**Video monitoring assessment of coral reefs in St. Croix, United States Virgin Islands**

Year Two Final Report
Submitted to
Department of Planning and Natural Resources

March 31, 2003

By

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Executive Summary

Coral reefs are biologically diverse and structurally complex systems that occur throughout tropical regions of the world. They are vital in terms of coastline protection, economic resources and biodiversity. However, coral reefs in the Caribbean, as throughout the world, are facing a dramatic decline due to both natural and anthropogenic stresses. To effectively manage and maintain these important ecosystems, the government of the Virgin Islands, in coordination with federal agencies and the University of the Virgin Islands, has implemented a long-term coral reef monitoring and assessment program. This program will help the US Virgin Islands establish a baseline condition of the surrounding coral reefs and fish populations for determining the effectiveness of various management initiatives, including the Virgin Islands Marine Parks Management Plan, on the sustainability of these important resources. The long-term monitoring program will also allow natural resource managers to gauge the immediate impacts of natural disturbances and human impacts on coastal habitats and their rates of recovery. This report presents results from the second year of monitoring and includes a comparison of data obtained in year one.

The assessment and monitoring programs utilized digital video to quantify coral diversity and the percent cover of corals, algae, and other organisms at ten permanent sites surrounding the island of St. Croix and at two rapid assessment sites within the East End Marine Park. Divers also performed surveys to document fish assemblage structure, incidence of coral bleaching and disease and the number of *Diadema antillarum* sea urchins. Eight of the permanent sites were established in 2001.

Turf algae covering dead coral comprised >50% of the substrata at the twelve St. Croix sites. The percent cover of other benthic organisms for all sites ranged from 5% to 25% for living hard coral, 2% to 35% for macroalgae, 2% to 4% for sponges, and 1% to 8% for gorgonians. Coral species composition was similar among sites, with ten species representing 95% of the coral community. Coral diversity (H') varied between 1.5 and 2.5 among sites. Coral condition varied greatly among sites with incidence of coral disease and bleaching ranging from 0 to 17% and 0 to 22 %, respectively. *Diadema* sea urchins were uncommon and observed along transects at only four sites. Fish diversity ranged from 28 species to over 50 while fish abundance averaged 300 to 700 fish per census. The St. Croix fish fauna was dominated numerically by wrasses (Labridae) and damselfishes (Pomacentridae), and followed by the herbivorous families, Acanthuridae and Scaridae. Piscivores and other specialized feeders were least abundant. No obvious relation of fish species richness and diversity to percent live coral cover or algal cover was found.

Annual comparisons of benthic organisms showed little change in live coral cover, turf algae, sponges or gorgonians. Macroalgal cover showed a significant increase at two sites and a significant decrease at one site between 2001 and 2002. Dead coral covered with turf algae showed a significant increase at one site and a significant decrease at one site. Coral diversity increased at all sites except one. Finally, changes in fish assemblage structure between years were not apparent. A detailed map of site locations and data for all sites are available on the University of the Virgin Islands web site at http://rps.uvi.edu/VIMAS/sitemap.html. The web site allows local and federal government agencies, public and private organizations and the general public to gain access to these data.

# I. Introduction:

The U.S. Virgin Islands consists of three large islands, St. Thomas, St. John and St. Croix, and numerous smaller islands surrounded by a diverse, tropical marine environment that includes coral reefs, seagrass beds, and mangrove forests. The islands of St. Thomas and St John are joined by an extensive shallow water platform that connects them to Puerto Rico and the British Virgin Islands. Forty miles to the south of St. Thomas and St. John, St. Croix lies on a separate platform. St. Croix is separated from St. Thomas and St. John by the Virgin Islands Trough (over 7,300 m deep).

Tourism drives the Virgin Islands economy. The marine environment with its clean, clear water and fringing sandy beaches is our major tourist attraction. The waters of the Virgin Islands are ideal for sailing because of the persistent trade winds and the numerous bays that provide protected anchorages. The diverse marine life in the coral reefs and other habitats attracts thousands of skin and scuba divers each year. Sport fishing also makes an important contribution to the economy, especially on St. Thomas.

In addition to their tourist appeal, the coral reefs and other habitats in the Virgin Islands are essential to the lives of hundreds of thousands of species including the economically important queen conch, whelk, snapper and grouper. Over three hundred full-time or part-time commercial fishermen fish in territorial and federal waters on all three islands. In tough economic times, fishing is an important means of supplemental income for many people.

Because many of the coral reefs of the Virgin Islands are found close to shore, they are susceptible to polluted runoff from adjacent watersheds; commercial activities such as the development and operation of hotels, marinas, and ports; anchor damage by boaters; over-fishing; and damage from careless skin and scuba divers. Many marine and near-shore environments around the world also face these problems.

**Objectives for Monitoring Coral Reefs**

In order to maintain the marine resources of the Virgin Islands in an ecologically and economically sustainable manner, the territorial and federal waters of the Virgin Islands must be effectively managed. By providing managers with fundamental information with which to make and enforce decisions, monitoring programs are essential for successful management. Monitoring establishes baseline data against which standards for resource protection can be measured. Also, monitoring provides the means to assess the status and trends of ecological resources, allowing managers to determine the effectiveness of current management plans and to develop effective management for the future. The intent of this project is to monitor the condition of coral reefs throughout the U.S. Virgin Islands to better manage these ecosystems.

## II. Methods:

Between April, 2001 and March, 2003, digital video transects were used to assess the benthic cover of twelve sites in St. Croix, USVI (Figure 1, Table 1). Ten of the sites are long- term monitoring sites that are sampled annually, with this being the first year of monitoring for the Great Pond and Mutton Snapper Spawning sites. Two of the sites are rapid assessment sites where permanent transects were not established. The intent of sampling these sites was to conduct a rapid assessment of the coral and fishery resources at multiple locations within the East End Marine Park to provide essential base-line data for the Marine Parks Management Plan. Both rapid assessment sites and three of the permanent sites are within the East End Marine Park boundary. For detailed video sampling methods and discussion of the advantages and disadvantages of video monitoring, see Nemeth and Herzlieb, 2002.

**Table 1**. Site location information and number of video transects at each site.

| Site | Date Sampled 2001 | 2002/03 | GPS Coordinates | Depth (ft.) | No. of Transects 2001 | 2002/03 |
|---|---|---|---|---|---|---|
| Buck Island | 8/10 | 1/14/02 | N 17° 47.122, W 64° 36.550 | 35 | 3 | 3 |
| Cane Bay | 4/25 | 5/29/02 | N 17° 46.433, W 64° 48.810 | 30 | 6 | 6 |
| Jacks/Isaac Bay | 8/02 | 6/11/02 | N 17° 44.588, W 64° 34.309 | 35 | 6 | 6 |
| Lang Bank | 8/01 | 5/29/02 | N 17° 44.443, W 64° 32.209 | 50 | 6 | 5 |
| Long Reef/Eagle Ray | 7/26 | 5/30/02 | N 17° 45.688, W 64° 41.929 | 30 | 6 | 6 |
| Salt River East wall | 10/12 | 5/23/02 | N 17° 47.221, W 64° 45.445 | 40 | 6 | 6 |
| Salt River West wall | 8/23<br>10/12 | 5/22/02 | N 17° 47.116, W 64° 45.564 | 20 | 6 | 6 |
| Sprat Hole | 9/25 | 6/14/02 | N 17° 44.038, W 64° 53.722 | 40 | 6 | 5 |
| Great Pond | - | 3/24/03 | N 17° 42.668, W 64° 39.148 | 14 | - | 6 |
| Mutton Snapper Site | - | 1/17/03 | N 17° 38.217, W 64° 51.683 | 75 | - | 5 |
| Castle[1] | - | 3/10/03 | N 17° 45.767, W 64° 35.846 | 20 | - | 6 |
| Gerson[1] | - | 3/14/03 | N 17° 47.914, W 64° 35.314 | 50 | - | 6 |

[1] Rapid assessment sites.

Divers videotaped six permanent 10m transects at each long-term monitoring site, except for Buck Island, Lang Bank, Mutton Snapper and Sprat Hole. Three 10m transects were videotaped at Buck Island. It was determined that six transects were not necessary since the National Park Service is also currently monitoring the coral reef at Buck Island. At Lang Bank, Mutton Snapper, and Sprat Hole, only five transects were videotaped due to logistical or equipment problems during sampling. At all long-term monitoring sites all coral colonies $> 10$ cm in diameter that were located directly under the transect lines were measured for maximum width and height and assessed for signs of disease or bleaching. Assessments of each coral were done by estimating the percent surface area (planar view) appearing bleached and diseased for each of these coral heads. Divers also counted the number of *Diadema antillerum* sea urchins within 1 m on either side of each transect at all long-term sites. At each rapid assessment site, divers videotaped six 10m non-permanent transects. Transects were marked by haphazardly laying transect line on areas judged to be representative of the reef. Disease, bleaching, and urchin data were not collected at rapid assessment sites.

As part of a joint study, fish surveys were conducted at seven of the long-term monitoring sites by divers from the Virgin Islands Division of Fish and Wildlife. For detailed methods, results and discussion of fish data for these sites, see Toller, 2002 (Appendix I). At Great Pond and Mutton Snapper, divers from the Virgin Islands Division of Fish and Wildlife and the University of the Virgin Islands Center for Marine and Environmental Studies conducted the surveys. Six surveys were conducted at Great Pond. Only 4 surveys were conducted at the Mutton Snapper site by the dive team due to limited bottom time at this deeper site. At all long-term sites, divers used the stationary visual census technique to census fish (Bohnsack and Bannerot 1986). Surveys at the two rapid assessment sites (Castle and Gerson) were conducted by divers from UVI CMES using the rover diver method. Divers using this method swim and search the census area for 30 minutes with the objective of finding the maximum number of species. All observed fish species are recorded and the density of each species is estimated and categorized in the following groups: single/rare (1 fish), few (2 – 10 fish), many/common (11 – 100 fish) and abundant (>100 fish). No fish surveys were performed at Buck Island. This methodology deviated from year one fish surveys which utilized 30m x 2m belt transects, thus comparisons of fish density and abundance could not be done.

## III. Results and Discussion

The percent cover of living coral ranged from a low of 4.4% at Lang Bank to a high of 39.1% at the Mutton Snapper Spawning site (Figure 2A). Turf algae covering dead coral was the most dominant substrate type at all twelve sites except for the Mutton Snapper Spawning site where coral was the most abundant substrate type (Figure 2A, B). Dead coral with turf algae ranged from 30.3% at the Mutton Snapper site to 81.1% at Salt River West Wall (Figure 2B). This category includes both long dead and recently killed coral covered with a layer of turf algae. Percent cover of macroalgae ranged from 3.2% at Salt River West Wall to 34.9% for Jack's Bay (Figure 2C). Percent cover of living coral was similar among years but we did find some significant changes in both turf algae and macro algae at several sites. We found a significant increase in turf algae and a subsequent decrease in macroalgae at Buck Island between year 1 and 2 (Figure 2 B, C). This trend was reversed at Sprat Hole showing an increase in macroalgae and decrease in turf algae (Figure 2B, C). Significant increases in macroalgae also occurred at Long Reef (Figure 2C). It is unlikely that *D. antillarum* sea urchins caused these annual changes since they were very uncommon at most sites. Urchins were only seen along transects at four sites: Great Pond (17 urchins), Cane Bay (4 urchins), Long Reef/Eagle Ray (1 urchin), and Salt River West Wall (1 urchin).

Since the randomly generated dots used in digital video analysis were classified as dead coral with turf algae in instances when it was unclear whether the dots fell on macro algae or turf algae, it is possible that these data may over-represent turf algal cover and under-represent macro algal cover (See Nemeth and Herzlieb, 2002). However, to reduce this chance of misidentification it is recommended that in future surveys the videotape should be analyzed as soon as possible following data collection and that video analysis should be conducted by a person who is familiar with the sites. Sponges and gorgonians each comprised less than 10% of the benthic cover at all sites (Figure 2D, E). Sand was the only non-living substrate type found at the sites, ranging from 0.0% at Castle, Gerson, Great Pond, and the Mutton Snapper site to 9.5% at Buck Island (Figure 2F).

No significant changes occurred at any site for sponges, gorgonians, or sand cover between year 1 and year 2 surveys.

The coral reefs of St. Croix were generally dominated by the genus *Montastraea* (Figure 3). The notable exceptions were Castle where *Porites porites* was most abundant, Great Pond where *Porites astreoides* was most abundant, and Gerson and Lang Bank where *Diploria strigosa* was most abundant (Table 2, Figure 4A-L). Unlike year one, all corals within the *Montastraea annularis* complex (*M. annularis*, *M. faveolata*, and *M. franksii*) were identified to species in year two. Corals that could not be classified to species, but could be identified as part of this complex were classified as UMX for unidentified *Montastraea* complex. For analysis purposes, all corals within the complex were grouped and classified as *Montastraea* complex (Table 2). The composition of the coral community was similar among sites, with ten species representing 95% of the coral community (Figure 3). Coral diversity ranged from a Shannon-Weaver diversity index (H') of 1.50 at Great Pond to 2.40 at Salt River West Wall (Figure 5).

**Table 2**. Percent composition of *Montastraea* corals within the *Montastraea annularis* complex. MA denotes *M. annularis*, MFAV *M. faveolata*, and MFR *M. franksii*. UMX denotes corals that could not be classified to species, but could be identified as part of the complex. MACX denotes all corals within the complex.

| Site | Depth | MA | MFAV | MFRA | UMX | Total MACX |
|---|---|---|---|---|---|---|
| Buck Island | 35 | 0 | 39.87 | 3.27 | 9.80 | 52.94 |
| Cane Bay | 30 | 25.31 | 18.36 | 1.24 | 3.72 | 48.64 |
| Jacks/Isaac Bay | 35 | 0 | 7.06 | 0 | 0 | 7.06 |
| Lang Bank | 50 | 3.57 | 0 | 0 | 0 | 3.57 |
| Long Reef/Eagle Ray | 30 | 1.56 | 0 | 0 | 6.25 | 7.81 |
| Salt River East wall | 40 | 0 | 14.49 | 4.35 | 13.04 | 31.88 |
| Salt River West wall | 20 | 0 | 16.36 | 0 | 11.82 | 28.18 |
| Sprat Hole | 40 | 44.47 | 3.53 | 5.65 | 8.94 | 62.59 |
| Mutton Snapper Site | 75 | 0 | 0 | 45.83 | 17.65 | 63.48 |
| Great Pond | 14 | 0 | 0 | 0 | 0 | 0 |
| Castle[1] | 20 | 1.31 | 0 | 0 | 0 | 1.31 |
| Gerson[1] | 50 | 16.04 | 0 | 0 | 0 | 16.04 |

[1] Rapid assessment sites.

Lang Bank showed the highest incidence of both diseased and bleached coral colonies (Figure 6A, B). The percentage of coral colonies with disease ranged from 0.0% Cane Bay, Great Pond, and Mutton Snapper to 17.39% at Lang Bank. The percentage of colonies with bleaching ranged from 0.0% at Buck Island, Cane Bay, Great Pond, and Mutton to 21.74% at Lang Bank (Figure 6A, B). Among the dominant coral species, *Siderastrea siderea* had the highest incidence of disease and bleaching (Figure 7A, B). Divers observed white plague, dark spots disease, yellow blotch/band disease, and white spots that were classified as disease, but could not be classified as a specific disease.

Detailed summaries of the video data from each site are included in Appendix II: Summary of Coral Video Data, Appendix III: Summary of Non-coral Video data, and Appendix III: Summary of Urchin, Bleaching, and Disease Data.
These data are also made available on the University of the Virgin Islands web site http://rps.uvi.edu/VIMAS/sitemap.html.

In general, fish communities were similar across sites, with all reefs supporting diverse and abundant fish assemblages. See Toller, 2002 (Appendix I) for detailed results and discussion regarding fish communities at seven of the long-term monitoring sites. Data for the remaining two long-term sites (Great Pond and Mutton Snapper) and the two rapid assessment sites (Castle and Gerson) were collected by UVI divers in conjunction with Fish and Wildlife divers and are presented here. Since the rover diver method was used at the rapid assessment sites, no abundance data are available for these sights. Based upon their commercial importance, we examine the following eight fish families: Acanthuridae (surgeonfish), Balistidae (triggerfish), Chaetodontidae (butterflyfish), Haemulidae (grunts), Lutjanidae (snappers) Pomacanthidae (angelfish), Scaridae (parrotfish), and Serranidae (grouper and sea bass). The fish community at Great Pond was dominated by herbivorous fishes (surgeonfish and parrotfish), while few piscivores were observed. Conies (*Epinephelus fulvus* ) represented the only grouper species observed and no snapper species were recorded. One french grunt (*Haemulon flavolineatum*) represented the grunt family. No triggerfish, butterflyfish, or angelfish were recorded during the censuses of Great Pond (Figure 8A). Diversity and abundance were higher at the Mutton Snapper site, where all eight commercially important families were represented. Triggerfish were the most dominant family, while snappers were the least abundant (Figure 8B). Amongst all of the nine long-term monitoring sites, herbivores (surgeonfish and parrotfish) were the most abundant, while angelfish were the least (Figure 9). Between sites, Cane Bay and Sprat Hole showed the highest abundance of fishes, while Great Pond showed the lowest abundance (Figure 10). The shallow depth of Great Pond (< 5 m) and the low coral diversity (mostly *Porites astreoides*, *Diploria Strigosa*, and *Millepora* spp.) at this site suggest that the lower fish abundance here may be related to the availability of suitable shelter habitat. The total number of fish species observed during all the censuses (including the rover diver censuses at the rapid assessment sites) varied between a low of 28 species at Great Pond and a high of 52 species at Long Reef (Figure 11). Graphical comparison of fish abundance and diversity with benthic composition showed no obvious relationships.

## IV. Summary and Recommendations

Turf algae covering dead coral was the dominant substrate, comprising >50% of the substrata at all twelve sites. The percent cover of other benthic organisms ranged from 5% to 25% for living hard coral, 2% to 35% for macroalgae, 2% to 4% for sponges, and 1% to 8% for gorgonians. Coral species composition was similar among sites, with ten species representing 95% of the coral community. Coral diversity (H') varied between 1.5 and 2.5 among sites. Coral condition varied greatly among sites with incidence of coral disease and bleaching ranging from 0 to 17% and 0 to 22 %, respectively. *Diadema* sea urchins were uncommon and observed along transects at only four sites. Fish diversity ranged from 28 to over 50 species, while fish abundance averaged 300 to 700 fish per census. The St. Croix fish fauna was numerically dominated by wrasses (Labridae) and damselfishes (Pomacentridae), and followed by the herbivorous families, Acanthuridae and Scaridae. Piscivores and other specialized feeders were least abundant. No obvious relation of fish species richness and diversity to percent live coral cover or algal cover was found. Detailed data from each site are included in Appendix I: Quantitative estimates of species composition and abundance of fishes, and fish species/habitat associations in St. Croix, U.S. Virgin Islands, Appendix II: Summary of Coral Video Data, Appendix III: Summary of Non-coral Video data, Appendix III: Summary of Urchin, Bleaching, and Disease Data, and on the University of the Virgin Islands web site http://rps.uvi.edu/VIMAS/sitemap.html.

During the second year of sampling, several problems and possible solutions involving data collection and analysis were identified. First, one of the limitations of the video monitoring method is the difficulty distinguishing between dead coral with turf algae and macroalgae from video images. While distinguishable in most images, variations in lighting and water clarity can make identification between the two difficult. To reduce this chance of misidentification it is recommended that in future surveys the videotapes should be analyzed as soon as possible following data collection and that video analysis should be conducted by a person who is familiar with the sites. Also, percent cover of macroalgae has been shown to vary seasonally, showing a peak during the spring and early summer months (R. Nemeth, unpublished data). Since many of the sites were sampled during different months, it is difficult to determine if changes in macroalgal cover observed between 2001 and 2002 were seasonal or caused by other factors. It is recommended that future surveys be conducted at the same time of year, in late May and early June. In addition, fish sampling methods varied between years and made comparisons between years difficult. Fish surveys were conducted using transects in 2001 and the stationary fish method and rover diver methods in 2002. It is recommended that the same method be used for all future samplings. We are currently reviewing the advantages and disadvantages of both methods to determine which is most appropriate for future monitoring efforts. Finally, we recommend that the Lang Bank and Salt River East Wall sites be dropped from future samplings. The substrata at Lang Bank can be characterized as hard bottom sparsely colonized with coral and gorgonians. Thus Lang Bank had the lowest living coral percent cover for both 2001 and 2002. Since Lang Bank is not typical of other coral reef sites on St. Croix and is a logistically difficult site to sample due to weather and sea conditions we recommend dropping this site from our long-term coral reef monitoring program. Salt River East Wall is located near the Salt River West Wall site and the two sites have similar values of percent cover for living coral and most other substrate categories. By discontinuing the monitoring of these sites, more resources can be utilized for the timely sampling and analysis of other sites in future monitoring efforts.

## Literature Cited

Bohnsack, J.A., and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fisher. NOAA Technical Report NMFS 41, U.S. Department of Commerce, 15 pp.

Nemeth, R.S., and S. Herzlieb. 2002. Video monitoring assessment of coral reefs in proposed marine parks St. Croix, United Sates Virgin Islands. Center for Marine and Environmental Studies, University of the Virgin Islands, St. Thomas, USVI. *In*: U.S. Virgin Islands Coral Reef Monitoring Project, Year 1 Final Report. USVI Department of Planning and Natural Resources, Division of Coastal Zone Management.

Toller, W.T. 2002. Quantititative estimates of species composition and abundance of fishes, and fish species/habitat associations in St. Croix, U.S. Virgin Islands. *In*: Final Report: Patterns of habitat utilization by reef fish on St. Croix. USVI Department of Planning and Natural Resources, Division of Fish and Wildlife.


**Fig. 1** Locations of video monitoring sites in St. Croix, USVI. Long Reef/Eagle Ray, Buck Island, Castle, Gerson, Lang Bank, and Jacks Bay are located within the East End Marine Park boundary. Castle and Gerson are rapid assessment sites, All others are long-term monitoring sites.

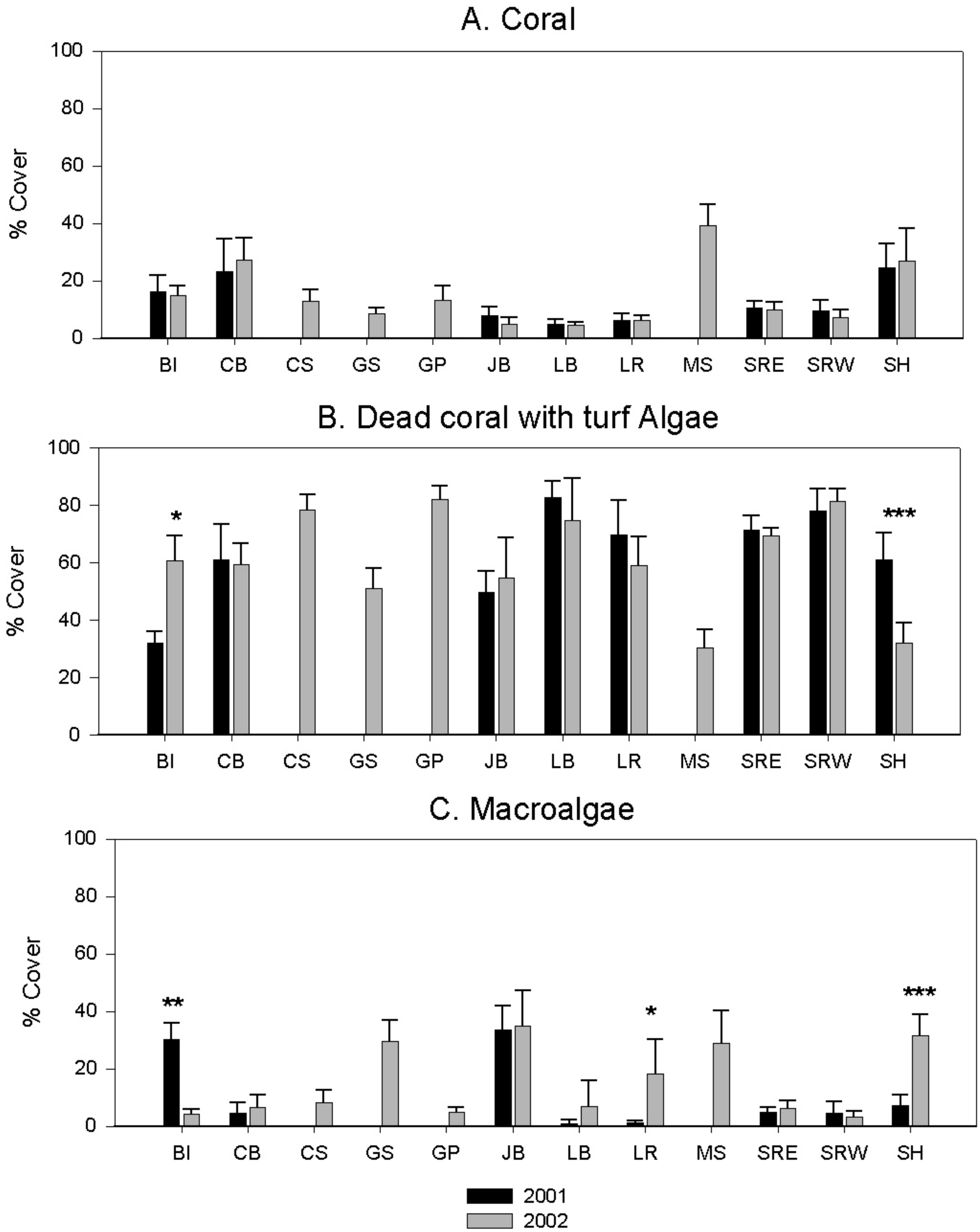



**Fig. 2A, B, C** Mean percent cover of A. Scleractinian corals, B. Dead coral with turf algae, and C. Macroalgae for the year one and year two sampling periods at twelve monitored sites: BI Buck Island; CB Cane Bay; CS Castle; GS Gerson; GP Great Pond; JB Jacks Bay; LB Lang Bank; LR Long Reef/Eagle Ray; MS Mutton Snapper; SRE Salt River East Wall; SRW Salt River West Wall; SH Sprat Hole. For BI, n = 3 transects, for MS, LB year two and SH year two, n = 5 transects. All other sites, n = 6 transects. Data collected only in year two for CS, GS, GP, and MS. Error bars represent standard deviation. Asterisks denote significant differences: * = P < 0.05; ** = P < 0.01; *** = P < 0.001

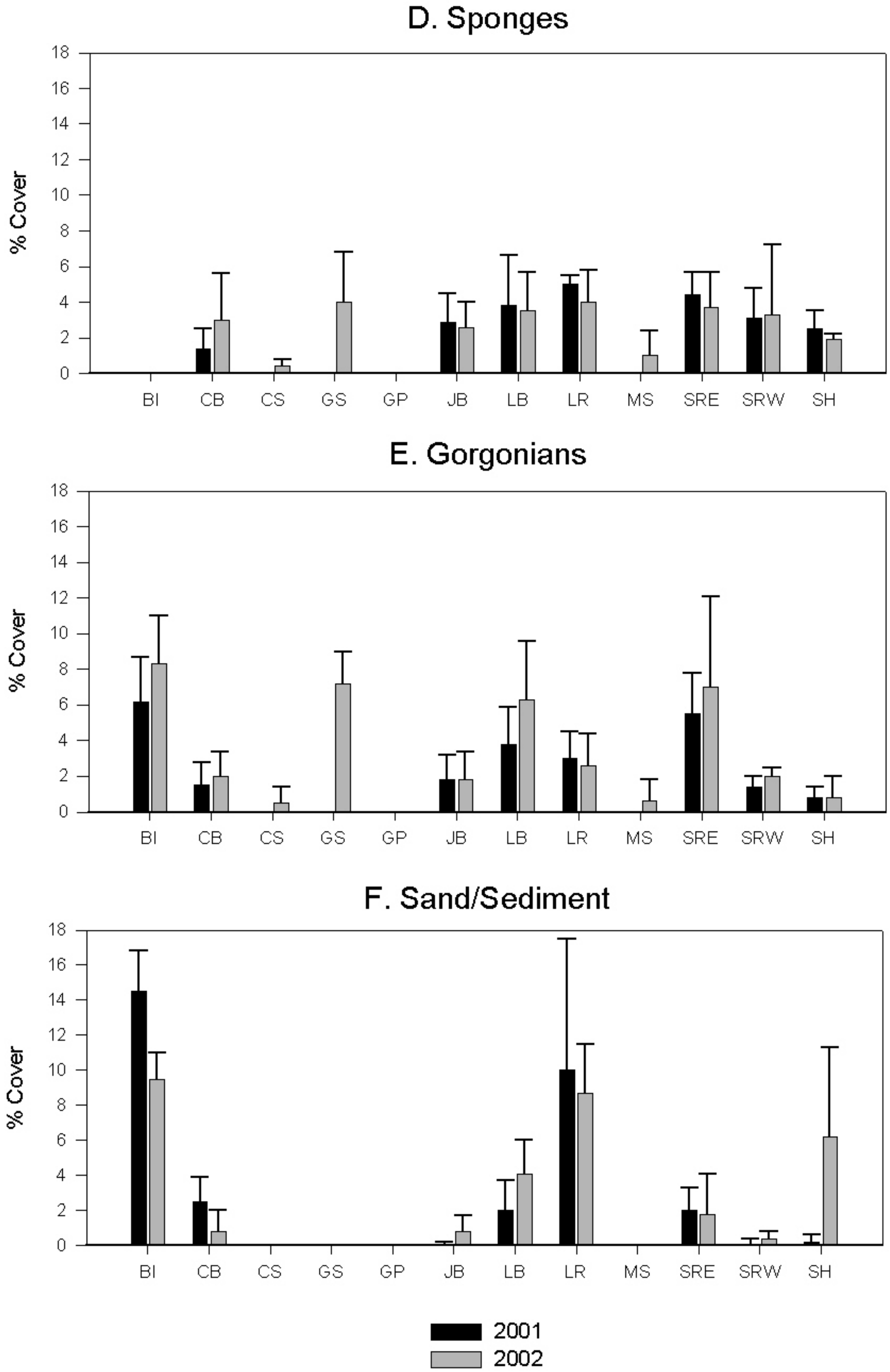



**Fig. 2D, E, F** Mean percent cover of D. Sponges, E. Gorgonians, and F. Sand/Sediment for the year one and year two sampling periods at twelve monitored sites. See Figure 2A, B, C for site codes.

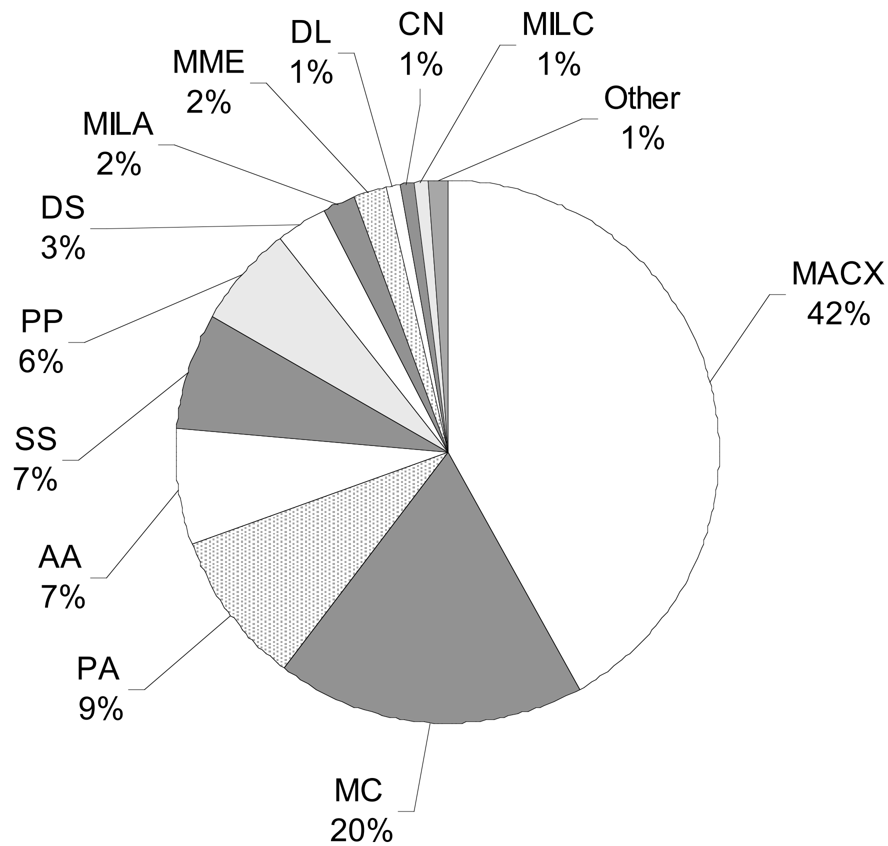



**Fig. 3** Percentage coral species composition at all sampled sites in St. Croix, USVI. MACX *Montastraea annularis* complex; MC *M. cavernosa*; PA *Porites astreoides*; AA *Agaricia agaricites*; *SS Siderastrea siderea*; PP *P. porites*; DS *Diploria strigosa*; MILA *Millepora alcicornis*; MME *Meandrina meandrites;* DL *D. labyrinthiformes*; CN *Colpophyllia natans*; MILC *M. complanata*. Other denotes percent of all other coral species combined and includes: *Stephanocoenia michelinii, Eusmilia fastigiata, D. clivosa, Madracis decactis, M. mirabilis, Mussa angulosa, Mycetophyllia danaana, M. ferox ,M.aliciae, Dichocoenia stokesii, Manicina areoloata,* and *P. divaricata.*

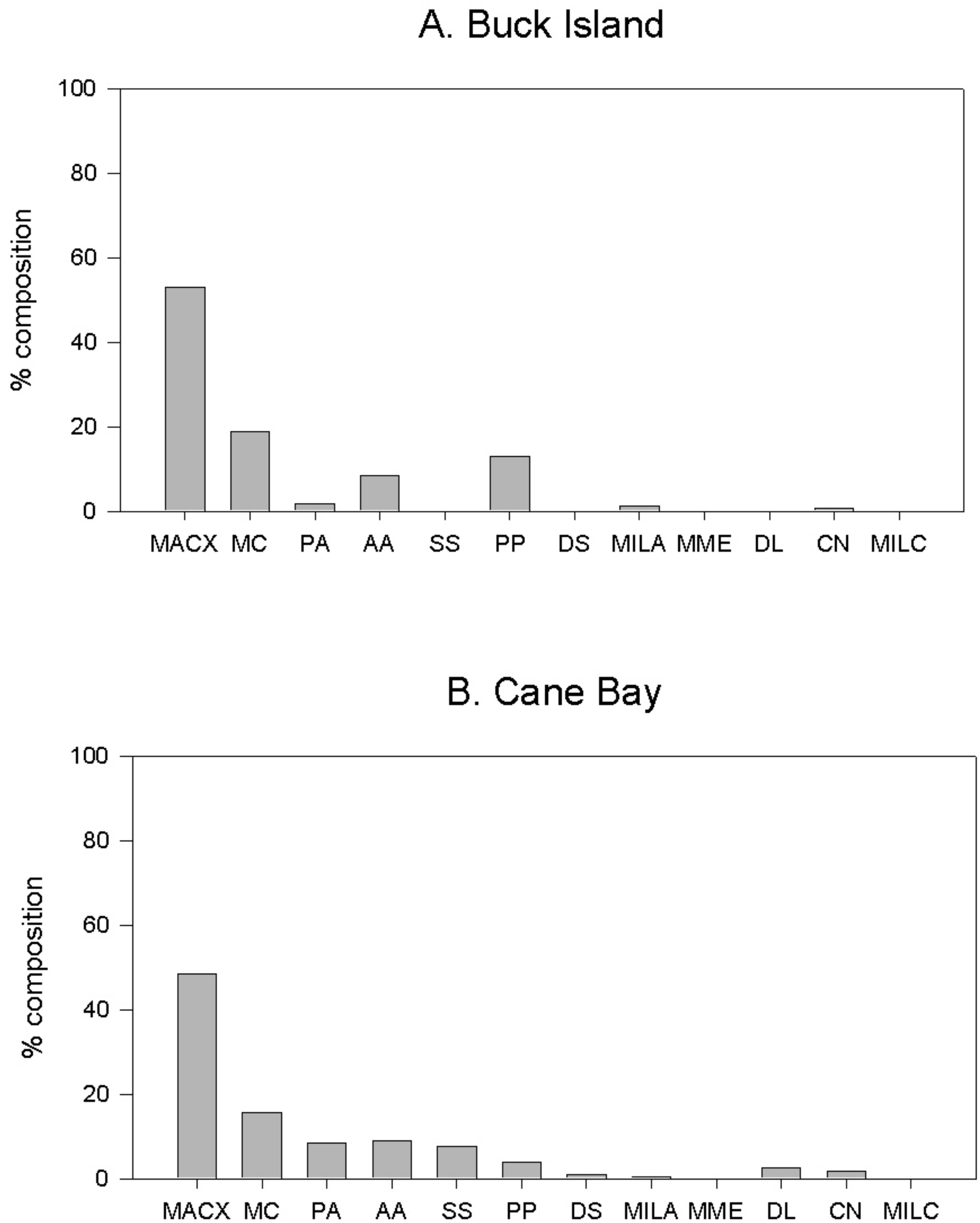



**Fig. 4A, B** Percent of species composition of living coral cover of the most common coral species at A.) Buck Island and B.) Cane Bay. MACX *Montastraea annularis* complex; MC *M. cavernosa;* PA *Porites astreoides;* AA *Agaricia agaricites; SS Siderastrea siderea;* PP *P. porites;* DS *Diploria strigosa;* MILA *Millepora alcicornis;* MME *Meandrina meandrites;* DL *D. labyrinthiformes;* CN *Colpophyllia natans;* MILC *Millepora complanata*.

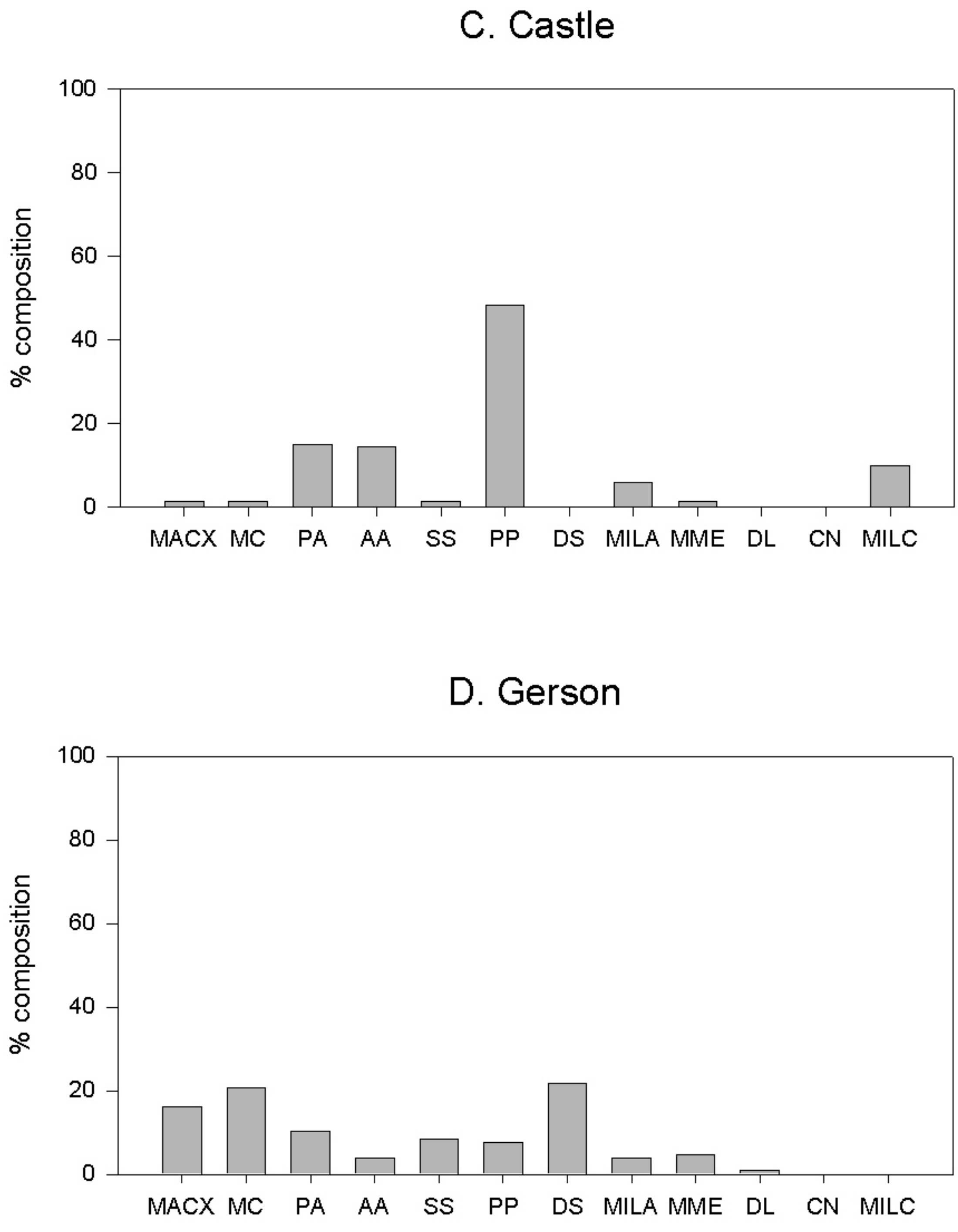
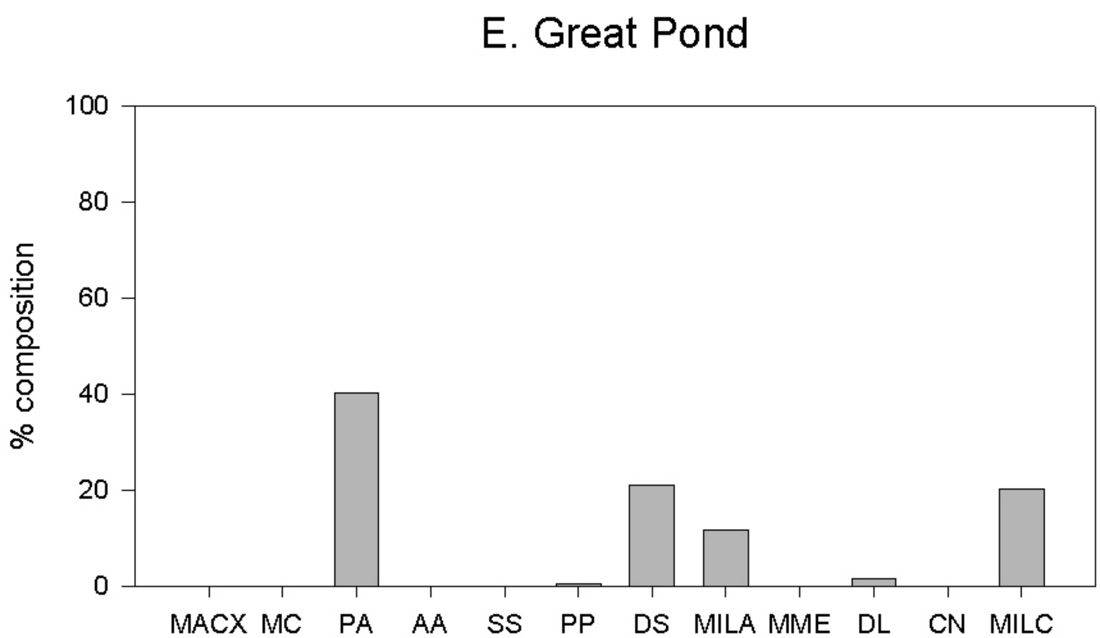



**Fig. 4C, D** Percent species composition of living coral cover of the most common coral species at C.) Castle and D.) Gerson. See figure 4A for species codes.



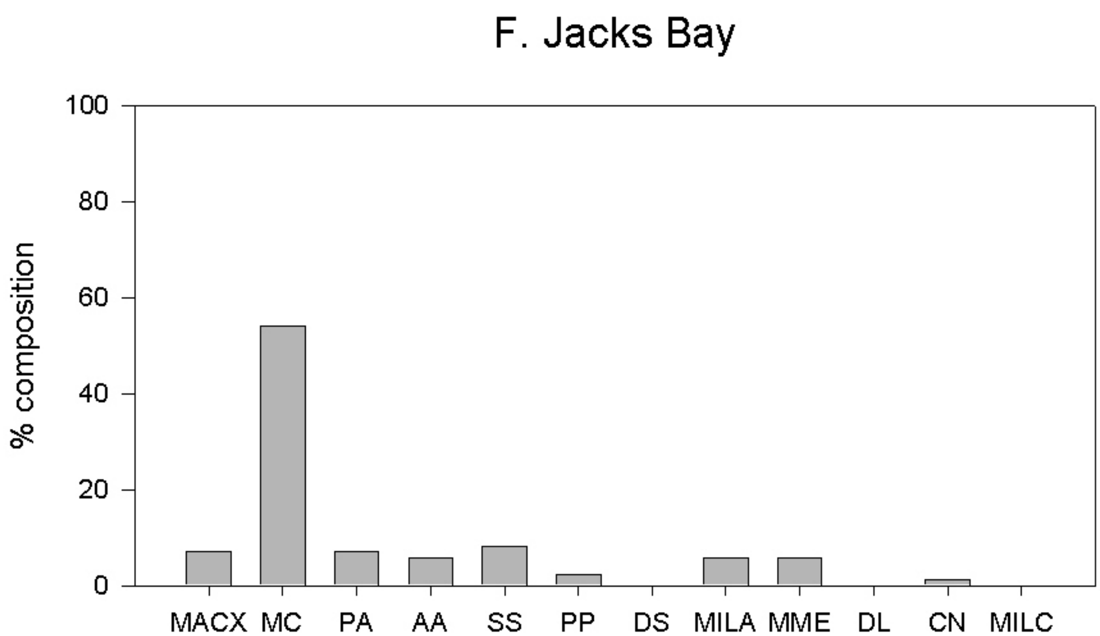
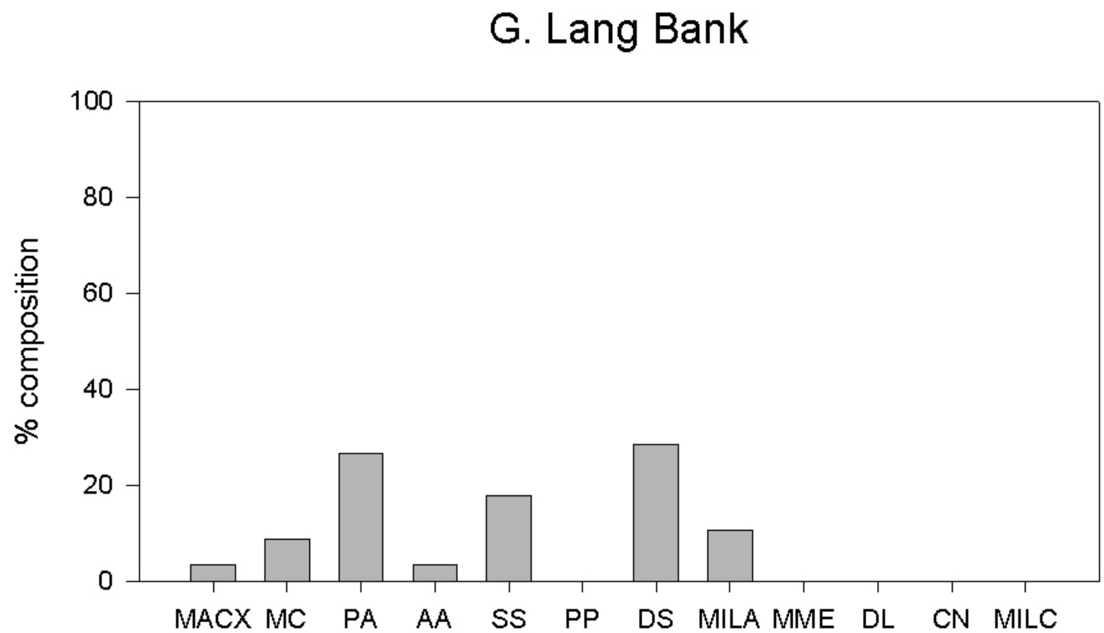




**Fig. 4E, F** Percent species compositon of living coral cover of the most common coral species at E.) Great Pond and F.) Jacks Bay. See figure 4A for species codes.



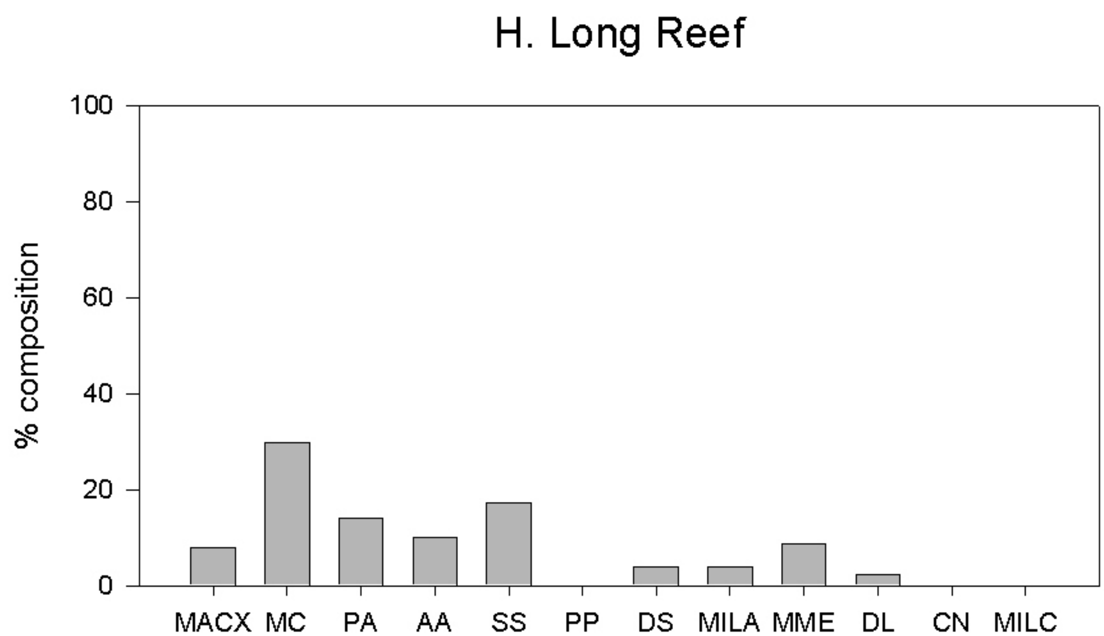
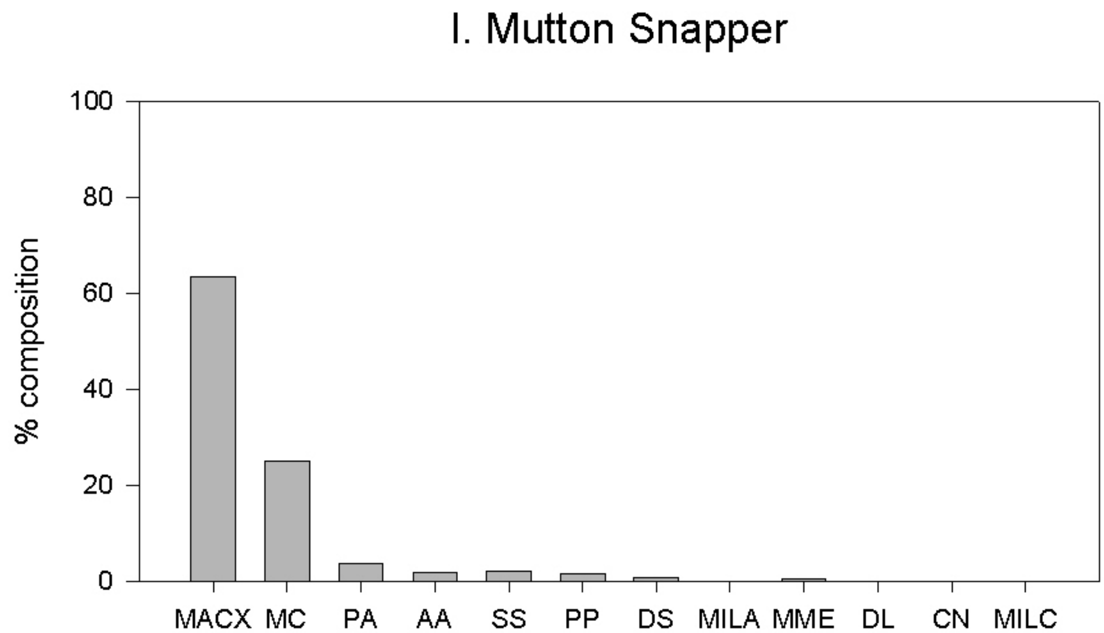




**Fig. 4G, H** Percent species compositio of living coral cover of the most common coral species at G.) Lang Bank and H.) Long Reef/Eagle Ray. See figure 4A for species codes.



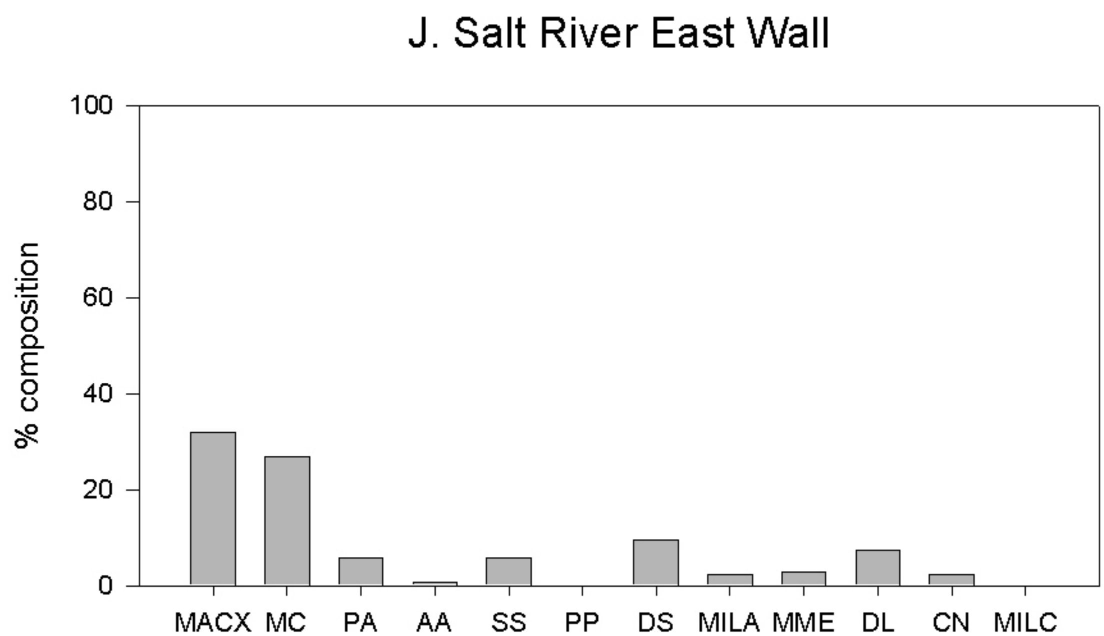




**Fig. 4I, J** Percent species composition of living coral cover of the most common coral species at I.) Mutton Snapper Spawning Site and J.) Salt River East Wall. See figure 4A for species codes.

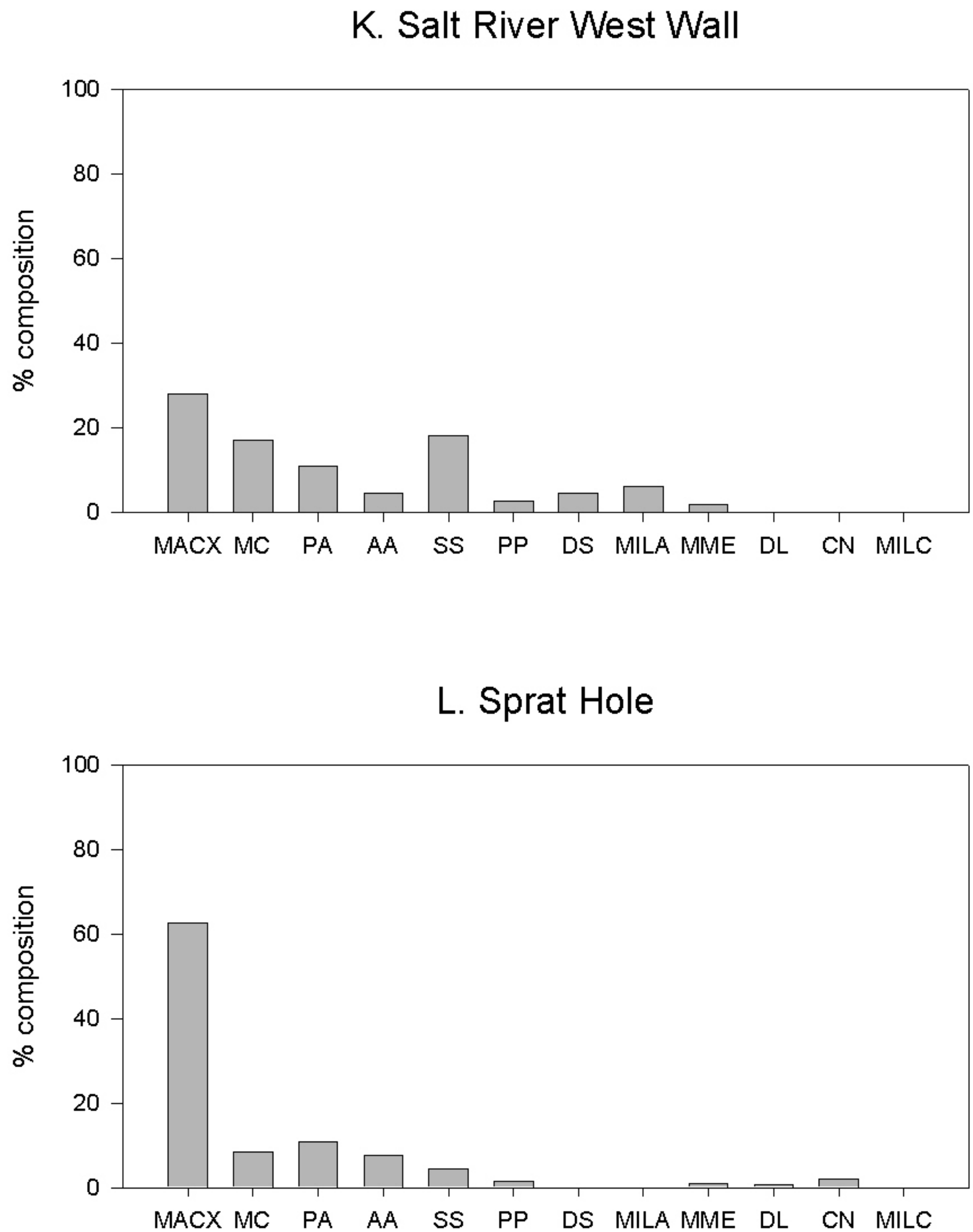



**Fig. 4K, L** Percent species composition of living coral cover of the most common coral species at K.) Salt River West Wall and L.) Sprat Hole. See figure 4A for species codes.

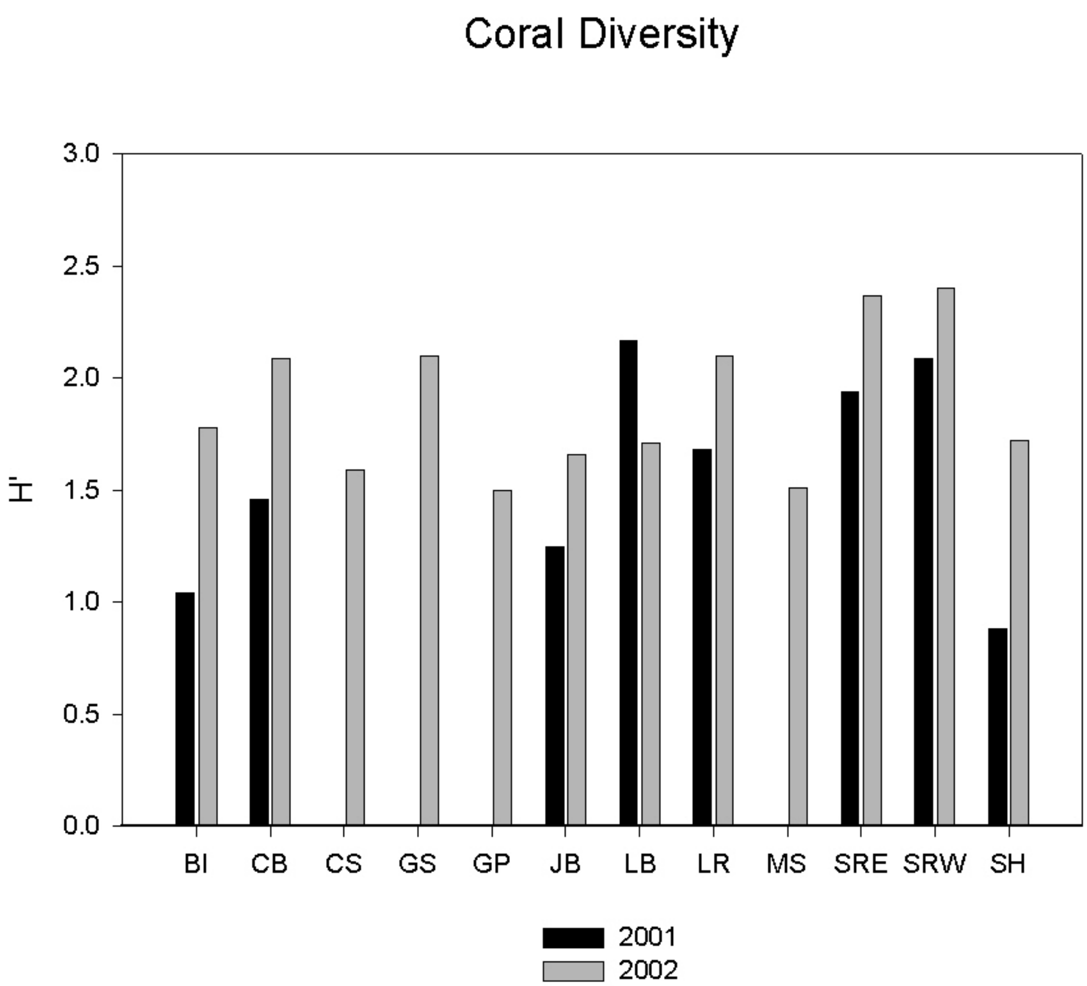
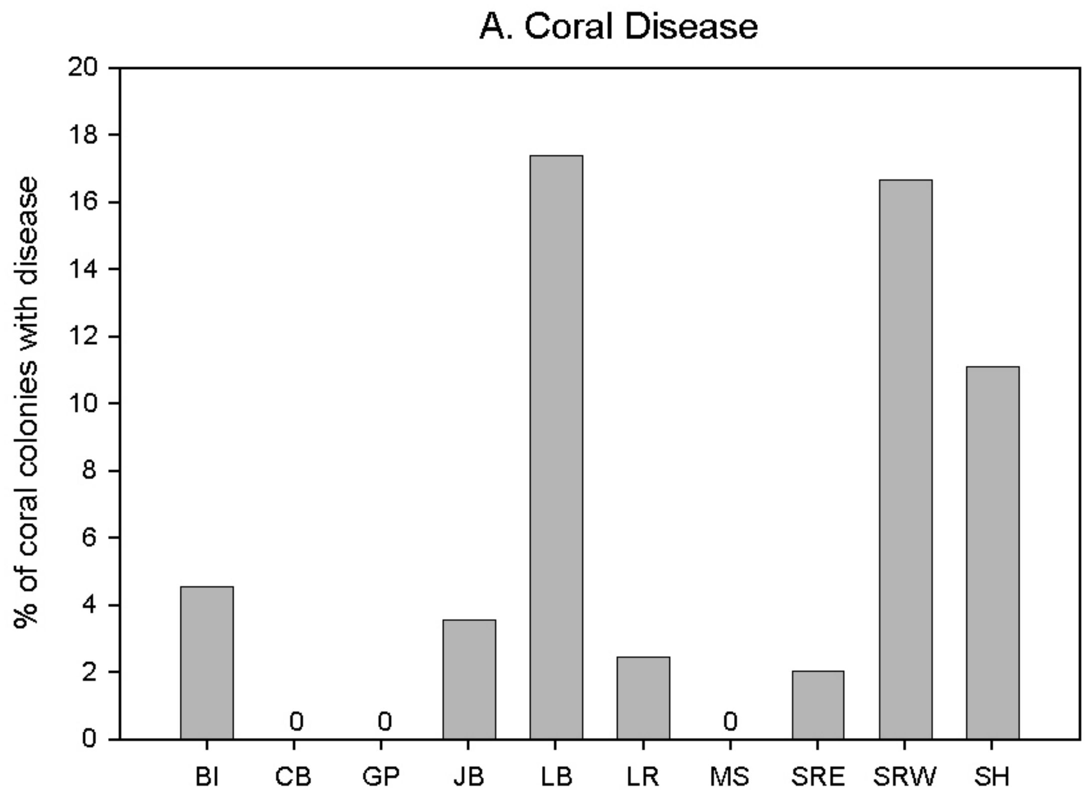



**Fig. 5** Shannon Weaver Diversity Index (H') for corals at twelve monitored sites: BI Buck Island; CS Castle; GS Gerson; GP Great Pond; CB Cane Bay; JB Jacks Bay; LB Lang Bank; LR Long Reef/Eagle Ray; MS Mutton Snapper; SRE Salt River East Wall; SRW Salt River West Wall; SH Sprat Hole. Data collected only in year two for CS, GS, GP, and MS.



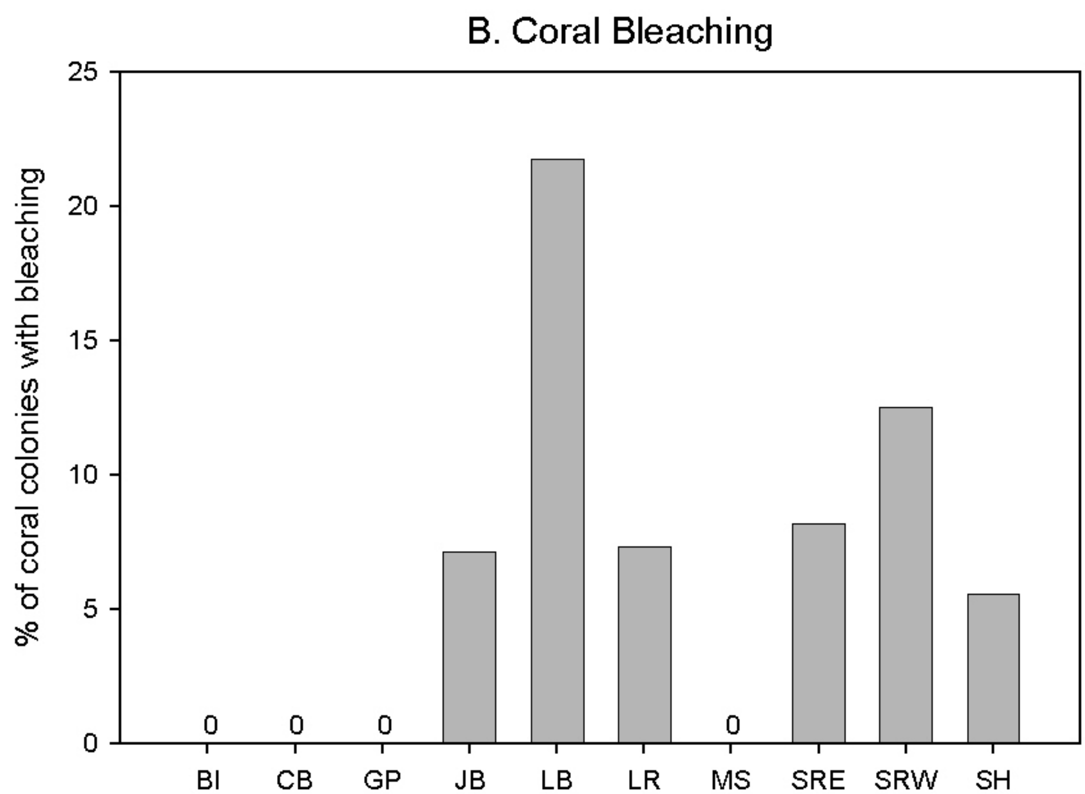
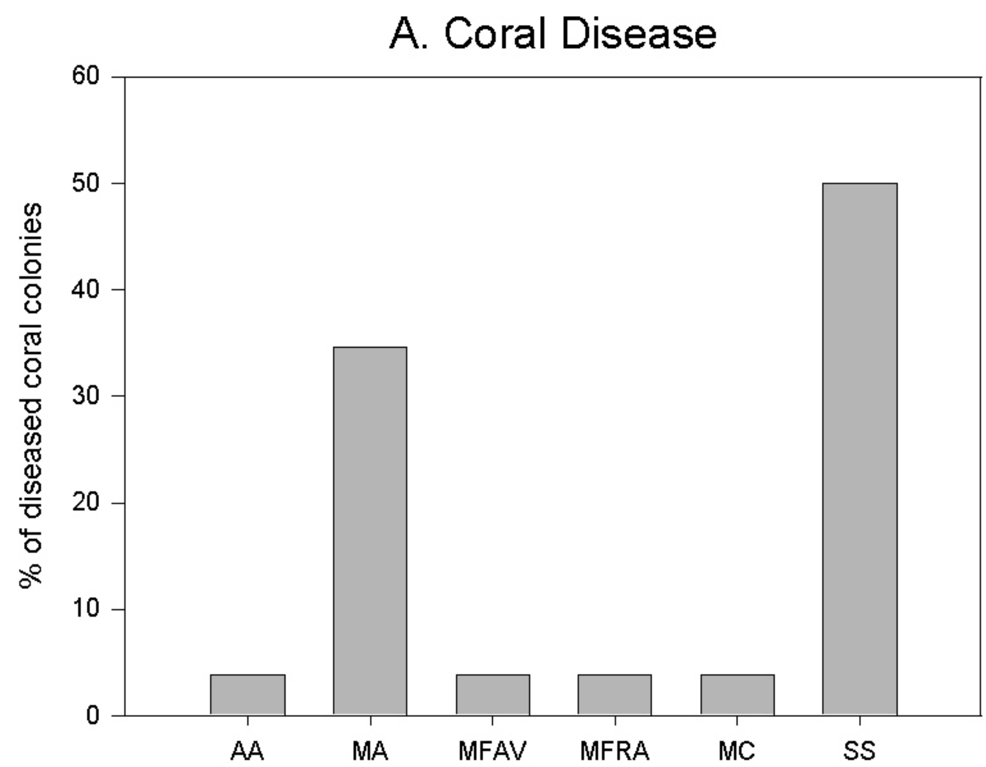




**Fig. 6** Percentage of A.) colonies with disease and B.) colonies with bleaching of all coral colonies sampled at each long-term monitoring site. Percentage calculated by dividing the number of diseased and bleached colonies by the total number of colonies sampled for each site.
BI Buck Island; CB Cane Bay; GP Great Pond; JB Jacks Bay; LB Lang Bank; LR Long Reef;
MS Mutton Snapper; SRE Salt River East Wall; SRW Salt River West Wall; SH Sprat Hole.



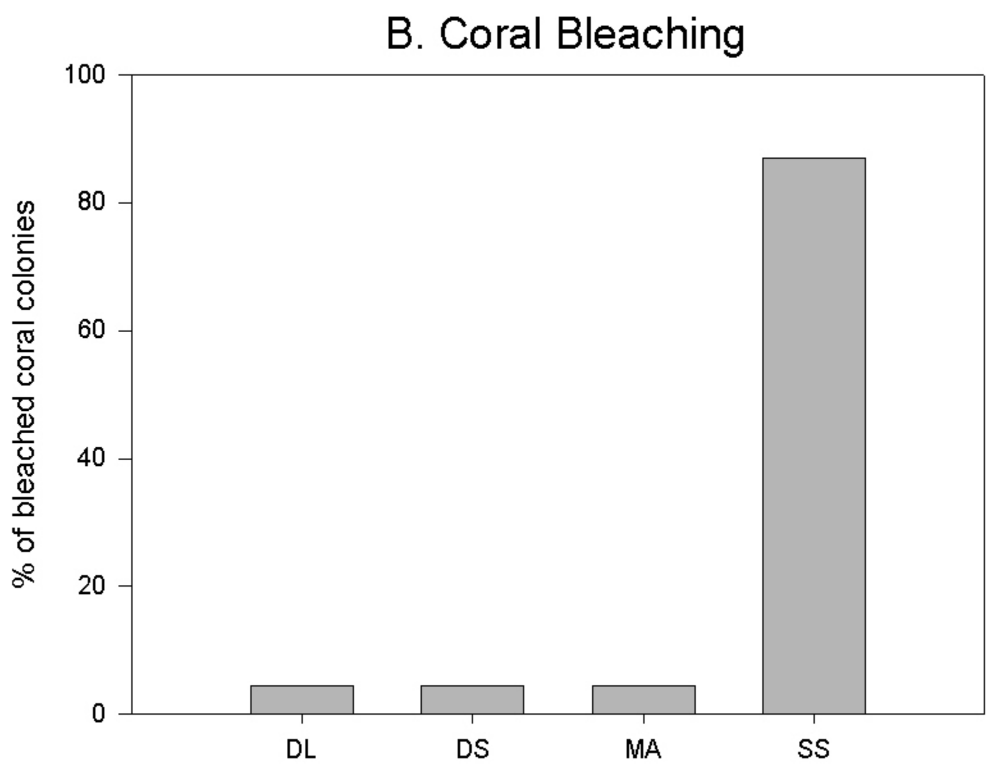




**Fig. 7** Percentage of A.) diseased colonies and B.) bleached colonies of all coral species with disease and bleaching for all long-term monitoring sites (n = 10).
Percentage calculated by dividing the number of diseased and bleached colonies of each species by the total number of diseased and bleached coral colonies, respectively.
AA *Agaricia agaricites*; DL *Diploria labyrinthiformis*; DS *D. strigosa*; MA *Montastaea annularis*; MFAV *M. faveolata*; MFRA *M. franksii*; MC *M. cavernosa*; SS *Siderastrea siderea*.

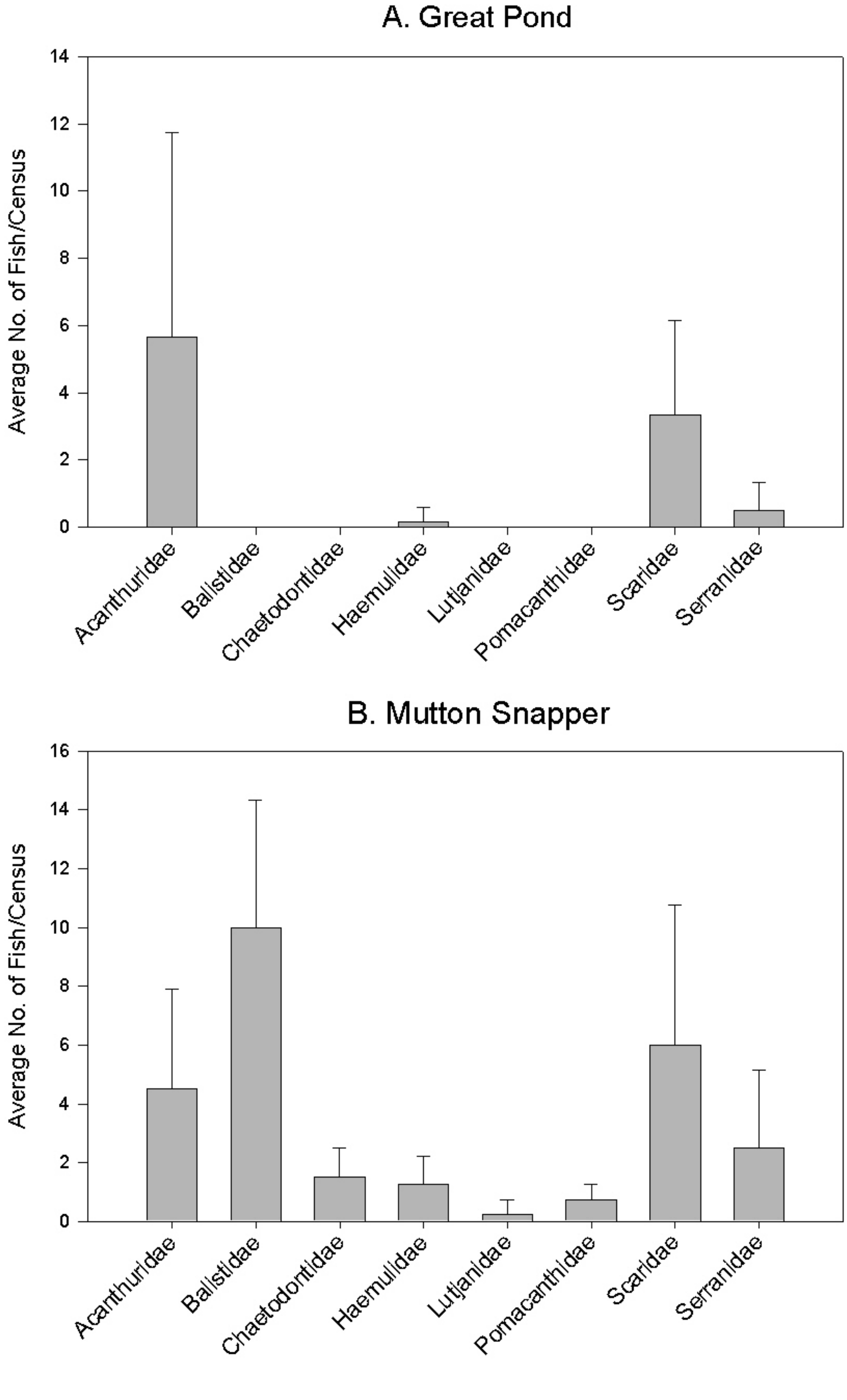



**Fig. 8** Average number of fish observed for each census for eight families of fishes at two long-term monitoring sites. For Great Pond, n = 6 censuses. For Mutton Snapper, n = 4 censuses. Error bars represent standard deviation.

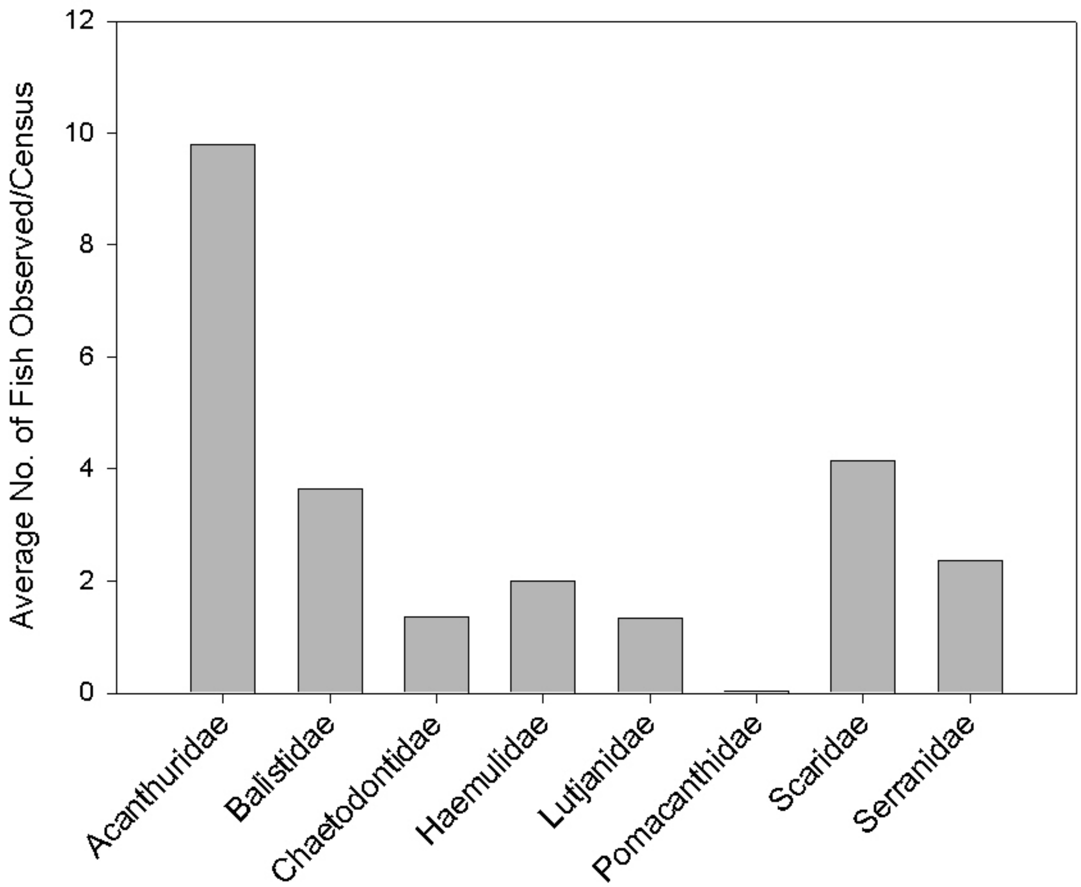



**Fig. 9** Abundance of fish observed in eight families for nine long-term monitoring sites.

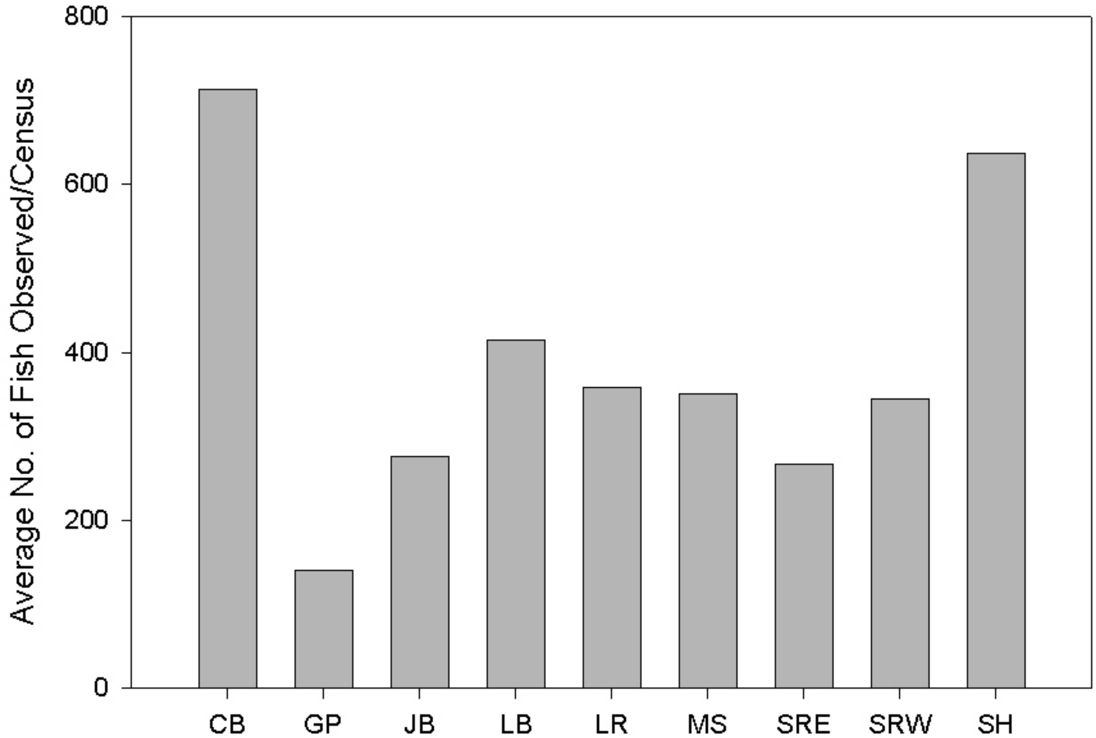



**Fig. 10** Abundance of fish observed in all surveys at nine long-term monitoring sites.
CB Cane Bay; GP Great Pond; JB Jacks Bay; LB Lang Bank; LR Long Reef;
MS Mutton Snapper; SRE Salt River East Wall; SRW Salt River West Wall; SH Sprat Hole.

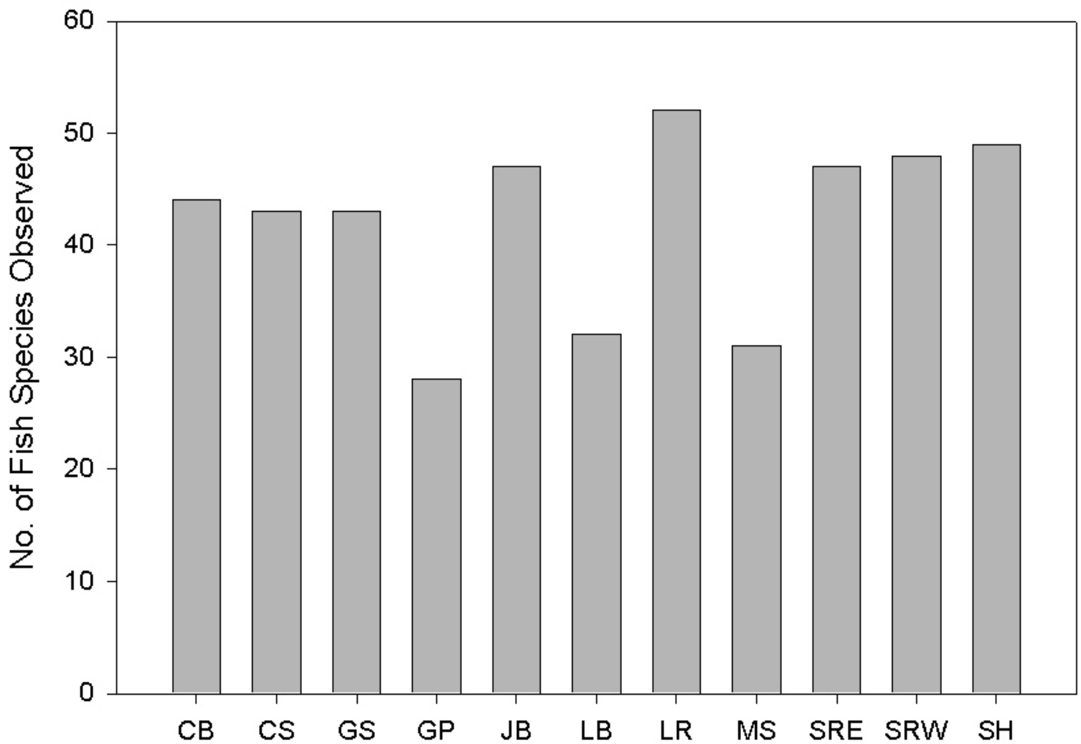



**Fig. 11** Total number of fish species observed in all surveys at nine long-term monitoring sites and two rapid assessment sites. CB Cane Bay; CS Castle; GS Gerson; GP Great Pond; JB Jacks Bay; LB Lang Bank; LR Long Reef; MS Mutton Snapper; SRE Salt River East Wall; SRW Salt River West Wall; SH Sprat Hole.