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 a few 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

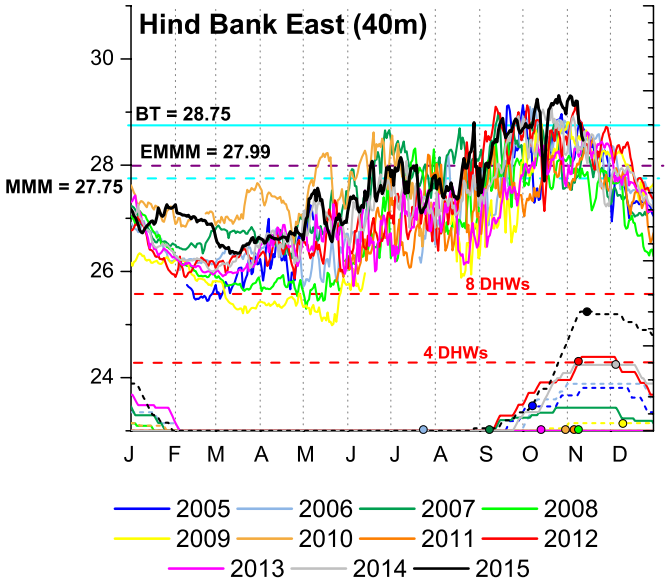
conditions introduce an unknown amount of error. Trends are shown for all available years of monitoring

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*[2], *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.

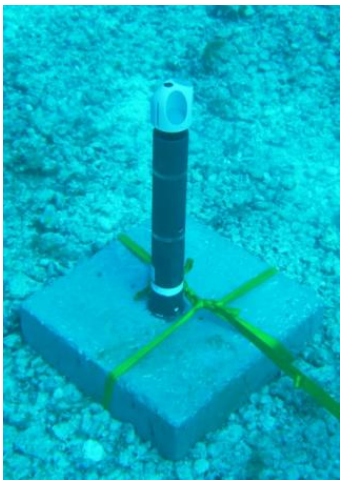
PHYSICAL CHARACTERISTICS.

Temperature. Benthic temperatures were recorded at each site with a calibration checked HoboTemp™ thermistor data logger (Onset Computer Corporation, Bourne, Massachusetts). Thermistors were



Temperature Figure Guide. Temperatures in degrees Celsius (left axis) and degree heating weeks (right axis). Line color indicates year of record. BT = Bleaching Threshold, calculated empirically or taken from linear relationship shown in Smith et al. (2016). MMM = BT – 1°C, EMMM = Empirical MMM derived from non-bleaching years over period of observation. DHW = Degree Heating Week (NOAA 2006). Dashed DHW line indicates incomplete temperature record; DHW provisional. Colored dot on DHW line indicates the date of annual sampling to put the bleaching observations in context.

[2] 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.*"



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.

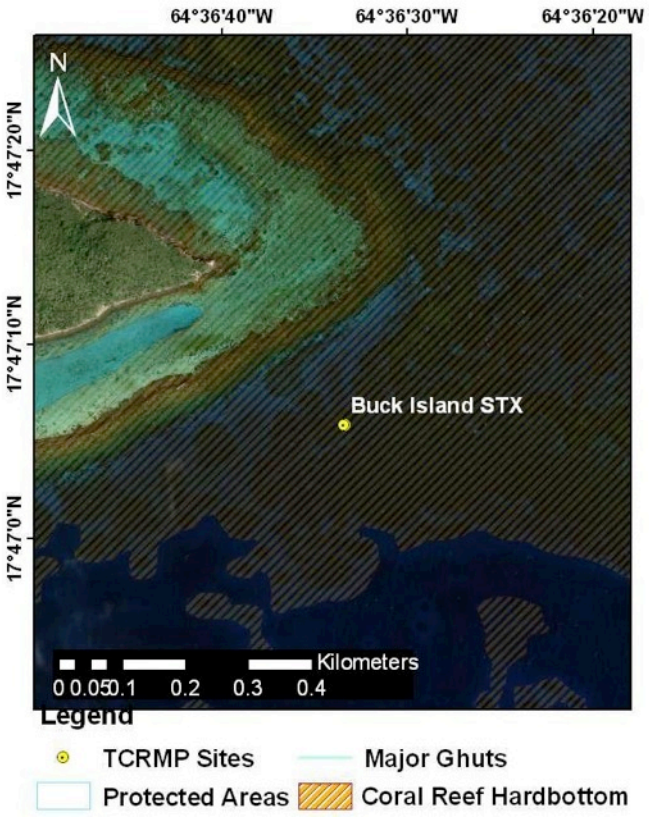
Currents. Water currents were recorded at a subset of sites and times with Nortek Aquadopp™ Acoustic Doppler Current Profilers (ADCPs). Profilers were set in bases on the seafloor and set to record current speed and direction within predefined depth bins above the substrate. The bin closest to the substrate 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.

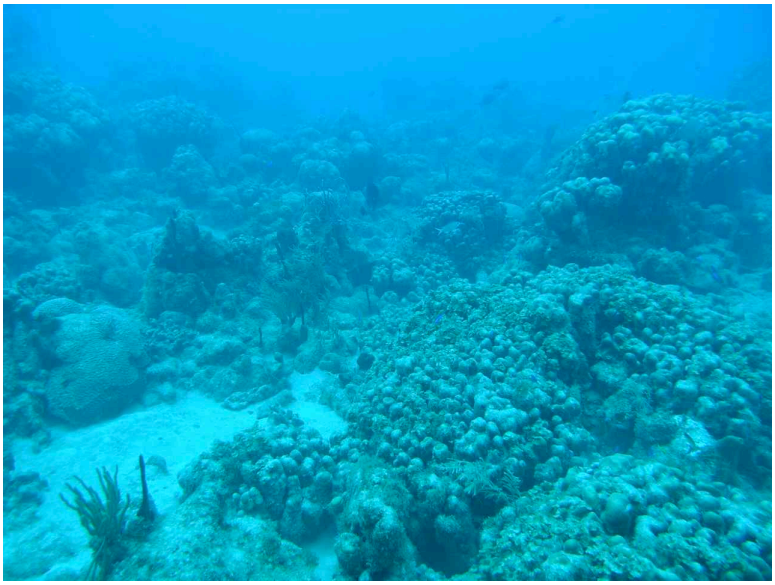


Figure 29. The Buck Island, St. Croix. (top) Position in the Buck Island Reef National Monument. (right)A representative photo.

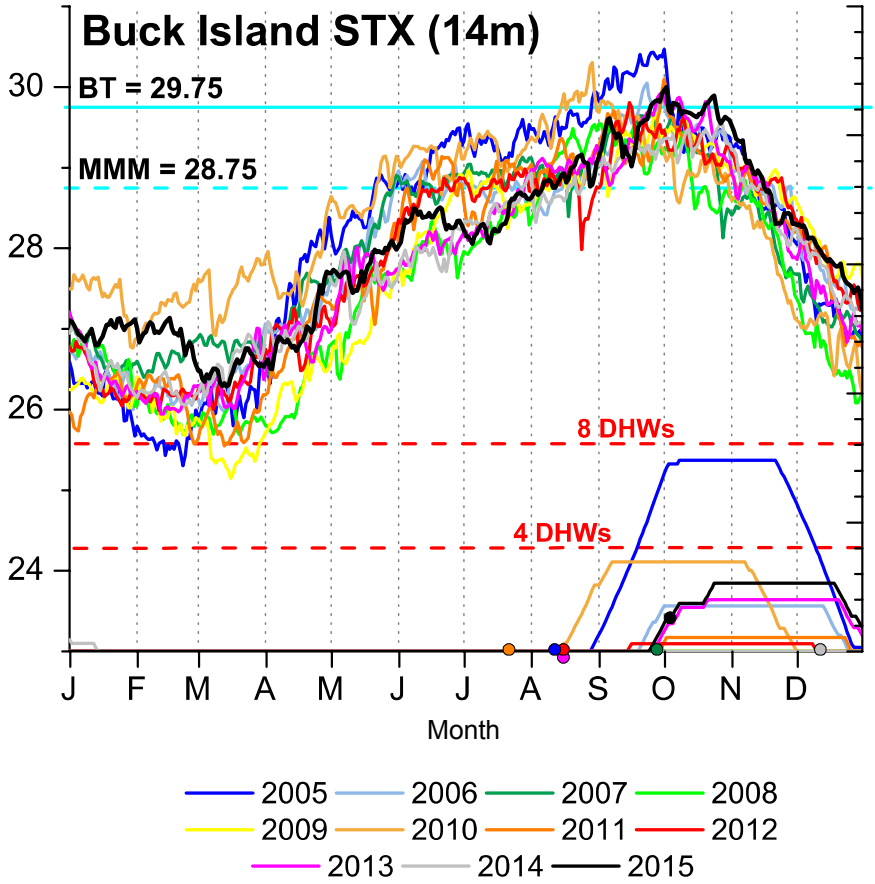


Figure 30. Buck Island, St. Croix benthic temperatures (14 m depth). Data provided by the National Park Service (site BUIS_SFR).

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 at or above 4 Degree Heating Weeks in 2005 and 2010.

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. 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, becoming stable over time in 2011.

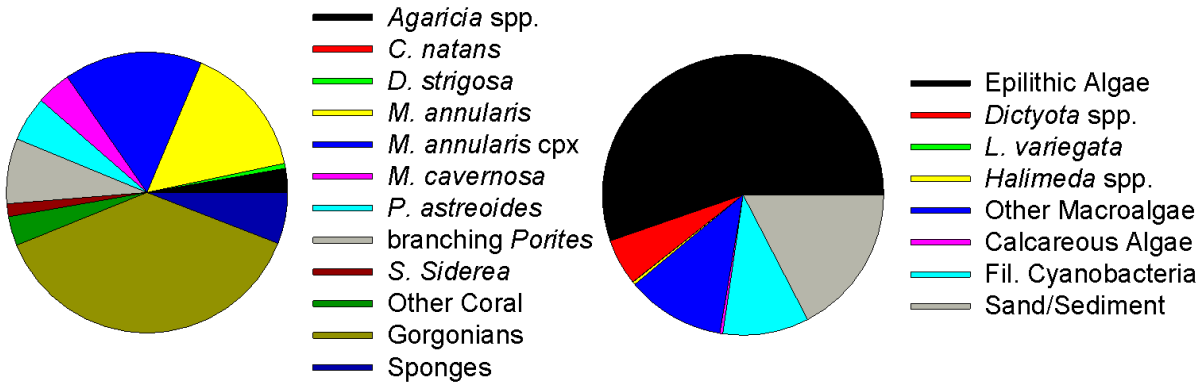


Figure 31. Buck Island, St. Croix. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

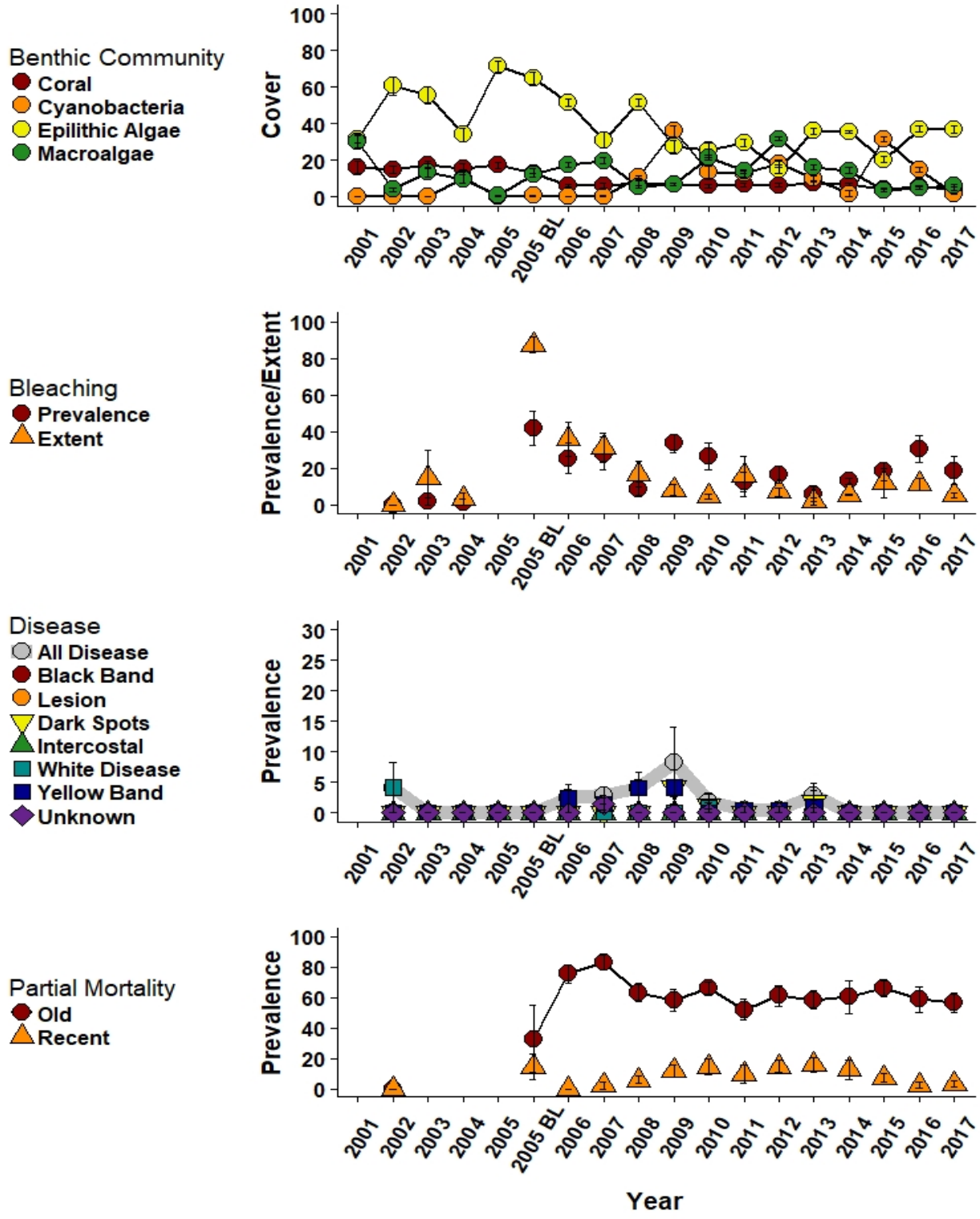


Figure 32. Buck Island, St. Croix benthic cover and coral health through time (mean ± SE).

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 large parrotfish. In addition, the Buck Island site is within the Buck Island Coral Reef 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.

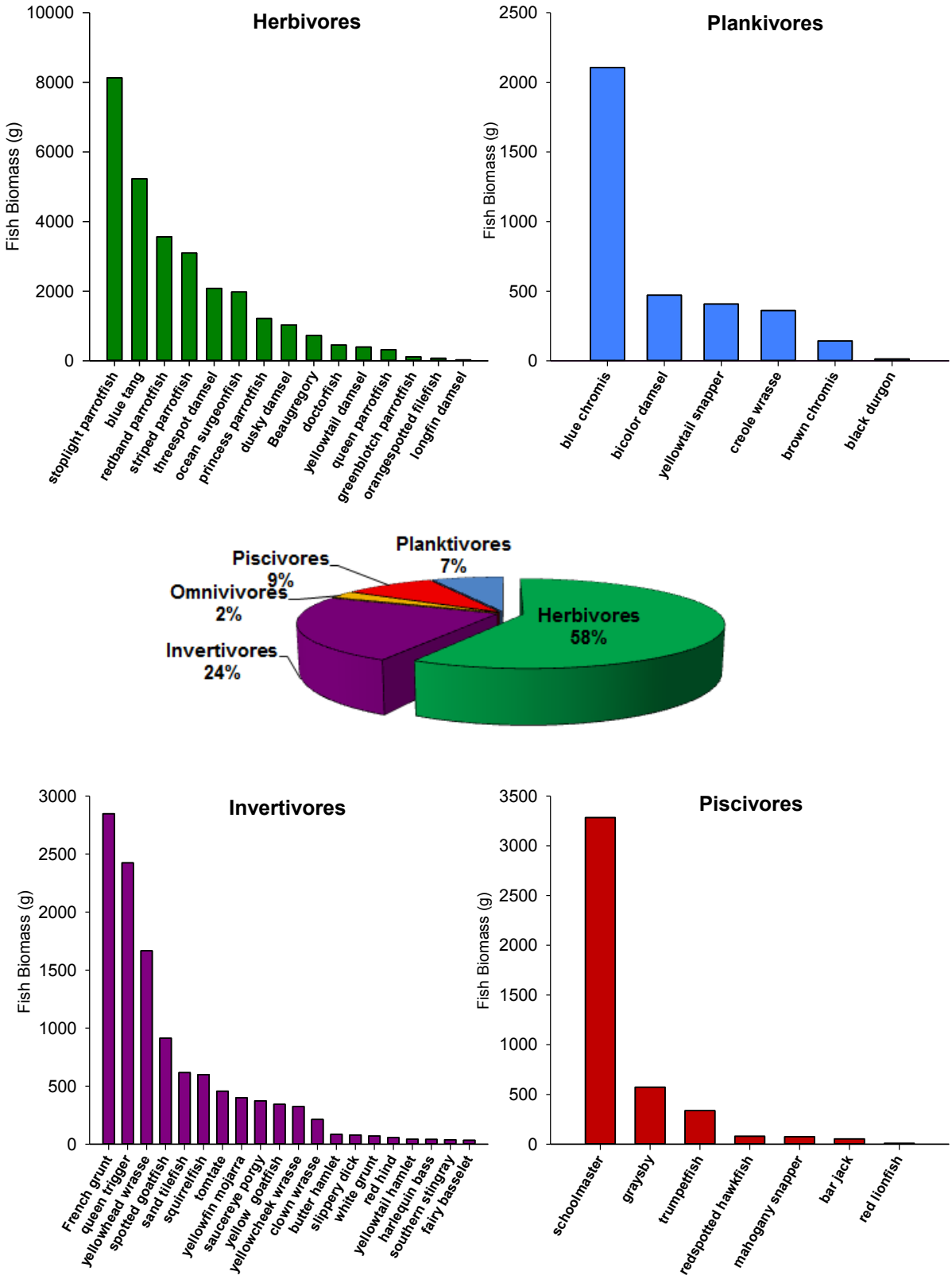
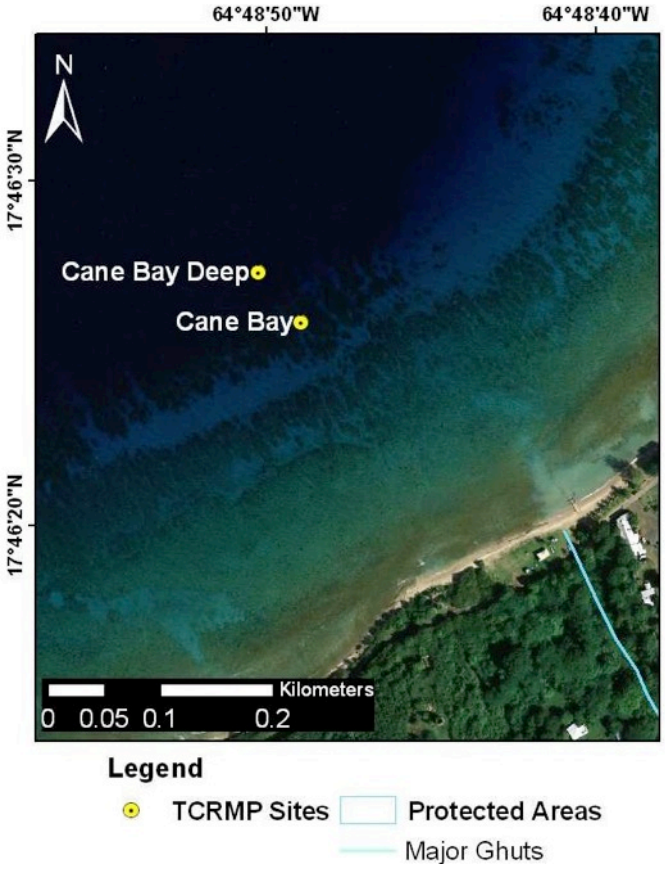


Figure 33. The Buck Island, St. Croix fish community by absolute and relative biomass.

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

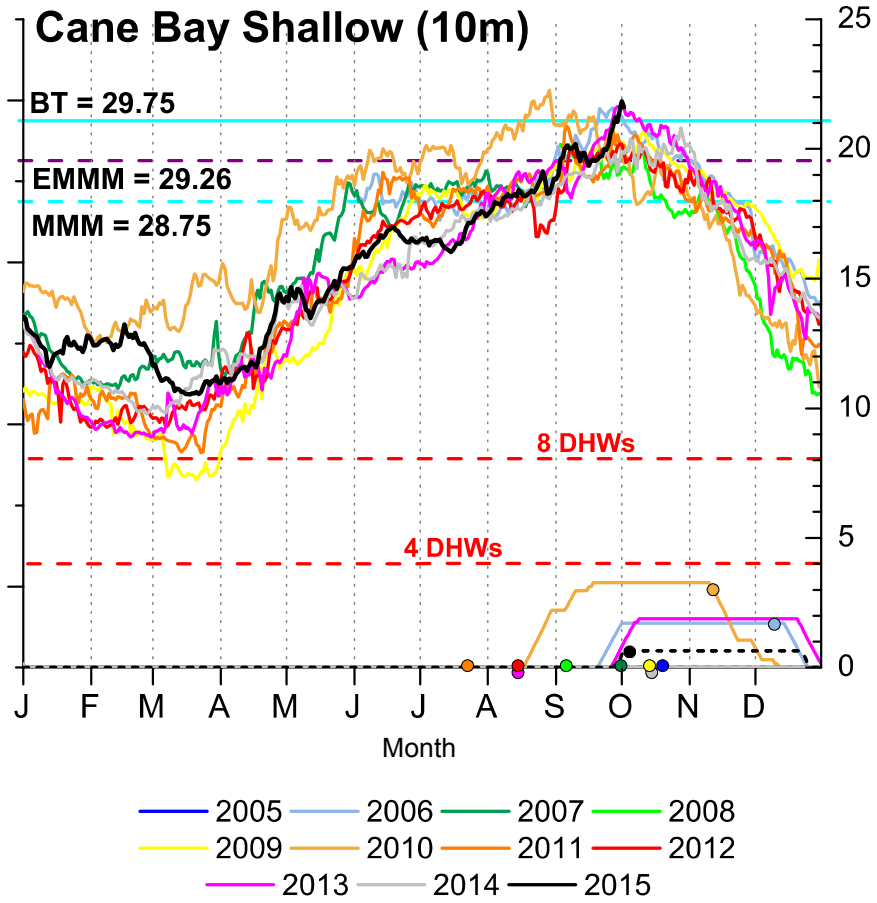


Figure 35. Cane Bay benthic temperatures (8 m depth)

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.

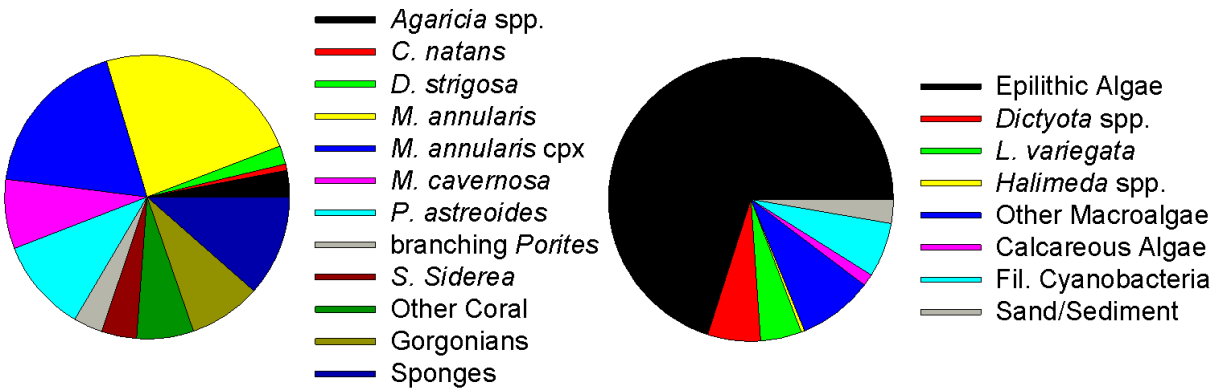


Figure 36. Cane Bay. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

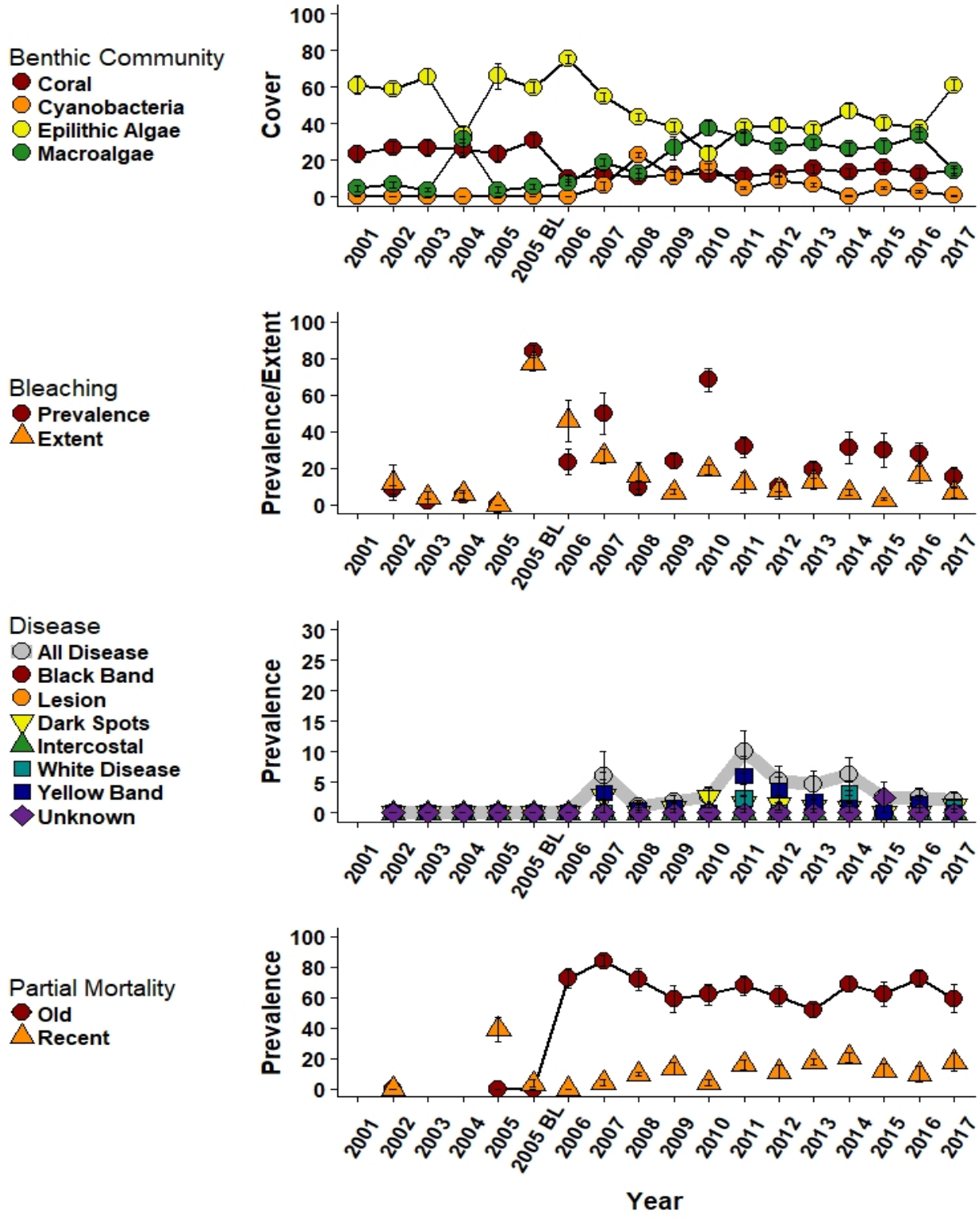


Figure 37. Cane Bay benthic cover and coral health through time (mean ± SE).

Fish Community. Cane Bay has a high diversity, abundance, and biomass of fish, reflecting the benthic diversity and high structural complexity. 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.

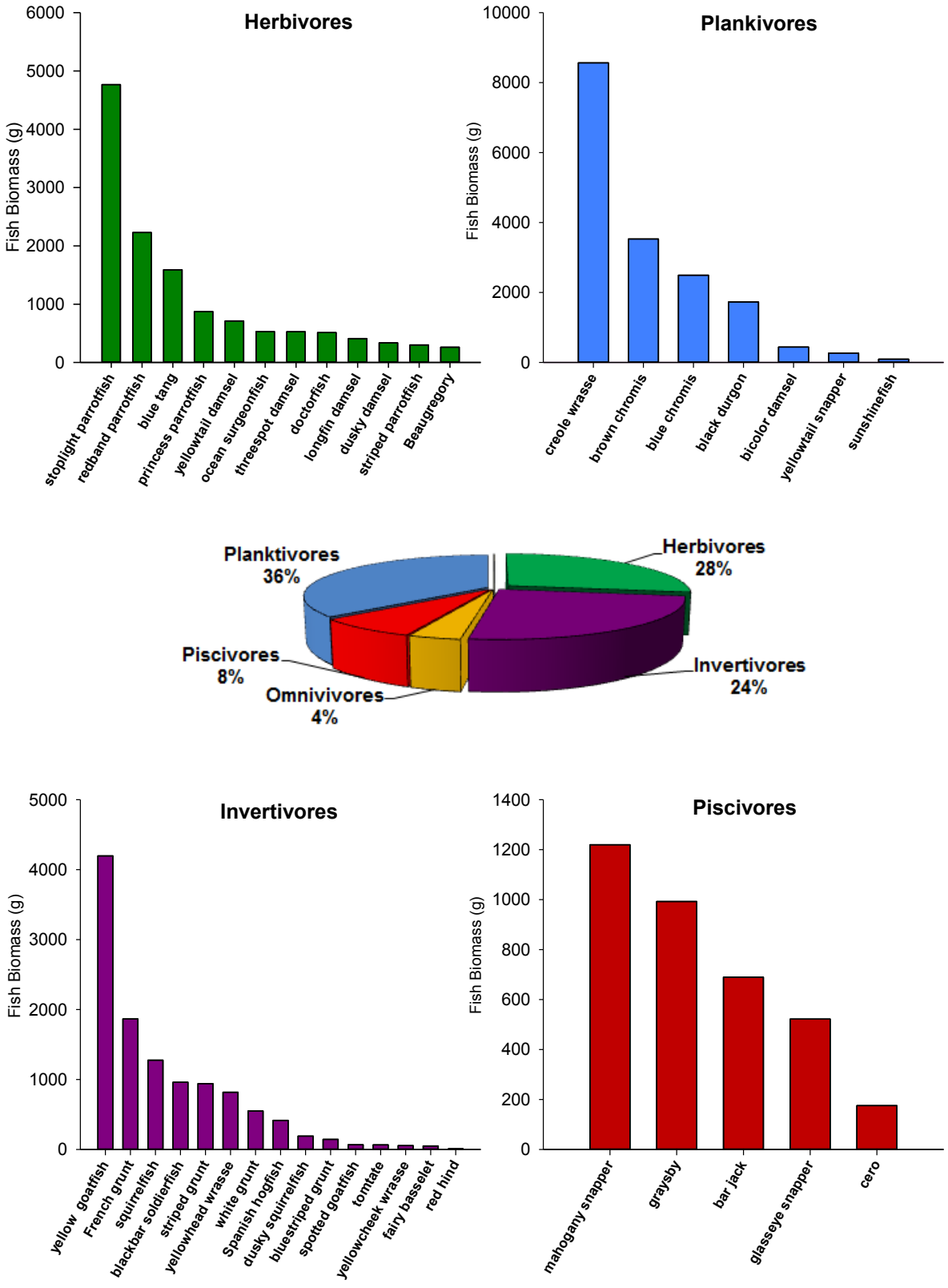
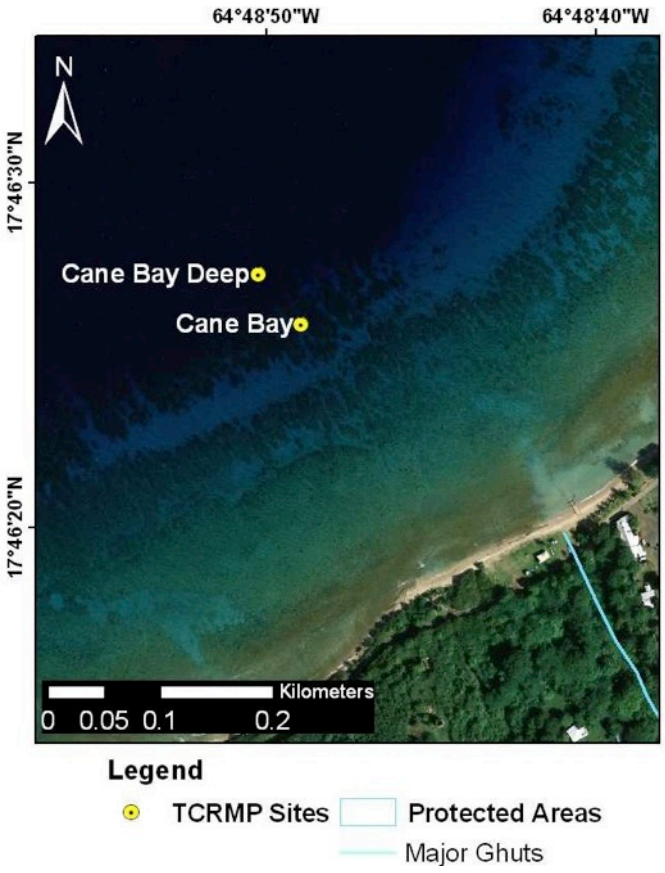


Figure 38. The Cane Bay fish community by absolute and relative biomass.

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).

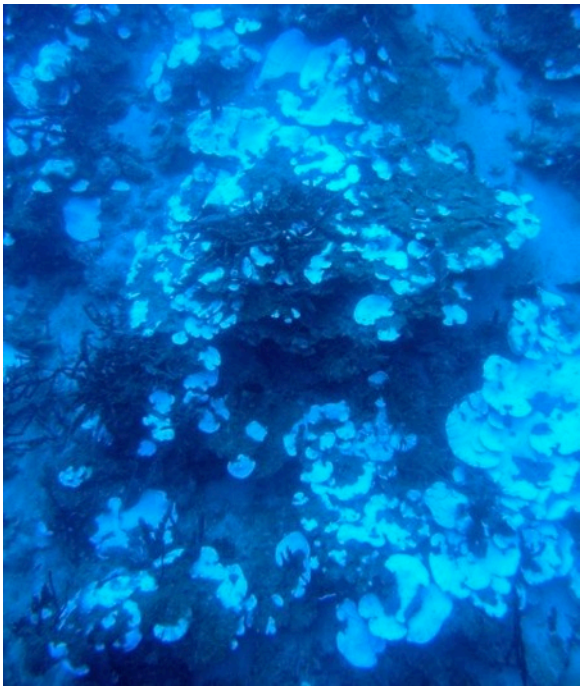


Figure 39. Cane Bay Deep. (top) Location. (right) A representative photo of the reef during the 2005 bleaching event. Bleached colonies are 0.5 – 3 m wide.

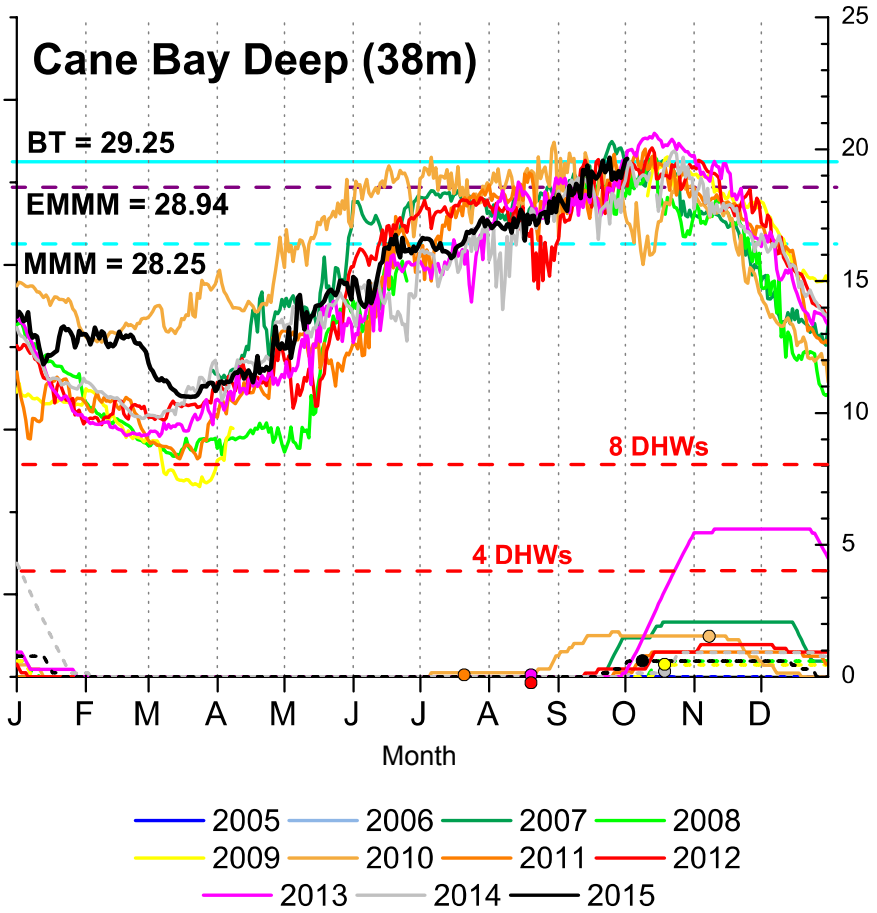


Figure 40. Cane Bay Deep temperature (39 m depth).

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.

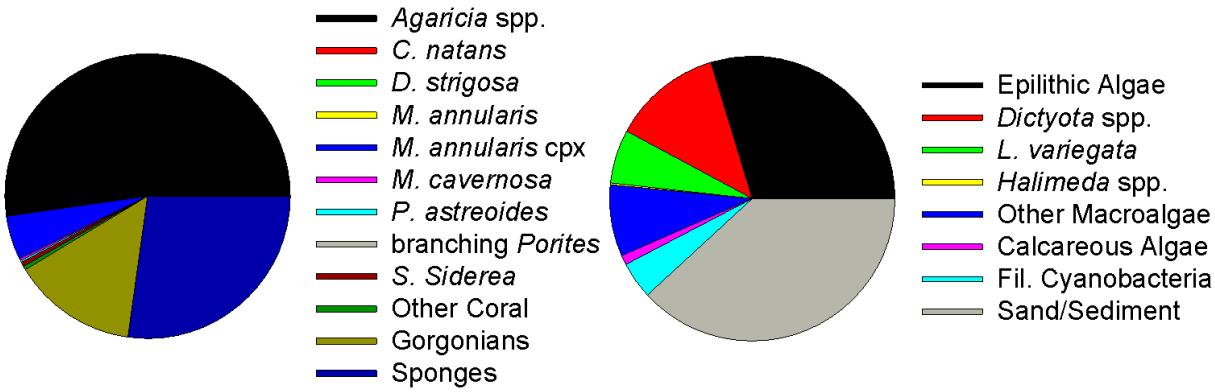


Figure 41. Cane Bay Deep. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

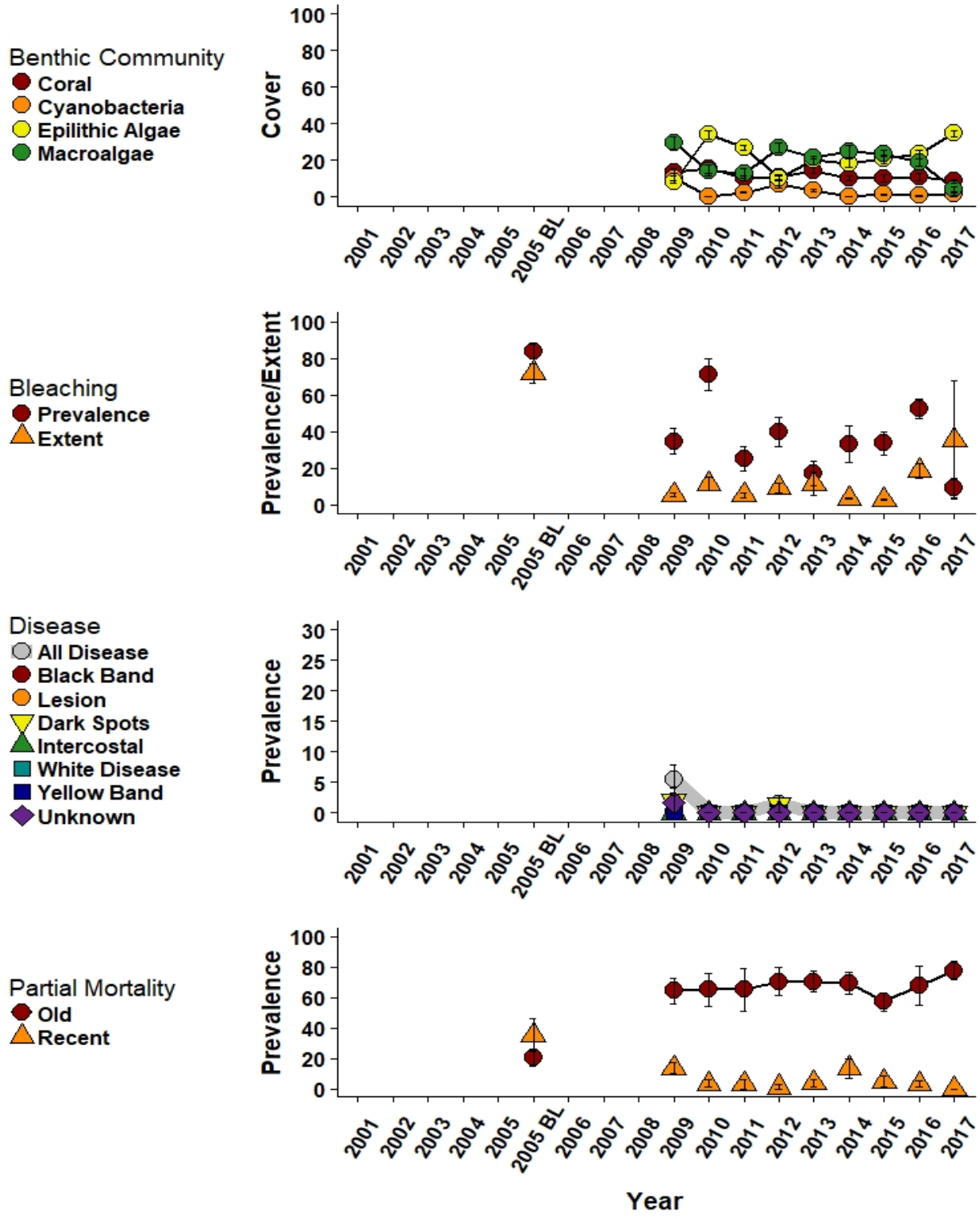


Figure 42. Cane Bay Deep benthic cover and coral health through time (mean ± SE).

Fish Community. Cane Bay Deep has maintained a very low fish biomass 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. 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. Deepwater reef species such as the bantum bass, fairly basslet, cherubfish, and sunshine fish are common.

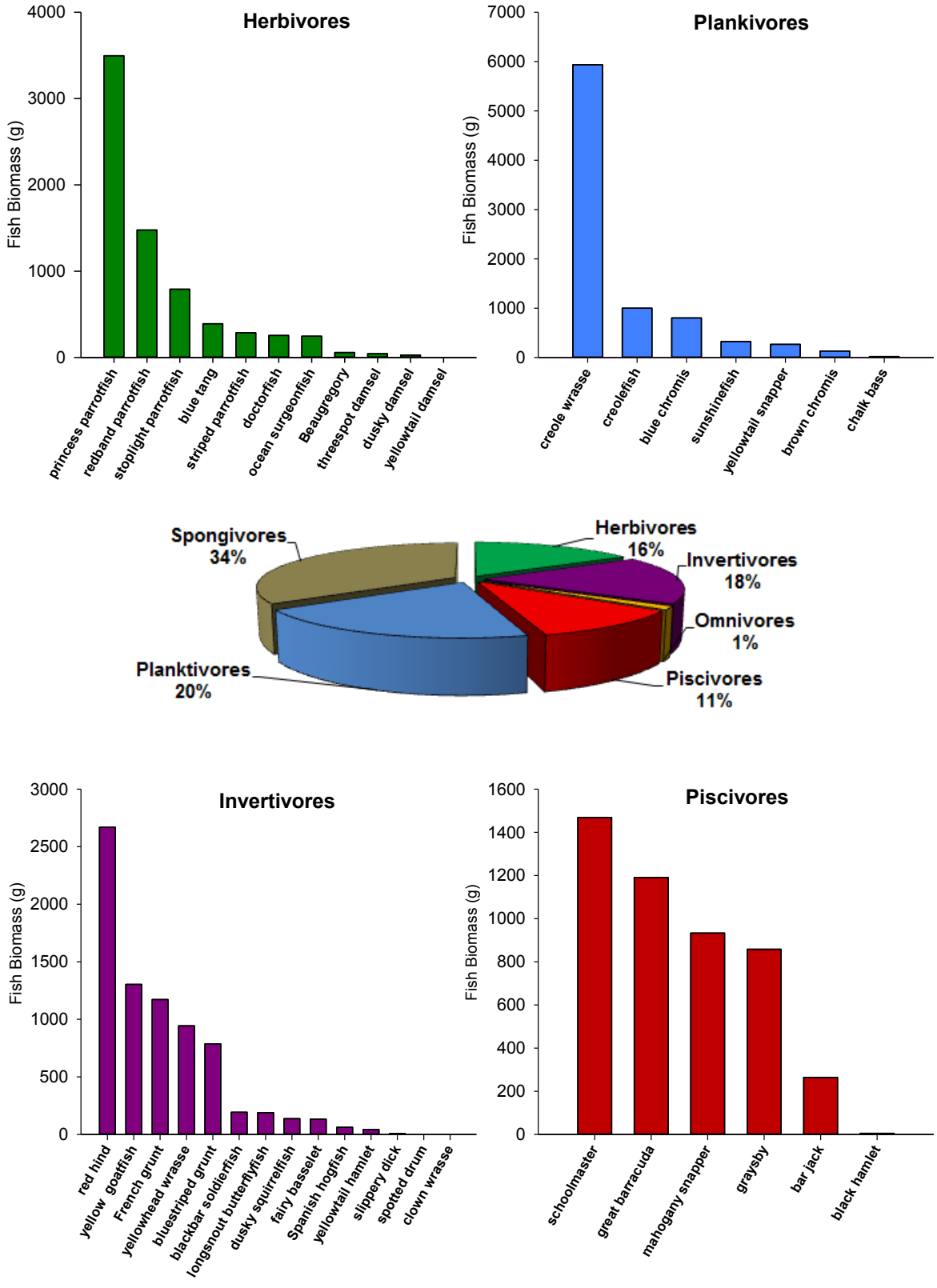
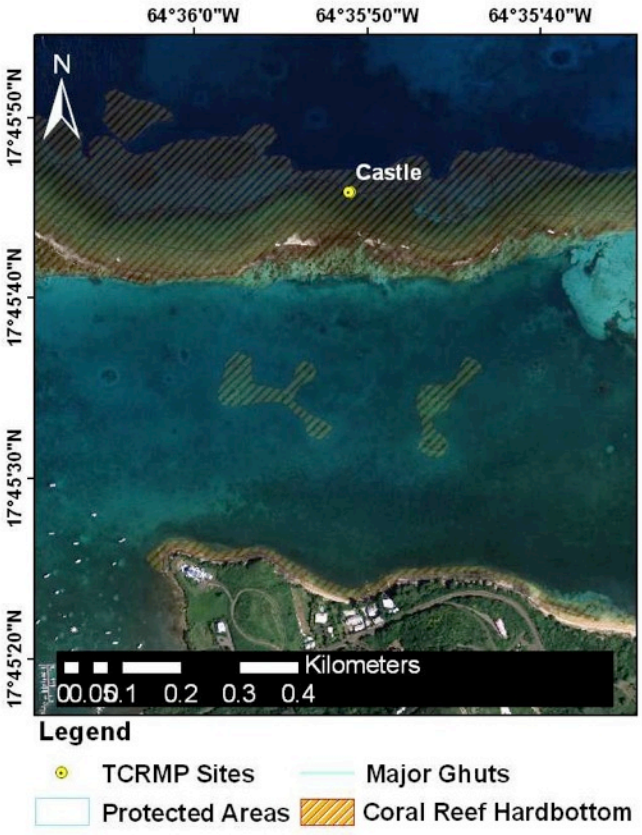


Figure 43. The Cane Bay Deep fish community by absolute and relative biomass.

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.

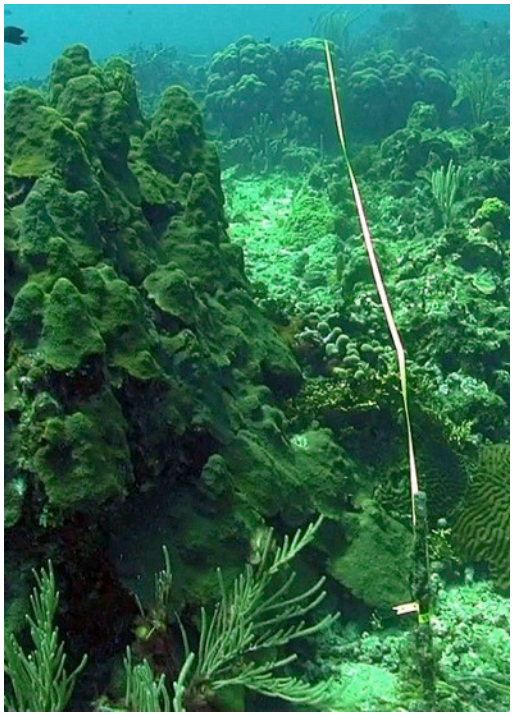


Figure 44. Castle. (top) Location. (right) A representative photo of the reef.

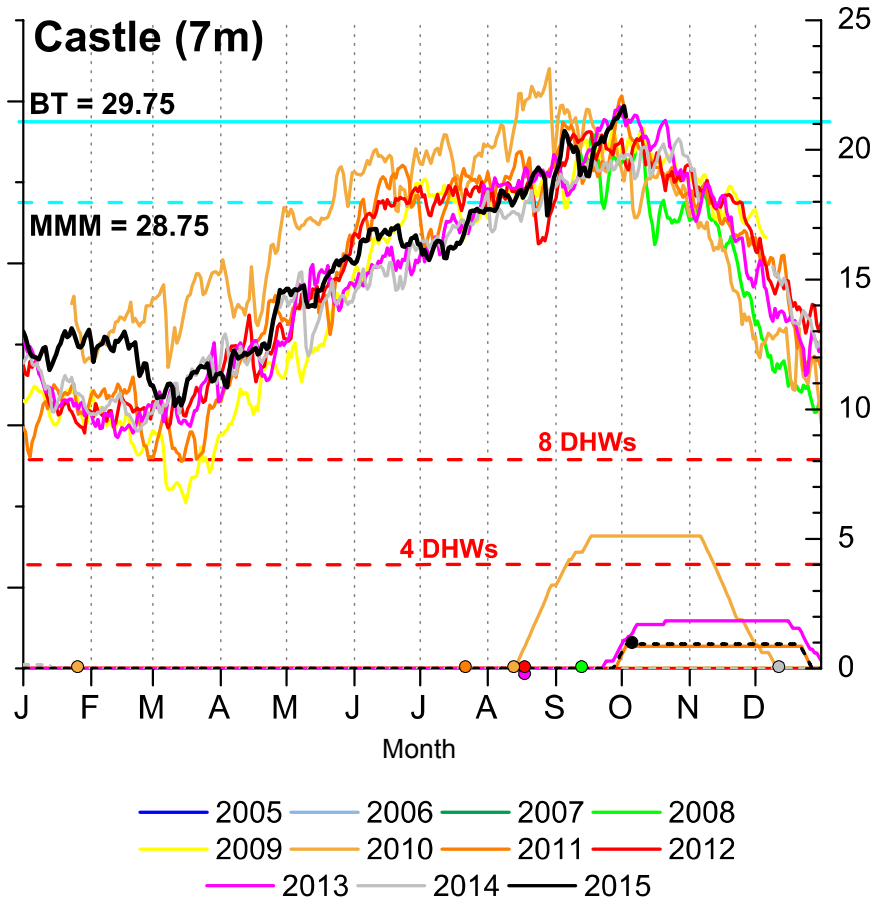


Figure 45. Castle benthic temperatures (9 m depth).

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 as the location of permanent transects established in 2008.

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.

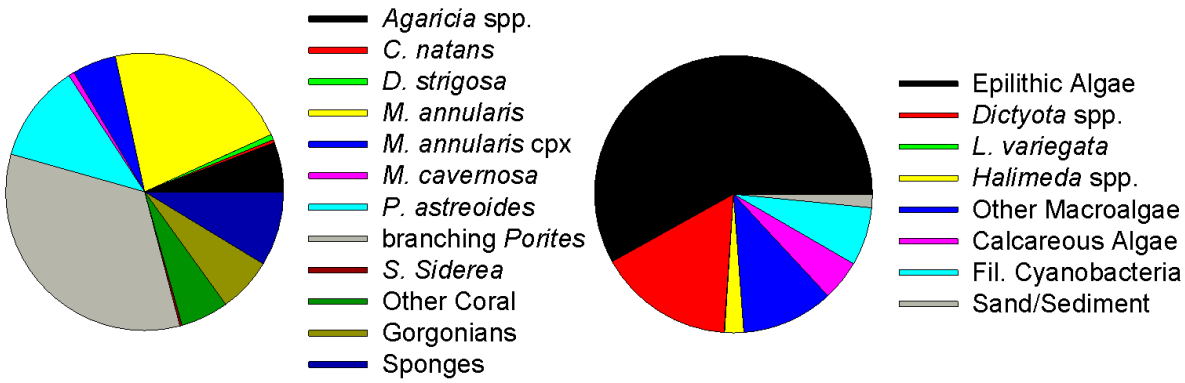


Figure 46. Castle. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

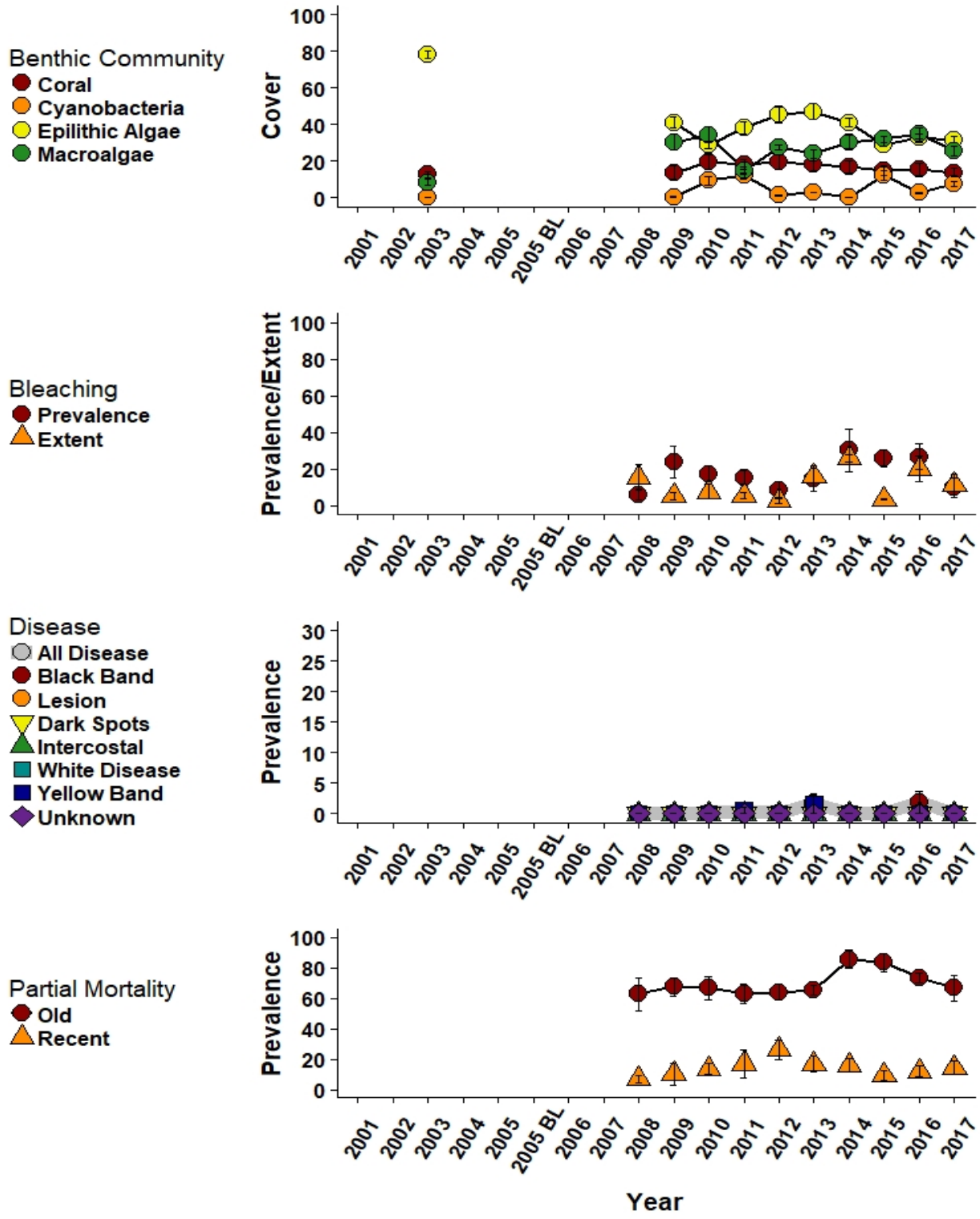


Figure 47. Castle benthic cover and coral health through time (mean ± SE).

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 have been recorded.

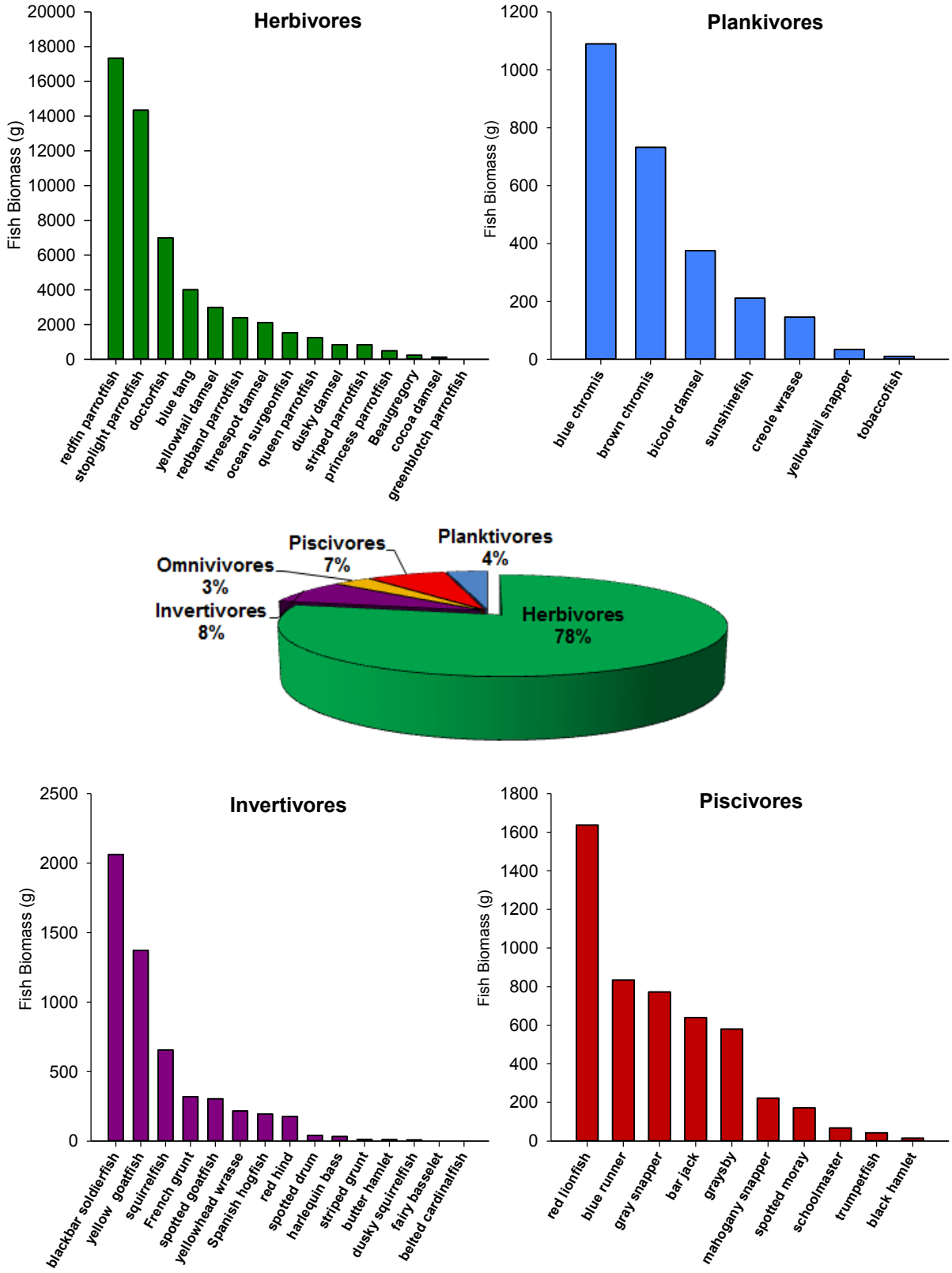
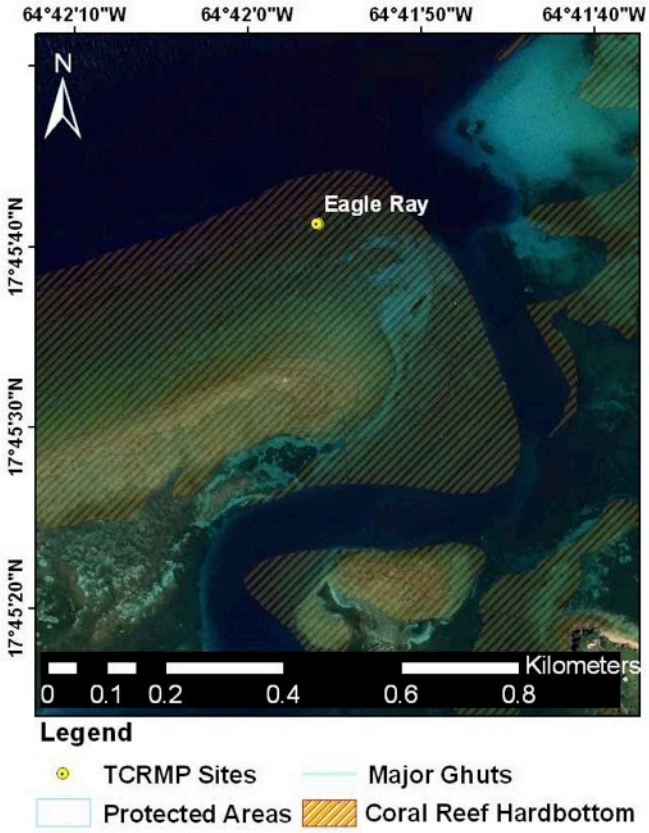


Figure 48. The Castle fish community by absolute and relative biomass.

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.

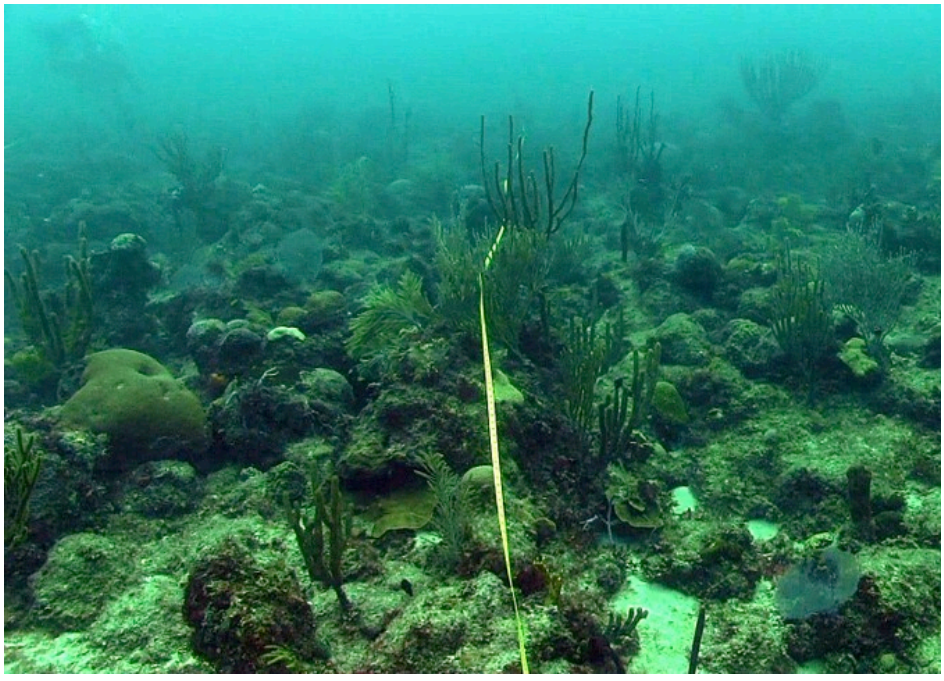


Figure 49. Eagle Ray. (top) Location. (right) A representative photo of the reef.

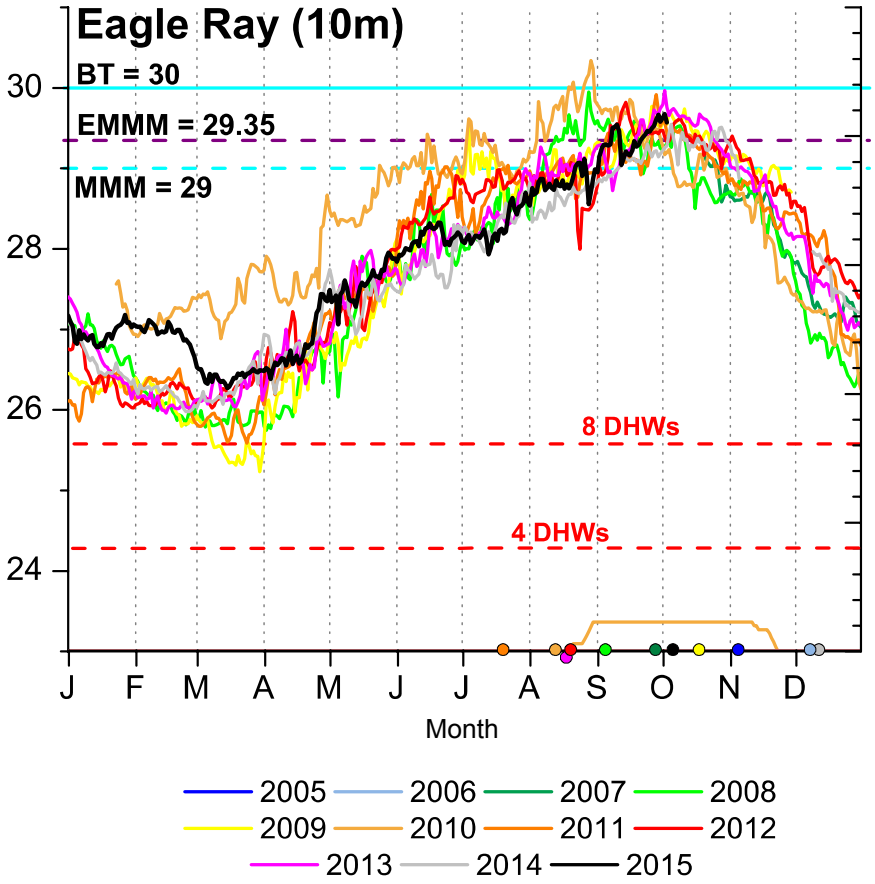


Figure 50. Eagle Ray benthic temperature at 9 m depth

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 the temperature relative to sites in more enclosed environments.

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 monitored in 2010 prior to the thermal stress event and bleaching is underestimated for that year. 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.

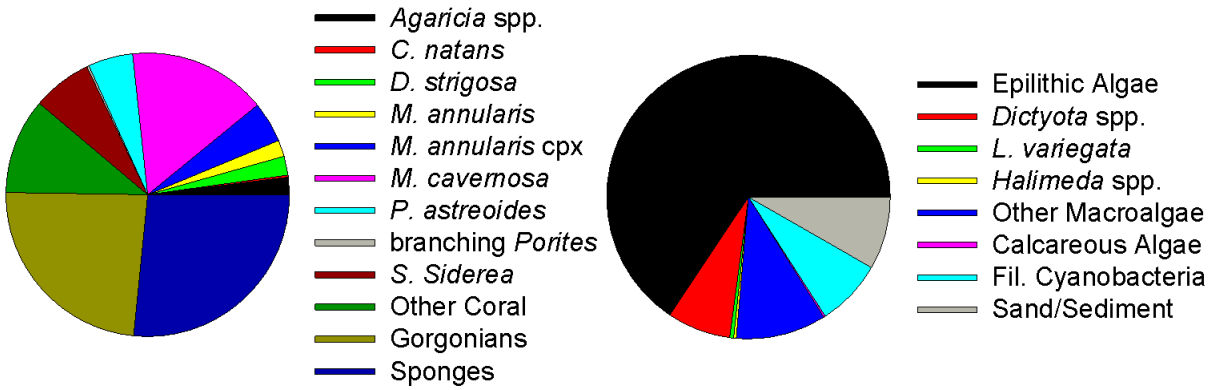


Figure 51. Eagle Ray. (left) Relative composition of the sessile epibenthic animal community. (right) Relative composition of the algal community and unconsolidated sediment.

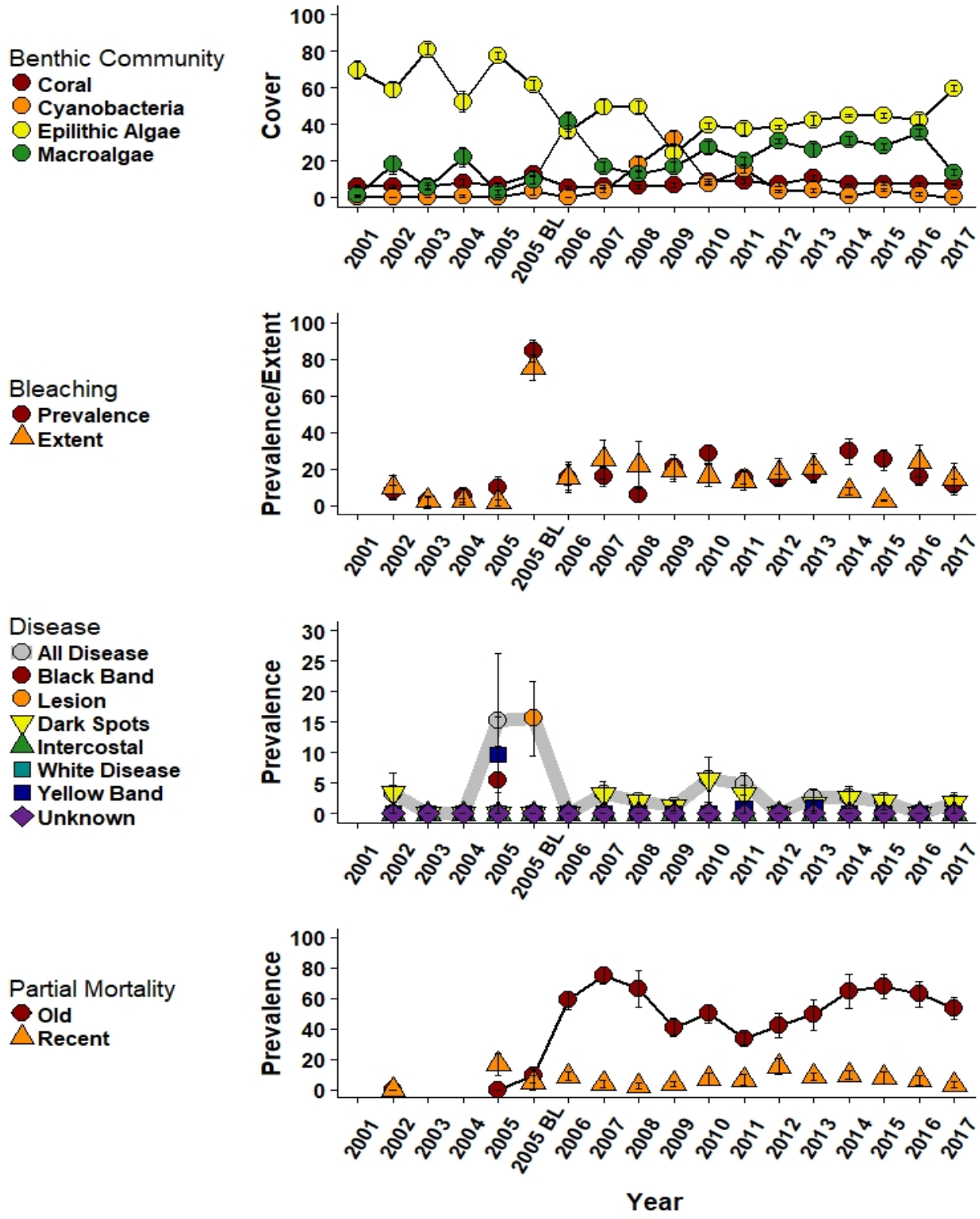


Figure 52. Eagle Ray benthic cover and coral health through time (mean ± SE).

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.

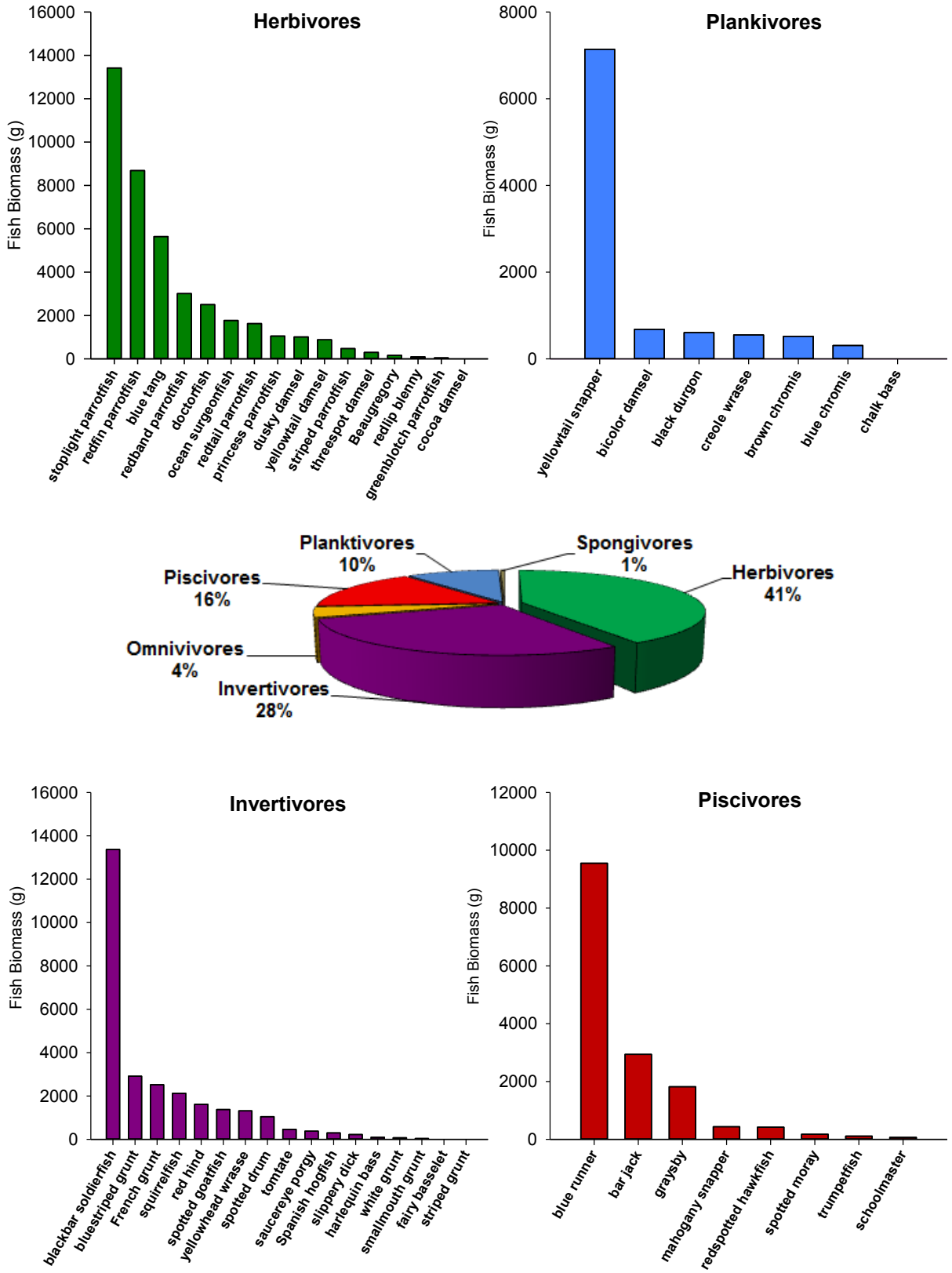


Figure 53. The Eagle Ray fish community by absolute and relative biomass.