Baseline Assessment of Fish and Coral Bays, St. John, U.S. Virgin Islands in Support of Watershed Restoration Activities

Part I: Fish, Coral and Benthic Habitats

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Part I: Fish, Coral and Benthic Habitats

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ABOUT THIS DOCUMENT

This report is the first part of a baseline ecological assessment of Coral and Fish Bays, St. John, USVI, being developed by the NOAA National Centers for Coastal Ocean Science. This part provides information on the status of fishes, corals and benthic habitats, and the second part, to be completed in 2013, will provide information on the status of nutrients and contaminants. The purpose of these reports is to provide resource managers with ecological data needed to assess the impacts of watershed stabilization projects on local coral reefs.

These reports supplement other work supported by the NOAA Restoration Center and funded by the American Recovery and Reinvestment Act of 2009 to monitor the ecology of Coral and Fish Bays, but uses data which is not within the scope of ARRA funded work. The majority of data used in this report were collected as part of the NOAA Caribbean Coral Reef Ecosystem Monitoring program (CREMP); a partnership effort between NOAA's Center for Coastal Monitoring and Assessment, the United States (US) Virgin Islands Department of Planning and Natural Resources – Division of Fish and Wildlife, US Geological Survey, National Park Service (NPS), University of the Virgin Islands, and University of Hawaii. This partnership has monitored coral reef ecosystems in the US Virgin Islands and Puerto Rico since 1999 to provide data and monitoring tools for effective management and conservation of coral reef ecosystems.

This report was funded by the Caribbean Coral Reef Institute, NOAA's Coral Reef Conservation Program, NOAA's Center for Sponsored Coastal Ocean Research, the NPS's Natural Resource Preservation Program at Virgin Islands National Park, and NPS's South Florida/Caribbean Inventory and Monitoring Program.

This report summarizes data collected from 2001 through 2010 on fish, corals and benthic habitats in Coral Bay and Fish Bay. These data were also included in a companion report by Friedlander et al. (2012) which examined broad-scale spatial and temporal trends in the coral reef ecosystems around the entire island of St. John, USVI. Where applicable, findings and observations on reef fish and benthic composition from Fish Bay and Coral Bay are presented in context of the broader-scale patterns observed by Friedlander et al. (2012).

For more information on the ARRA-funded USVI Watershed Stabilization Project please visit the Virgin Islands Resource Conservation and Development Council webpage.

For more information on this report and similar NCCOS assessments developed by the Biogeography Branch please visit the NCCOS web page or direct questions and comments to:

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EXECUTIVE SUMMARY

This report provides baseline biological data on fishes, corals and habitats in Coral and Fish Bays, St. John, USVI. A similar report with data on nutrients and contaminants in the same bays is planned to be completed in 2013.

Figure 1. An image of a healthy Caribbean coral reef. Photo credit: NCCOS/CCMA/Biogeography Branch

Data from NOAA's long-term Caribbean Coral Reef Ecosystem Monitoring program was compiled to provide a baseline assessment of corals, fishes and habitats from 2001 to 2010, data needed to assess the impacts of erosion control projects installed from 2010 to 2011. The baseline data supplement other information collected as part of the USVI Watershed Stabilization Project, a project funded by the American Recovery and Reinvestment Act of 2009 and distributed through the NOAA Restoration Center, but uses data which is not within the scope of ARRA funded work.

We present data on 16 ecological indicators of fishes, corals and habitats. These indicators were chosen because of their sensitivity to changes in water quality noted in the scientific literature (e.g., Rogers 1990, Larsen and Webb 2009). We report long-term averages and corresponding standard errors, plot annual averages, map indicator values and list inventories of coral and fish species identified among surveys. Similar data will be needed in the future to make rigorous comparisons and determine the magnitude of any impacts from watershed stabilization.

Over the course of ten years 30 distinct species of coral and 194 species of fish were observed in Coral Bay, and 21 species of coral and 84 species of fish were observed in Fish Bay. As is common in most coral reefs in the USVI, algae cover was one of the most abundant taxonomic components of the benthic communities in both bays and live coral cover was generally low. Plots of indicators over time and maps of indicators across space showed variation among fishes, corals and habitats across a range of spatial and temporal scales. Although many reefs in both bays were dominated by algae, pockets of coral refuges with very high coral cover were identified in Coral Bay and sites with healthy seagrass beds were found in Fish Bay (Figure 1). These observed patterns in the spatial occurrence and abundance of algae, live coral, and reef fishes were similar with and reflected the broader-scale spatial patterns observed by Friedlander et al. (2012) around the island of St. John.

The CREMP monitoring dataset investigated in this report offers a dataset which is well distributed in space and time for management strata similar in size to Coral Bay. For smaller strata like Fish Bay the monitoring program offered too little information to prepare rigorous baseline data. More data will be needed within Fish Bay in the future to better understand spatio-temporal heterogeneity.

Accurately defining the spatial and temporal heterogeneity in these bays is critical to assessing the baseline status among corals, fishes and habitats, and detecting any future impacts to coral reef communities resulting from watershed improvements. The variability described in this report underscores the need for sampling replicates throughout each bay and over time. These data can effectively be used in a BACI (Before, After, Control, Impact) design to conclusively assess impacts. Continued monitoring of Coral and Fish Bays will be needed to provide sufficient data to detect and understand changes among coral reefs.

1. BACKGROUND

Coral reefs are among the most productive and diverse ecosystems in the world (Bryant et al. 1998), and provide a variety of goods and services ranging from commercial and subsistence fisheries, tourism and recreation, sources of new medicines, to natural coastal protection against storms. Worldwide, coral reef ecosystems are declining at an alarming rate (Wilkinson 2004, Bellwood et al. 2004, Pandolfi et al. 2005) and the U.S. Virgin Islands (USVI) is no exception (Rogers and Beets 2001, Jeffrey et al. 2005, Rogers et al. 2008a, 2008b).

Caribbean coral reefs have changed dramatically in the past 40 years, with live coral cover estimated to have declined by 80% and many reefs exhibiting a new ecosystem steady-state dominated by macroalgae (Hughes 1994, Gardner et al. 2003). Numerous natural and anthropogenic stressors such as coral diseases (Miller et al. 2009), hurricanes (Rogers et al. 1991), anchor damage (Rogers and Garrison 2001), and loss of herbivores due to overfishing (Rogers et al. 2008a) have negatively impacted coral reefs. To reduce stressors and improve the health of coral reefs, coastal managers in the USVI have implemented marine protected areas, fishing restrictions, reef monitoring programs, and land use management strategies (see Waddell and Clarke 2008 for compilation).

In 2010, over $2.7 million was awarded through the American Recovery and Reinvestment Act (ARRA) of 2009 (www.recovery.gov; award 39857) and distributed through the NOAA Restoration Center to conduct targeted watershed stabilization projects in the USVI and reduce terrestrial runoff. Sediments in the water column resulting from terrestrial runoff are a key cause of coral reef degradation among many local reefs (Figure 2; Dahl 1985, Rogers 1990). There is ample evidence to show that terrestrial runoff and related increases in nearshore sedimentation, nutrient enrichment and turbidity can degrade coral reefs by impacting coral growth and survival, reproduction and recruitment, and population interactions (Rogers 1990, Richmond 1993, Fabricius 2005).

The USVI watershed stabilization project, funded by ARRA and led by the Virgin Islands Resource Conservation and Development Council (VIRCDC), has reduced sediment runoff through road stabilization and native plantings, and the reef monitoring sites were implemented to evaluate sediment reduction measures in Coral and Fish Bays on St. John. The project was designed using watershed management plans developed by the VIRCDC, the Virgin Islands Department of Planning and Natural Resources and other partners, and included community outreach and education. To assess the effectiveness of watershed stabilization, the project includ-

Figure 2. Sediment plumes along coasts adjacent to reefs can introduce nutrients, toxins, pathogens, and sediment onto reefs, smothering and otherwise damaging reef ecosystems (left). Photo credit: NOAA Restoration Center. Sediment plume initiating from the mouth of a river in Puerto Rico enters a bay, impacting local reefs (right). Photo credit: Dave Burdick, http://coralreef.noaa.gov/threats/pollution/

ed plans to monitor sediment runoff (e.g., Ramos-Scharrón 2012), as well as ecological conditions in receiving bays.

This report provides supplemental information to the VIRCDC scope of work by presenting and analyzing ten years of monitoring data collected in Fish and Coral Bays, St. John, USVI (Figure 3). Most of the used data were collected as part of the NOAA's Caribbean Coral Reef Ecosystem Monitoring program (CREMP), and provide a critical long-term dataset before erosion control measures were completed in 2011. For example, as management actions are implemented to reduce sediment and other contaminant loads entering Coral Bay and Fish Bay, the rigorous assessment of fishes, corals and benthic habitats presented in this report, will provide a baseline against which future changes in benthic composition, habitats, reef fish assemblages, and coral community structure could be measured, and ultimately correlated with watershed improvements.

2. STUDY SITES

The island of St. John is part of the US Virgin Islands and is located east of Puerto Rico in the Caribbean Sea. The island has undergone tremendous ecological changes in the past three hundred years altering its forests and coral reefs. To protect the island's cultural and natural resources, the **Vi**rgin **Is**lands National Park (VIIS) and the **V**irgin **I**slands **C**oral **R**eef National Monument (VICR) were established in 1956 and in 2001, respectively. Marine portions of VIIS were added in 1962. The parks cover approximately 58% of the island of St. John and a significant amount of the surrounding coral reefs. In addition to federally managed areas, the U.S. Virgin Islands Department of Planning and Natural Resources (DPNR) designated 18 Areas of Particular Concern throughout the U.S. Virgin Islands, three of which occur on St. John and one of which is Coral Bay.

The seascape surrounding the island of St. John consists of coral reefs, sparsely colonized hardbottoms, seagrass beds, algal meadows and sand plains (Kendall et al. 2001). The underwater environment has also seen dramatic changes caused by anthropogenic and natural disturbances. Intensive fishing has caused the loss of several spawning aggregations, as well as severe declines in size and abundance of important reef fish species (Beets and Friedlander 1999, Beets and Rogers 2002). Hurricanes, thermal events, coral diseases and biological phase shifts have destroyed some coral reefs and seagrass beds, and led to an ecosystem that is now dominated by macroalgae (Rogers and Beets 2001, Beets and Rogers 2002, Miller et al. 2006).

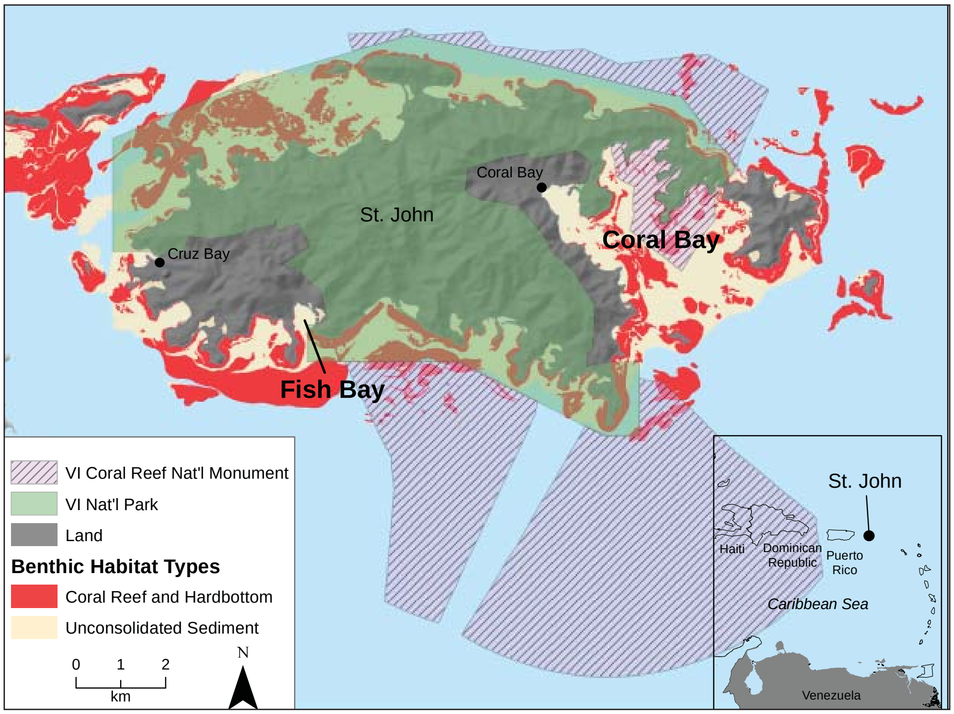

Figure 3. A map of St John with the study sites of Fish Bay and Coral Bay identified.

2.1 Coral Bay

Coral Bay is a large bay on the eastern side of St. John. DPNR identified it as an Area of Particular Concern due to its proximity to human populations and unique physical and biological attributes. Approximately 30% of the bay is within the VICR and the rest is in territorial waters (Figure 4).

Coral Bay is 13.3 km^2 and encompasses over 16 km of shoreline, including some of St. John's largest salt ponds, extensive mangrove habitat, seagrass beds and fringing reefs. The bay links to the largest catchment area on St. John draining into an individual bay (Figure 3). Coral Bay supports protected *Acropora* corals and sea turtle nesting areas and may be an important juvenile habitat for several commercially important fisheries species such as yellowtail snapper, schoolmaster snapper, and several species of parrotfishes (Friedlander et al. 2012). Hurricane Hole is likely the most pristine nursery habitat remaining in the USVI (Boulon 1992).

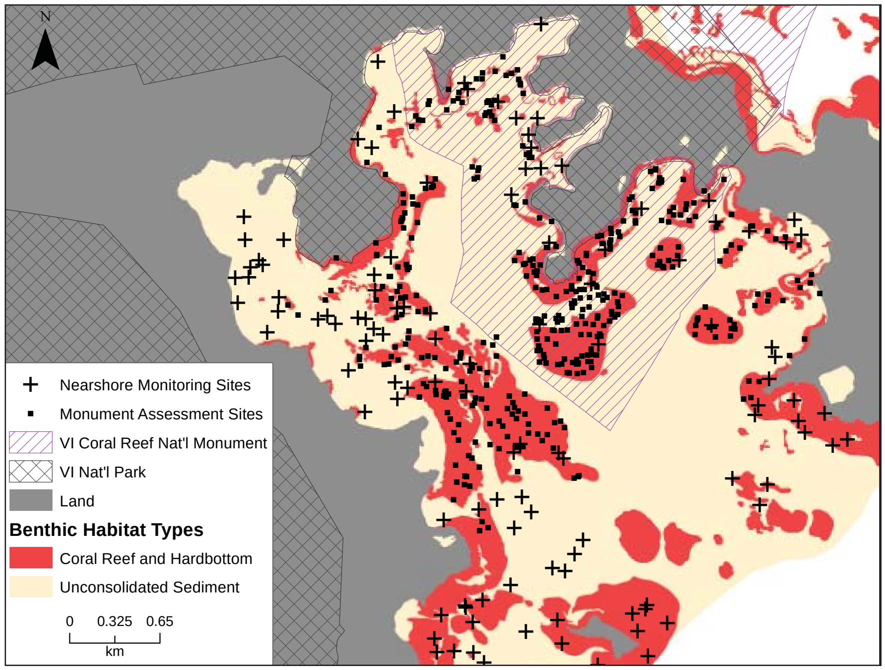

Figure 4. Map of Coral Bay study sites.

The watershed adjacent to Coral Bay is characterized by steep slopes (averaging 18% grade, with a large percentage over 35%), highly erodible soils, and high runoff volumes associated with average rain events. These factors, combined with numerous dirt roads, active construction, and a lack of storm water management, have contributed to excessive sediment loading to the bay (Devine et al. 2003, Ramos-Scharrón and MacDonald 2005, Brooks et al. 2007). In addition, the watershed experienced an approximate 80% population increase between 1990 and 2000, making it the fastest growing area in the USVI. The Coral Bay Community Council, Inc. (CBCC), a local nonprofit watershed management association, identified erosion and bay sedimentation as priority issues threatening both marine ecosystem health and the community's quality of life.

2.2 Fish Bay

Fish Bay is a small bay on the south shore of St. John. Although it is less than 1 km^2 and significantly smaller than Coral Bay, Fish Bay is also an area of management concern and was identified as a high management priority by coral reef managers to achieve stable, sustainable coral reef ecosystems (USVI and CRCP 2010). Fish Bay is connected to a watershed with a significant land surface area draining into an individual bay on St. John and includes extensive mangrove habitat, seagrass beds and coral reefs (Figure 5). A portion of the eastern side of the bay is within the limits of VIIS. The watershed adjacent to Fish Bay is characterized by steep slopes, highly erodible soils, and high runoff volumes that occur during rain events.

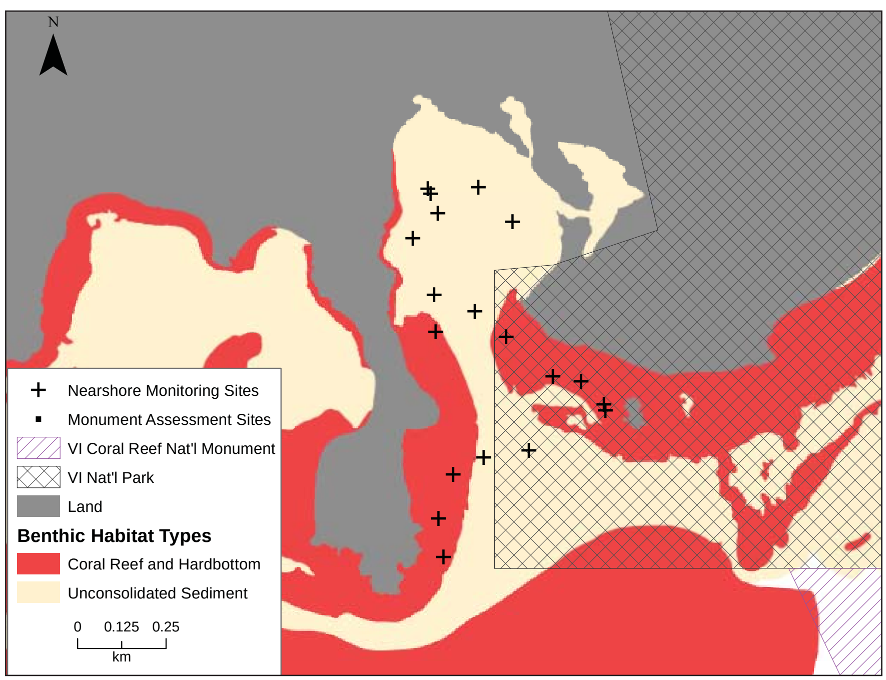

Figure 5. Map of Fish Bay study sites.

3. METHODS

3.1 Field survey methods

NOAA's Caribbean Coral Reef Ecosystem Monitoring program (CREMP) monitored coral reefs around the island of St. John using underwater visual surveys (Menza et al. 2006). Surveys began in 2001 and were conducted annually in the month of July. Divers or snorkelers surveyed fish, coral and benthic habitat along a 25 m long × 4 m wide belt transect (Figure 6). Fish were identified, counted, and sized. Benthic habitat measurements included: habitat type, physical (e.g., sand, rubble, reef) and biological (e.g., algae, coral, seagrass) cover, rugosity, and depth. Survey sites were selected using a stratified random sampling design incorporating hard and soft benthic habitat type strata derived from NOAA's nearshore benthic habitat maps (Kendall et al. 2001), and two management strata; inside VICR and outside VICR. Comprehensive descriptions of the measurement methods and sampling design are available online at: http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish/protocols.aspx.

Figure 6. NOAA trained observers recording fish species abundance and body length along a timed belt transect (left); and benthic habitat composition recorded within a quadrat (right).

Two distinct methodologies were used to acquire benthic information in Coral Bay: a comprehensive habitat assessment to evaluate the reef ecosystem and a rapid habitat assessment to measure the efficacy of marine protected areas. The comprehensive habitat assessment (CHA) used quadrats to increase precision of measurements and collected detailed species-level information. Alternatively, the rapid habitat assessment (RHA) collected data using visual estimation for the whole transect, and measured benthos in broad taxonomic categories (i.e., algae, stony coral, gorgonians, sponges, etc.). The comprehensive assessment was conducted around the entire island of St. John on hardbottom and softbottom habitats, while the RHA was implemented inside and adjacent to VICR and only on hardbottom sites. The RHA was implemented after several years of using the comprehensive assessment in order to decrease bottom time and increase the number of dives a survey team could perform during a sampling mission. Fish Bay was sampled only using the CHA and fishes were surveyed using the same protocol independent of the benthic methodology.

Although CREMP has surveyed over 1,000 sites while monitoring the coral reef ecosystem around St. John, this report examines only sites within the limits of Fish Bay and Coral Bay (Figures 4 and 5). Since 2001, 530 and 19 surveys have been conducted in Coral and Fish Bays, respectively. There are fewer surveys conducted in Fish Bay, because it is a much smaller bay. The 19 sites allocated in Fish Bay include five sites surveyed by NCCOS in 2010 which were outside of the normal monitoring program and were added for this report.

3.2 Data Analysis

This report focuses on 16 ecological indicators to assess the status of fishes, corals and benthic habitats (Table 1). These indicators were chosen because of their potential sensitivity to changes in water quality noted in the scientific literature (Rogers 1990, Larsen and Webb 2009). For each indicator we present long-term averages, corresponding standard errors and the probability of occurrence. We also plot annual averages, map indicator values and list inventories of all coral and fish species identified among surveys.

Percent cover estimates reflect the amount of a benthic component detected on a transect, and probability of detection is the probability a taxa or habitat type is detected on a transect. Species richness is defined as the number of species in a specific taxonomic category (i.e., corals, fish). Species diversity refers to the Shannon diversity index. Branching corals include: *Acropora cervicornis*, *Acropora palmata*, *Dendrogyra cylindrus*, *Porites porites*, *Madracis formosa*, *Madracis decactis*, and *Madracis mirabilis*. Groupers include species in the genera: Mycteroperca, Cephalopholis and Epinephelus. Total live coral cover estimates are taken from summing hard (stony), soft (octocoral) and hydrocoral taxa.

Table 1. Coral reef indicators used to report the baseline condition of corals, fishes and habitats in Fish and Coral Bays, St. John, USVI.

Coral Reef Indicators	
% Hard coral cover	Counts of All Fish
% Soft coral cover	Counts of Grunts
% Hydrocorals cover	Counts of Snappers
% Bleached coral cover	Counts of Parrotfish
% Branching coral cover	Counts of Groupers
Coral richness	Diversity of All Fish
% Algae cover	Biomass of All Fish
% Seagrass cover	Number of Fish Species

Analyzed data were extracted from the CREMP database by selecting sites within the limits of Coral Bay and Fish Bay (see Figures 4 and 5 for extracted sites in each bay). Summary statistics for benthic metrics were derived separately for transects using the comprehensive habitat assessment stratified by habitat and using the rapid habitat assessment. In Coral Bay, CHA and RHA habitat and coral data were not merged due to irreconcilable differences in precision, species detection and type of data collected. In Fish Bay, only CHA data was collected. Fish data collected among all sites for each bay were merged since the same protocol was used to assess the fish community. Habitat and fish data collected before 2003 were omitted from assessments of the long-term average and annual variation because of low sampling effort and changes to the sampling design. Measurements of coral bleaching began in 2006 and consequently only 2007-2010 data are presented. Species inventories reflect all species observed from 2001 to 2010. All summary statistics were calculated using JMP (SAS Inc., v. 9.0.0).

Interpolations for fish, corals, benthic cover, and other site specific data were accomplished using the ArcGIS 10.0 Spatial Analyst extension interpolation tool. The method utilized was Inverse Distance Weighted (IDW). IDW assumes that each measured point has a local influence that diminishes with distance and weights the points closer to the prediction location greater than those farther away. Barrier polygons representing the boundaries of study regions of Coral Bay and Fish Bay were used to limit the interpolations to areas where monitoring was conducted. IDW is a useful tool to visualize general spatial patterns in point data, but should be used with a full understanding that it only incorporates spatial correlation among sample locations, does not incorporate anisotropy, and is not an exact interpolator.

4. RESULTS

4.1 Coral Bay

Over the course of ten years 30 distinct species of coral and 194 species of fish were observed in Coral Bay (see Appendix C for species lists). Sampling was predominantly on hardbottom sites and where water visibility was greater than 2 meters. Large areas of Coral Bay, especially shallow bays with significant terrestrial runoff, such as Coral Harbor and the upper reaches of Hurricane Hole, were not sampled due to poor visibility. Areas deeper than 30 m were also not surveyed due to SCUBA diving constraints.

One of the principal reasons CREMP uses belt transects to collect data instead of point counts (i.e., visual surveys within a relatively large cylinder) is to gather as much data as possible even in areas of limited visibility. This choice has no doubt increased the amount of data available for studies in areas like Coral Bay where turbidity in the water column can be high.

As is common in most coral reefs in the USVI, algae cover was one of the most abundant taxonomic components of the benthic community. Estimates of algae cover among hardbottom habitats ranged from 32.6% to 21.8%, depending on the method used to collect data, and among softbottom sites was 37.4% (Table 2). Corresponding estimates of total live coral were 17.9%, 8.5%, and 3.6%.

Table 2. Long-term averages for coral reef indicators in Coral and Fish Bays, St. John, USVI. Averages are provided separately for each habitat survey and bottom type combination. CHA = comprehensive habitat assessment. RHA = rapid habitat assessment. The long-term mean, standard error and probability of detection are represented by x, SE and P, respectively. The (-) symbol indicates the indicator was not measured or was not detected in sufficient quantities to make a valid estimate.

INDICATOR	Coral Bay									Fish Bay					
	CHA Softbottom Sites			CHA Hardbottom Sites			RHA Sites			CHA Softbottom Sites			CHA Hardbottom Sites		
	x	SE	P	x	SE	P	x	SE	P	x	SE	P	x	SE	P
% Hard coral cover	2.15	0.88	0.55	5.25	1.59	0.80	5.92	0.91	0.98	0	N/A	0.00	1.15	0.39	0.47
% Soft coral cover	1.36	0.56	0.49	3.00	0.86	0.96	11.9	1.73	0.93	0	N/A	0.00	1.02	0.40	0.42
% Hydrocorals cover	0.11	0.05	0.39	0.22	0.08	0.98	-	-	-	0	N/A	0.00	0.11	0.05	0.32
% Bleached coral cover	0.07	0.04	0.09	0.18	0.08	0.20	-	-	-	0	N/A	0.00	0.01	0.01	0.16
% Branching coral cover	0.14	0.06	0.34	0.43	0.12	0.68	-	-	-	0	N/A	0.00	0.06	0.03	0.21
Coral species richness	9.67	1.69	0.55	11.2	1.41	0.98	-	-	-	0	N/A	0.00	4.10	1.22	0.47
% Algae cover	37.4	7.68	0.98	21.8	4.82	0.98	32.6	1.02	0.99	20.7	14.3	1.00	46.8	10.0	1.00
% Seagrass cover	7.97	3.50	0.40	-	-	-	-	-	-	19.2	4.51	1.00	1.51	0.86	0.21

Estimates of algae and coral were quite variable in time (Appendix A) and in space (Appendix B) across Coral Bay. Among individual survey sites, estimates of live coral and algae cover varied from 0% to 90% and 1% to 90%, respectively. Together, comprehensive and rapid habitat assessments identified 148 sites where live coral cover was greater than 20% and 15 sites greater than 50%. Sites with relatively high coral cover may indicate refuge areas where stressors are low or where demographic processes have resulted in resilient populations. The reefs in the northeast of Coral Bay, specifically in Round Bay and south of Turner Point, tended to possess sites with the highest coral cover compared to other reefs in Coral Bay (Appendix B).

Table 3. Long-term averages for coral reef fish indicators in Coral and Fish Bays, St John, USVI (N=517 and N=19, respectively). The long-term mean, standard error and probability of detection of indicators are represented by x, SE and P, respectively. The (-) symbol indicates the indicator was not measured or was not detected in sufficient quantities to make a valid estimate.

INDICATOR	Coral Bay			Fish Bay		
	x	SE	P	x	SE	P
Counts of All Fish	228.26	41.98	1.00	202.58	7.94	0.89
Counts of Grunts	39.62	27.24	0.56	0.95	0.31	0.42
Counts of Snappers	3.90	0.87	0.63	2.68	0.77	0.58
Counts of Parrotfish	30.51	3.26	0.95	21.52	6.22	0.74
Counts of Groupers	1.89	0.20	0.46	0.32	0.17	0.21
Diversity of All Fish	1.78	0.15	-	2.18	0.01	-
Biomass of All Fish	4211.85	785.28	-	20933.00	2330.00	-
Number of Fish Species	20.05	0.91	-	24.21	0.39	-

Grunts and parrotfish were major components of the fish assemblage detected in Coral Bay (~17% and ~13%) (Table 3). Other investigated fish families tended to proportionally contribute much less to the long-term average fish community density estimate (< 2%). We found that most sites had few grunts, but several sites had much higher numbers and these schools had an enormous influence on the long-term average density estimate. The map of grunt density in Appendix B shows this heterogeneous distribution pattern well. In contrast to grunts, parrotfish were more cosmopolitan and are found in moderate numbers among more sites. These distinct characteristics in spatial variability were mirrored in corresponding plots of temporal variability (Appendix A). For instance, parrotfish density was relatively similar among years and standard errors were small, and grunt density fluctuated greatly over time and standard errors were very large in some years.

4.2 Fish Bay

A total of 19 sites distributed over nine years were surveyed in Fish Bay. Across all sites, 84 species of fish and 21 species of coral were sighted (Appendix C). Sampling was distributed throughout the Bay and included both hardbottom (N=14) and softbottom (N=5) habitats. Unlike Coral Bay, depth and visibility did not regularly constrain surveys.

Due to its size, in most years one or two sites were sampled in Fish Bay and due to random site placement around the island of St. John, sites were not placed within Fish Bay in 2006. We did not find it appropriate to calculate annual estimates from so few data in each year. Tables 2 and 3 show long-term averages of investigated community metrics calculated from combining all years of data in Fish Bay without stratification by year.

Algae covered 47% of hardbottom sites and 21% of softbottom sites and were the predominant benthic cover among all sites (Table 2). Algae covered more than 80% of the seafloor on four of the 14 hardbottom sites and exceed 13% on only one softbottom site. Seagrass covered 1.5% and 19.2% of hardbottom and softbottom sites, respectively, and wherever algae cover was low, seagrass cover was relatively high. Average total live coral cover was 2.3% among hardbottom sites and there weren't any sites with more than 9% total live coral cover. Approximately four species of corals were observed on average among hardbottom sites and no corals were found on softbottom sites. Branching corals, soft corals, and hydrocorals were uncommon in Fish Bay.

Although the cumulative number of fish species and individuals observed in Fish Bay were lower than in Coral Bay, average estimates of diversity and biomass per transect were higher in Fish Bay (Table 3). Tangs, wrasses and parrotfishes were the most commonly observed fishes, while groupers, snappers and grunts were rare. Parrotfish were the most common investigated taxonomic group, comprising about 10% of all observed fishes. Fish Bay has the undesirable distinction of being the first place a lionfish (*Pterois volitans*) was detected among CREMP sites. A single lionfish was observed in Fish Bay in 2010. Lionfish are an invasive species from the Pacific Ocean, which has spread throughout the Caribbean after first being sighted in 1985 off the coast of Florida (Whitfield et al. 2002).

5. DISCUSSION

Fish and Coral Bays have dynamic coral reef communities, exhibiting variation among fishes, corals and habitats across a range of spatial and temporal scales. Both bays showed characteristics of a degraded coral reef community (e.g., Hughes 1994) with low coral cover and high algae cover, yet surveys identified pockets of coral refuges with very high coral cover in Coral Bay and sites in Fish Bay with healthy seagrass beds.

Interestingly, Friedlander et al. (2012) found that parts of Coral Bay were among the areas with highest coral richness, coral cover, and structural complexity in St. John. In addition, these areas of high coral cover and richness in Coral Bay also correlated with hotspots of several fish assemblage metrics such as richness, numerical abundance, biomass, and diversity (Friedlander et al. 2012). Furthermore, the broader scale analyses by Friedlander et al. (2012) suggest that Coral Bay may be an important juvenile habitat for commercially important fisheries species such as Yellowtail Snapper, Schoolmaster Snapper, and several species of parrotfishes. These ecosystem attributes along with the nursery function of the Coral Bay area highlights the importance and need to mitigate known stressors through watershed improvements.

Accurately defining the spatial and temporal heterogeneity of natural resources in these bays is critical to assessing the baseline status among corals, fishes and habitats, and detecting changes to coral reef communities resulting from watershed improvements. Without information on spatial and temporal heterogeneity, any identified changes to the community could debatably correspond to differences in sampling effort, natural variation or unmeasured anthropogenic impacts. This is the critical issue with any study attempting to detect measurable changes due to some management action. Both baseline and monitoring data have to be completely comparable and of fine enough resolution that changes are apparent and measurable. The variability described in this report underscores the need for sampling replicates throughout each bay and throughout time.

Long-term and consistent monitoring data are needed to critically assess the impacts of runoff on coral reefs and the differential effects from other impacts (e.g., fishing, hurricanes, bleaching, anchoring). Coral reef ecosystems are dynamic and the magnitude and periodicity of disturbances greatly affect spatiotemporal patterns observed on coral reefs (Done et al. 1991, Connell 1997). To adequately identify and evaluate changes, monitoring needs to be conducted over time scales commensurate with the periodicity and spatial scale of disturbance events.

The CREMP monitoring dataset investigated in this report offers a dataset which is well distributed in space around the island of St. John. Hundreds of surveys were collected over ten years in Coral Bay, providing information on natural variation and long-term trends present before watershed improvements were put in place. These data can effectively be used in a BACI (Before, After, Control, Impact) design to conclusively assess impacts (Underwood 1994), and if needed allows for multiple control sites to be investigated and compared to impacted sites.

For smaller strata like Fish Bay, survey densities collected in CREMP are too low to offer a rigorous baseline. Too few data were collected to provide information on natural variation or long-term trends. In Fish Bay and other areas with similar amounts of data, only major community changes, such as phase shifts or catastrophes, will be generally detectable. A targeted survey with more sites in Fish Bay is needed to provide sufficient data to adequately measure spatial and temporal variation. Friedlander and Beets (2008) offer an alternative dataset, but is limited in spatial scope.

The data described in this report must be compared to similar data collected in the future to assess impacts of watershed improvements. We have presented information on key ecological attributes using a conventional framework to simplify the task of compiling and analyzing this information in future comparisons.

According to Rogers (1990) one might expect to see the following changes in coral communities if watershed improvements reduce sedimentation: higher species diversity and live coral cover; a smaller proportion of corals resistant to smothering from sediments, like branching corals or soft corals; larger coral colonies; higher recruitment and growth rates; and a downward shift in depth zonation. Much less is known about how fishes are affected by runoff and sedimentation.

Changes to fishes, corals and benthic habitats related to changes in terrestrial runoff may not be clearly identifiable. Several studies have shown that different fish and coral species and habitats are affected by changes in runoff and sedimentation unequally and responses will vary over space and time (Rogers 1990, McClanahan and Obura 1997, Airoldi 2003). These differences are generally attributed to characteristics of the depositional environment, species life histories, the surrounding seascapes and historical patterns. A continuation of CREMP or a new well-planned survey program with spatiotemporal replicates and a broad taxonomic scope will maximize the probability of accurately assessing future community changes.

The indicators examined in this report were chosen to identify some of the expected changes by Rogers (1990), but not all possible changes can be measured using data collected by CREMP (e.g., coral recruitment). Other work by the University of the Virgin Islands and the Southeast Fisheries Science Center funded by ARRA and yet to be published will examine additional fish, coral and habitat indicators. Taken together this report and these future ARR-funded reports will provide a more comprehensive assessment of the coral reef communities than either assessment on its own.

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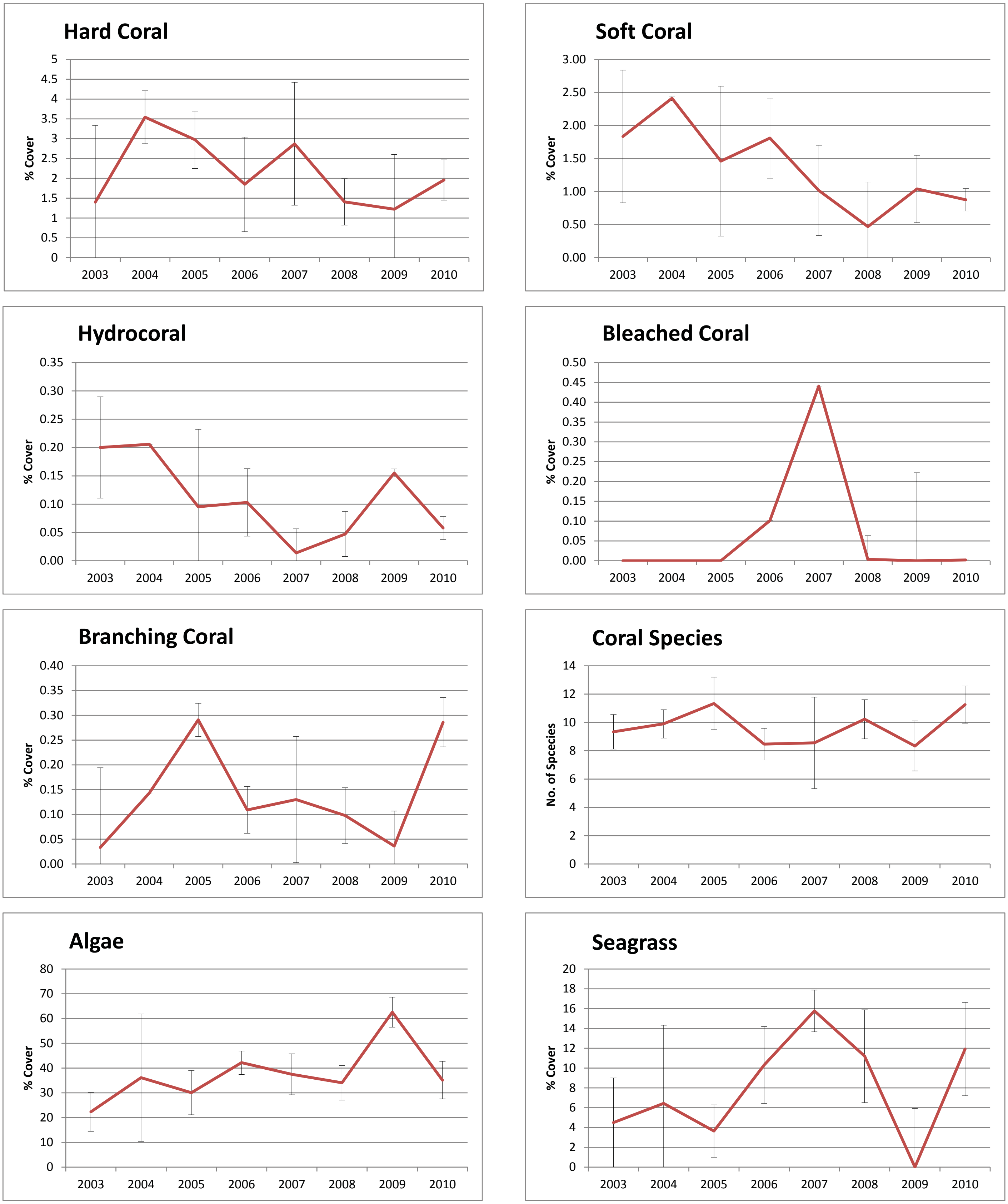

Figure A1. Annual means in percent hard coral cover, soft coral cover, hydrocoral cover, bleached coral cover, branching coral cover, number of coral species, algae cover, and seagrass cover between 2003 and 2010 in Coral Bay, St. John, USVI. Error bars show annual standard errors.

APPENDIX A: PLOTS OF ANNUAL VARIATION IN REEF COMMUNITY INDICATORS IN CORAL BAY

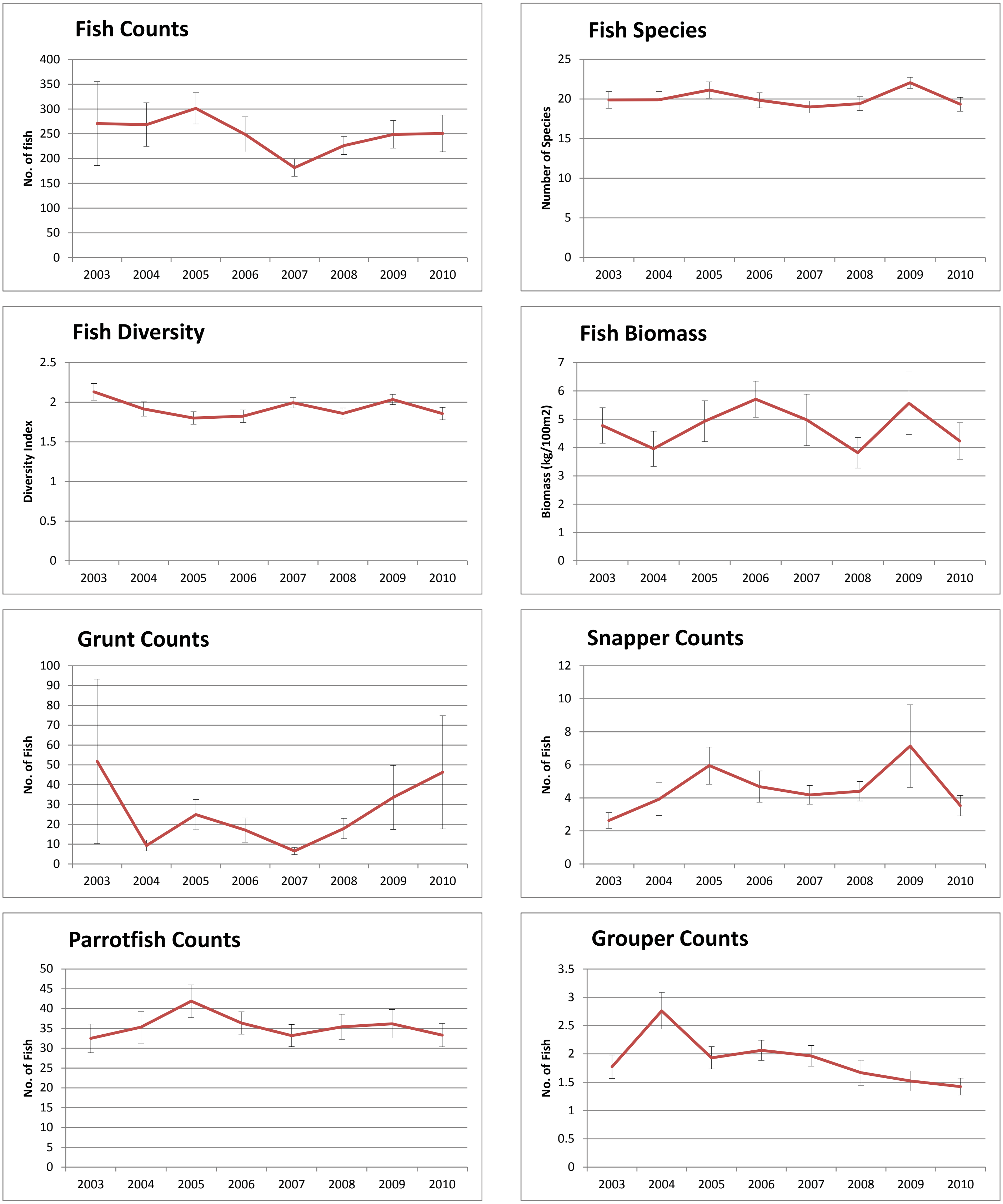

Figure A2. Annual means in fish community diversity metrics and counts of important taxonomic families between 2003 and 2010 in Coral Bay, St. John, USVI. Error bars show annual standard errors.

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

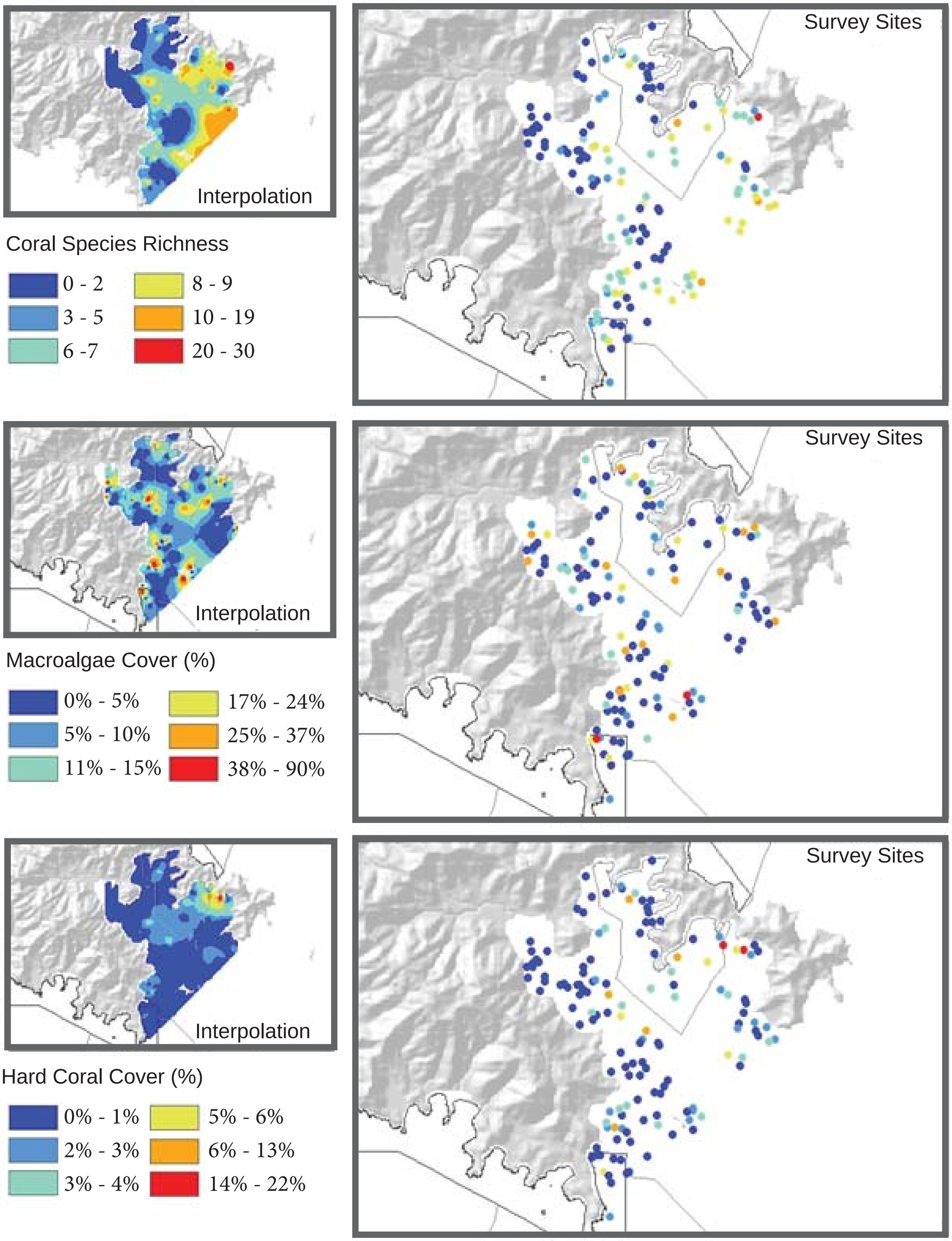

Figure B1. Maps of coral species richness, macrolagae cover, and hard coral cover at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

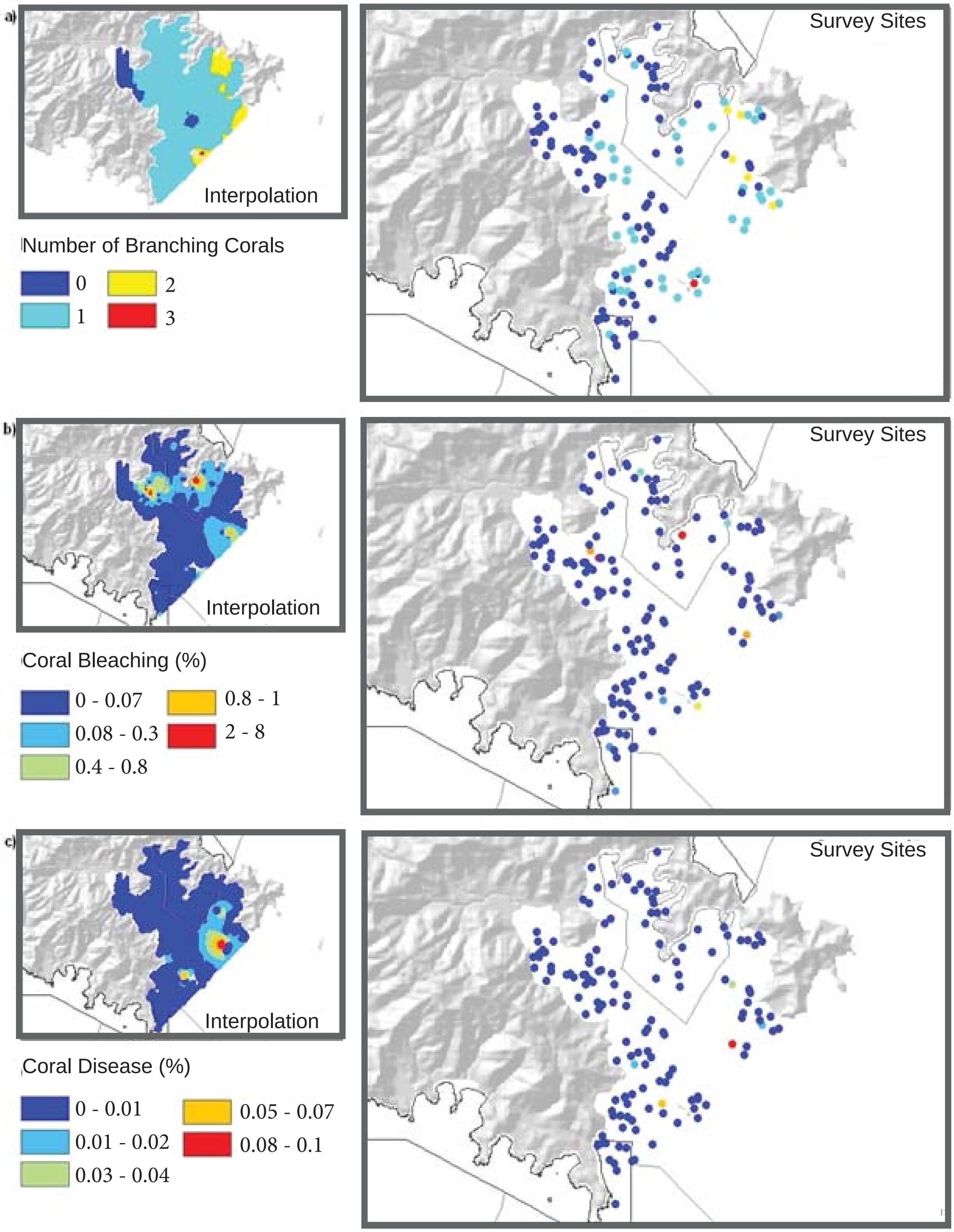

Figure B2. Maps of branching corals, coral bleaching, and coral disease at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

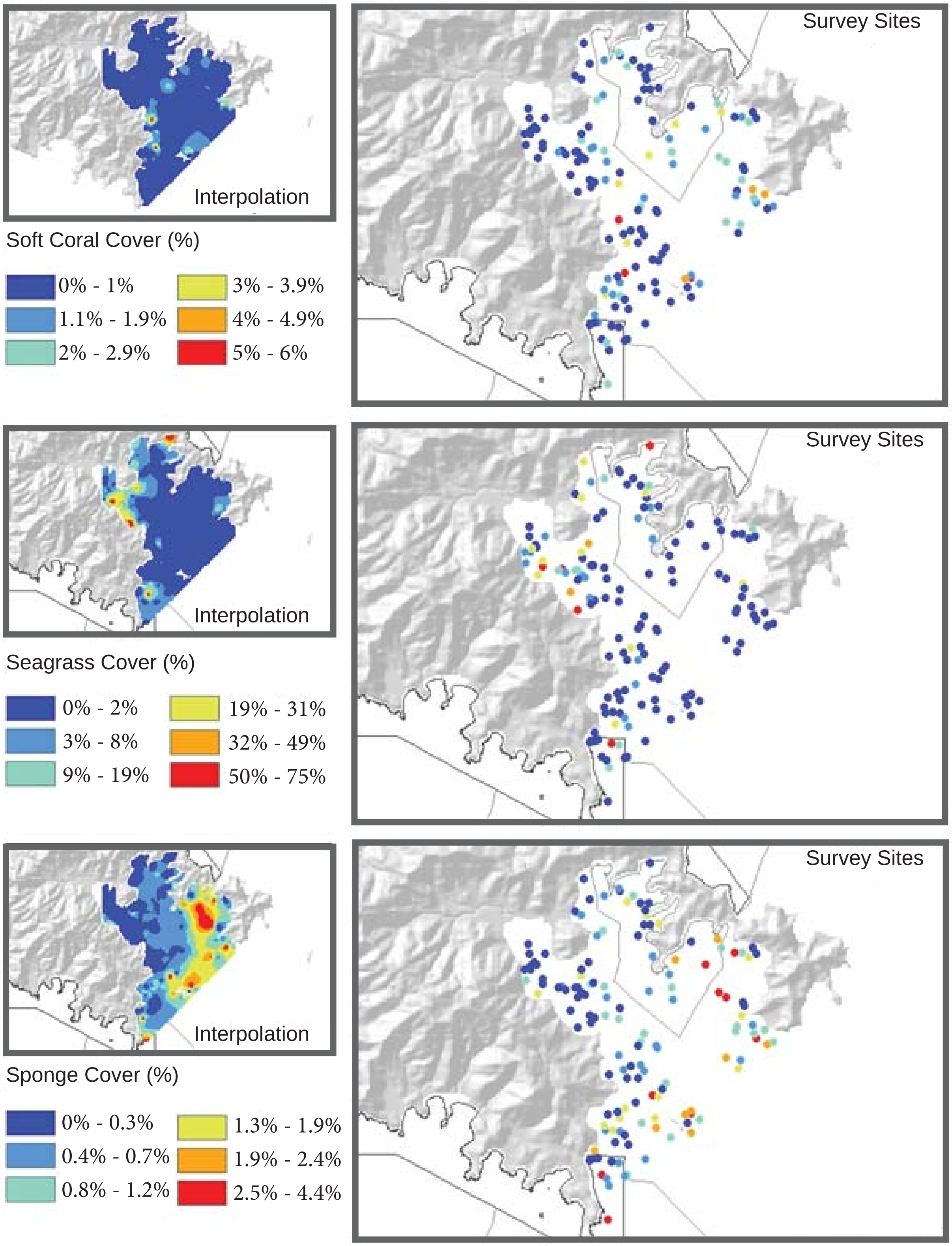

Figure B3. Maps of soft coral cover, seagrass cover, and sponge cover at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

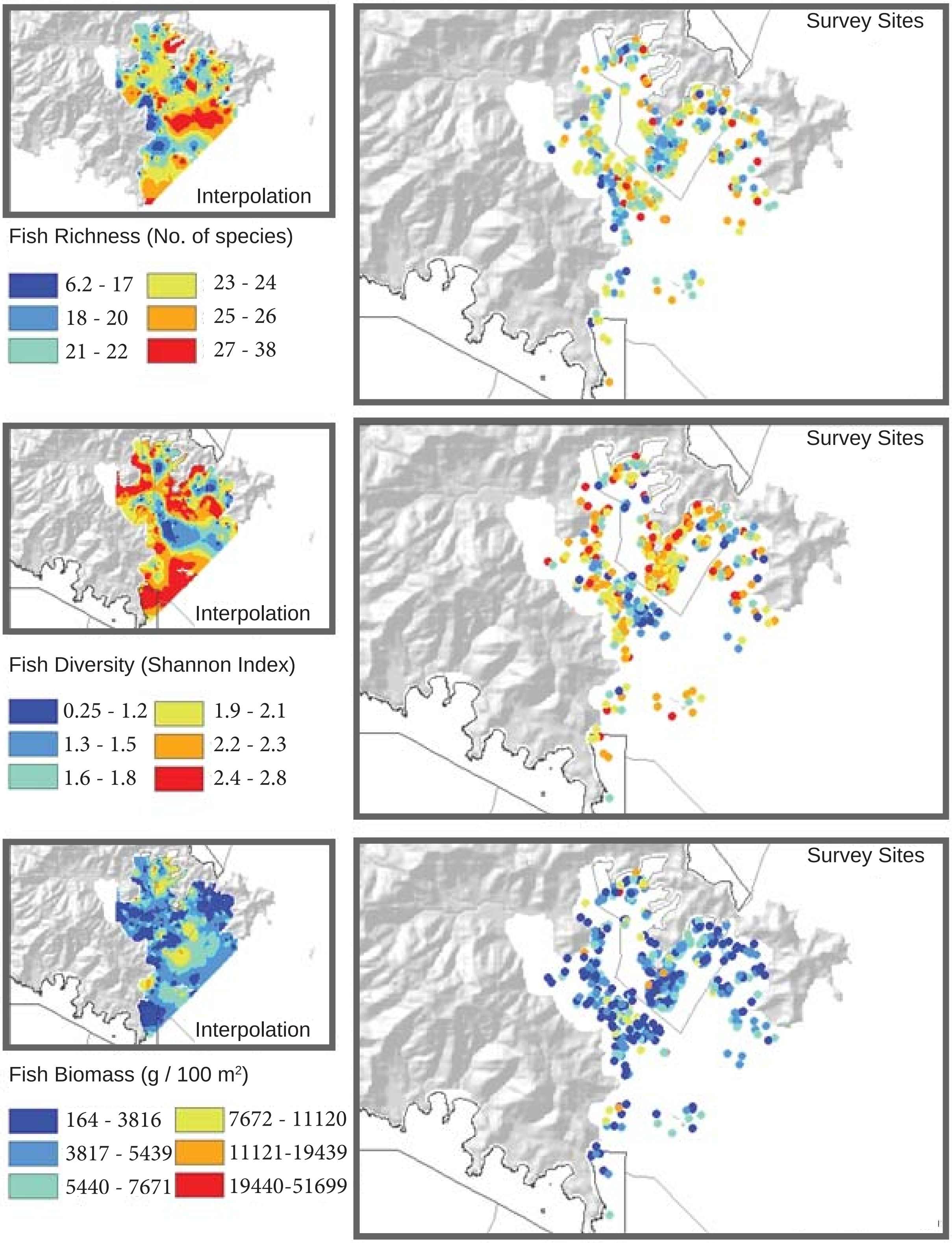

Figure B4. Maps of fish richness, fish diversity, and fish biomass at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

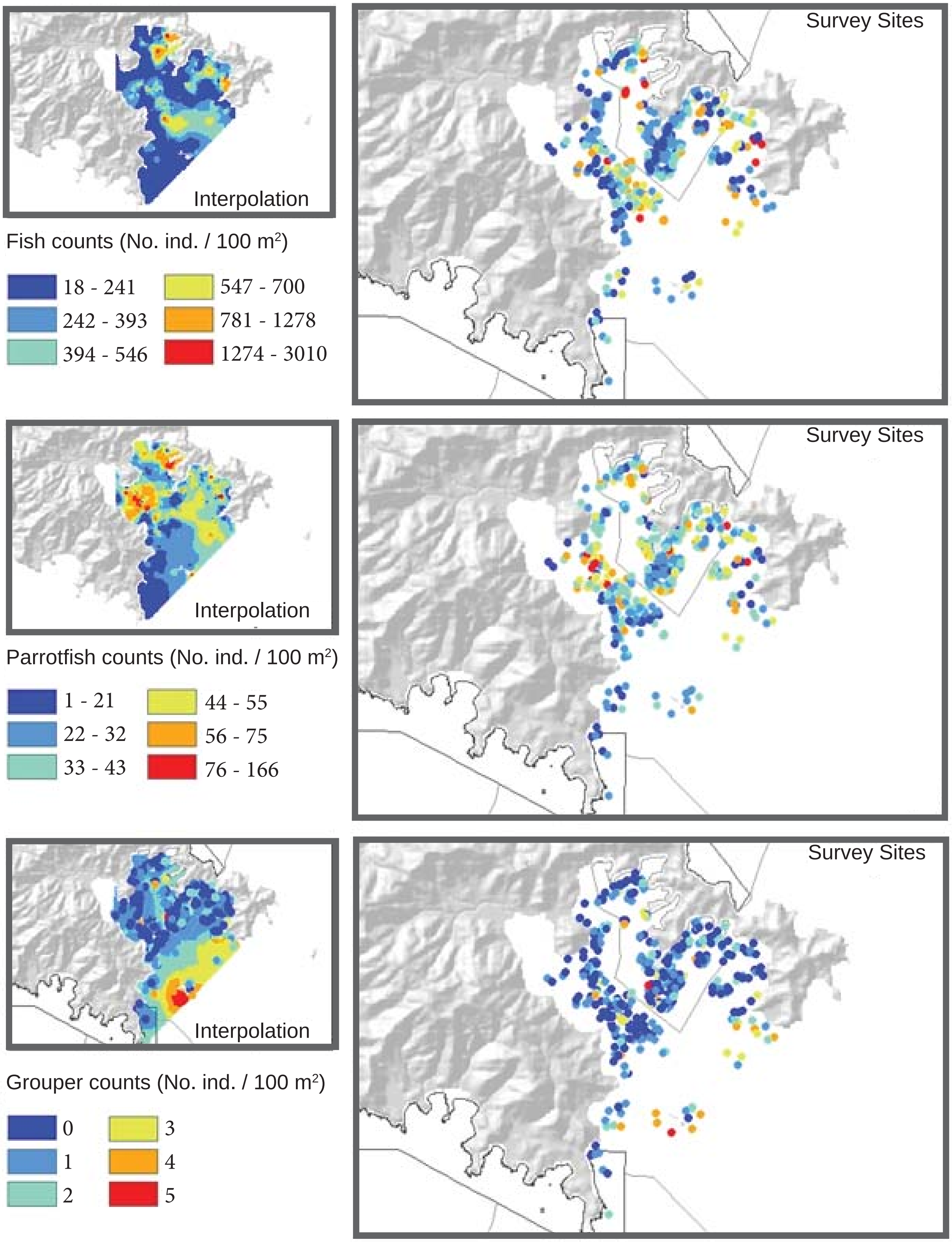

*Figure B5. Maps of all fish, parrotfish (*Scaridae*), and grouper (*Serranidae*) counts at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.*

APPENDIX B: MAPS OF REEF COMMUNITY INDICATORS

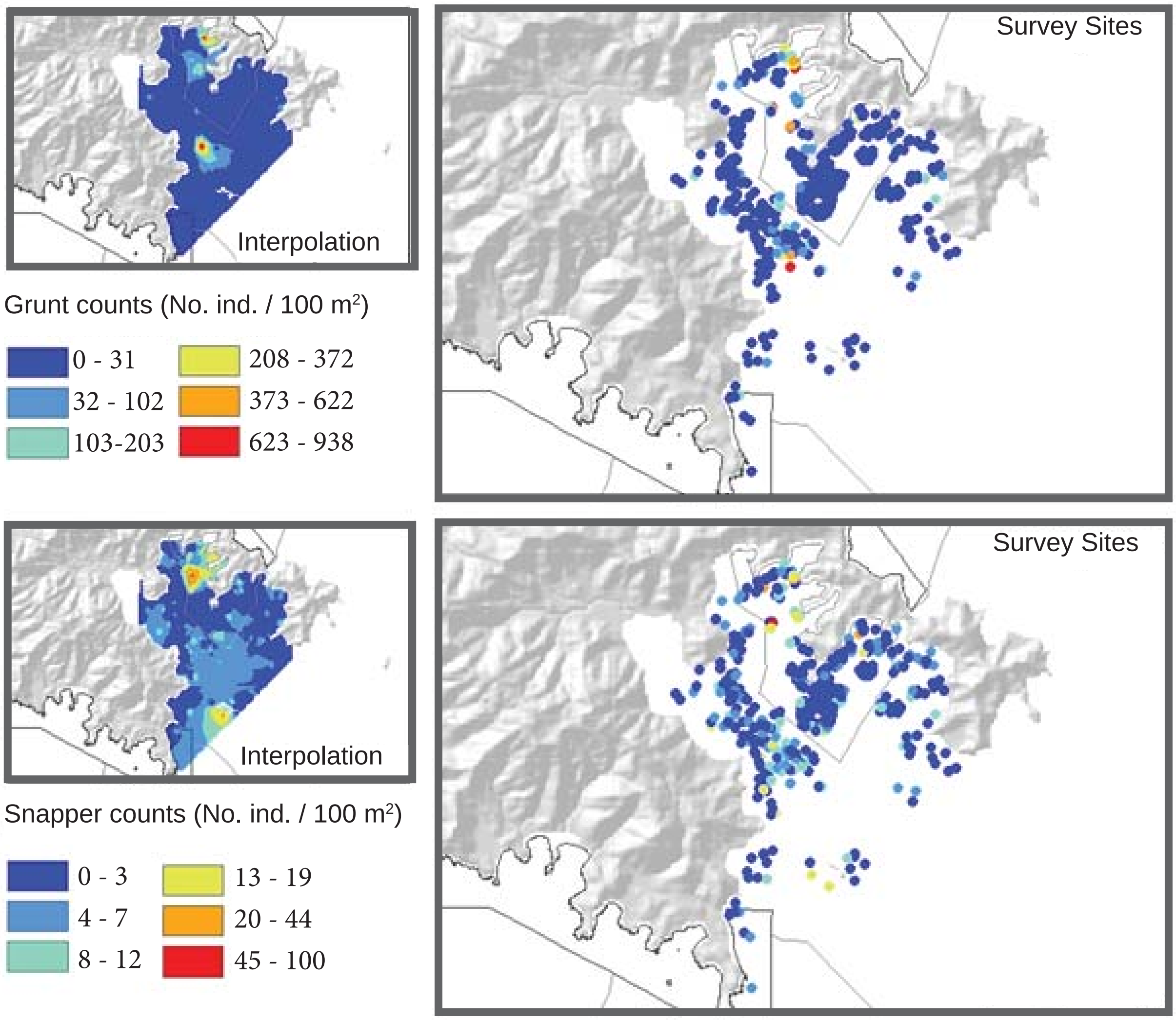

*Figure B6. Maps of grunts (*Haemulidae*) and snapper (*Lutjanidae*) counts at Coral Bay sites from 2003 to 2010. Interpolations in side panel produced using inverse distance weighting.*

APPENDIX C: CORAL AND REEF FISH INVENTORIES FOR CORAL BAY AND FISH BAY

Table C1. Coral Inventory - Coral Bay

Species Name	Percent Cover Mean	Percent Cover SE	Surveys Present	Frequency of Encounter
Montastraea annularis Complex	2.29	0.52	49	0.7
Porites astreoides	0.73	0.10	67	0.96
Siderastrea siderea	0.62	0.11	59	0.84
Montastraea cavernosa	0.34	0.07	41	0.59
*Porites porites**	0.29	0.05	49	0.7
Siderastrea radians	0.24	0.07	31	0.44
Colpophyllia natans	0.19	0.06	15	0.21
Agaricia agaricites	0.17	0.04	33	0.47
Diploria strigosa	0.11	0.03	34	0.49
Agaricia spp	0.09	0.05	18	0.26
Meandrina meandrites	0.08	0.02	23	0.33
Diploria labyrinthiformis	0.07	0.02	22	0.31
Stephanocoenia intercepta	0.05	0.01	27	0.39
Dichocoenia stokesii	0.03	0.01	25	0.36
Madracis decactis	0.02	0.01	6	0.09
Favia fragum	0.02	0.01	10	0.14
Diploria clivosa	0.02	0.01	6	0.09
Eusmilia fastigiata	0.02	0.00	15	0.21
Mycetophyllia reesi	0.01	0.01	1	0.01
*Dendrogyra cylindrus**	0.01	0.01	1	0.01
*Madracis mirabilis**	0.01	0.01	3	0.04
*Acropora cervicornis**	0.01	0.01	1	0.01
Scolymia spp	0.00	0.00	6	0.09
Mycetophyllia danaana	0.00	0.00	2	0.03
*Acropora palmata**	0.00	0.00	1	0.01
Mycetophyllia lamarckiana	0.00	0.00	2	0.03
Helioceris cucullata	0.00	0.00	2	0.03
Mycetophyllia aliciae	0.00	0.00	1	0.01
Mussa angulosa	0.00	0.00	2	0.03
Manicina areolata	0.00	0.00	2	0.03

* branching corals

Table C2. Fish Inventory - Coral Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Coryphopterus personatus/hyalinus	55687	105.07	239	0.45
Scarus iseri	10083	19.02	425	0.80
Thalassoma bifasciatum	5906	11.14	422	0.80
Haemulon aurolineatum	5694	10.74	115	0.22
Chromis cyanea	4871	9.19	170	0.32
Halichoeres bivittatus	4599	8.68	284	0.54
Sparisoma aurofrenatum	3933	7.42	433	0.82
Acanthurus coeruleus	3901	7.36	416	0.78
Halichoeres garnoti	3808	7.18	407	0.77
Acanthurus bahianus	3572	6.74	364	0.69
Stegastes partitus	2374	4.48	315	0.59
Jenkinsia UNK	2300	4.34	4	0.01
Stegastes planifrons	2200	4.15	203	0.38
Clupeidae UNK	2130	4.02	3	0.01
Sparisoma viride	1838	3.47	352	0.66
Haemulon UNK	1419	2.68	20	0.04
Haemulon flavolineatum	981	1.85	234	0.44
Stegastes variabilis	957	1.81	237	0.45
Scarus taeniopterus	884	1.67	166	0.31
Ocyurus chrysurus	845	1.59	287	0.54
Stegastes leucostictus	727	1.37	170	0.32
Carangoides ruber	670	1.26	105	0.20
Canthigaster rostrata	625	1.18	311	0.59
Hypoplectrus puella	576	1.09	285	0.54
Acanthurus chirurgus	572	1.08	106	0.20
Holocentrus rufus	565	1.07	229	0.43
Stegastes adustus	562	1.06	94	0.18
Coryphopterus glaucofraenum	552	1.04	182	0.34
Decapterus macarellus	487	0.92	3	0.01
Stegastes diencaeus	482	0.91	101	0.19
Clepticus parrae	466	0.88	35	0.07
Chaetodon capistratus	464	0.88	217	0.41
Pseudupeneus maculatus	337	0.64	163	0.31
Serranus tortugarum	312	0.59	23	0.04
Sparisoma atomarium	301	0.57	93	0.18
Halichoeres poeyi	284	0.54	95	0.18
Elacatinus evelynae	281	0.53	158	0.30
Halichoeres maculipinna	275	0.52	90	0.17
Lutjanus apodus	269	0.51	101	0.19
Chromis multilineata	257	0.48	43	0.08
Microspathodon chrysurus	248	0.47	115	0.22
Lutjanus synagris	225	0.42	41	0.08

Table C2 (continued from page 22). Fish Inventory - Coral Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Haemulon plumierii	224	0.42	57	0.11
Sparisoma rubripinne	217	0.41	59	0.11
Epinephelus guttatus	213	0.40	148	0.28
Inermia vittata	188	0.35	12	0.02
Hypoplectrus nigricans	182	0.34	132	0.25
Abudefduf saxatilis	179	0.34	50	0.09
Gramma loreto	177	0.33	57	0.11
Gnatholepis thompsoni	161	0.30	74	0.14
Hypoplectrus UNK	160	0.30	99	0.19
Lutjanus griseus	159	0.30	21	0.04
Sparisoma chrysopterum	155	0.29	63	0.12
Halichoeres pictus	150	0.28	38	0.07
Nes longus	137	0.26	26	0.05
Cephalopholis fulva	131	0.25	85	0.16
Halichoeres radiatus	120	0.23	60	0.11
Heteroconger longissimus	118	0.22	5	0.01
Mulloidichthys martinicus	118	0.22	42	0.08
Hypoplectrus unicolor	113	0.21	91	0.17
Opistognathus aurifrons	113	0.21	38	0.07
Sparisoma radians	101	0.19	38	0.07
Holacanthus tricolor	97	0.18	83	0.16
Holocentrus adscensionis	97	0.18	48	0.09
Cephalopholis cruentata	95	0.18	78	0.15
Serranus tigrinus	95	0.18	61	0.12
Cryptotomus roseus	94	0.18	32	0.06
Pomacanthus arcuatus	87	0.16	58	0.11
Malacoctenus triangulatus	86	0.16	61	0.12
Holacanthus ciliaris	84	0.16	59	0.11
Aulostomus maculatus	82	0.15	75	0.14
Coryphopterus dicrus	74	0.14	46	0.09
Haemulon sciurus	73	0.14	29	0.05
Hypoplectrus aberrans	68	0.13	49	0.09
Atherinomorus UNK	60	0.11	1	0.00
Malacoctenus macropus	60	0.11	35	0.07
Serranus tabacarius	59	0.11	40	0.08
Xyrichtys martinicensis	57	0.11	9	0.02
Synodus intermedius	56	0.11	54	0.10
Ctenogobius saepepallens	45	0.08	9	0.02
Calamus calamus	43	0.08	31	0.06
Myripristis jacobus	41	0.08	24	0.05
Pomacanthus paru	40	0.08	32	0.06
Scarus vetula	40	0.08	28	0.05

Table C2 (continued from page 23). Fish Inventory - Coral Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Chaetodon striatus	35	0.07	28	0.05
Haemulon carbonarium	35	0.07	20	0.04
Ophioblennius macclurei	35	0.07	23	0.04
Sparisoma UNK	34	0.06	5	0.01
Bodianus rufus	31	0.06	22	0.04
Lactophrys triqueter	31	0.06	30	0.06
Hypoplectrus chlorurus	30	0.06	26	0.05
Sphyraena barracuda	29	0.05	28	0.05
Malacoctenus boehlkei	28	0.05	20	0.04
Serranus baldwini	26	0.05	9	0.02
Xyrichtys splendens	25	0.05	7	0.01
Cantherhines pullus	24	0.05	21	0.04
Gobiidae UNK	24	0.05	7	0.01
Ptereleotris helenae	24	0.05	12	0.02
Caranx crysos	23	0.04	7	0.01
Monacanthus tuckeri	23	0.04	16	0.03
Balistes vetula	19	0.04	17	0.03
Bollmannia boqueronensis	18	0.03	3	0.01
Hypoplectrus guttavarius	18	0.03	14	0.03
Odontoscion dentex	18	0.03	4	0.01
Hypoplectrus indigo	17	0.03	7	0.01
Malacoctenus UNK	17	0.03	5	0.01
Gerres cinereus	16	0.03	5	0.01
Lutjanus UNK	16	0.03	5	0.01
Paradiplogrammus bairdi	16	0.03	13	0.02
Sphoeroides spengleri	15	0.03	8	0.02
Scomberomorus regalis	14	0.03	12	0.02
Equetus punctatus	13	0.02	12	0.02
Lutjanus analis	13	0.02	12	0.02
Carangoides bartholomaei	12	0.02	3	0.01
Lutjanus jocu	11	0.02	11	0.02
Calamus pennatula	10	0.02	8	0.02
Epinephelus striatus	10	0.02	10	0.02
Lutjanus cyanopterus	10	0.02	3	0.01
Monacanthus ciliatus	10	0.02	7	0.01
Apogon townsendi	9	0.02	3	0.01
Ginglymostoma cirratum	9	0.02	9	0.02
Haemulon macrostomum	8	0.02	7	0.01
Amblycirrhitus pinos	7	0.01	7	0.01
Coryphopterus eidolon	7	0.01	2	0.00
Epinephelus adscensionis	7	0.01	5	0.01
Lonchopisthus micrognathus	7	0.01	2	0.00

Table C2 (continued from page 24). Fish Inventory - Coral Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Malacoctenus versicolor	7	0.01	4	0.01
Opistognathus UNK	7	0.01	1	0.00
Anisotremus surinamensis	6	0.01	1	0.00
Decapterus UNK	6	0.01	1	0.00
Elacatinus UNK	6	0.01	1	0.00
Lutjanus mahogoni	6	0.01	6	0.01
Malacoctenus aurolineatus	6	0.01	3	0.01
Anisotremus virginicus	5	0.01	5	0.01
Bothus lunatus	5	0.01	3	0.01
Chaenopsis UNK	5	0.01	3	0.01
Sargocentron vexillarium	5	0.01	5	0.01
Diodon holocanthus	4	0.01	4	0.01
Elacatinus dilepis	4	0.01	4	0.01
Lactophrys bicaudalis	4	0.01	4	0.01
Malacanthus plumieri	4	0.01	4	0.01
Acanthostracion polygonius	3	0.01	3	0.01
Diodon hystrix	3	0.01	3	0.01
Heteropriacanthus cruentatus	3	0.01	3	0.01
Lactophrys trigonus	3	0.01	2	0.00
Selar crumenophthalmus	3	0.01	1	0.00
Sphyraena picudilla	3	0.01	1	0.00
Acanthemblemaria spinosa	2	0.00	2	0.00
Acanthurus UNK	2	0.00	1	0.00
Apogon binotatus	2	0.00	2	0.00
Bothus UNK	2	0.00	2	0.00
Chaetodon sedentarius	2	0.00	2	0.00
Coryphopterus lipernes	2	0.00	1	0.00
Cosmocampus elucens	2	0.00	2	0.00
Dasyatis americana	2	0.00	2	0.00
Echeneis naucrates	2	0.00	2	0.00
Epinephelus morio	2	0.00	2	0.00
Gymnothorax moringa	2	0.00	2	0.00
Haemulon chrysargyreum	2	0.00	2	0.00
Haemulon striatum	2	0.00	2	0.00
Halichoeres caudalis	2	0.00	1	0.00
Microgobius carri	2	0.00	1	0.00
Scartella cristata	2	0.00	1	0.00
Trachinotus falcatus	2	0.00	2	0.00
Abudefduf taurus	1	0.00	1	0.00
Aetobatus narinari	1	0.00	1	0.00
Astrapogon stellatus	1	0.00	1	0.00
Calamus bajonado	1	0.00	1	0.00

Table C2 (continued from page 25). Fish Inventory - Coral Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Calamus penna	1	0.00	1	0.00
Calamus UNK	1	0.00	1	0.00
Cantherhines macrocerus	1	0.00	1	0.00
Chaenopsis limbaughi	1	0.00	1	0.00
Chaenopsis ocellata	1	0.00	1	0.00
Dactylopterus volitans	1	0.00	1	0.00
Diplectrum formosum	1	0.00	1	0.00
Emblemaria pandionis	1	0.00	1	0.00
Gymnothorax miliaris	1	0.00	1	0.00
Gymnothorax vicinus	1	0.00	1	0.00
Haemulon parra	1	0.00	1	0.00
Hippocampus reidi	1	0.00	1	0.00
Kyphosus sectator	1	0.00	1	0.00
Lachnolaimus maximus	1	0.00	1	0.00
Lactophrys UNK	1	0.00	1	0.00
Liopropoma rubre	1	0.00	1	0.00
Megalops atlanticus	1	0.00	1	0.00
Mycteroperca interstitialis	1	0.00	1	0.00
Mycteroperca tigris	1	0.00	1	0.00
Neoniphon marianus	1	0.00	1	0.00
Pareques acuminatus	1	0.00	1	0.00
Remora remora	1	0.00	1	0.00
Scarus guacamaia	1	0.00	1	0.00
Sphoeroides testudineus	1	0.00	1	0.00
Sygnathus dawsoni	1	0.00	1	0.00
Triglidae UNK	1	0.00	1	0.00

Table C3. Coral Inventory - Fish Bay.

Species Name	Percent Cover Mean	Percent Cover SE	Surveys Present	Frequency of Encounter
Siderastrea siderea	0.25	0.12	7	0.37
Gorgonacea fan	0.23	0.14	6	0.32
Erythropodium caribaeorum	0.18	0.17	3	0.16
Porites astreoides	0.13	0.07	8	0.42
Montastraea cavernosa	0.08	0.06	4	0.21
Diploria strigosa	0.06	0.05	5	0.26
Porites porites	0.06	0.03	4	0.21
Agaricia spp	0.05	0.03	5	0.26
Montastraea annularis complex	0.05	0.03	3	0.16
Dichocoenia stokesii	0.04	0.04	2	0.11
Millepora alcicornis	0.04	0.04	1	0.05
Millepora spp	0.04	0.02	5	0.26
Stephanocoenia intercepta	0.04	0.02	5	0.26
Siderastrea radians	0.03	0.02	6	0.32
Colpophyllia natans	0.03	0.03	1	0.05
Meandrina meandrites	0.01	0.01	1	0.05
Agaricia agaricites	0.01	0.01	1	0.05
Manicina areolata	0.01	0.01	1	0.05
Diploria labyrinthiformis	0.00	0.00	1	0.05
Favia fragum	0.00	0.00	1	0.05

Table C4. Fish Inventory - Fish Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Acanthurus coeruleus	406	10	21.37	0.53
Thalassoma bifasciatum	339	9	17.84	0.47
Scarus iseri	256	10	13.47	0.53
Acanthurus bahianus	201	10	10.58	0.53
Halichoeres bivittatus	150	11	7.89	0.58
Halichoeres garnoti	52	7	2.74	0.37
Acanthurus chirurgus	51	2	2.68	0.11
Sparisoma viride	47	9	2.47	0.47
Sparisoma aurofrenatum	46	10	2.42	0.53
Halichoeres maculipinna	35	8	1.84	0.42
Sparisoma rubripinne	28	8	1.47	0.42
Stegastes diencaeus	27	5	1.42	0.26
Stegastes partitus	27	4	1.42	0.21
Ocyurus chrysurus	26	9	1.37	0.47
Chromis multilineata	23	3	1.21	0.16
Stegastes variabilis	20	3	1.05	0.16
Stegastes leucostictus	18	9	0.95	0.47
Chromis cyanea	17	1	0.89	0.05
Halichoeres radiatus	17	7	0.89	0.37
Lutjanus apodus	17	6	0.89	0.32
Decapterus UNK	15	1	0.79	0.05
Haemulon flavolineatum	15	6	0.79	0.32
Stegastes adustus	15	5	0.79	0.26
Microspathodon chrysurus	14	6	0.74	0.32
Malacoctenus triangulatus	12	4	0.63	0.21
Stegastes planifrons	12	3	0.63	0.16
Canthigaster rostrata	11	5	0.58	0.26
Coryphopterus glaucofraenum	10	3	0.53	0.16
Gramma loreto	9	5	0.47	0.26
Scarus vetula	9	2	0.47	0.11
Sparisoma radians	9	3	0.47	0.16
Scarus taeniopterus	8	5	0.42	0.26
Bodianus rufus	5	2	0.26	0.11
Elacatinus evelynae	5	3	0.26	0.16
Holocentrus rufus	5	4	0.26	0.21
Pseudupeneus maculatus	5	2	0.26	0.11
Coryphopterus personatus/hyalinus	4	1	0.21	0.05
Lutjanus UNK	4	1	0.21	0.05
Nes longus	4	1	0.21	0.05
Sphoeroides spengleri	4	3	0.21	0.16
Abudefduf saxatilis	3	3	0.16	0.16
Aulostomus maculatus	3	3	0.16	0.16

Table C4 (continued from page 28). Fish Inventory - Fish Bay.

Species Name	Total Count	Mean Abundance	Surveys Present	Frequency of Encounter
Carangoides ruber	3	2	0.16	0.11
Cephalopholis fulva	3	2	0.16	0.11
Clepticus parrae	3	1	0.16	0.05
Halichoeres poeyi	3	2	0.16	0.11
Hypoplectrus puella	3	2	0.16	0.11
Lutjanus synagris	3	1	0.16	0.05
Mulloidichthys martinicus	3	2	0.16	0.11
Serranus tigrinus	3	1	0.16	0.05
Sparisoma chrysopterum	3	1	0.16	0.05
Balistes vetula	2	2	0.11	0.11
Carangoides bartholomaei	2	1	0.11	0.05
Chaetodon capistratus	2	2	0.11	0.11
Chaetodon striatus	2	1	0.11	0.05
Ctenogobius saepepallens	2	1	0.11	0.05
Epinephelus guttatus	2	2	0.11	0.11
Gerres cinereus	2	1	0.11	0.05
Hypoplectrus UNK	2	1	0.11	0.05
Malacoctenus macropus	2	2	0.11	0.11
Malacoctenus versicolor	2	1	0.11	0.05
Ophioblennius macclurei	2	2	0.11	0.11
Amblycirrhitus pinos	1	1	0.05	0.05
Cantherhines macrocerus	1	1	0.05	0.05
Cantherhines pullus	1	1	0.05	0.05
Chaenopsis limbaughi	1	1	0.05	0.05
Coryphopterus dicrus	1	1	0.05	0.05
Cryptotomus roseus	1	1	0.05	0.05
Dasyatis americana	1	1	0.05	0.05
Diodon holocanthus	1	1	0.05	0.05
Epinephelus adscensionis	1	1	0.05	0.05
Haemulon aurolineatum	1	1	0.05	0.05
Haemulon carbonarium	1	1	0.05	0.05
Haemulon sciurus	1	1	0.05	0.05
Holacanthus tricolor	1	1	0.05	0.05
Lutjanus griseus	1	1	0.05	0.05
Monacanthus ciliatus	1	1	0.05	0.05
Myripristis jacobus	1	1	0.05	0.05
Pomacanthus paru	1	1	0.05	0.05
Pterois volitans	1	1	0.05	0.05
Sargocentron vexillarium	1	1	0.05	0.05
Scarus guacamaia	1	1	0.05	0.05
Scorpaena plumieri	1	1	0.05	0.05
Sparisoma atomarium	1	1	0.05	0.05

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