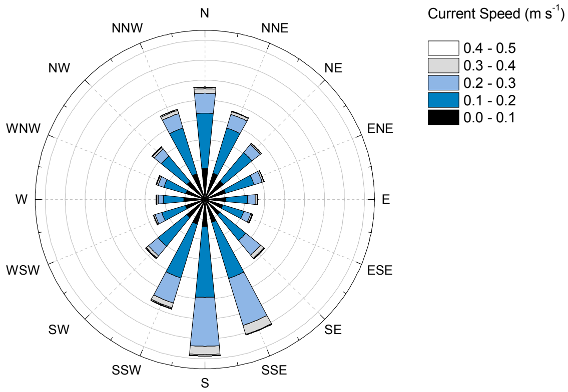


Description. The Hind Bank is a mesophotic tertiary bank in depths of 38 – 42 m. The reef is part of a patchy complex of star coral (*Orbicella* spp.) dominated reefs that stretch across the eastern Red Hind Marine Conservation District. The Hind Bank has been monitored since 2003, with permanent benthic transects installed in 2007.

Outstanding Feature. The Hind Bank is within a no-take marine reserve and fish populations are recovering and robust. The Hind Bank monitoring site hosts a multispecies spawning aggregation, including a recovering mating population of the commercially important red hind grouper (*Epinephelus guttatus*).

Threats. The Hind Bank and surrounding dense reefs are somewhat buffered from high thermal stress, but they are susceptible to chronic coral white diseases. Periodic disease outbreaks follow high thermal stress. The Indo-Pacific lionfish (*Pterois volitans*) has formed dense populations within the study area and may be affecting native fish populations.

Figure 149. Hind Bank (top) Location. (right) A representative photo of the reef.



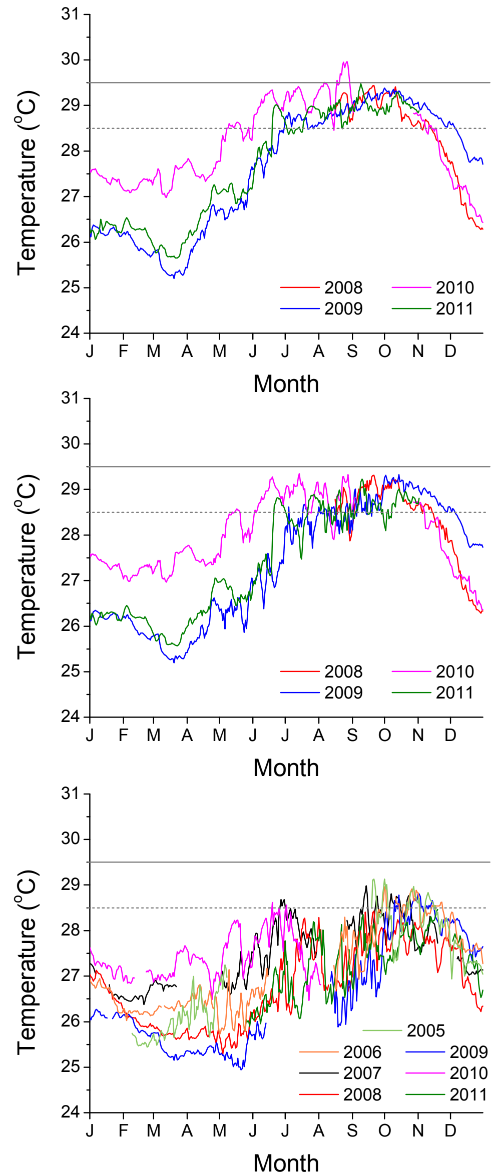


Figure 150. Hind Bank benthic current speed (40m depth). Benthic temperature record at 20, 30, and 40 m depth.

Physical Characteristics.

Current. Hind Bank has moderately strong unidirectional near-benthic currents that are dominated by a north to south components. Currents can be moderate to strong (>20cm s^{-1}). Current speeds are based on near-continuous ADCP deployments from February 2005 to May 2012, with measurements at 30 or 60 min. intervals. Oscillatory currents are not known from the Hind Bank.

Temperature. Benthic temperatures at the Hind Bank were augmented with a subsurface buoyed thermistor string carrying thermistors at 20 and 30 m depth. Benthic temperatures show strong inter-annual variability, but were much cooler than temperatures in the mixed layer at 20 m depth. This was particularly evident in 2010; when temperatures were warmest at 20 m in late August during coral bleaching, temperatures were unseasonably cool on the bottom. One caveat for the accuracy of the 20 and 30 m thermistors is that they can change depth to some degree by bowing of the buoy line by currents.

Benthic Community. The Hind Bank site is dominated by boulder star corals (*Orbicella* spp.), but also has a high abundance of lettuce corals (*Agaricia* spp.). The Hind Bank site lost 21.8% of its coral cover in the 2005 bleaching event, but had regained 71.4% of this cover by 2011. The algal community is co-dominated by epilithic algae and the macroalga *Lobophora variegata*. There is also high representation of crustose coralline algae and other unidentified macroalgal species.

Coral Health. Bleaching during the 2005 event was nearly indistinguishable from background levels of bleaching in both prevalence and extent. The prevalence of bleaching was actually higher during the 2010 coral bleaching event. In later years, the high prevalence of moderate prevalence, low colony extent bleaching was often associated with granular bleaching. This bleaching pattern shows pigmented spots surrounded by bleached tissue. Coral diseases are common at the Hind Bank and may be increasing. White disease was the dominant disease, and 2011 showed a peak of disease signs. In 2009 there was a high prevalence of intercostal mortality syndrome, which is only known from mesophotic coral reefs (Smith et al. 2010b). Old partial mortality increased after the 2005 bleaching event and the high prevalence was not reduced until 2011. Recent partial mortality prevalence is often high and reflects the impacts of disease and predation.

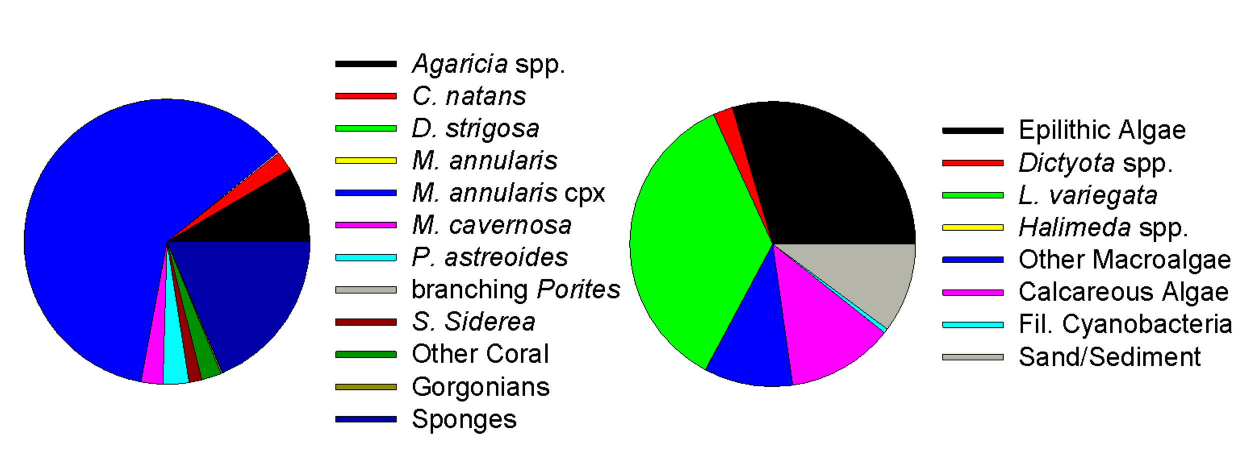


Figure 151. Hind Bank. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

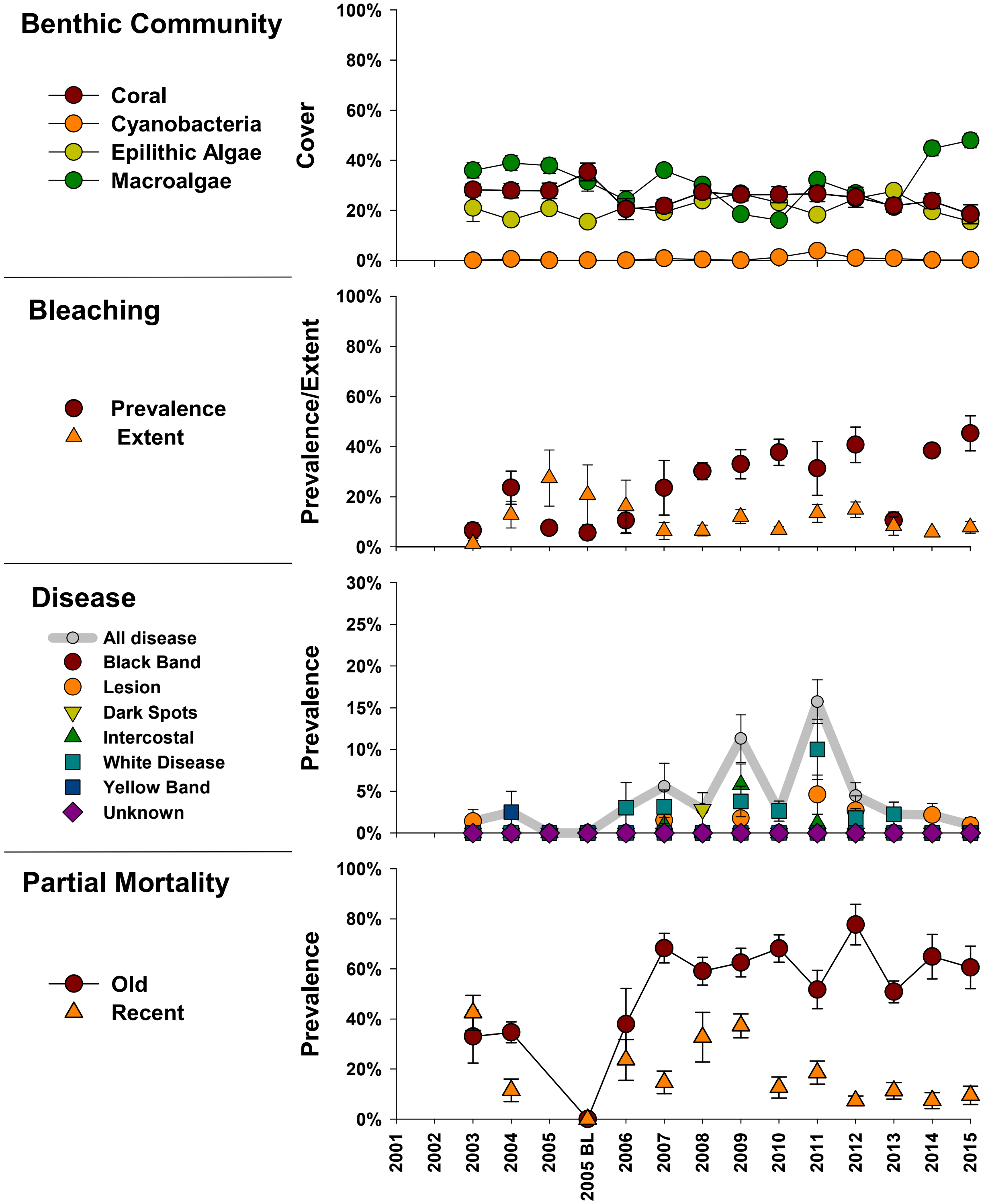


Figure 152. Hind Bank benthic cover and coral health through time (mean ± SE).

Fish Community. Like the Grammanik Bank, the Hind Bank is characterized by a high number of piscivorous fish. The site is within the Marine Conservation District (MCD) and is protected year round from all fishing, except surface trolling. It is the spawning site for several species including red hind, mutton snapper, tiger grouper, and schoolmaster snapper. Surveys often coincide with the occurrence of schoolmaster snapper, which has a protracted spawning season. This drives up the relative piscivore biomass; however, there are also commonly members of the pelagic jack family (Carangidae), large barracuda, and resident groupers. Benthic invertivores are dominated by goatfish as the likely result of the proximity of sand areas along the reef. Creole wrasse are not nearly as dominant on the Hind Bank as on other mesophotic sites. Herbivores, as on other mesophotic sites, are less common than on nearshore sites. This group is dominated by adult or semi-adult princess parrotfish and juvenile parrotfish are uncommon. Yellowhead wrasse are fairly common on the Hind Bank, however bluehead wrasse are not. Mesophotic species such as the fairy basslet, sunshinefish, and longsnout butterflyfish are also common.

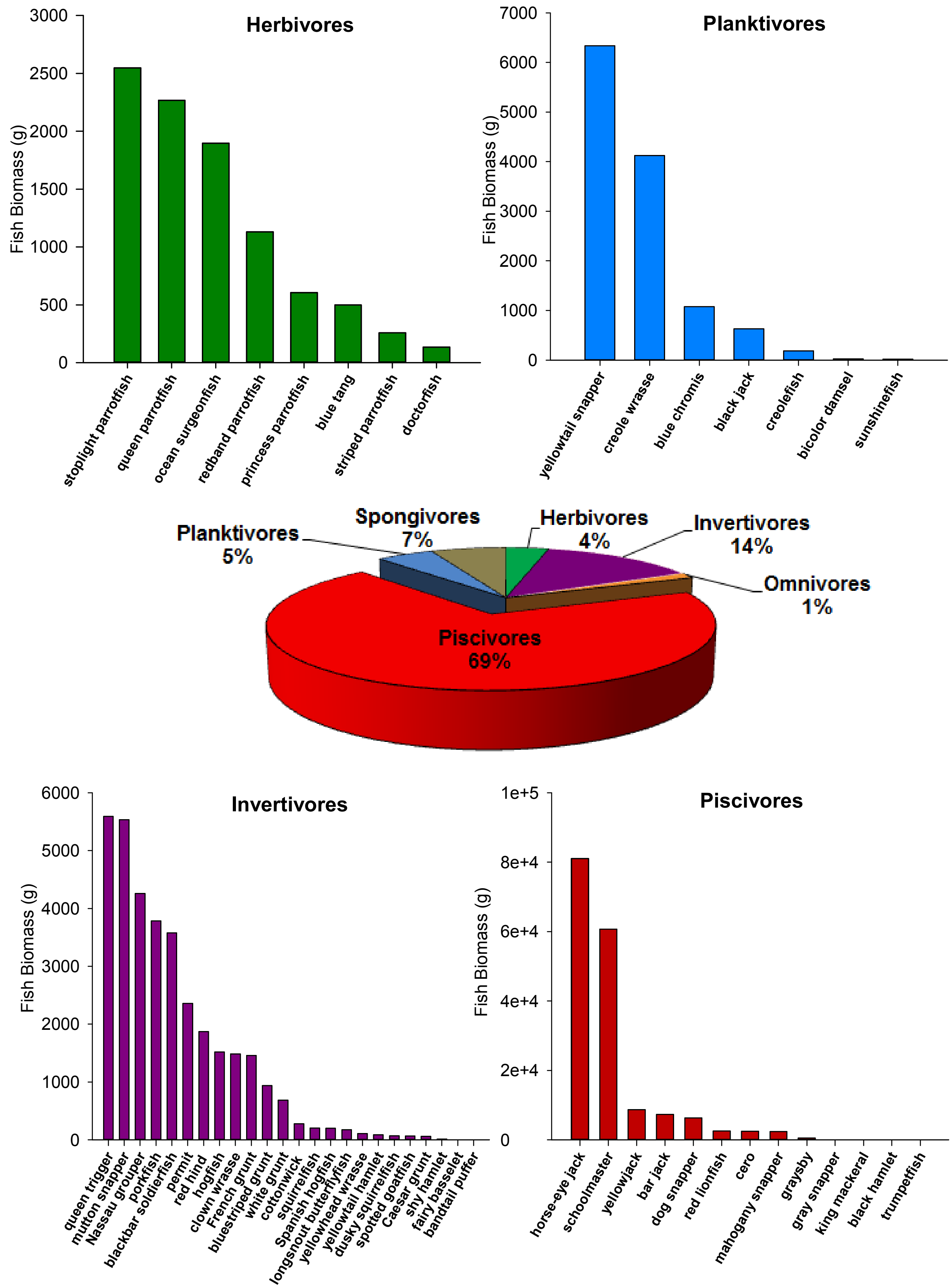
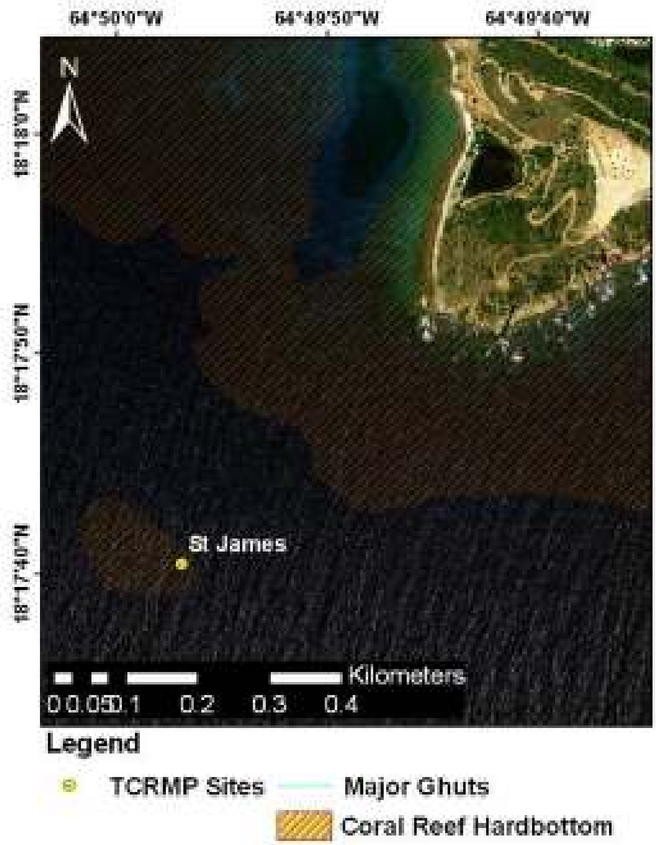


Figure 153. The Hind Bank East fish community by absolute and relative biomass.

LITTLE SAINT JAMES



Description. The Little St. James site is a midshelf hardbottom reef in depths of 16-22 m. The reef is a patch reef surrounded by sand/rhodolith plain. Little St. James has been monitored since 2005, with permanent benthic transects installed in 2007.

Outstanding Feature. The Little St. James site is just outside the St. Thomas East End Reserve and supports occasional high densities of snappers, grunts, and queen trigger.

Threats. Commercial fisherman target the Little St. James site and active and derelict fish traps are in high abundance. The site is down-current of development on Little St. James Island and is potentially threatened by land-based source of pollution.

Figure 154. Little St. James. (top) Location. (right) A representative photo of the reef.

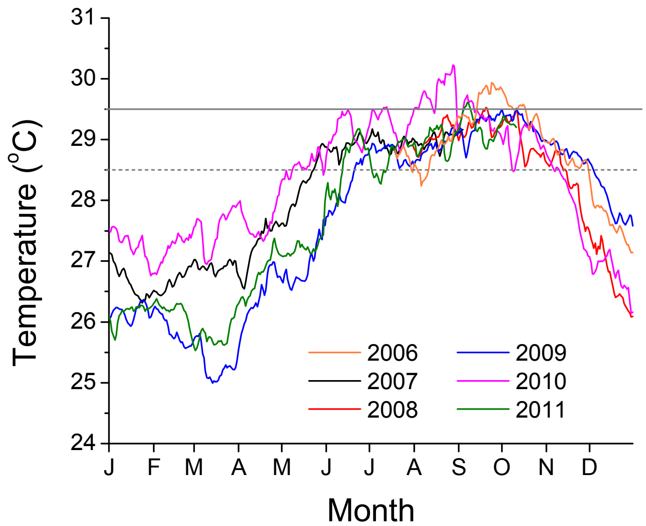


Figure 155. Little St. James benthic temperature record (19 m depth).

Physical Characteristics.

Current. Currents have not been directly measured at St. James. Unidirectional benthic currents have only been weak during monitoring. Strong wave-driven oscillatory currents may take place, as evidenced by the high proportion of gorgonians and *Sargassum* spp. at the site.

Temperature. Benthic temperatures at St. James can be high during warm years, such as 2010.

Benthic Community. The sparse coral community of the Little St. James site is diverse. There is a high proportion of rare species, such as *Eusmilia fastigiatum*, *Madracis* spp., and *Mycetophyllia* spp.. The site lost 16.5% of coral cover in the 2005 bleaching event but had apparently regained 376.2% of this loss by 2011. This large increase above bleaching losses may be explained by the fact that transects were not made permanent until 2007 and were then sited in areas with the densest coral. The sessile epibenthic community overall is largely composed of sponges and gorgonians. The algal community is dominated by the macroalgae *Dictyota* spp. and the *Sargassum* spp.. *Lobophora variegata* and epilithic algae are also in high proportional abundance.

Coral Health. The coral community at Little St. James was highly affected by the 2005 coral bleaching event, with all corals assessed completely bleached. Half the corals were affected by low extent bleaching in 2010. Low-level bleaching is a common feature of the site. Diseases are less common, with the exception of a white disease outbreak that preceded the coral bleaching event in June 2005. Dark spots disease can also be common. Old partial mortality increased rapidly after the 2005 bleaching event. Recent partial mortality is not very prominent.

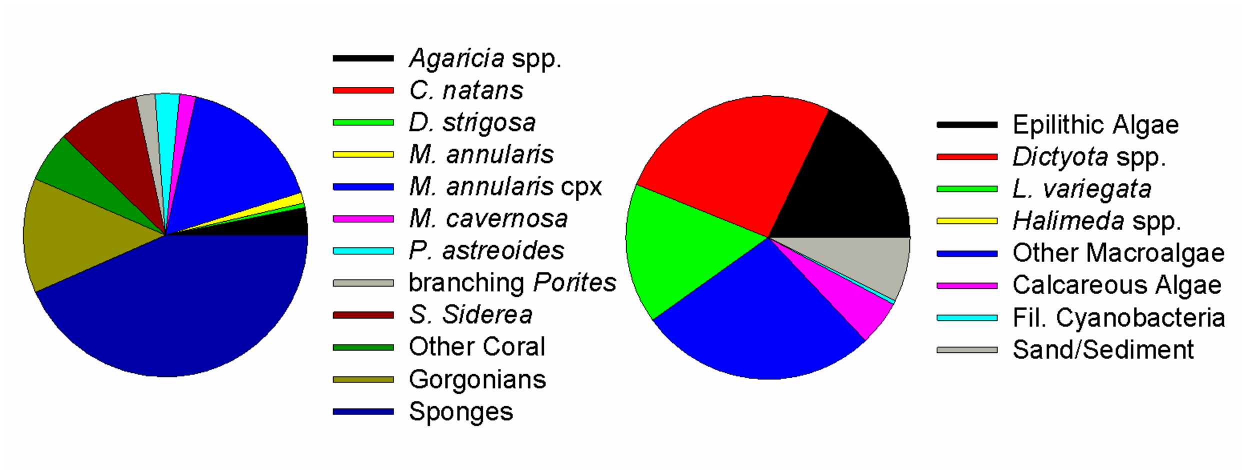


Figure 156. Little St. James. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

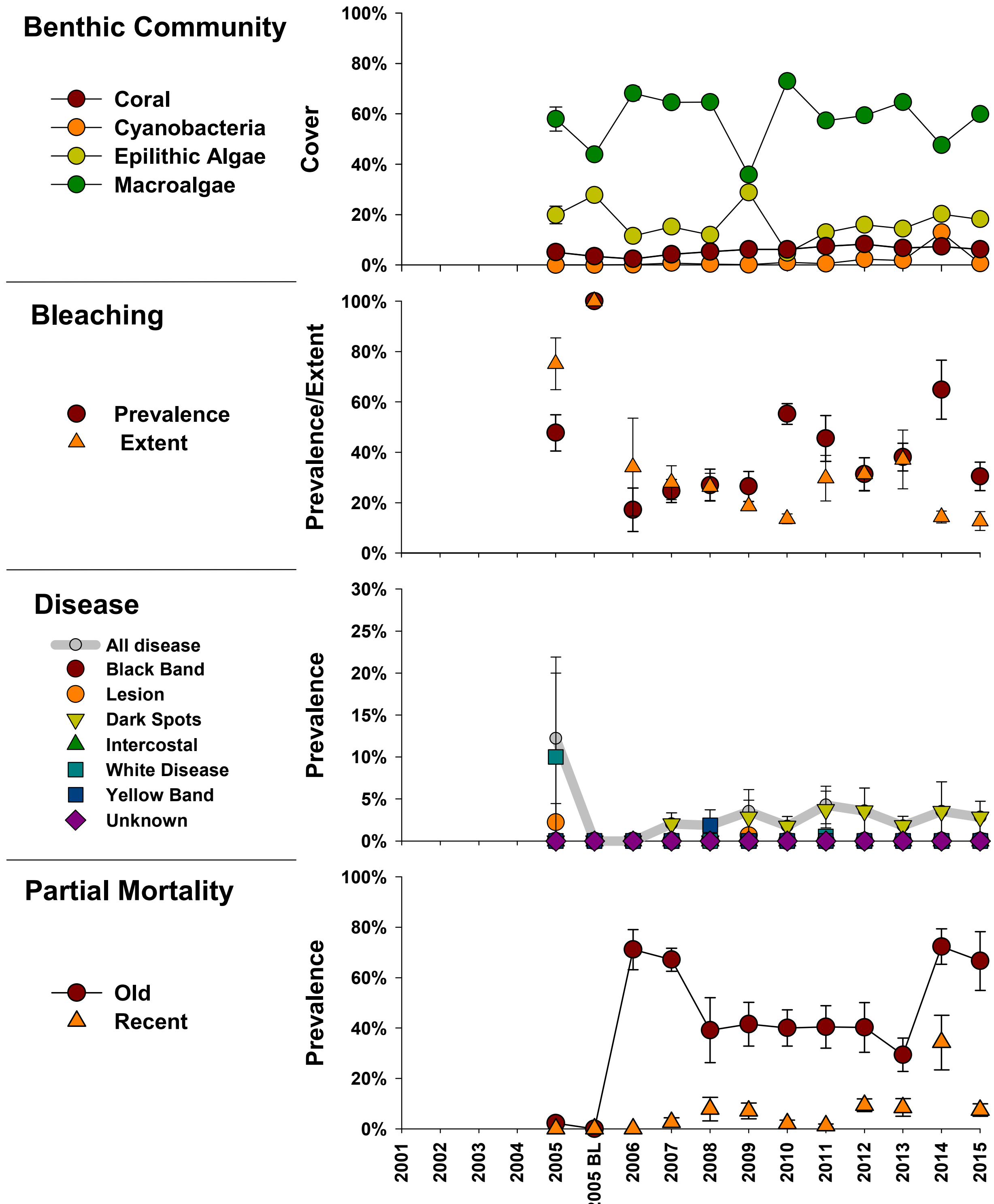


Figure 157. Little St. James benthic cover and coral health through time (mean ± SE).

Fish Community. The fish community of Little St. James differs slightly from those of the more developed reef habitats, representing both reef and hard bottom fish community. Queen triggerfish and mutton snapper are far more common on Little St. James than on other TCRMP sites. Red hind are also very common. These three benthic invertivores are indicative of sand mixed with hard bottom sites. The Little St. James reef is outside of the boundaries of the St. Thomas East End Reserves, and fish traps are observed regularly on the site. During parts of the year, grunts (French and white) have been observed in huge numbers, and may use the site for spawning. Bar and yellow jacks are very common swimming in the water column above the Little St. James site, and the schoolmaster, gray, and mahogany snapper are all prolific. All of these species are considered ciguatoxic in this area and so are not targeted by hook and line, trap, or spear fishermen. Notably the queen triggerfish is observed in large numbers and sizes at Little St. James. Lobster are generally found during monitoring events on transects or roving dives.

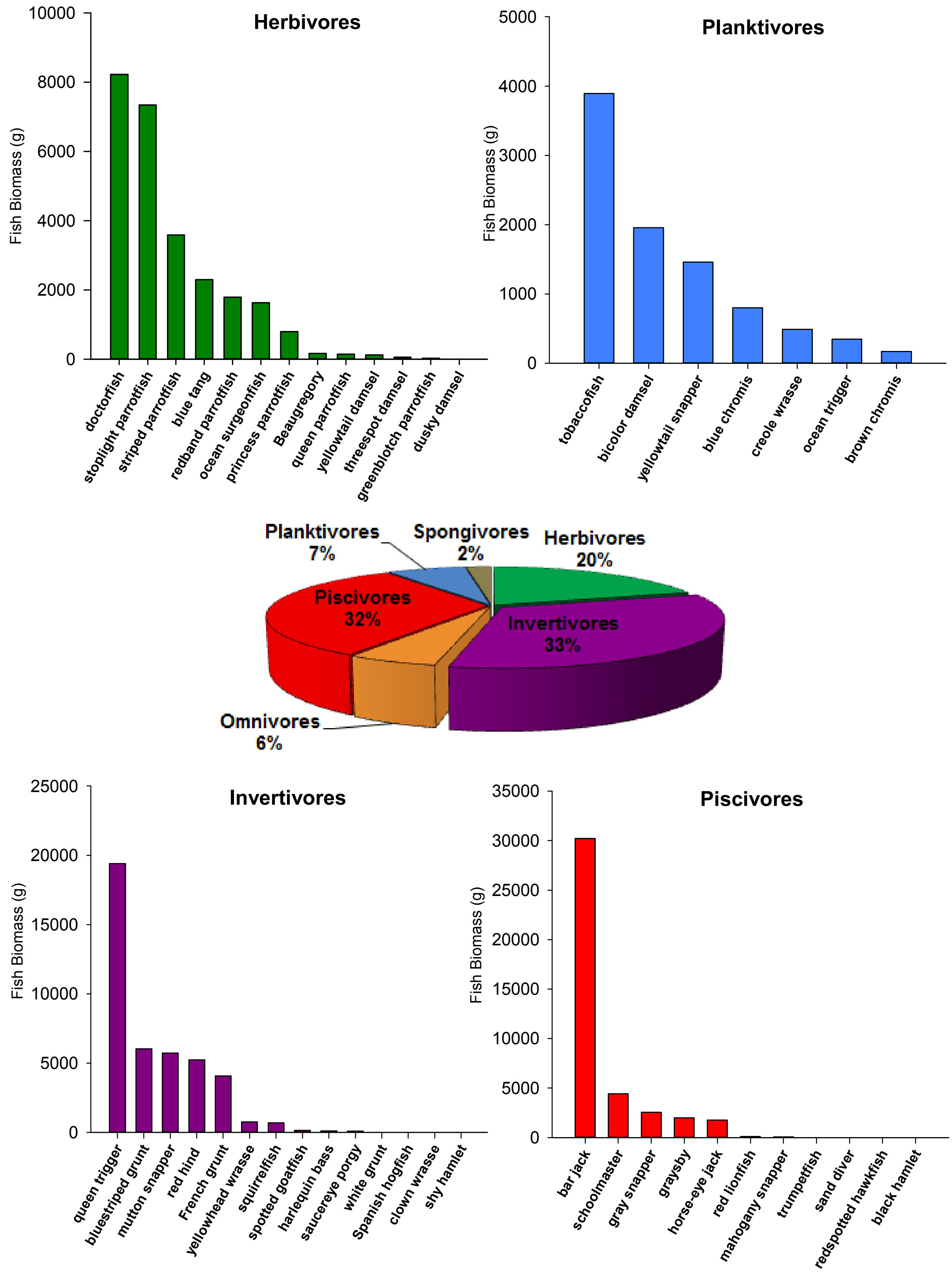
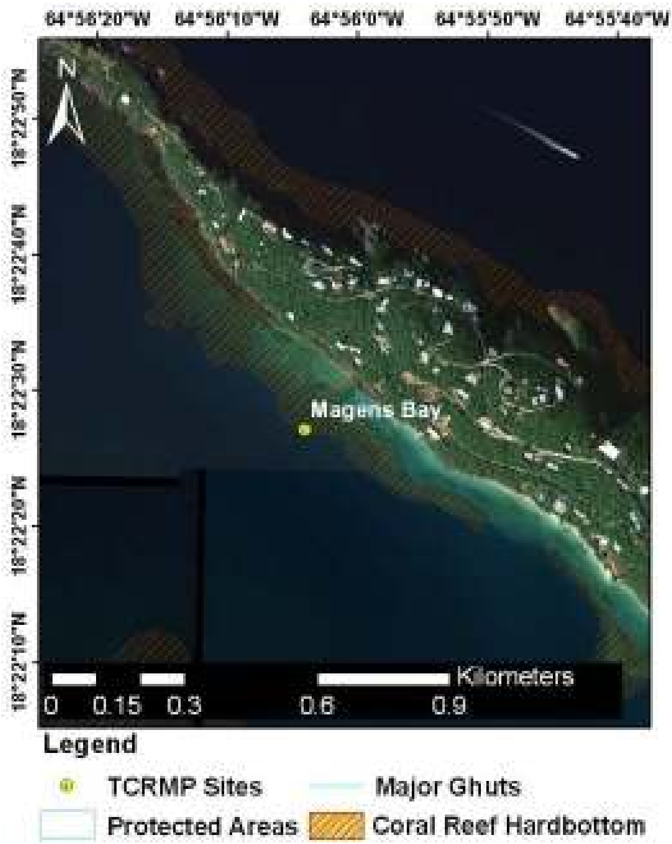


Figure 158. The Little St. James fish community by absolute and relative biomass.

MAGENS BAY



Description. The Magens Bay site is a nearshore fringing reef located along Peterborg Point in depths of 4 – 14 m. The reef has a sharp break in slope leading to a steep escarpment that terminates in a sand/sediment plain at the reef base. Magens Bay has been monitored since 2001.

Outstanding Feature. The Magens Bay site is a well protected northside St. Thomas reef near one of the most popular tourist beaches in the Caribbean.

Threats. Magens Bay is in a highly enclosed embayment receiving a very large and developed watershed. Sediment run-off is high and deposition on reefs is favored by slow current speeds. The turbidity after rain and swell events can be extreme in the bay and water visibility is often less and 3m. In addition, leaky septic systems may impair bay waters.

Recreational/artisanal fishers frequently fish this site with hand line and spear.

Figure 159. Magens Bay. (top) Location. (right) A representative photo of the reef.

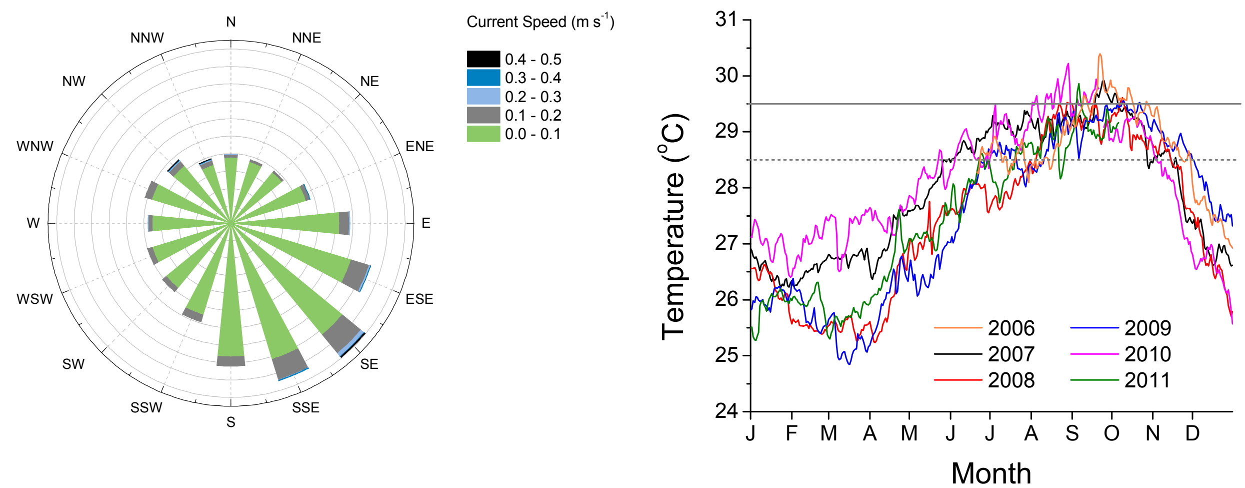


Figure 160. Magens Bay current speed and benthic temperature record (9 m depth).

Physical Characteristics. **Current**. Magens Bay has restricted water flow dominated by weak currents running counter or orthogonally to the left of the dominant wind direction. This may indicate that there is a counter flowing eddy. Current data are based on average data from Dec. 2006-Oct. 2007 7.5 m above the sensor head. **Temperature**. Magens Bay has low circulation, but temperatures are kept cooler by exposure to the Atlantic. **Chlorophyll & Turbidity**. Magens Bay is susceptible to very high chlorophyll and turbidity values indicating very high productivity that is likely fueled by terrestrial run-off. By blocking light this shallows the depth limits for coral growth and water column productivity favors heterotrophic organisms, such as sponges and gorgonians.

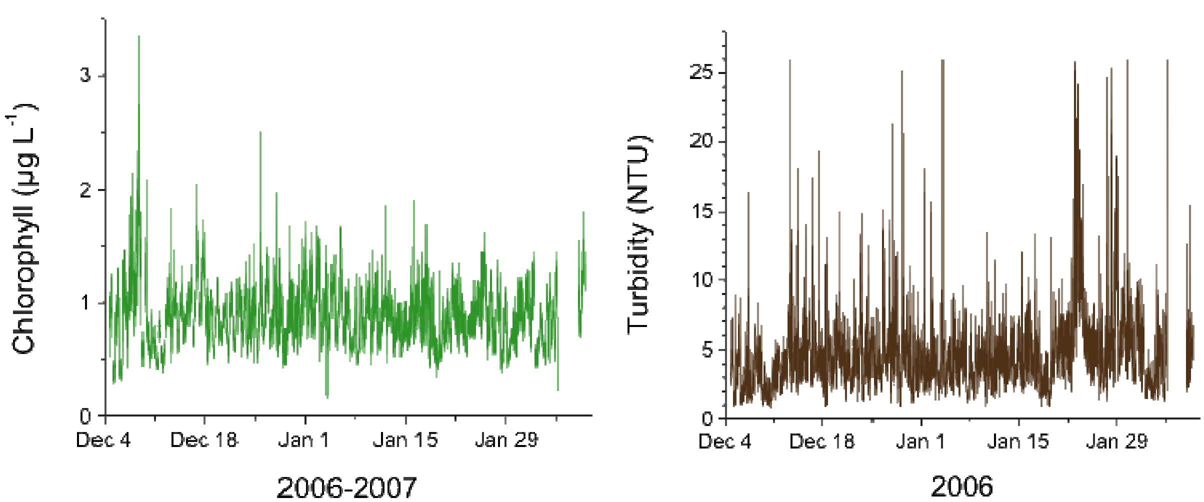


Figure 161. Magens Bay chlorophyll (left) and turbidity (right) record (16 m depth).

Benthic Community. The sparse coral community at Magens Bay is very diverse, with no real dominance by any one species. The site lost 12.4% of its coral cover in the 2005 bleaching and has continued to lose coral, with a cover loss of 33.1% from 2005 pre-bleaching to 2011. Gorgonians and then sponges dominate the sessile epibenthic community. Epilithic algae and the macroalga *Dictyota* spp. dominate the algal community. Filamentous cyanobacteria are also common. There is a high proportion of sand/sediment around corals at the Magens Bay site.

Coral Health. Corals were highly affected by the 2005 bleaching event, with about 80% of all corals about 80% affected across the colony surface. This site also showed a strong response to the 2010 bleaching event with about 60% of corals bleached at a low extent. Diseases can be high and are dominated by dark spots disease. Old partial mortality increased after the 2005 bleaching event and then declined, with a slight increase from 2009 to 2011. Recent partial mortality is common at the Magens Bay site, largely as the result of biting by territorial damselfish (*Stegastes* spp.; data not shown).

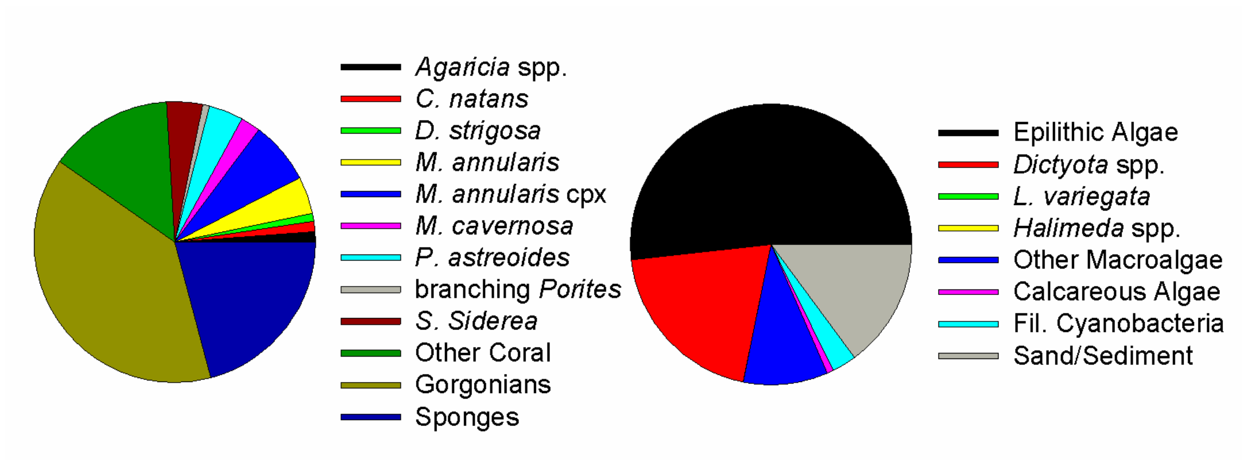


Figure 162. Magens Bay. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

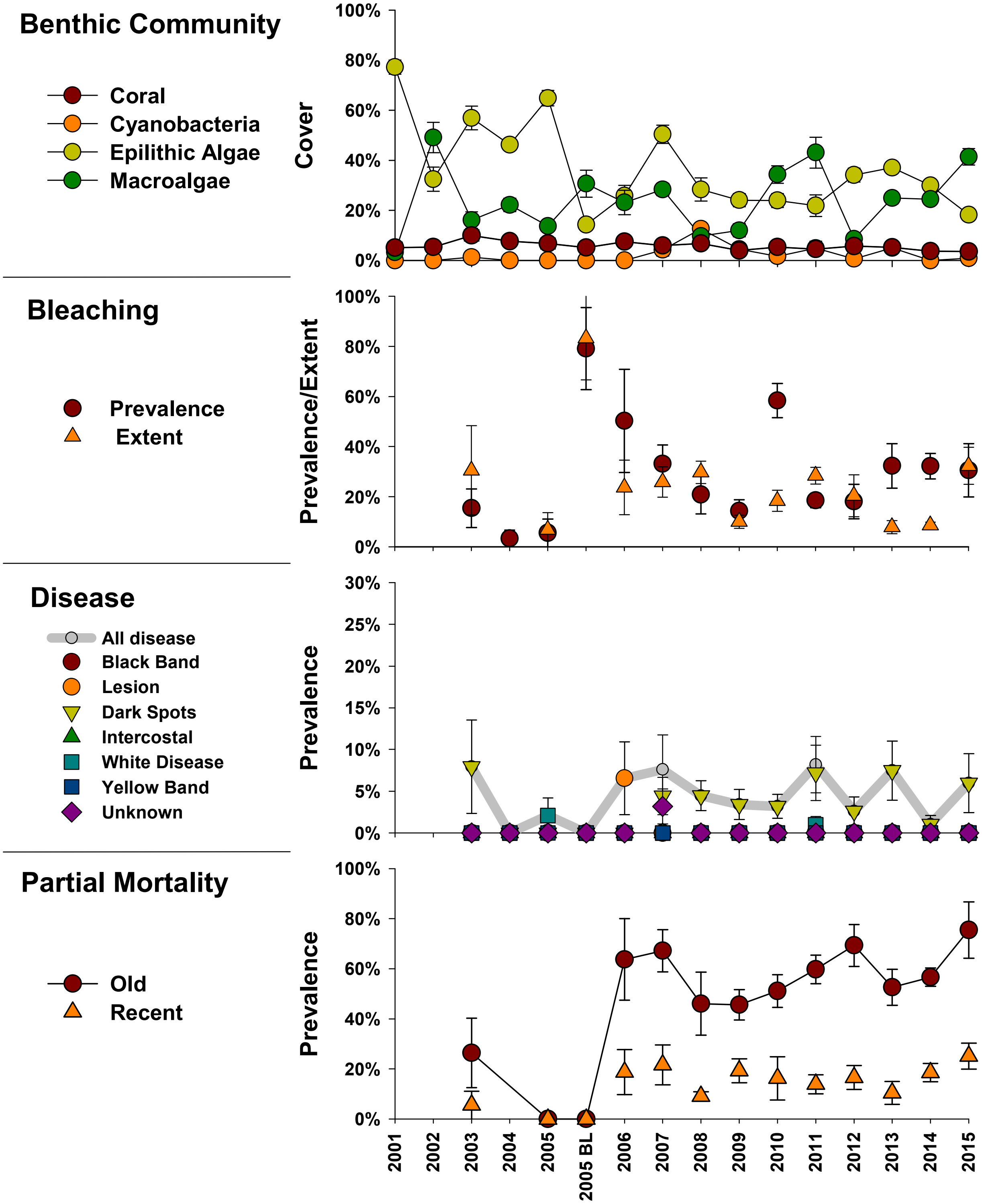


Figure 163. Magens Bay benthic cover and coral health through time (mean ± SE).

Fish Community. Magens Bay once supported its own rich fishery and was the notorious site of the only fatality by shark attack recorded in St. Thomas (Randall 1963a). The days of large, commercially important fish in Magens Bay have been gone since the 1970's; however, the bay is connected to the deeper Puerto Rican shelf to the north and large sharks are known to frequent the bay. Tiger sharks are still caught commonly off either point defining the bay to the east or west. Anecdotally, hammerheads mate in the middle of Magens Bay during one moon phase of the year, and along the mile long sandy beach it is not uncommon to see young of the year sharks swimming in the clear water, suggesting that the deep protected bay is the pupping ground for at least one species of shark. Along the reef that is the TCRMP monitoring site, large fish are rare, and herbivores make up the bulk of the fish biomass. The largest fish swim along the reef edge, where occasional mahogany and lane snapper reside, along with grunts, goatfish, and larger parrotfishes. Schools of wrasse, mixed with juvenile parrotfish, and damselfishes occupy the top of the reef. The threespot damselfish is extremely prolific. No large groupers or snappers were observed in Magens Bay from 2012 to 2014, the first three years of fish monitoring.

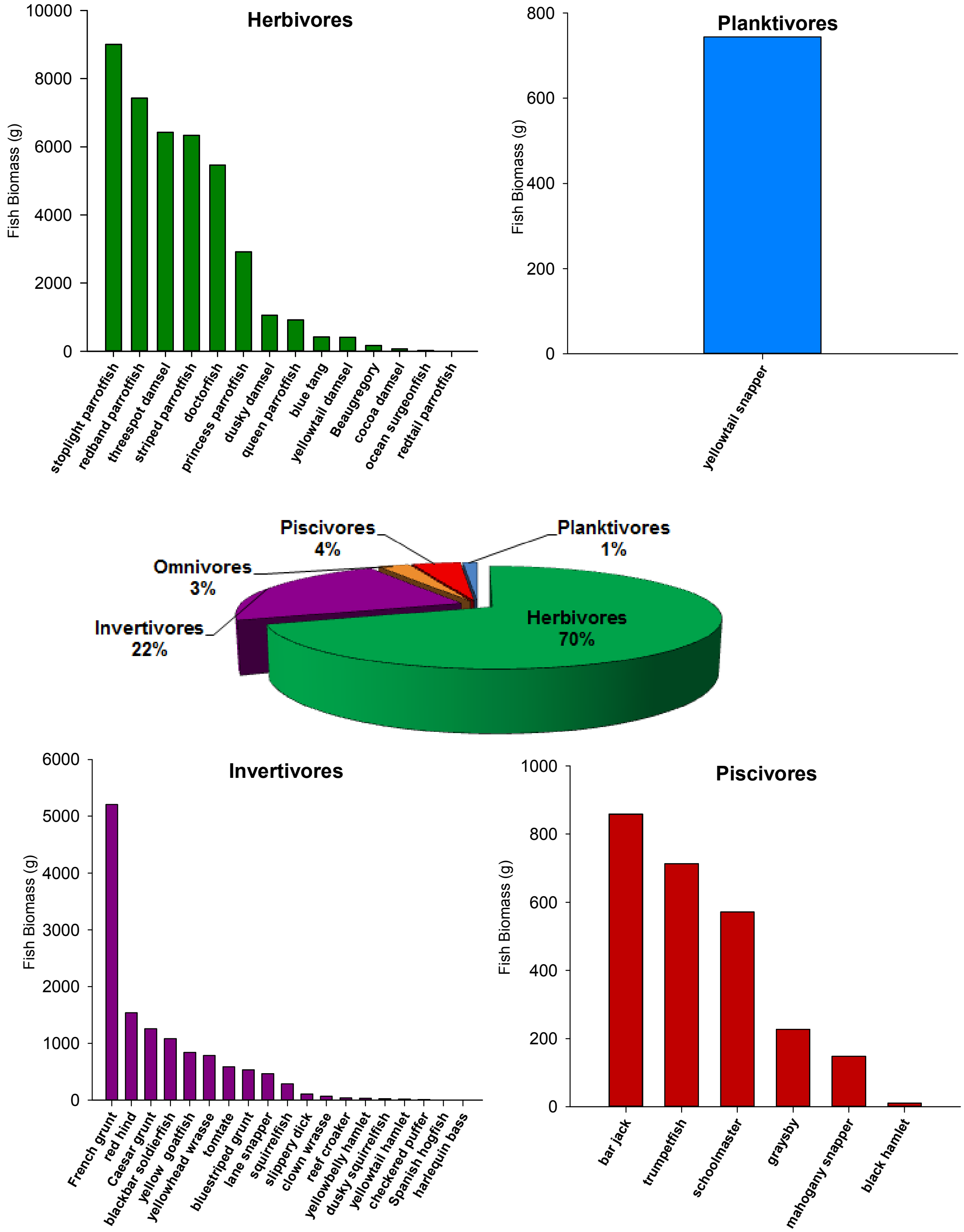
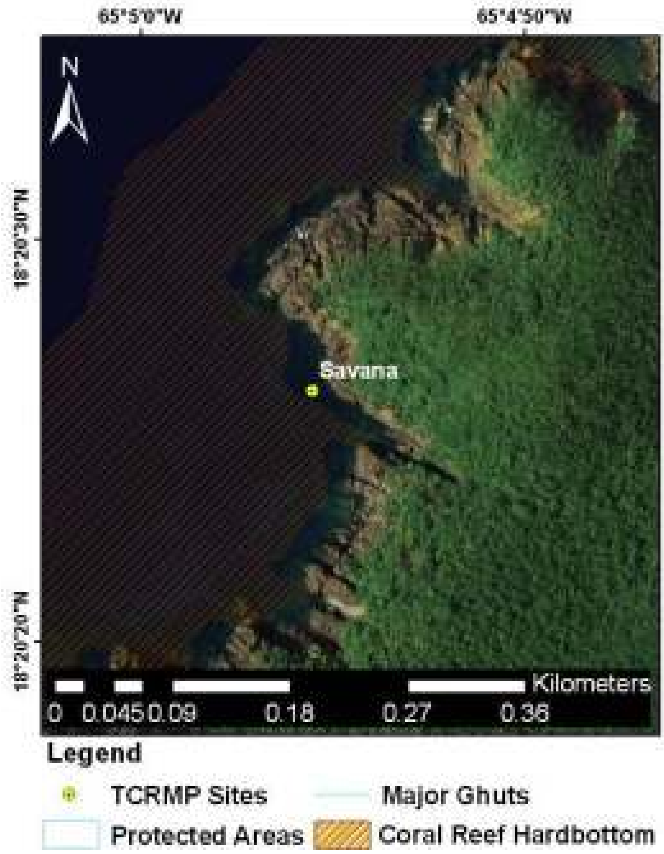


Figure 164. The Magens Bay fish community by absolute and relative biomass.

SAVANA ISLAND



Description. The Savana Island site is a midshelf fringing reef facing the Atlantic Ocean to the northwest in depths of 5 – 17 m. The reef is a well-developed coral community atop bedrock, with some insipient carbonate accumulation. Savana has been monitored since 2003, with permanent benthic transects installed in 2007.

Outstanding Feature. Savana harbors behemoth colonies of boulder star coral (*Orbicella faveolata*) and a diverse and abundant fish community.

Threats. Savana is threatened by warming ocean temperatures, as *O. faveolata* can be susceptible to bleaching, disease, and partial mortality. The area is also open to fishing and the occasional accumulation of debris can be seen.

Figure 165. Savana. (top) Location. (right) A representative photo of the reef showing large colonies of *Orbicella faveolata* (Nov. 17, 2015).

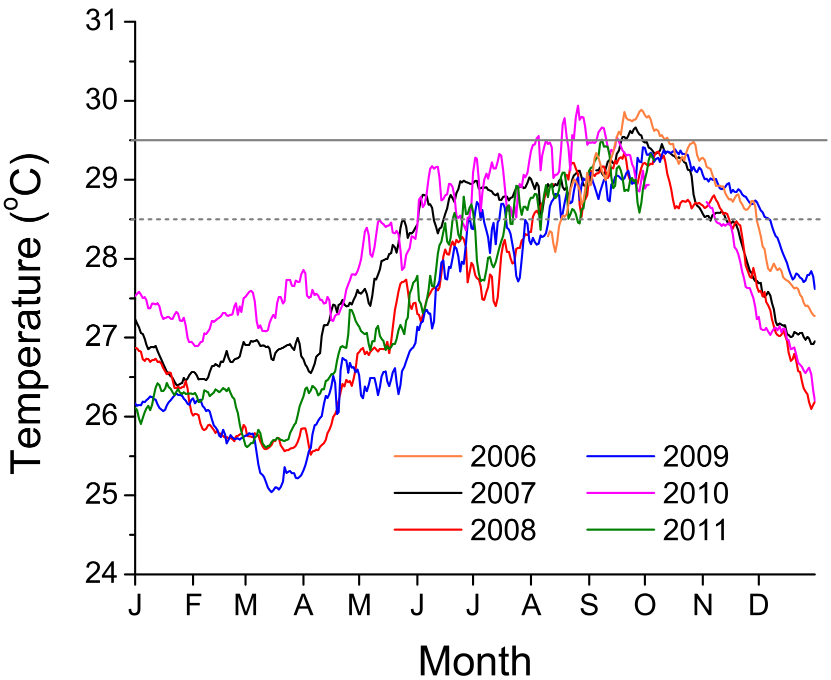


Figure 166. Savana benthic temperature record (10 m depth).

Physical Characteristics.

Current. Currents have not been measured directly at Savana. Strong unidirectional currents can influence the surface near the site. Wave-driven oscillatory currents are common and occasionally strong.

Temperature. Savana has temperatures cooler than other shallow sites, likely due to the proximity of the open Atlantic Ocean.

Benthic Community. Boulder star corals, predominately large (>2m wide) colonies of *Orbicella faveolata*, dominate the coral community at the Savana monitoring site. The site lost 45.2% of its coral cover in the 2005 bleaching event. Some of the largest losses occurred between 2010 and 2011, but there was no indication of the cause, since the site bleached moderately and no disease outbreaks were noted. Recent coral cover is being lost by overgrowth of *Peyssonnelia* spp., an encrusting red algae, which has spiked many-fold over the last two years of monitoring (see macroalgal cover). Gorgonians and sponges are also prominent components of the sessile epibenthic animal community.

Coral Health. The coral community at Savana was highly affected in the 2005 bleaching event, with 80% of corals affected on almost 90% of the colony surface. Bleaching was also very prominent in 2006, but at a lower extent. Bleaching was moderate during the 2010 bleaching event, with over 50% of colonies bleached at a low extent. Coral diseases can reach high prevalence and are diversely represented. Particularly noticeable is the dramatic outbreak of white disease in 2006. Dark spots disease has also affected a high proportion of corals from 2008 onwards. Old partial mortality increased markedly after the 2005 coral bleaching event and has declined only slightly. Recent partial mortality after the 2005 coral bleaching event was unprecedented for any site.

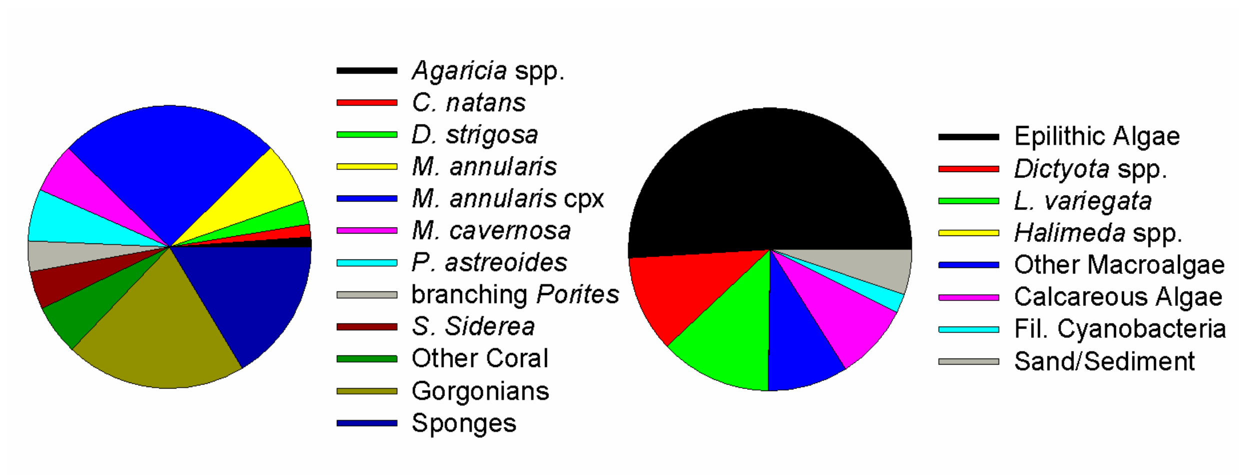


Figure 167. Savana Island. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

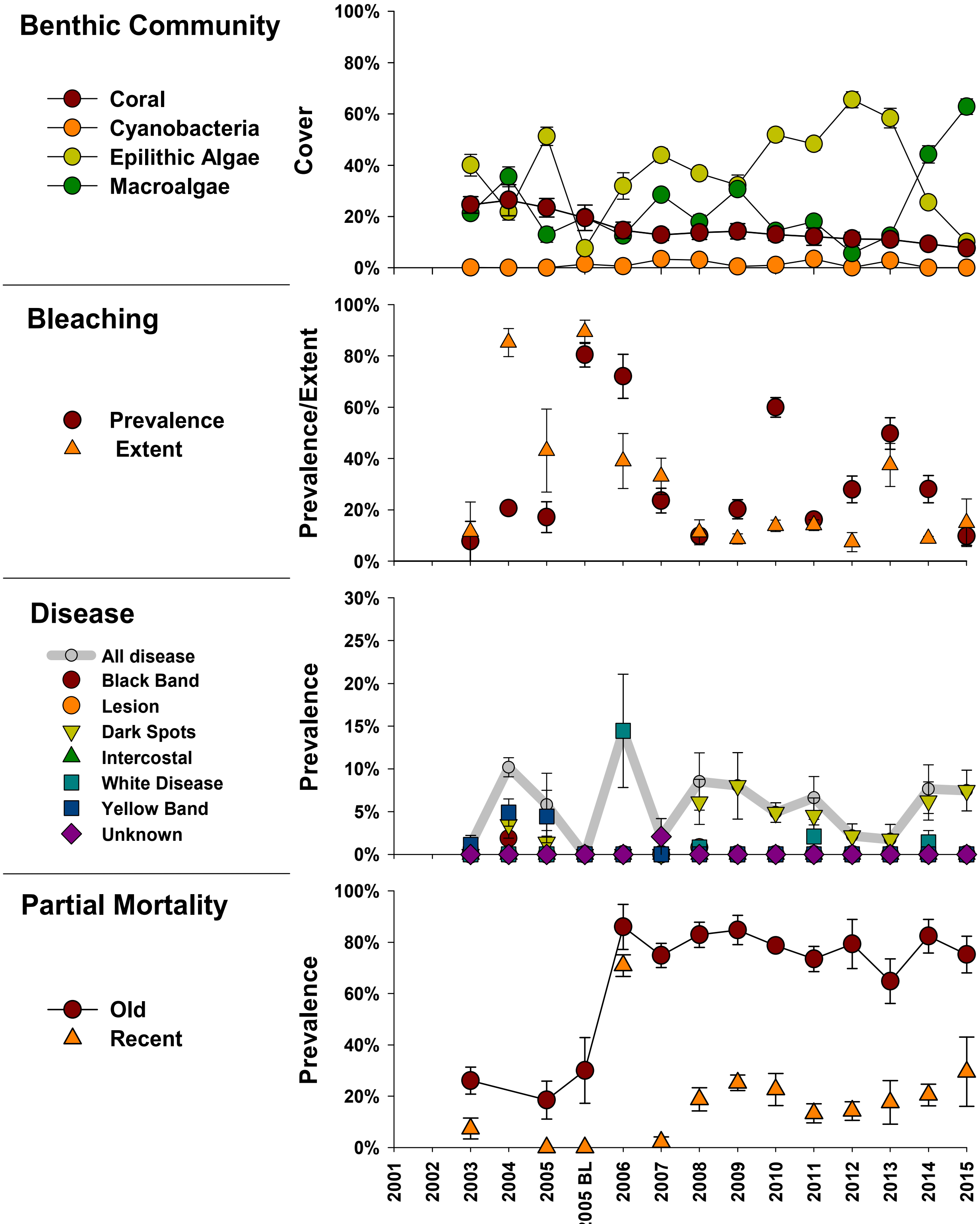


Figure 168. Savana Island benthic cover and coral health through time (mean ± SE).

Fish Community. The Savana Island fish community is fairly small in biomass, but is quite diverse, and highlights the variety of benthic resources available to fishes in the area. The site is dominated by herbivores, but it also supports a diverse invertivore community. Planktivores in the quiet protected bay are limited to the smaller pomocentrids and wrasses. However, these fish groups are all quite prolific. The most numerous piscivore observed in the first three years of fish monitoring has been the schoolmaster snapper. One small yellowmouth grouper (11-20 cm) was observed on a belt transect in 2012, the first seen on a site in shallow water located near land. The area around Savana is subject to strong currents and potential larva flow, however the area is highly fished with fish traps. No large commercially important fish have been seen in the bay.

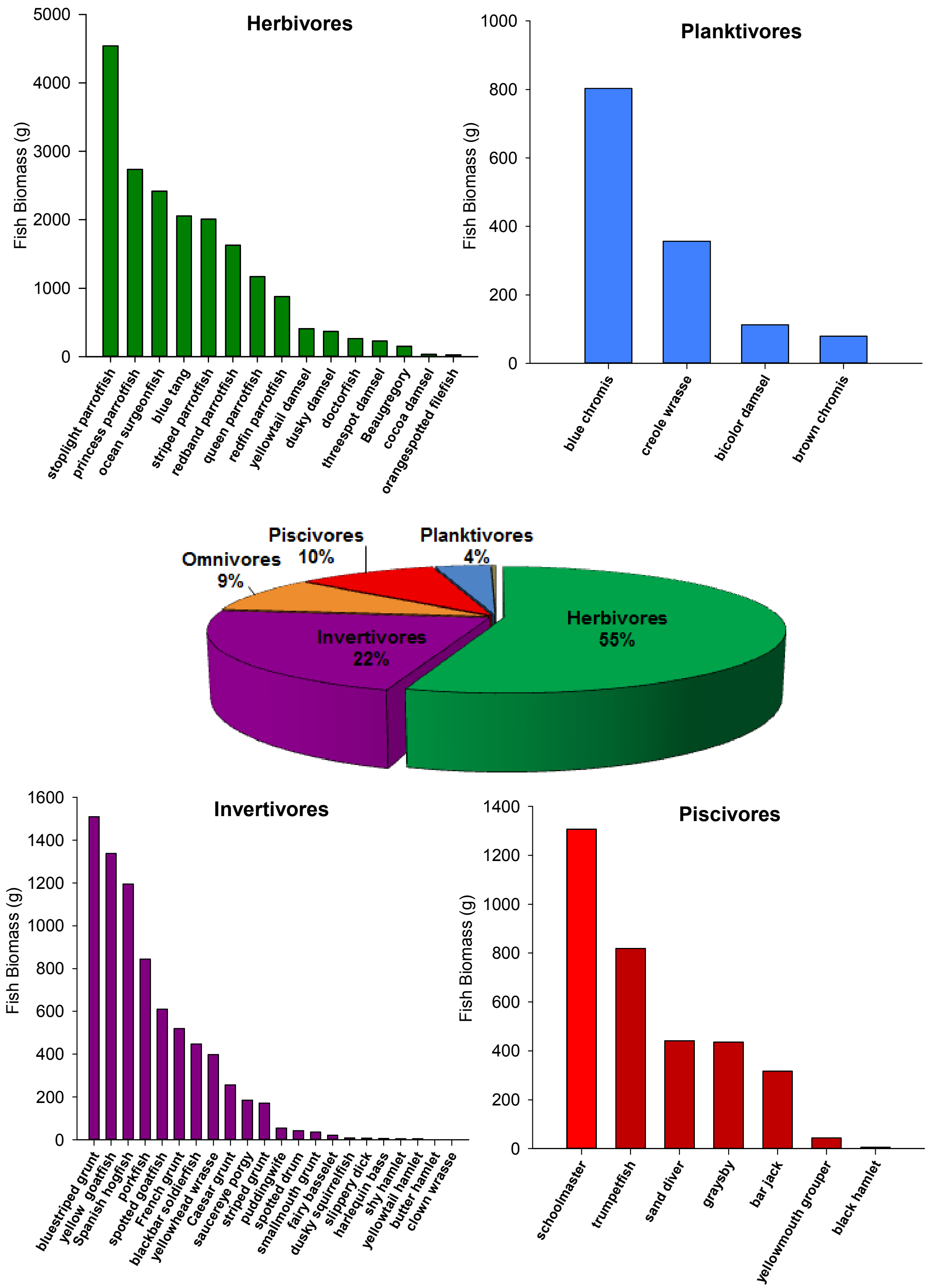
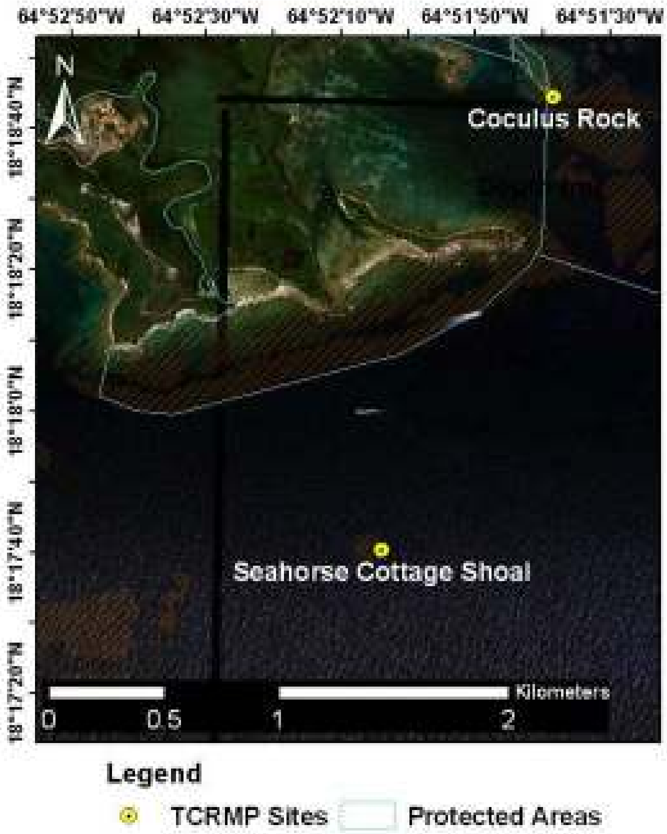


Figure 169. The Savana Island fish community by absolute and relative biomass.



SEAHORSE COTTAGE SHOAL

Description. The Seahorse Cottage Shoal site is a large patch reef surrounded by sand and rhodolith in depths of 17 – 23m. The isolated reef is flat topped and dominated by *Orbicella* spp.. Seahorse has been monitored since 2003, with permanent benthic transects installed in 2007. A ciguatera study with monthly sampling has been ongoing since 2009.

Outstanding Feature. Seahorse supports a diverse and abundant coral and fish community adjacent to the St. Thomas East End Reserves.

Threats. Seahorse is buffered from land-based sources of pollution. The site is a targeted site in the St. Thomas trap fishery and trap strings have been observed over and adjacent to the site.

Figure 170. Seahorse Cottage Shoal. (top) Location. (right) A representative photo of the reef.

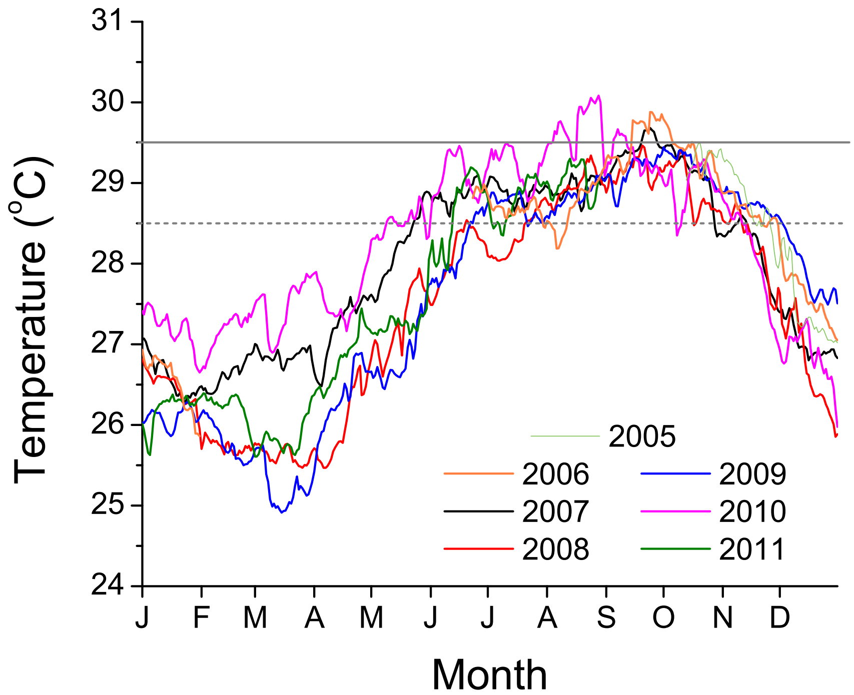


Figure 171. Seahorse benthic temperature record (21 m depth).

Physical Characteristics.

Current. Currents have not been directly measured at Seahorse Cottage Shoal. Unidirectional benthic currents tend to be slow and wave-driven oscillatory currents only occur during heavy storm activity.

Temperature. Benthic temperatures are moderate to high during warming events.

Benthic Community. The coral community of the Seahorse site is dominated by the boulder star coral (*Orbicella* spp.), but hosts a high diversity of other coral species. The site lost 46.6% of its cover in the 2005 bleaching event and had only regained 4.7% of this loss by 2011. Gorgonians and sponges are also common components of the sessile epibenthic animal community. The algal community is co-dominated by epilithic algae and the macroalgae *Lobophora variegata* and *Dictyota* spp..

Coral Health. The coral community bleached severely in the 2005 bleaching event with nearly 100% of corals bleaching over about 100% of their surface. Bleaching prevalence after 2005 was slow to decline due to delayed recovery in large *Orbicella* spp. colonies. The site also had a high prevalence of bleaching in the 2010 event, but at a low extent on colonies. Bleaching was also moderately prevalent in 2011. Coral diseases are common and diverse at Seahorse. White disease was also prevalent in 2004, which is rare for a site at this depth. Dark spots disease is also ubiquitous. Old partial mortality increased to a very high prevalence after the 2005 bleaching event, but had declined by 2011.

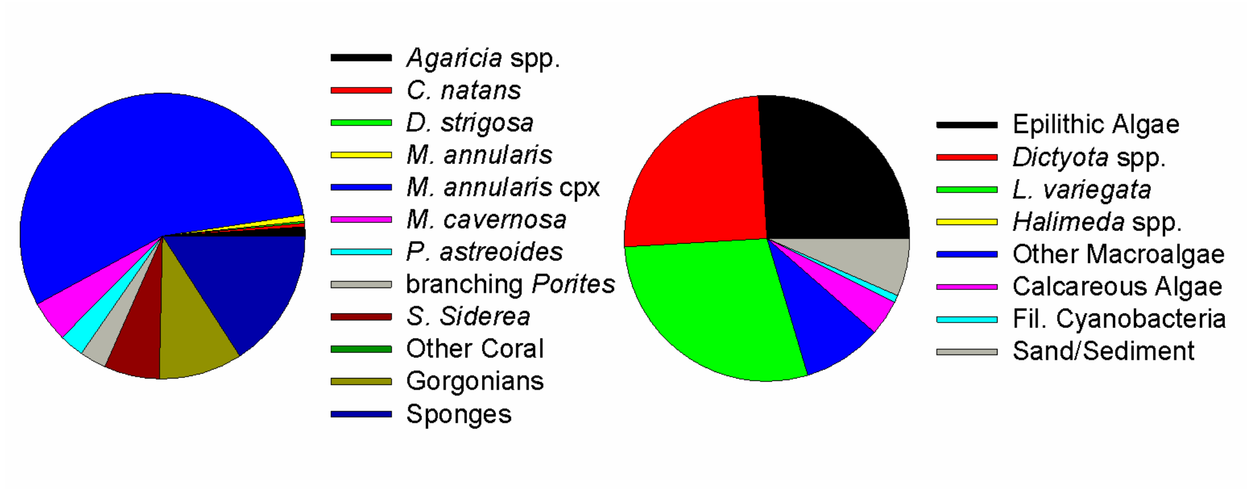


Figure 172. Seahorse Cottage Shoal. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

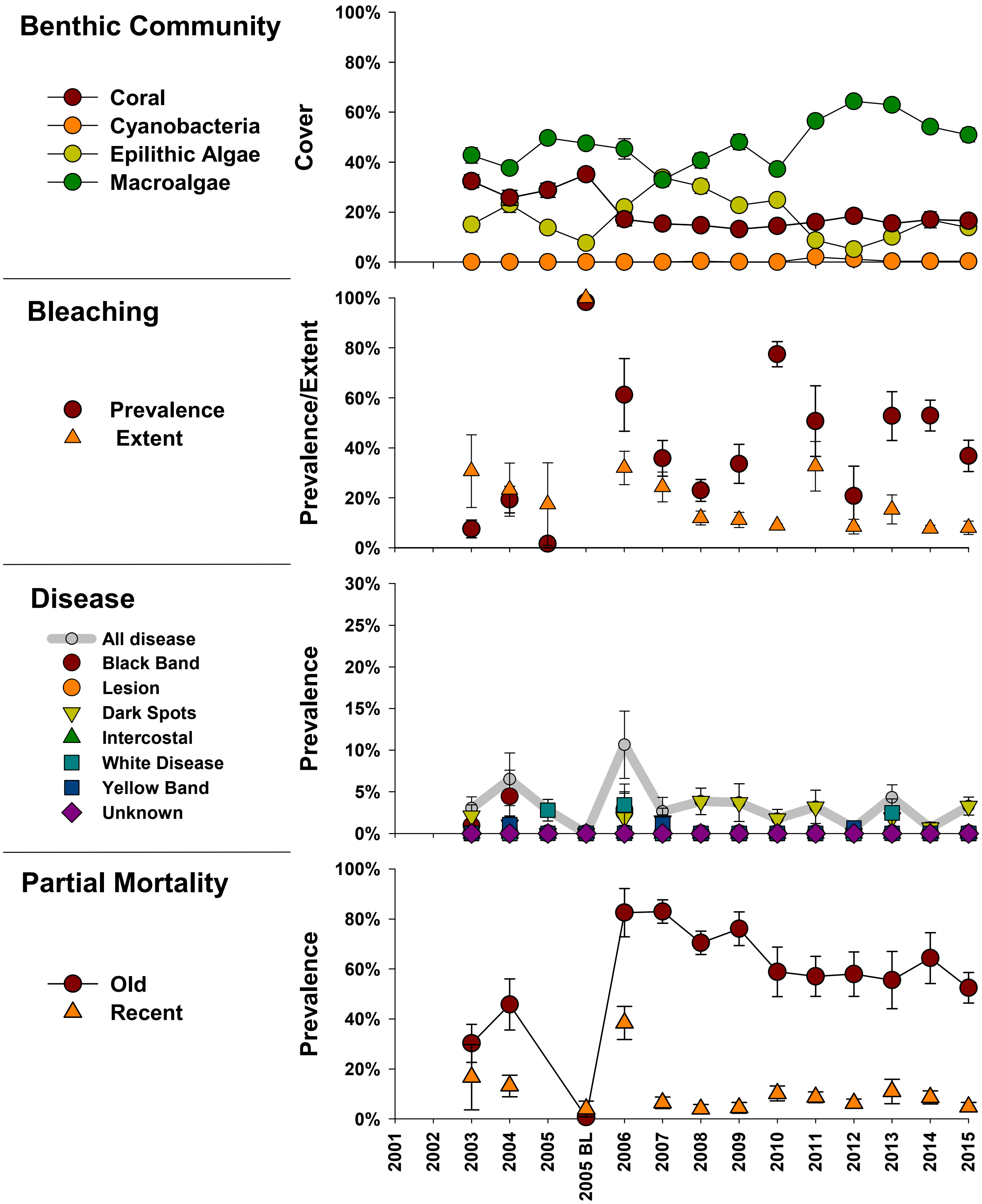


Figure 173. Seahorse Cottage Shoal benthic cover and coral health through time (mean ± SE).

Fish Community. Seahorse Cottage Shoal supports a large variety of reef fish and hosts aggregations of gray snapper and lane snapper during the summer months. The trophic guilds on the offshore reef are split relatively evenly between herbivores, invertivores, and piscivores. This reflects the heterogeneity of reef substrate and the availability of unconsolidated sand and rhodolith habitat surrounding the reef. Mutton snapper and queen triggerfish are relatively common. Adult stoplight and redband parrotfish dominate herbivores, although most of the larger parrotfish species do occur, including both adult and juvenile phase. Glasseye snapper and graysby dominate the piscivores trophic guild. Large groupers have never been seen on the reef. Seahorse Cottage Shoal is well known to fishermen and fairly heavily fished. Traps on the reef are common during surveys. However, schoolmaster, lane, gray, and mahogany snapper are all common. This may reflect the proximity to nursery habitats in the St. Thomas East End Reserves and the mangrove habitats therein.

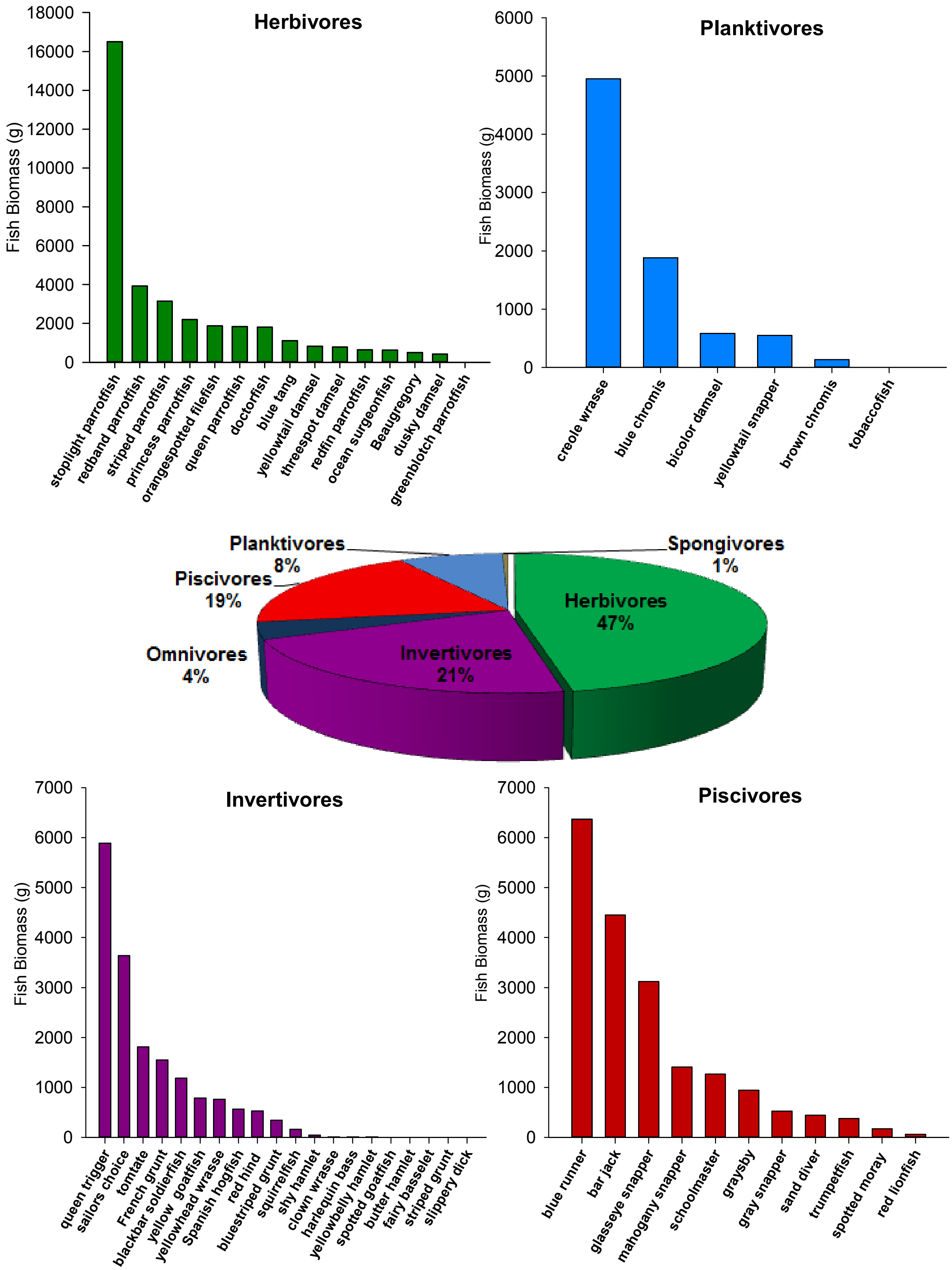
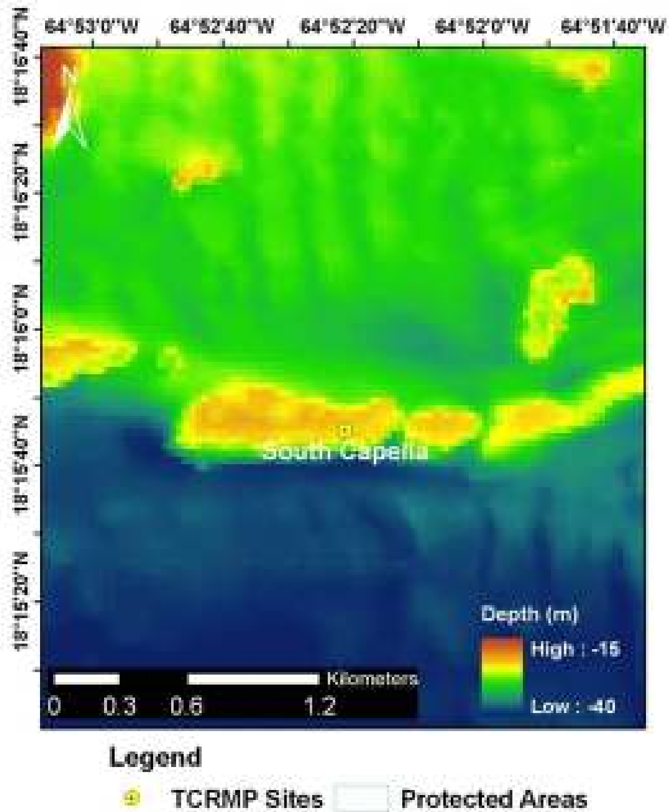


Figure 174. The Seahorse Cottage Shoal fish community by absolute and relative biomass.

SOUTH CAPELLA



Description. The South Capella site is located on a rise of the St. Thomas-St. John midshelf reef complex in depths of 16 - 25 m. The reef is made of rolling ridges of coral and pavement interspersed with sand grooves. South Capella has been monitored since 2003, with permanent benthic transects installed in 2007.

Outstanding Feature. The South Capella site is part of an outstanding shallow water midshelf reef system that is essential fish habitat.

Threats. The St. Thomas trap fishery heavily targets South Capella. Active and derelict trap strings crisscross the site and a derelict trap appeared in permanent transect 1 in 2008 and has been degrading there since. The trap was still fully intact as of 2012 but open to fish passage. The reef was also highly affected by the 2005 coral bleaching event, suggesting a susceptibility to rising sea surface temperatures.

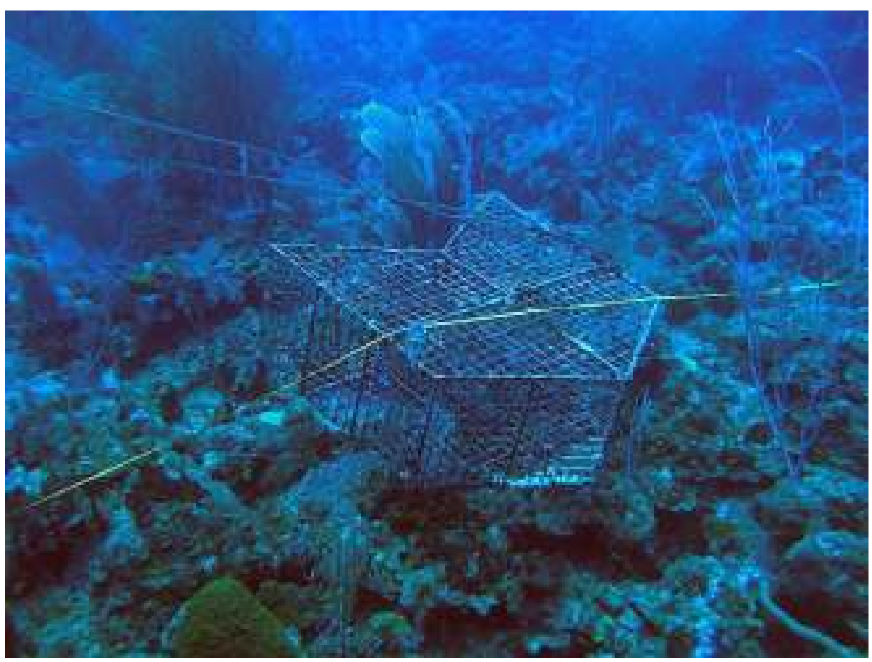


Figure 175. South Capella. (top) Location. (right) The reef with a derelict Antillean fish trap in Transect #1.

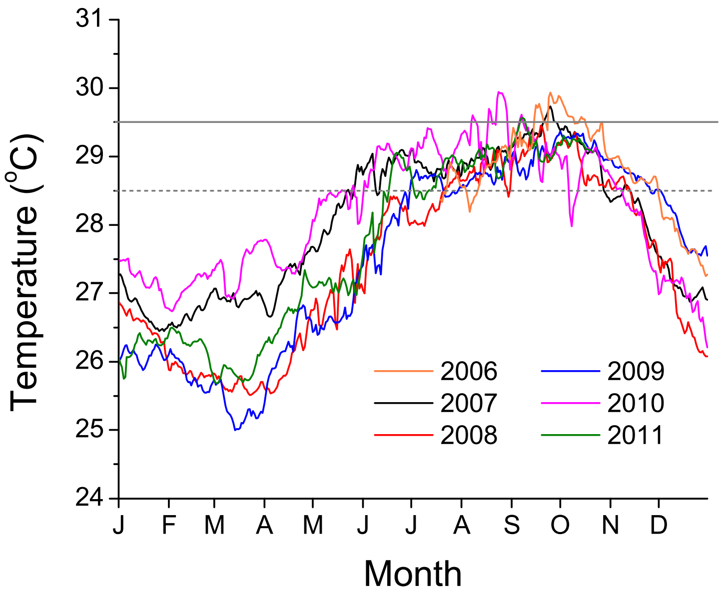


Figure 176. South Capella benthic temperature record (24 m depth).

Physical Characteristics.

Current. Currents were directly measured at South Capella and this data will be included in a future report. Wave-driven oscillatory currents have not been experienced but are likely during swells and storms. Unidirectional benthic currents are usually weak, but strong currents can develop from the surface to midwater.

Temperature. South Capella has relatively cool benthic temperatures for a shallow site during warm years, which may be a reflection of its moderately deep depth and proximity to deep water to the south.

Benthic Community. Boulder star corals (*Orbicella* spp.) dominate the coral community at South Capella. These corals were very heavily affected by mortality due to the 2005 coral bleaching event. The site lost 56.4% of its cover and had not regained any cover by 2011 (-3.7% recovery). Gorgonians and sponges are also common components of the sessile epibenthic animal community. The macroalga *Lobophora variegata* dominates the algal community, with epilithic algae and *Dictyota* spp. comprising the second largest shares. There was also a high abundance of crustose coralline algae and filamentous cyanobacteria.

Coral Health. Corals were moderately-heavily affected by the 2005 bleaching event, with a prevalence of 80%, but an extent on colonies of only about 50%. Bleaching prevalence also increased during the 2010 bleaching event, but at a low extent. Bleaching is moderately prevalent at this site even in years without notable thermal stress. Coral diseases are common and diverse at South Capella. White disease was prevalent after the 2005 bleaching event in 2006, and then again in 2009 and 2011. Black band disease was found in 2002, which is unusual for a site at these depths. Dark spots disease was also typically present in most years. Old partial mortality increased after the 2005 bleaching event and has declined to 2011. Recent partial mortality was prevalent in most years of monitoring, particularly in 2006. In years not following thermal stress the highest identifiable source of recent partial mortality was biting from territorial damselfish (*Stegastes* spp.).

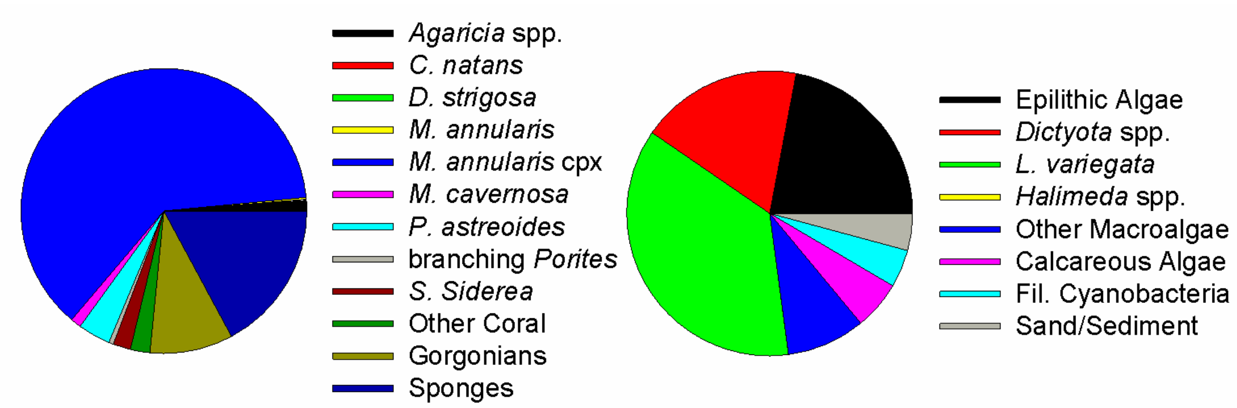


Figure 177. South Capella. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

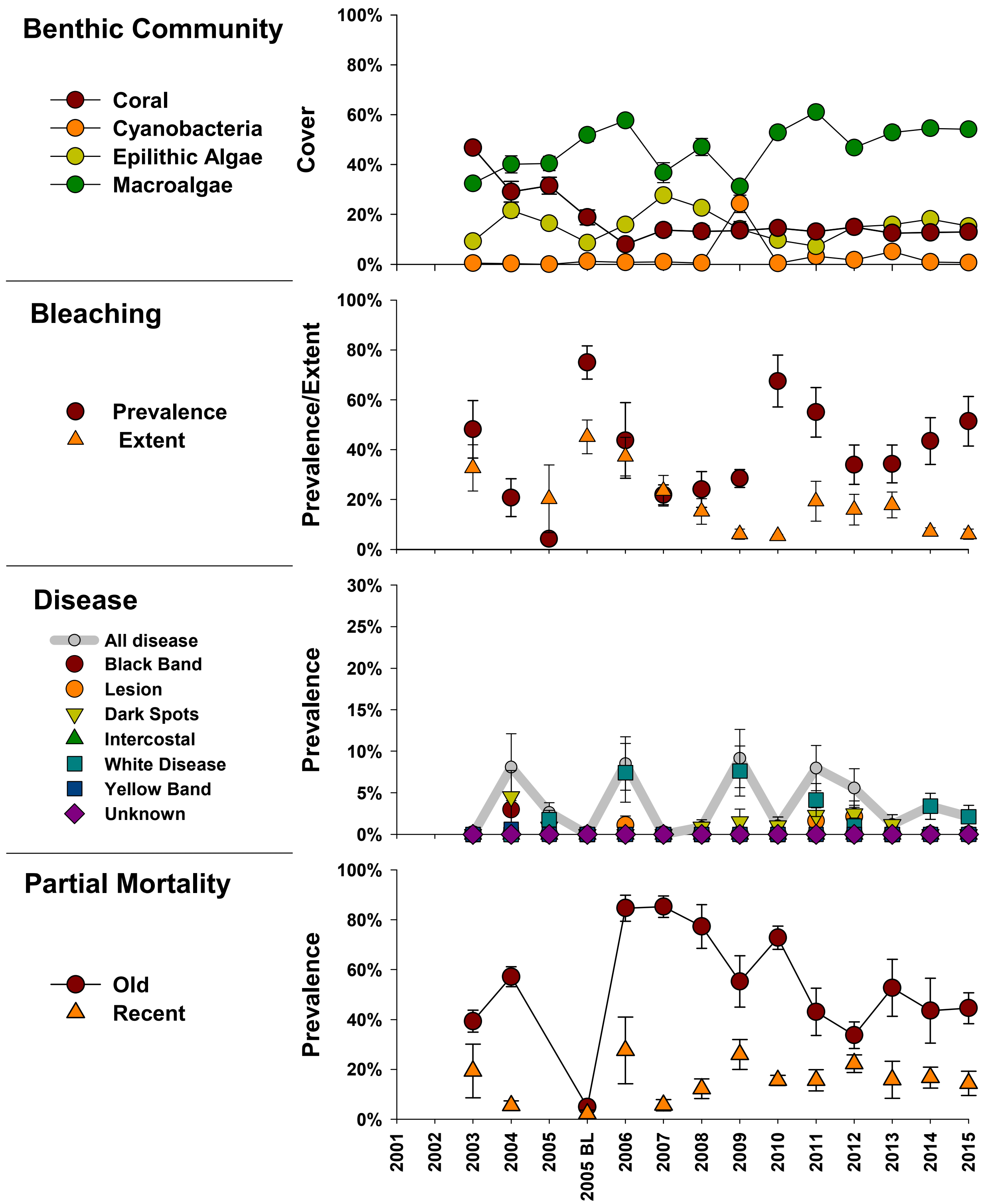


Figure 178. South Capella benthic cover and coral health through time (mean ± SE).

Fish Community. South Capella is characterized by a fairly diverse fish community that is fairly well split between trophic levels. In 2011, a large school of schoolmaster snapper skewed this balance toward piscivores; however, this was probably a spawning event, and not typical of the daily fish community. The reef is spur and groove with complex reef edges and sand channels that support a large number of invertivores and variety of omnivores. Planktivores include yellowtail snapper and black durgeon. Benthic herbivores are dominated in biomass by large stoplight parrotfish. The South Capella reef is highly fished and traps are commonly seen during our survey events. The rich, complex reef is noticeably bare of large snappers and groupers. The serranid group is represented only by the graysby and small hamlets, with an occasional red hind observed. Lionfish are more common on this site than other offshore sites.

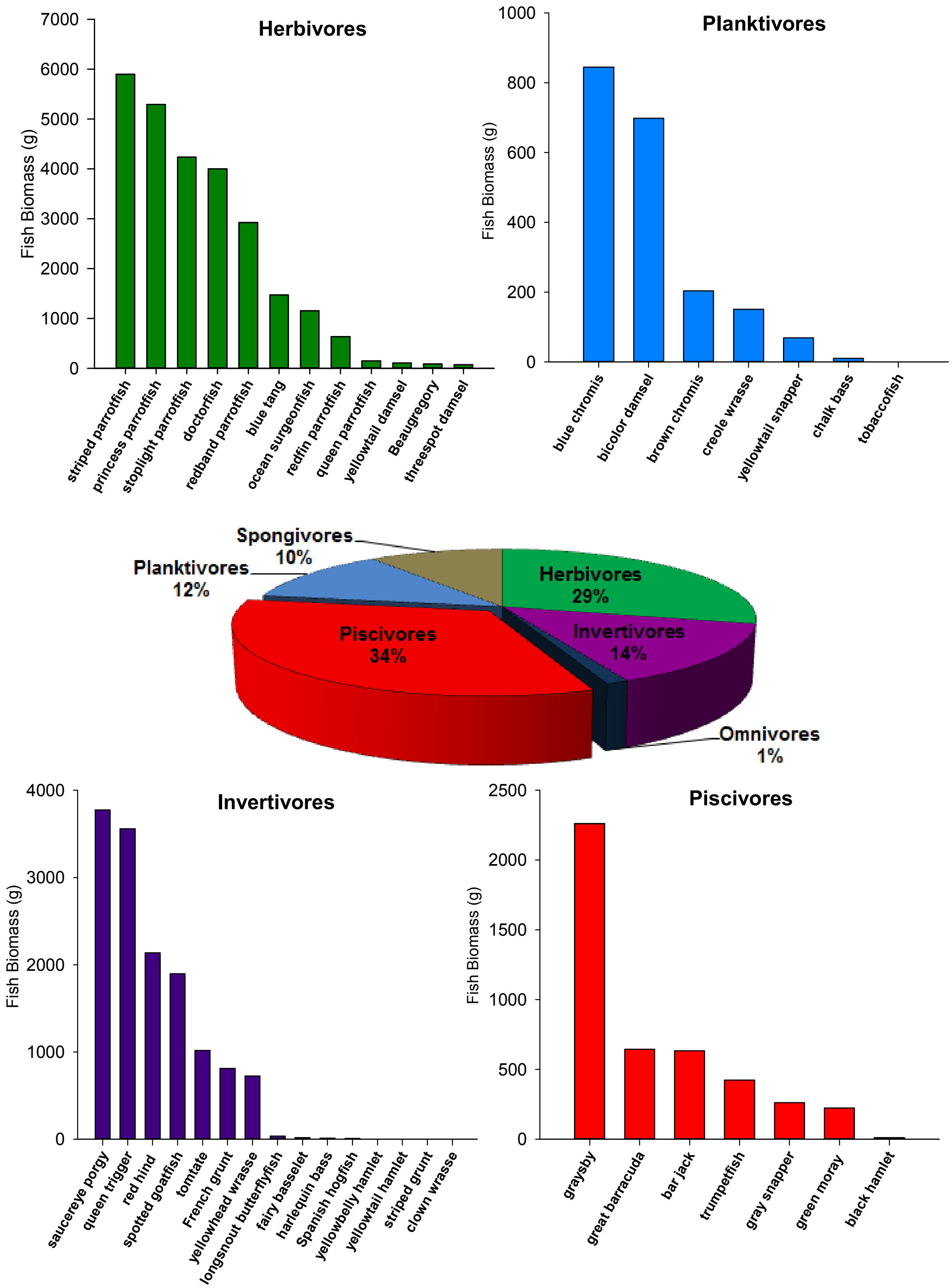
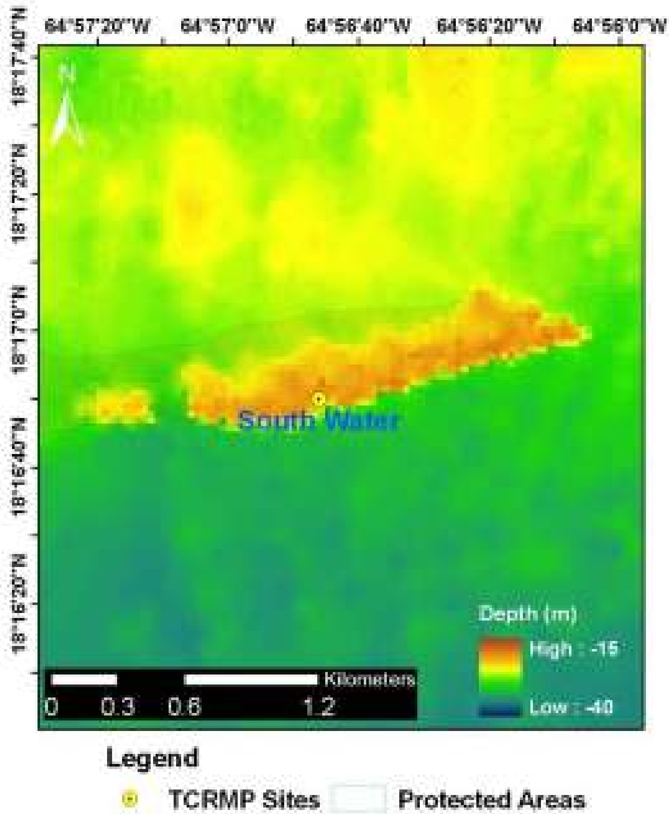


Figure 179. The South Capella fish community by absolute and relative biomass.

SOUTH WATER

Description. South Water is a hardbottom coral community along the sharp break of a midshelf reef complex in depths of 17 – 28 m. The reef has a sharp break in slope leading to a steep escarpment that terminates in a sand/sediment plain at the reef base. South Water has been monitored since 2005, with permanent benthic transects installed in 2007.



Outstanding Feature. South Water is a commercially important fishing ground for reef fishes and spiny lobster.

Threats. South Water is primarily threatened by fishing and strings of fish and lobster traps are common over the site.

Figure 180.South Water. (top) Location. (right) A representative photo of the reef.

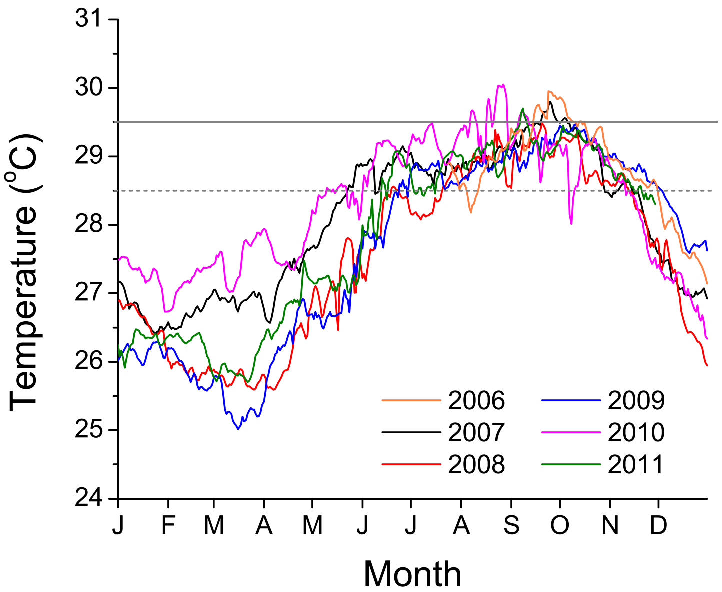


Figure 181. South Water benthic temperature record (24 m depth)

Physical Characteristics.

Current. Current measurements have not been taken at the South Water site. Unidirectional benthic currents can be moderate on the hardbottom reef top and strong from the surface to midwater. Wave-driven oscillatory currents are likely to be felt on the reef top during swells and storms.

Temperature. South Water has relatively moderate temperatures compared with other shallow water sites during warm years. This may be due to the deeper depths of the site and the proximity of deep water.

Benthic Community. The sparse coral community at South Water is very diverse. Coral cover increased by 21.3% over the 2005 bleaching event and had increased by 42.6% between 2005 and 2011. However, permanent transects were not installed until 2007 and the low coral cover means that small variations in detection of corals can lead to large apparent year-to-year differences in cover. Sponges and gorgonians dominate the sessile epibenthic animal community. The algal community is nearly equally divided between *Lobophora variegata*, *Dictyota* spp., and epilithic algae. Crustose coralline algae and filamentous cyanobacteria are also very common.

Coral Health. Corals were severely affected by the 2005 coral bleaching event, with over 80% of corals bleaching over nearly the entire coral surface. Corals were moderately affected in the 2010 bleaching event, with just less than 50% of corals bleaching at a low extent. Bleaching tends to be moderately prevalent even in non-thermal stress years. Coral diseases are not common, although there is a trend of increasing dark spots disease. Old partial mortality increased in prevalence after the 2005 bleaching event, but at a lower prevalence than most other sites. Recent partial mortality is rare.

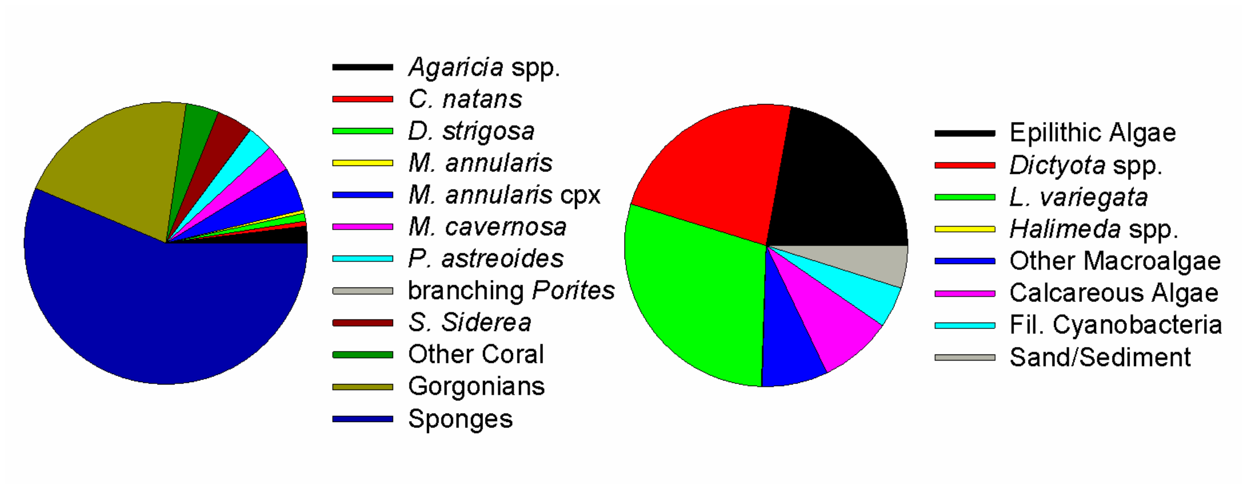


Figure 182. South Water. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

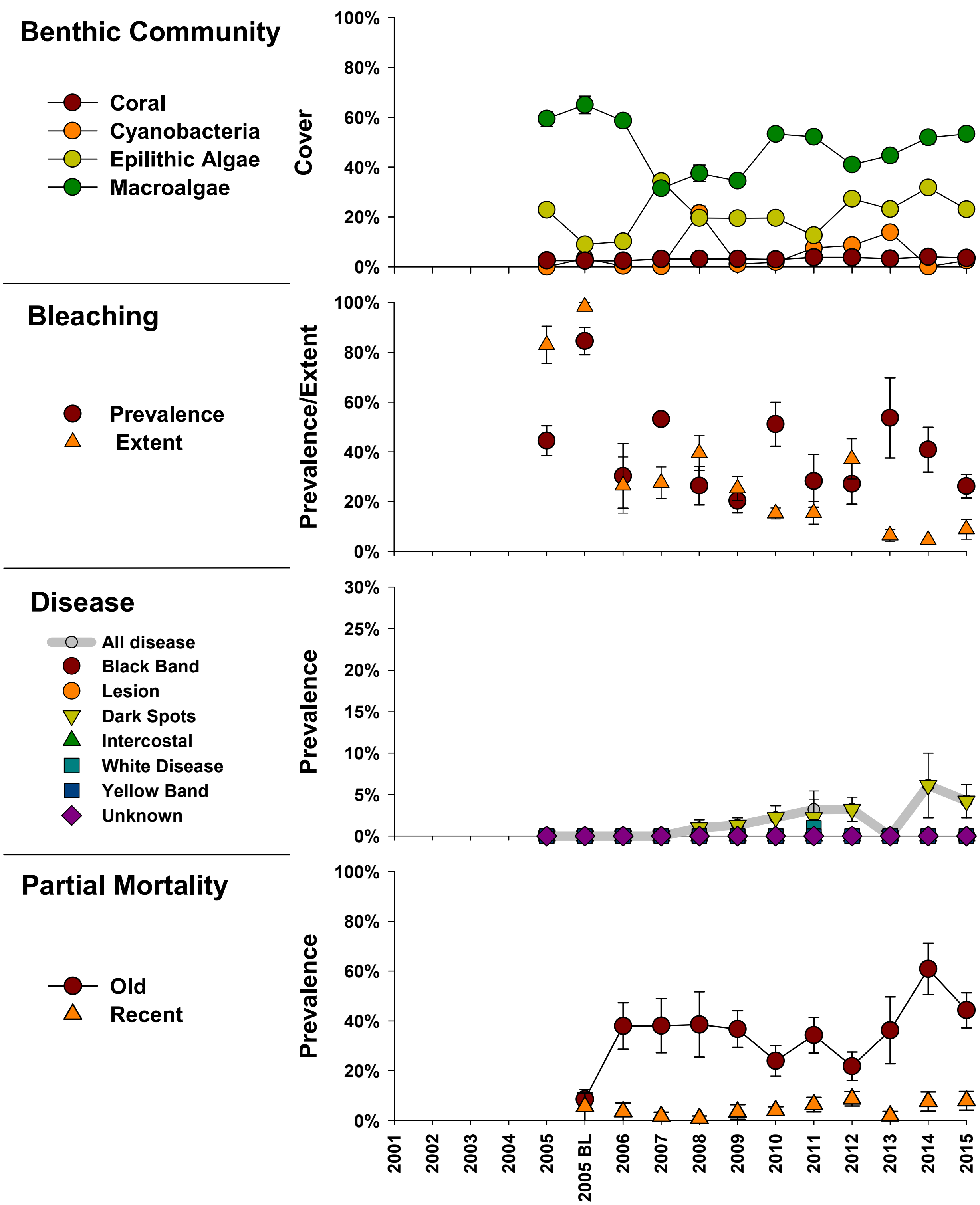


Figure 183. South Water benthic cover and coral health through time (mean ± SE).

Fish Community. South Water Island is a low lying reef with hard bottom that supports primarily invertivores. Fish biomass is lower on this site than other offshore St. Thomas sites. Queen trigger and red hind dominate invertivore biomass. Mutton snapper are occasional. Stoplight and princess parrotfish dominate herbivores, and many juvenile and sub-adults of these species occur on the site. Piscivores make up only 5% of the biomass on the South Water Island site; the guild is primarily composed of the graysby. South Water Island is highly fished and traps are commonly seen during our survey events. Lobsters are common on this low-lying reef, hiding in the hard bottom ledges that extend across the site. Except for mutton snapper, the reef is bare of large snappers and groupers.

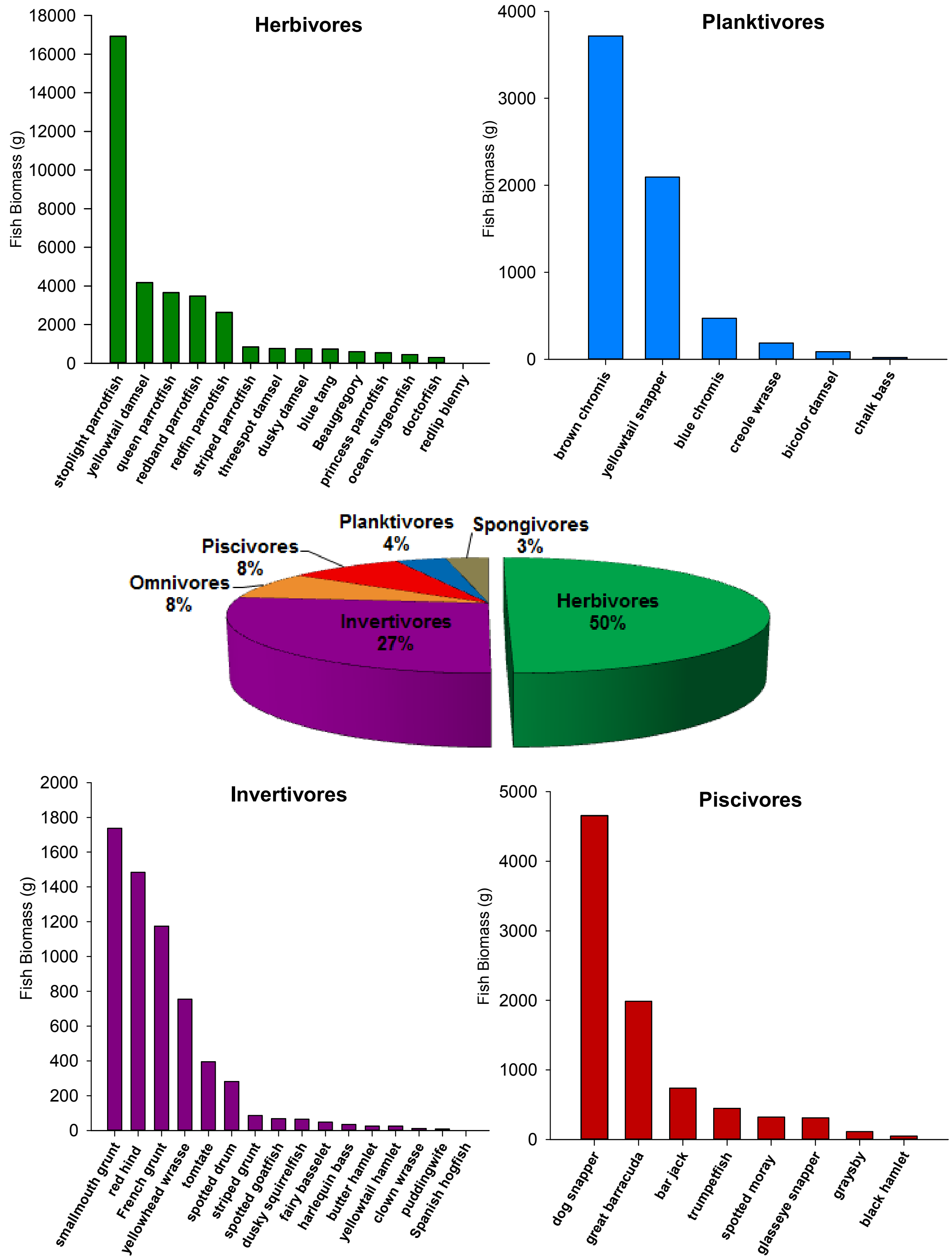


Figure 184. The South Water fish community by absolute and relative biomass.

Literature Cited

Acevedo R, Morelock J (1988) Effects of terrigenous sediment influx on coral zonation in southwestern Puerto Rico. Proceedings of the Sixth International Coral Reef Symposium 2:189-194

Albins M, Hixon M (2011) Worst case scenario: potential long-term effects of invasive predatory lionfish (Pterois volitans) on Atlantic and Caribbean coral-reef communities. Environmental Biology of Fishes:1-7

Anderson D, Macdonald L (1998) Modelling road surface sediment production using a vector geographic information system. Earth Surface Processes and Landforms 23:95-107

Armstrong R, Singh H, Torres J (2002) Benthic survey of insular slope coral reefs using the Seabed AUV. Backscatter 13:22-25

Armstrong RA (2007) Deep zooxanthellate coral reefs of the Puerto Rico: US Virgin Islands insular platform. Coral Reefs 26:945

Armstrong RA, Singh H, Torres J, Nemeth RS, Can A, Roman C, Eustice R, Riggs L, Garcia-Moliner G (2006) Characterizing the deep insular shelf coral reef habitat of the Hind Bank marine conservation district (US Virgin Islands) using the Seabed autonomous underwater vehicle. Continental Shelf Research 26:194-205

Bellwood DR, Fulton CJ (2008) Sediment-mediated suppression of herbivory on coral reefs: decreasing resilience to rising sea-levels and climate change? Limnology and Oceanography 53:2695-2701

Betancur-R R, Hines A, Acero P A, Ortí G, Wilbur AE, Freshwater DW (2011) Reconstructing the lionfish invasion: insights into Greater Caribbean biogeography. Journal of Biogeography 38:1281-1293

Brooks GR, Devine B, Larson RA, Rood BP (2007) Sedimentary development of Coral Bay, St. John, USVI: a shift from natural to anthropogenic influences. Caribbean Journal of Science 43:226-243

Bruckner AW (2007) Field Guide to Western Atlantic Coral Diseases and Other Causes of Coral Mortality. NOAA, UNEP-WCMC, PADI

Budd AF, Fukami H, Smith ND, Knowlton N (2012) Taxonomic reclassification of the coral reef coral family Mussidae (Cnidaria: Anthozoa: Scleractinia). Zoological Journal of the Linnean Society 166:465-529

Calnan J, Smith T, Nemeth R, Kadison E, Blondeau J (2008) Coral disease prevalence and host susceptibility on mid-depth and deep reefs in the US Virgin Islands. Revista Biologia Tropical 56 (suppl. 1):223-224

Cote IM, Maljkovic A (2010) Predation rates of Indo-Pacific lionfish on Bahamian coral reefs. Marine Ecology Progress Series 404:219-225

De'ath G, Fabricius K (2010) Water quality as a regional driver of coral biodiversity and macroalgae on the Great Barrier Reef. Ecological Applications 20:840-850

Eakin CM, Morgan JA, Heron SF, Smith TB, Liu G, Alvarez-Filip L, Baca B, Bartels E, Bastidas C, Bouchon C, Brandt M, Bruckner AW, Bunkley-Williams L, Cameron A, Causey BD, Chiappone M, Christensen TRL, Crabbe MJC, Day O, de la Guardia E, Díaz-Pulido G, DiResta D, Gil-Agudelo DL, Gilliam DS, Ginsburg RN, Gore S, Guzmán HM, Hendee JC, Hernández-Delgado EA, Husain E, Jeffrey CFG, Jones RJ, Jordán-Dahlgren E, Kaufman LS, Kline DI, Kramer PA, Lang JC, Lirman D, Mallela J, Manfrino C, Maréchal J-P, Marks K, Mihaly J, Miller WJ, Mueller EM, Muller EM, Orozco Toro CA, Oxenford HA, Ponce-Taylor D, Quinn N, Ritchie KB, Rodríguez S, Ramírez AR, Romano S, Samhouri JF, Sánchez JA, Schmahl GP, Shank BV, Skirving WJ, Steiner SCC, Villamizar E, Walsh SM, Walter C, Weil E, Williams EH, Roberson KW, Yusuf Y (2010) Caribbean corals in crisis: record thermal stress, bleaching, and mortality in 2005. PLoS ONE 5:e13969

Edmunds PJ, Witman JD (1991) Effect of Hurricane Hugo on the primary framework of a reef along the south shore of St. John, US Virgin Islands. Marine Ecology Progress Series 78:201-204

Fabricius K (2005) The effects of terrestrial runoff on the ecology of corals and coral reefs: a review and synthesis. Marine Pollution Bulletin 50:125-146

Fong P, Paul VJ (2011) Coral Reef Algae. In: Dubinsky Z, Stambler N (eds) Coral Reefs: An Ecosystem in Transition. Springer Science, pp241-272

Fong P, Smith TB, Wartian MJ (2006) Epiphytic cyanobacteria maintain shifts to macroalgal dominance on coral reefs following ENSO disturbance. Ecology 87:1162-1168

Furnas M, Mitchell A, Skuza M, Brodie J (2005) in the other 90%: phytoplankton responses to enhanced nutrient availability in the Great Barrier Reef Lagoon. Marine Pollution Bulletin 51:235-265

LITERATURE CITED

Gladfelter WB (1982) White-band disease in *Acropora palmata* - implications for the structure of shallow reefs. Bulletin of Marine Science 32:639-643

Glynn PW (1996) Coral reef bleaching: Facts, hypotheses and implications. Global Change Biology 2:495-509

Gray SC, Gobbi KL, Narwold PV (2008) Comparison of sedimentation in bays and reefs below developed versus undeveloped watersheds on St. John, US Virgin Islands. Proceedings of the 11th International Coral Reef Symposium 1:345-349

Green SJ, Akins JL, Côté IM (2011) Foraging behaviour and prey consumption in the Indo-Pacific lionfish on Bahamian coral reefs. Marine Ecology Progress Series 433:159-167

Hatcher BG (1984) A maritime accident provides evidence for alternate stable states in benthic communities on coral reefs. Coral Reefs 3:199-204

Hatcher BG, Larkum AWD (1983) An experimental analysis of factors controlling the standing crop of the epilithic algal community on a coral reef. Journal of Experimental Marine Biology and Ecology 69:61-84

Herzlieb S, Kadison E, Blondeau J, Nemeth RS (2005) Comparative assessment of coral reef systems located along the insular platform south of St. Thomas, US Virgin Islands and the relative effects of natural and human impacts. Proc 10th Int Coral Reef Symp 4-2:1144-1151

Hinderstein L, Marr J, Martinez F, Dowgiallo M, Puglise K, Pyle R, Zawada D, Appeldoorn R (2010) Theme section on mesophotic coral ecosystems: characterization, ecology, and eanagement. Coral Reefs 29:247-251

Jackson A, Semmens BX, Sadovy Y, Nemeth RS, Heppell S, Chapman R, Aguilar-Perera A, Claydon J, Calosso M, Sealey K, Sharer M, Bernardi G (2014) Population structure and phylogeography in Nassau grouper (*Epinephelus striatus*), a mass-aggregating marine fish. PLoS ONE in press

Kadison E, Nemeth R, Herzlieb S, Blondeau J (2006) Temporal and spatial dynamics of Lutjanus cyanopterus and L. jocu (Pisces: Lutjanidae) spawning aggregations on a multi-species spawning site in the USVI. Revista Biologia Tropical 54(suppl. 3):69-78

Kadison E, Nemeth RS, Blondeau J, Smith TB, Calnan JM (2010) Nassau grouper (Epinephelus striatus) in St. Thomas, US Virgin Islands, with evidence for a spawning aggregation site recovery. Proceedings of the Gulf and Caribbean Fisheries Institute 62:273-279

Kohler K, Gill SM (2006) Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32:1259-1269

Kramer P, Lang J, Marks K, Garza-Perez R, Ginsburg R (2005) AGRRA Methodology, version 4.0, June 2005. University of Miami, Miami

Kuffner I, B., Walters L, J., Becerro M, A., Paul V, J., Ritson-Williams V, J., Beach K, S. (2006) Inhibition of coral recruitment by macroalgae and cyanobacteria. Marine Ecology Progress Series 323:107-117

Manzello DP, Brandt ME, Smith TB, Lirman D, Hendee JC, Nemeth RS (2007) Hurricanes benefit bleached corals. Proceedings of the National Academy of Science 104:12035-12039

Menza C, Kendall M, Hile S (2008) The deeper we go the less we know. Revista Biologia Tropical 56:11-24

Menza C, Kendall M, Rogers C, Miller J (2007) A deep reef in deep trouble. Continental Shelf Research 27:2224-2230

Miller J, Muller E, Rogers C, Waara R, Atkinson A, Whelan K, Patterson M, Witcher B (2009) Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands. Coral Reefs 28:925-937

Morris JAJ, Whitfield PE (2009) Biology, ecology, control and management of the Invasive Indo-Pacific Lionfish: An Updated Integrated Assessment. National Oceanographic and Atmospheric Administration, Washington D.C., NOAA Technical Memorandum NOS NCCOS 9

Mumby PJ (2006) The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean coral reefs. Ecological Applications 16:747-769

Mumby PJ, Harborne AR (2010) Marine Reserves Enhance the Recovery of Corals on Caribbean Reefs. PLoS ONE 5:e8657

Mumby PJ, Dahlgren CP, Harborne AR, Kappel CV, Micheli F, Brumbaugh DR, Holmes KE, Mendes JM, Broad K, Sanchirico JN, Buch K, Box S, Stoffle RW, Gill AB (2006) Fishing, trophic cascades, and the process of grazing on coral reefs. Science 311:98-101

Nemeth R, Kadison E (2013) Temporal patterns and behavioral characteristics of aggregation formation and spawning in the Bermuda chub (Kyphosus sectatrix). Coral Reefs 32:1067-1076

Nemeth RS (2005) Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. Marine Ecology Progress Series 286:81-97

Nemeth RS, Sladeck Nowlis J (2001) Monitoring the effects of land development on the near-shore reef environment of St. Thomas, USVI. Bulletin of Marine Science 69:759-775

Nemeth RS, Kadison E, Herzlieb S, Blondeau J, Whiteman E (2006) Status of a yellowfin grouper (Mycteroperca venenosa) spawning aggregation in the US Virgin Islands with notes on other species. Proc 57th Gulf Carib Fish Inst 57:543-558

Nemeth RS, Smith TB, Blondeau J, Kadison E, Calnan JM, Gass J (2008) Characterization of deep water reef communities within the marine conservation district, St. Thomas, U.S. Virgin Islands. Submitted to the Caribbean Fisheries Management Council. University of the Virgin Islands, St. Thomas 90 + appendices

NOAA (2006) Tropical Ocean Coral Bleaching Indices. National Oceanic and Atmospheric Administration, Silver Springs, Maryland

Pastorok R, Bilyard G (1985) Effects of sewage pollution on coral-reef communities. Marine Ecology Progress Series 21:175-189

Ramos-Scharrón CE, MacDonald LH (2007a) Measurement and prediction of natural and anthropogenic sediment sources, St. John, U.S. Virgin Islands. Catena 71:250-266

Ramos-Scharrón CE, MacDonald LH (2007b) Runoff and suspended sediment yields from an unpaved road segment, St John, US Virgin Islands. Hydrological Processes 21:35-50

Randall JE (1963a) A fatal attack by the shark *Carcharhinus galapagensis* at St. Thomas, Virgin Islands. Caribbean Journal of Marine Science 3:201-205

Randall JE (1963b) An analysis of the reef fish populations of artificial and natural reefs in the Virgin Islands. Caribbean Journal of Marine Science 3:31-47

REEF (2012) Reef Environmental Education Foundation-Volunteer Fish Survey Project Database

Riegl B, Piller WE (2003) Possible refugia for reefs in times of environmental stress. International Journal of Earth Sciences 92:520-531

Rogers C, Garrison V (2001) Ten years after the crime: lasting effects of damage from a cruise ship anchor on a coral reef in St. John, U.S. Virgin Islands Bulletin of Marine Science 69:793-803

Rogers CS (1982) The Marine Environments of Brewers Bay, Perserverence Bay, Flat Cay and Saba Island, St. Thomas, U.S.V.I., with Emphasis on Coral Reefs and Seagrass Beds, November 1978-July 1981 181

Rogers CS (1990) Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series 62:185-202

Rogers CS, McLain LN, Tobias CR (1991) Effects of Hurricane Hugo (1989) on a coral reef in St. John USVI. Marine Ecology Progress Series 78:189-199

Rothenberger J, Blondeau J, Cox C, Curtis S, Fisher B, Garrison G, Hillis-Starr Z, Jeffrey C, Kadison E, Lundgren I, Miller W, Muller E, Nemeth RS, Paterson S, Rogers CS, Smith TB, Spitzack A, Taylor M, Toller W, Wright J, Wusinich-Mendez D (2008) The State of Coral Reef Ecosystems of the U.S. Virgin Islands. In: Waddell JE, Clarke AM (eds) The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Center for Coastal Monitoring and Assessment's Biogeography Team, Silver Spring, MD, pp567

Schofield PJ (2009) Geographic extent and chronology of the invasion of non-native lionfish (*Pterois volitans* [Linnaeus 1758] and *P. miles* [Bennett 1828]) in the Western North Atlantic and Caribbean Sea. Aquatic Invasions 4:473-479

Smith TB, Fong P, Kennison R, Smith J (2010a) Spatial refuges and associational defenses promote harmful blooms of the alga *Caulerpa sertularioides* onto coral reefs. Oecologia 164:1039-1048

Smith TB, Nemeth RS, Blondeau J, Calnan JM, Kadison E, Herzlieb S (2008) Assessing coral reef health across onshore to offshore stress gradients in the US Virgin Islands. Marine Pollution Bulletin 56:1983-1991

Smith TB, Gyory J, Brandt ME, Miller WJ, Jossart J, Nemeth RS (in press) Caribbean mesophotic coral ecosystems are unlikely climate change refugia. Global Change Biology:10.1111/gcb.13175

LITERATURE CITED

Smith TB, Blondeau J, Nemeth RS, Pittman SJ, Calnan JM, Kadison E, Gass J (2010b) Benthic structure and cryptic mortality in a Caribbean mesophotic coral reef bank system, the Hind Bank Marine Conservation District, U.S. Virgin Islands. Coral Reefs 29:289-308

Smith TB, Brandt ME, Calnan JM, Nemeth RS, Blondeau J, Kadison E, Taylor M, Rothenberger JP (2013) Convergent mortality responses of Caribbean coral species to seawater warming. Ecosphere 4:art87

Smith TB, Brandtneris VW, Brandt ME, Martens J, Brewer RS, Holstein DM, Kadison E, Kammann M, Keller J (submitted) Potential structuring forces of a Caribbean mesophotic coral ecosystem in the US Virgin Islands

Strand J, Jørgensen A, Tairova Z (2009) TBT pollution and effects in molluscs at US Virgin Islands, Caribbean Sea. Environment International 35:707-711

Tobias W (1997) Three Year Summary Report: Cooperative Fisheries Statistics Program #SF-42 (NA27FT0301-01). Department of Fish and Wildlife, United States Virgin Islands 41 pp

Weinstein DK (2014) Deep Reef Bioerosion and Deposition: Sedimentology of Mesophotic Coral Reefs in the U.S. Virgin Islands. University of Miami, p275pp

Weinstein DK, Smith TB, Klaus JS (2014) Mesophotic bioerosion: Variability and structural impact on U.S. Virgin Island deep reefs. Geomorphology 222:14-24

Weinstein DK, Klaus JS, Smith TB (2015) Habitat heterogeneity reflected in mesophotic reef sediments. Sedimentary Geology 329:177-187

Weinstein DK, Sharifi A, Klaus JS, Smith TB, Giri SJ, Helmle KP (submitted) Coral growth, bioerosion, and secondary accretion of living orbicellid corals from mesophotic reefs in the US Virgin Islands

Williams ID, Polunin NVC, Hendrick VJ (2001) Limits to grazing by herbivorous fishes and the impact of low coral cover on macroalgal abundance on a coral reef in Belize. Marine Ecology Progress Series 222:187-196

Woody K, Atkinson A, Clark R, Jeffrey C, Lundgren I, Miller J, Monaco M, Muller E, Patterson M, Rogers C, Smith TB, Spitzack T, Waara R, Whelan K, Witcher B, Wright A (2008) Coral Bleaching in the U.S. Virgin Islands in 2005 and 2006. In: Wilkinson C, Souter D (eds) Status of Caribbean Coral Reefs After Bleaching and Hurricanes in 2005. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Center, Townsville, pp152