F-7 Recreational Fisheries Habitat Assessment Project:

Final Completion Report –
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Part 2.

An Investigation of Anchor Damage to the Frederiksted Reef System: Impacts to Substrate, Benthic Communities, and Reef Fish Assemblages

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SUMMARY

The Frederiksted Reef System of western St. Croix, U.S. Virgin Islands, is threatened by a number of anthropogenic activities including physical destruction caused by the anchoring of large commercial vessels. Little was known of this coral reef system prior to the 1994 designation of an anchorage on top of it, and no studies were made subsequently. Therefore, this investigation was undertaken to determine the ecological impacts of anchoring. Preliminary mapping surveys were made to delineate the damaged area. From these maps, four damaged sites and four reference (non-impact) reef sites were selected for survey work to compare: 1) reef substrate topographic complexity and composition, 2) coral and benthic community composition, and 3) fish assemblage structure.

Preliminary mapping with towed-diver surveys delineated a large area of contiguous anchor damage: an estimated 21.2 hectares of reef crest zone with a maximum observed cross-shelf width of 256 m. Damage was greatest in the southern part of the study area near the Frederiksted Pier. Independent measures of substrate topographic complexity from damaged and non-impact sites indicated that anchoring resulted in a marked change in the physical structure of the reef. Rugosity was significantly reduced (by 43.5 %) and vertical relief was substantially reduced (67.9 %). The composition of abiotic substrate at damaged sites showed a 6.3-fold increase in rubble, a 2.5-fold increase in sand cover, and 44.1 % decrease in consolidated reef/rock substrate relative to non-impacted sites. Benthic community composition was strongly negatively impacted by anchor damage. Coral cover at non-impact sites was high (average 25 %) and dominated by a single species, *Montastraea annularis*, which accounted for 51 % of coral cover. At damaged sites, coral cover was reduced by > 87 % and coral richness was reduced by 54 %. Total macroalgal cover was not significantly different between areas although *Halimeda* was more abundant at non-impact sites and *Dictyota* was more abundant at damaged sites. Percent cover by dead coral with turf algae was significantly greater at damaged sites (57.5 %) than at non-impact sites (44.6 %). Fish assemblages from damaged areas were significantly less diverse than those of non-impact sites, in terms of average number of species (20 % fewer species), cumulative number of species (19 % fewer species), and Shannon-Weaver index (H' ~ 17 % lower). Planktivores were exceptionally abundant at all sites and the five predominant species showed individually variable patterns of response to anchor damage. Excluding these five species, total abundance of fish assemblages was significantly lower (reduced by 43 %) at damaged sites. Additional differences in the composition of fish assemblages between areas are identified and discussed.

Results from this study indicate that anchoring has caused pronounced changes in the architecture of the reef and in the structure of biological communities associated with it. Although the large reduction in coral cover has not caused a phase shift to macroalgal-dominance, recovery of impacted reef areas has progressed very little. Full recovery will require decades. Damage to the Frederiksted Reef serves to illustrate the pressing need for regulatory agencies to implement policies for improved management of maritime activities. Adequate planning for the accommodation of large and small vessel traffic should include mechanisms to obviate or mitigate damage to coral reefs and associated marine habitats. A program for maritime accident response is needed to assess coral reef impacts and initiate restoration.

INTRODUCTION

Coral reefs of the United States Virgin Islands (USVI) are increasingly threatened by anthropogenic activities (Rogers and Beets 2001, Catanzaro et al. 2002, Jeffrey et al. 2005). Among these, impacts from anchoring of large vessels are of great concern because they result in severe disruption of the reef framework and reduction or elimination of much of the scleractinian coral community (Jaap 2000). Anchoring impacts to coral reefs are further exacerbated because reef recovery is very slow. For example, one USVI anchoring incident which resulted in a severe loss of corals and change in benthic community structure showed almost no sign of recovery after more than a decade (Rogers and Garrison 2001). Off Grand Cayman, damages caused by cruise ship anchoring were estimated to require more than 50 years for recovery (Smith 1988).

In addition to perturbations of the benthic community, the physical destruction of coral reefs by anchoring may also affect reef-associated fishes that depend upon intact coral reef habitat for all or part of their life cycle. How fish assemblages respond to physical habitat destruction has yet to receive study on coral reefs of the USVI. Results from studies conducted elsewhere on analogous coral reef impacts, however, suggest that such physical destruction of habitat may lead to marked and long-term changes in fish assemblages. Riegl (2001) reported that destructive impacts from ship groundings and dynamite fishing on coral reefs in the Red Sea were similar, and that both resulted in comparable reductions in diversity and abundance of associated fish assemblages. Ebersole (2001) studied fish assemblages at ship grounding sites on coral reefs in the Florida Keys more than 15 years post impact and observed low diversity, low abundance fish assemblages more typical of natural hard grounds.

In the face of physically destructive impacts, how do coral reefs and associated fish assemblages respond? A potentially illustrative example is that of the Frederiksted Reef of western St. Croix. Areas of extensive damage were created by frequent anchoring of large vessels in the near shore waters off Frederiksted (IRF 1993a, b). Although the Frederiksted Reef was considered among the most important areas to the local fishery (IRF 1977), the existence of a robust coral reef at the shelf edge was not known or was simply ignored (see Toller 2005), and anchoring caused an unquantified amount of habitat destruction. The Frederiksted Reef thus presents an opportunity to assess, characterize and document the magnitude of coral reef damage caused by anchoring of commercial vessels. It also represents a case study that may provide insight into how benthic communities and fish assemblages respond to large-scale physical alteration of coral reef habitat.

Available historic information about anchoring on the Frederiksted Reef is rather incomplete. Anchoring at Frederiksted appears to have been a common practice that dates back to the colonial era. Danish maps of St. Croix from 1764 show a Frederiksted anchorage, and subsequent British charts indicate two anchorages, which roughly correspond to present-day north and south anchorage areas. The peak of anchoring activity probably occurred more recently, between 1960 and the mid-1980s, when the town of Frederiksted served as the primary commercial port for the island of St. Croix (B. Lawaetz, former USVI Senator, pers. com.).

From 1970 through the late 1980's, large commercial vessels were commonly anchored north of the Frederiksted Pier (S. Rodriguez, former Frederiksted pilot boat captain, pers. com.).

The only previous description of anchor damage to the Frederiksted Reef is a brief 1994 survey report (Appendix 1). The Virgin Islands Port Authority (VIPA) requested establishment of anchorage areas at the Frederiksted Pier, citing this survey report as evidence that taking such action would confine damage to areas already heavily impacted by anchoring. The U.S. Army Corps of Engineers (ACOE) granted the permit modification to establish two anchorages (northern and southern), concluding that the designated anchorages would have "insignificant" impacts upon the environment. Subsequently, no further accounts of anchor impacts or anchoring frequency were recorded. In the following years, however, commercial traffic at Frederiksted declined. Since ~ 1999, the frequency of large vessel anchoring on the Frederiksted Reef has decreased to less than one per year on average (W. Tobias, pers. com.).

The foregoing indicates that most of the anchoring on the Frederiksted Reef, and therefore most of the damage, occurred prior to formal designation of anchorage areas in 1994. With the limited information available, it is not possible to apply specific dates with any great certainty to individual anchor scars. On the other hand, it is reasonable to infer that almost all of the observed anchor damage is at least 10 years old and much of it is 20-30 years old or older. Thus, damage observations from the Frederiksted Reef can be used to address questions about more protracted (decadal or more) aspects of anchoring impacts.

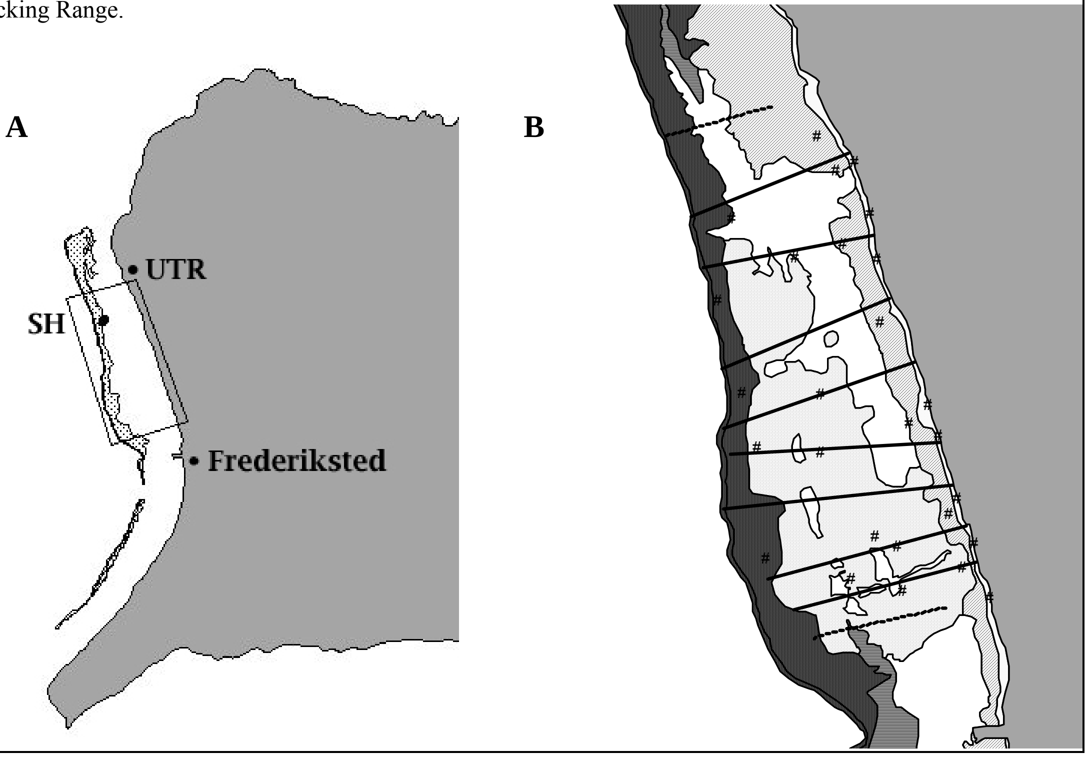
The specific objectives of this study were to: 1) obtain preliminary mapping information to delineate areas of damaged reef habitat from non-impacted reef areas, 2) determine the changes in substrate topographic complexity associated with anchoring, and 3) evaluate the extent to which benthic communities and fish assemblages have been altered as a result of habitat damage caused by anchoring. The latter two goals were addressed using a study design which compared damaged and non-impacted sites.

MATERIALS AND METHODS

Study Location

This study was conducted on the Frederiksted reef system located on the western (leeward) side of St. Croix, U.S. Virgin Islands. Toller (2005) provides a general description of inshore, hard bottom habitats of the Frederiksted Reef System. Surveys were conducted in the reef crest zone in an area north of the Frederiksted pier (Fig. 1A). Although a southern anchoring area was also designated in 1994, only the northern anchorage was investigated in this study. This choice was made based upon previous accounts of greater damage to reef habitats from anchoring north of the Frederiksted Pier (DFW unpublished, also see Appendix 1).

Figure 1. Map of western St. Croix and study area. **A.** Map showing the Frederiksted Reef (stippled polygons) and study area (rectangle). **B.** Location of towed-diver survey transects superimposed on benthic habitat map (see Kendall et al. 2001 and Toller 2005). SH = Sprat Hole monitoring site, UTR = Underwater Tracking Range.



Preliminary Mapping and Identification of Survey Sites

Towed diver surveys were conducted across the Frederiksted Reef system to identify impacted areas (see Toller 2005). Eight transects were run from shore to the 18.3 m (60 ft) depth contour, with an additional (partial) transect added to the northern and southern portions of the study area (Fig. 1B).

Damaged areas were identified by a combination of scoring criteria. In many cases, physical disruptions from large anchors left pronounced scars in the reef framework. Large gouges (5 to > 30 m long) oriented offshore with paired grooves separated by about 1.5 m were evidently caused by the digging of anchor forks during anchor retrieval. Areas of "sweeped" reef substrate (numerous independent coral heads broken off at a uniform height) were also evident and presumably caused by anchor chains. Adjacent areas of unconsolidated rubble and boulders, or overturned skeletons of massive corals (especially *Montastraea annularis*) were also included. Extensive areas of unconsolidated coral rubble (i.e. "rubble-ized" reef areas) were scored as damaged reef when evidence from adjacent zones indicated that the zone formerly supported coral reef (i.e. presumptive reef crest zone).

The preliminary mapping data were used to select sites for surveys of benthic communities and fish assemblages. A total of eight sites were chosen: four sites from damaged reef areas and four from undamaged (non-impact) sites (Table 1). In this report, the name of each sampling site is abbreviated with a two letter code (e.g. Sprat Hole = SH). Site codes are shown in Table 1 and used throughout this report. Figure 2 shows the spatial distribution of sampling sites across the Frederiksted Reef System.

Table 1. Survey sites and sampling dates.

Site Code	Site Name	Impact Designation	Location Lat. (N)	Location Lon. (W)	Avg. Depth (m)	Fish Survey Date	Fish Survey No.*	Benthic Survey Date	Benthic Survey No.*
RF	Rubblefield	Damaged	17° 43.101’	64° 53.448’	12.4	17 Mar 05	6	4 May 05	10
TC	The Corner	Damaged	17° 43.209’	64° 53.570’	13.7	1 Dec 04	6	2 Jun 05	10
LP	La Piedra	Damaged	17° 43.310’	64° 53.671’	14.3	13 Apr 05	6	26 May 05	10
MA	Midank	Damaged	17° 43.384’	64° 53.677’	12.6	6 May 05	6	7 Jun 05	10
PB	Paul's Buoy	Non-Impact	17° 43.208’	64° 53.416’	9.4	27 Apr 05	6	19 May 05	10
BP	Black Point	Non-Impact	17° 43.642’	64° 53.688’	11.4	5 May 05	6	3 Jun 05	10
RB	Rainbow	Non-Impact	17° 43.858’	64° 53.749’	11.8	6 Apr 05	6	12 May 05	10
SH	Sprat Hole	Non-Impact	17° 44.049’	64° 53.715’	9.6	22 Mar 05	6	1 Jun 05	10

* Number of replicates for fish surveys (stationary point counts) and benthic surveys (quadrats)

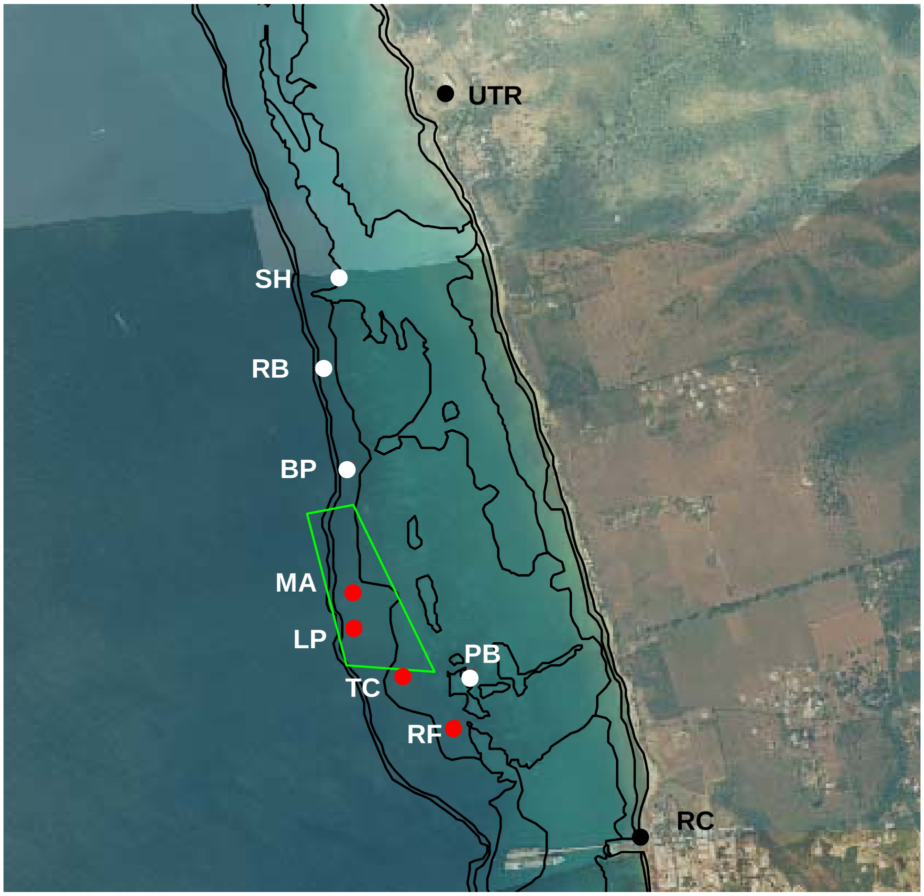
Benthic Communities

Benthic surveys were conducted between May and July of 2005. Benthic communities were assessed using quadrats (1.0 m^2 with a 10 cm interior grid) following published methods (Rogers et al. 1994). A diver descended and affixed a transect tape (marked in 1 cm intervals) to a haphazardly selected non-living bottom feature. The diver then swam out 30 m of transect tape following a pre-selected random compass bearing. A second transect was established parallel to the first, approximately 10 m away, using the same compass bearing [paired transects were used to allow dive teams to stay within constant visual contact]. Quadrats were placed at pre-selected random distances along the transect tape. Quadrats were placed on the right-hand side of the tape for even numbered distances and the left-hand side for odd numbered distances.

The surface area of all organisms occupying the quadrat was estimated to the nearest 0.1 % as judged from planar view. Organisms which collectively occupied less than 0.1 % of the quadrat (< 10 cm^2 surface area) were excluded. Corals were identified to species. Estimates of percent cover were based only upon spatial extent of living coral tissue. For analyses, hydrocorals (fire corals of the genus *Millepora*) were grouped together with scleractinian corals. Algae were identified to genus, or to species in a limited number of samples. Sponges were identified according to coarse morphological groupings (encrusting, branching/tubular, vase, or irregular/erect forms) except for three taxa (*Cliona* spp., *Xestospongia muta*, and *Neofibularia nolitangere*), which were identified to genus. Gorgonians (subclass Octocorallia, order Gorgonacea) were categorized into encrusting or branching forms. Only the bases of branching gorgonians were considered for estimates of percent cover. Percent cover by filamentous and turf forming algae was estimated visually or calculated based upon available surface area of hard carbonate substrate. Such surfaces were scored as "dead coral with turf algae," or DCTA.

For each quadrat, divers also scored the percent composition of abiotic substrate underlying the benthic community. Abiotic substrate was classified as reef/rock, rubble, sand, or other. Percent abiotic cover was assessed independently from any overlying biotic cover. Digital photos were taken of each quadrat and all data were recorded onto standardized forms.

Figure 2. Aerial photo of study area showing location of survey sites. Locations of fish and benthic surveys are shown for damaged sites (red circles) and non-impact sites (white circles). See Table 1 for site codes. Geo-referenced photomosaic and polygons which show habitat types (black lines) are from Kendall et al. (2001). Green trapezoid shows the buoyed corners of the designated anchorage area based upon DFW coordinates. UTR = Underwater Tracking Range station located at Estate Sprat Hall, RC = red crane at the base of the Frederiksted Cruise Ship Pier.



Topographic complexity was measured using the chain method [several versions of the chain method exist; Luckhurst and Luckhurst 1978, Rogers et al. 1994, C. Jeffrey, pers. com] as described here. A chain made of fine-linked galvanized steel and 5.00 m in length was wound onto a plastic spool with a short section of monofilament fishing line at the terminus. Beginning from a random point on the transect tape, divers conformed the entire length of the chain to the bottom, directly beneath the transect line. Conformed chain length was read directly from the transect tape to the nearest cm using the monofilament tab for vertical alignment. Only surfaces of "hard" features were included (e.g. live coral, dead coral skeleton, bare substrate, encrusting sponges). Soft features (macroalgae, gorgonian stalks, branching sponges, etc.), were gently moved aside. A rugosity index (RI) was calculated using the following equation:

$$RI = L / D$$

where L is the straight length of the chain (5.0 m) and D is the linear distance covered by the chain when conformed to the substrate. Using this index, a flat surface would have an RI of 1.0 and a vertical surface would have infinite rugosity. For comparative purposes, a larger value of RI indicates a substrate with greater rugosity.

An attempt to measure vertical relief was also made at all survey sites. Divers estimated average vertical relief and maximal vertical relief along each transect line (i.e. two estimates per site). Measures were obtained by “dropping and sweeping” the weighted chain (vertically) beneath the transect line, along ~ 2 m distance and then recording the length of chain required to touch the substrate. Although poor inter-observer consistency was obtained with the method, the measurements of vertical relief were nonetheless qualitatively consistent with rugosity indices and with visual observation. Information on vertical relief was therefore treated as qualitative data in analyses.

Fish Assemblages

The stationary point count method (Bohnsack and Bannerot 1986) was used to assess fish assemblages at damaged and non-impacted sites. Compared to other visual census methods (belt transects, timed random swim methods), point counts are advantageous because estimates of fish abundance are recorded within a defined area of survey (i.e. as density). In addition, the geometry of the survey area is circular and compact relative to belts. Such compactness allows for more discrete sampling of selected habitat zones. Generally, results from stationary point counts are comparable to results obtained from belt transects (e.g. Bortone et al. 1989).

The census protocol was only slightly modified from Bohnsack and Bannerot (1986). A 15 m diameter census "cylinder" was defined by transect tape with the observer positioned in the center at the 7.5 m mark (cylinder area = 176 m^2 per replicate). Fish within this cylinder were censused as follows. During an initial 5-minute “listing” period, the names of all observed fish species were recorded onto pre-printed data forms. At the end of the listing period, the observer began enumerating all individuals of each species, working from the bottom of the list upward and making one 360° sweep. Species observed after the listing period (i.e. species that swam into the cylinder after the first five minutes) were excluded from counts. Divers estimated fish fork length (or total length) by reference to a measuring “T-bar” held during surveys. Fish were recorded into one of six size categories: <5 cm, >5 to 10 cm, >10 to 20 cm, >20 to 30 cm, >30 to 40 cm, or > 40 cm. Divers also recorded a brief description/sketch of habitat features within the census area. All fish were identified to species. Small and/or cryptic species (gobiids, blenniids, apogonids) were excluded from counts.

Fish surveys were conducted between December of 2004 and May of 2005. For each reef site, six replicate censuses were made. This is a level of replication thought to adequately sample > 90 % of fish species richness at a site (Bohnsack and Bannerot 1986). Total survey area (six replicates) was 1,056 m^2 per reef site. A summary of fish survey sites, dates and number of replicates is shown in Table 1.

Data Analysis

Statistical analyses were performed with Statistica (StatSoft, Inc., Tulsa, OK) using either parametric (two tailed *t*-tests) or non-parametric tests, as appropriate. Datasets were examined with Kolmogorov-Smirnov and Lilliefors test for normality. If datasets failed normality tests (before and after log-transformation) then non-parametric tests were applied. For analyses, site data were pooled by impact group (damaged vs. non-impact). Data are also presented individually by site in this report. To identify changes in specific abundance between fish assemblages from damaged and non-impact sites, the difference in average abundance (delta abundance) was calculated using ln(x+1)-transformed data.

Mapping data were collected with handheld GPS units and analyzed with ArcView GIS 3.2a (Environmental Systems Research Institute, Inc.) as described previously (Toller 2005).

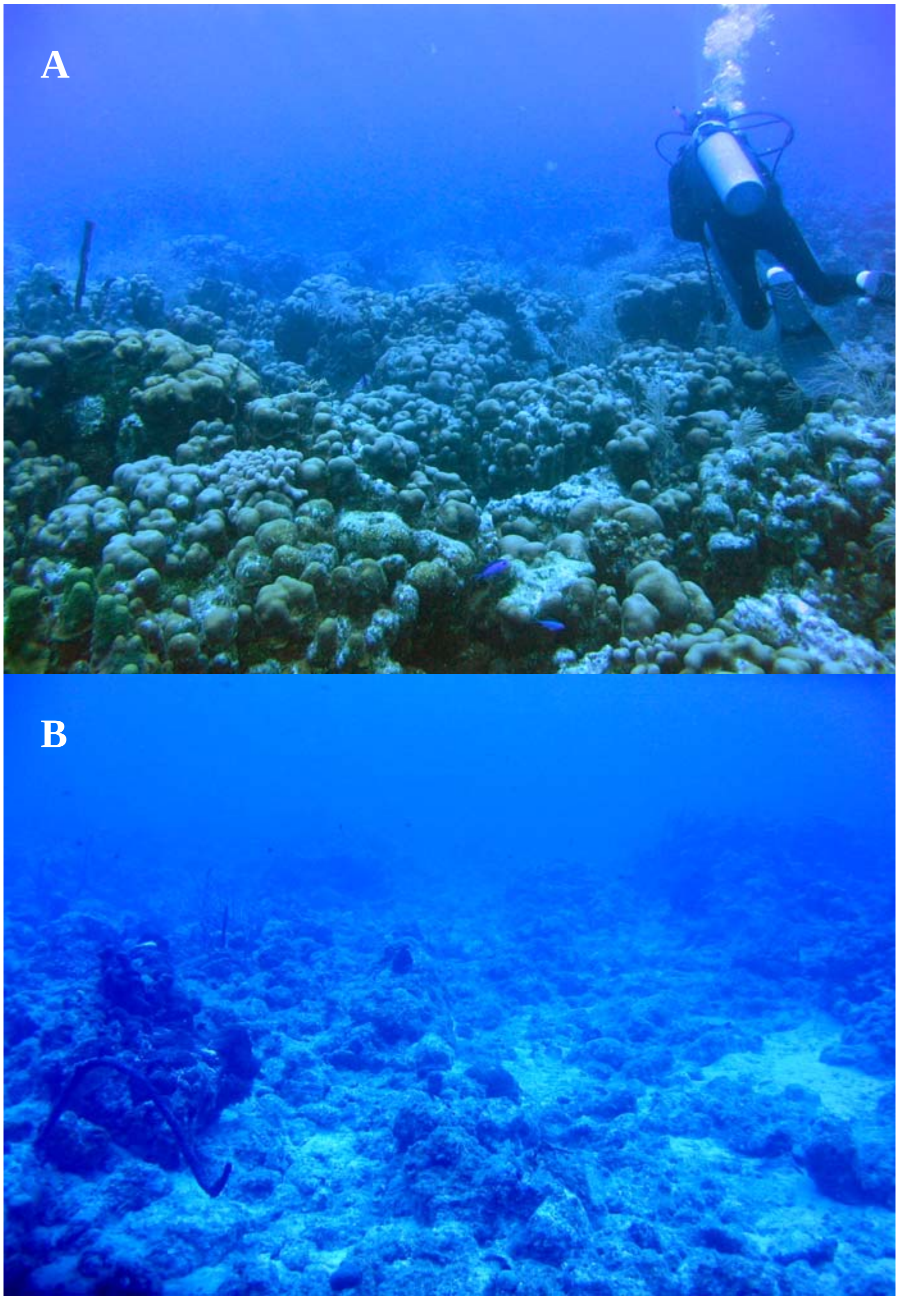
RESULTS

Observations on the Extent of Anchor Damage

The following account presents some general observations regarding the distribution and extent of anchor damage to the Frederiksted Reef. Within the study area, large areas (1000's of m^2) of unconsolidated boulders and coral rubble or "rubblefields" were observed (e.g. Fig. 3B). Gouges and tracks were evident and overlapped in areas of damage, suggesting that the rubble substrate had been "overturned" multiple times. Such rubblefields were most extensive in the southern part of the study area, inshore of the shelf break, in a cross-shelf position which corresponds to the reef crest zone. At rubblefield margins, abrupt transitions to topographically complex reefs were accompanied by large boulders lifted from substrate. Surprisingly, it was also observed that small areas (100's of m^2) of high-relief reefs (or "reef islands") which appeared to be unimpacted by anchoring, occurred amidst rubblefields. The PB site is an example of one such reef island area.

An exploratory dive through the designated anchorage area, following the 14 m depth contour which roughly parallels the shelf-break, indicated that damage was near-continuous across more than 500 m distance. Additional forays along reef slope indicated that anchor damage extends deeper (> 30 m), however these areas were not surveyed in this study. In the northern part of the study area, isolated scars were discernable within linear reef habitat that otherwise appeared unimpacted. North of the SH site, little evidence of anchor damage was found. A comparison of habitat appearance is shown in Figure 3.

Figure 3. Example photos of reef substrate from the two impact groups. **A.** Non-impacted site. Photo from Rainbow sampling site (RB). **B.** Damaged reef site. Photo from Midank sampling site (MA).



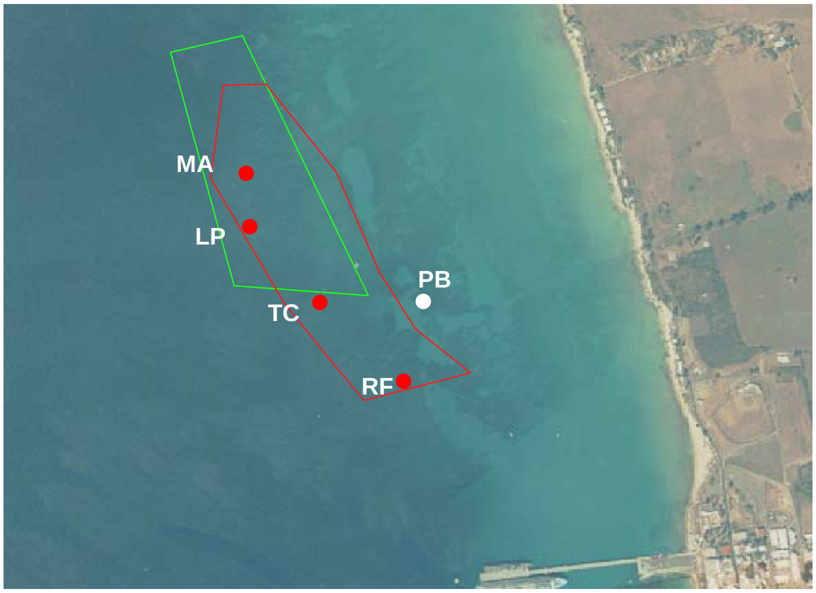
An estimate for percentage of habitat damaged by anchoring can be derived from observations made along towed-diver transects. Toller (2005) estimated that 48.2 % of the reef crest zone was damaged. The reef crest corresponds, approximately, to linear reef as delineated in NOAA

Benthic habitat maps, which show ~ 350,000 m^2 of linear reef within the study area. Using the percentage cited above, it can be estimated that approximately 169,000 m^2 (16.9 hectares) of linear reef has been damaged by anchoring.

The areal extent of anchor damage can also be estimated from the size of the designated anchorage area itself, assuming that all reef habitat within the anchorage has been impacted. By reference to the ACOE permit, the officially designated anchorage boundaries (see Appendix 1) delineated an area of 389,396 m^2 (38.9 hectares). There was, however, a substantial discrepancy between coordinates of the permitted area and that of the area marked by VIPA buoys. DFW recorded GPS position of the four buoys marking corners of the north anchorage in 1995 (A. Adams, unpublished DFW memo, Appendix 1). These buoys delineated an anchorage (Fig. 2) that was in a different position than the permitted anchorage, and also represented a smaller area (161,243 m^2 or 16.1 hectares).

Using the location/area of the designated anchorage as a proxy for estimating the spatial extent of habitat impact has at least three shortcomings. First, damage caused by anchoring was evident beyond the boundaries of the anchorage area. Extensive damage was seen to the south of the boundary, and, to a lesser extent, also to the north of the anchorage area. Second, not all habitat within the designated anchorage is (or was) linear coral reef. Third, some small sections of linear reef habitat that occurred within the designated area were also seen to be unimpacted.

Figure 4. Aerial photo showing the approximate perimeter of contiguously impacted reef habitat on the northern Frederiksted reef. Red polygon shows damage perimeter as estimated from towed-diver surveys. Green trapezoid shows the buoyed corners of the designated anchorage. Locations of five survey sites are also shown: four damaged sites (red circles; MA, LP, TC, RF) and one non-impact site (white circle; PB). See Table 1 for site codes. Geo-referenced photomosaic is from Kendall et al. (2001).



An alternative approach was to use observations from towed-diver surveys. GIS mapping of a limited number of positions provided an approximation for the perimeter of contiguous damage (Fig. 4). The damage polygon encloses an area of 212,023 m^2 (21.2 ha) and its position also coincides rather imprecisely with the designated anchorage area (ACOE permit) and the VIPA-buoyed anchorage area (Fig. 4). However, this approach may have still underestimated the actual spatial extent anchor damage because: 1) the perimeter of contiguous damage extended further southward towards the Frederiksted Pier (outside the study area), 2) the area of contiguous damage does not include the numerous isolated anchor scars that were observed further to the north, and 3) mapping efforts extended only to the 18.3 m depth contour although anchoring impacts were also observed at greater depths on the Frederiksted Reef.

Substrate

Rugosity measurements were obtained at all four damaged sites and all four non-impact sites (10 replicates per site) for a total of 80 measurements. Rugosity indices were non-normally distributed. The data were pooled by impact group (damaged vs. non-impact) and examined further with non-parametric tests. Rugosity indices were significantly lower at damaged sites (Kruskal-Wallis ANOVA by Ranks; $H_{1,\,80} = 58.53$, $p < 0.001$). At damaged sites, average RI (± st.dev.) was 1.29 ± 0.11 (range 1.02 – 1.56). At non-impact sites, average RI was 2.31 ± 0.61 (range 1.45 – 4.72). RI was more variable within and among non-impact sites (Fig. 5A).

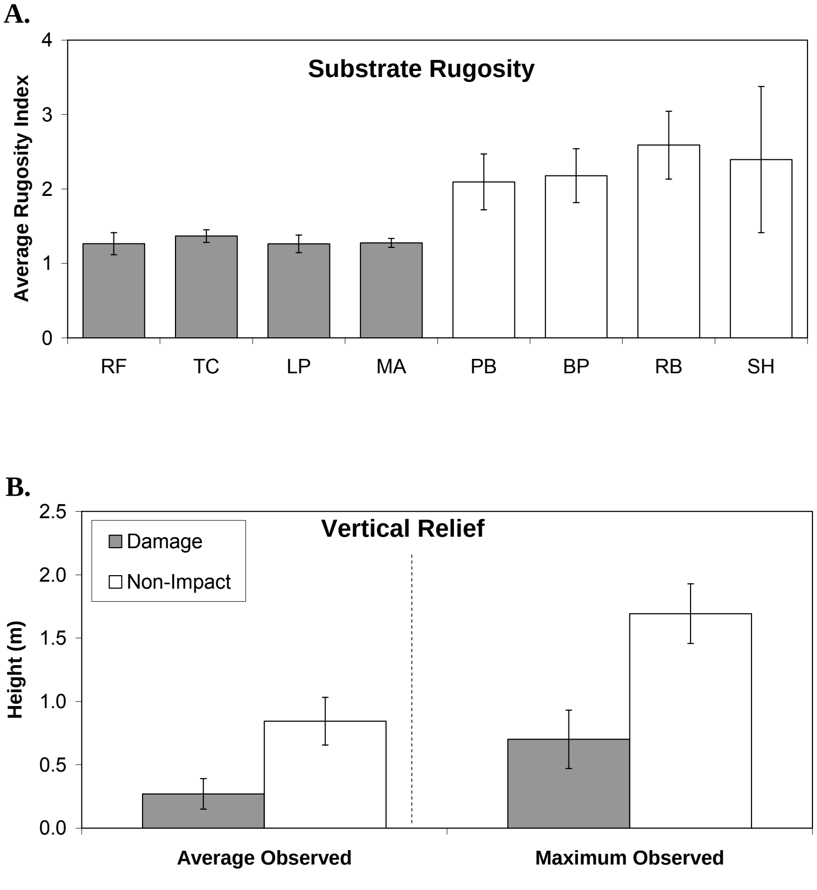
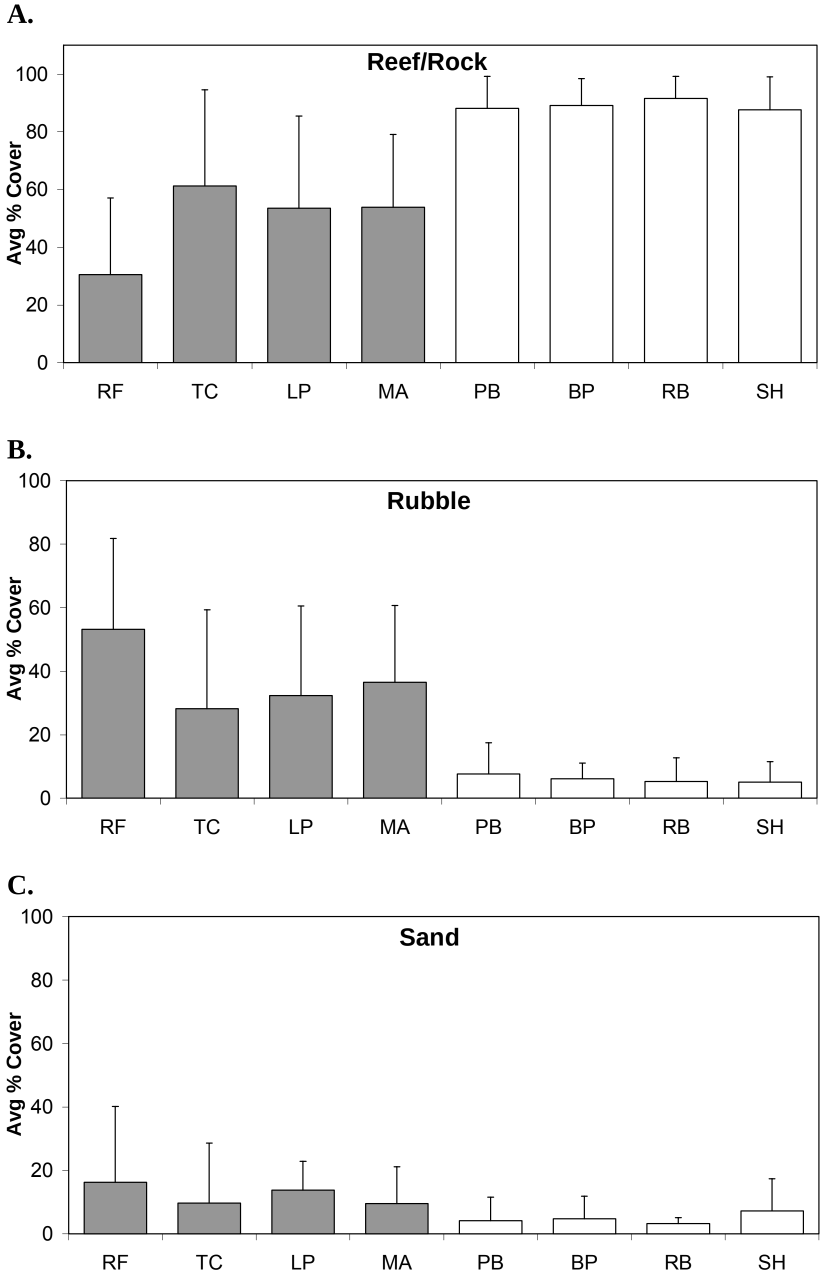


Figure 5. Substrate topographic complexity at damaged and non-impacted sites. **A.** Rugosity index. Columns show average rugosity indices (from 10 replicate measures) as determined with the chain method (see text) at damaged sites (gray columns) and non-impacted sites (white columns). Error bars show standard deviation. See Table 1 for site codes. **B.** Estimated vertical relief from pooled data at damaged sites (gray columns) and non-impacted sites (white columns). Average and maximum values are shown. Error bars show standard deviation.

Vertical relief also differed between damaged and non-impact sites. From pooled data, average estimated vertical relief was 0.27 ± 0.12 m at damaged sites compared to 0.84 ± 0.19 m at non-impact sites (Fig. 5B). Average estimated maximum vertical relief was 0.70 ± 0.23 m at damaged sites and 1.69 ± 0.24 m at non-impact sites (Fig. 5B). Data for rugosity and vertical relief are shown in Appendix 2.

The composition of abiotic substrate at each survey site is shown in Figure 6. Analysis of pooled data showed that substrate composition differed significantly between damaged and non-impact areas. On average, damaged areas had greater cover of rubble (37.6 ± 28.7 %) than non-impact areas (6.0 ± 7.2 %; *t*-test assuming unequal variance, $t = -7.73$, $p < 0.001$) and damaged areas had a greater coverage of sand (12.4 ± 16.5 %) than non-impact areas (4.9 ± 7.2 %; *t*-test assuming unequal variance, $t = 2.63$, $p < 0.012$). Non-impact areas had a greater percent coverage of reef/rock (89.1 ± 9.7 %) than was observed at damaged areas (49.8 ± 30.6 %; *t*-test assuming unequal variance, $t = 6.74$, $p < 0.001$).

Figure 6. Abiotic substrate composition at damaged sites (gray columns) and non-impact sites (white columns). **A.** Reef or consolidated limestone rock. **B.** Unconsolidated rubble. **C.** Sand. Error bars show standard deviation. See Table 1 for site codes.



Benthic Communities

Corals

Coral cover was higher at non-impact sites than at damaged sites (Fig. 7A). Average percent coral cover was 25.1 ± 10.3 % at non-impact sites and 3.1 ± 4.0 % at damaged sites. This difference was significant (*t*-test assuming unequal variance, *t* = -12.5, p < 0.001), and represents an 87.5 % reduction in coral cover.

A total of 28 coral species (including two nominal taxa), representing 10 families, were observed in this study (Table 2). More species were observed at non-impact sites (27 species) than at damaged sites (17 species). Average richness was higher at non-impact sites than at damaged sites (Fig. 7B). On average, damaged sites had 3.1 ± 1.8 species per m^2 and non-impact sites had 6.7 ± 1.9 species per m^2. Average richness at damaged sites was significantly lower than at non-impact sites (*t*-test, *t* = -8.45, p < 0.001). Cumulative number of species observed was also higher at non-impact sites (Average = 18.5 species) than at damaged sites (Average = 11.0 species).

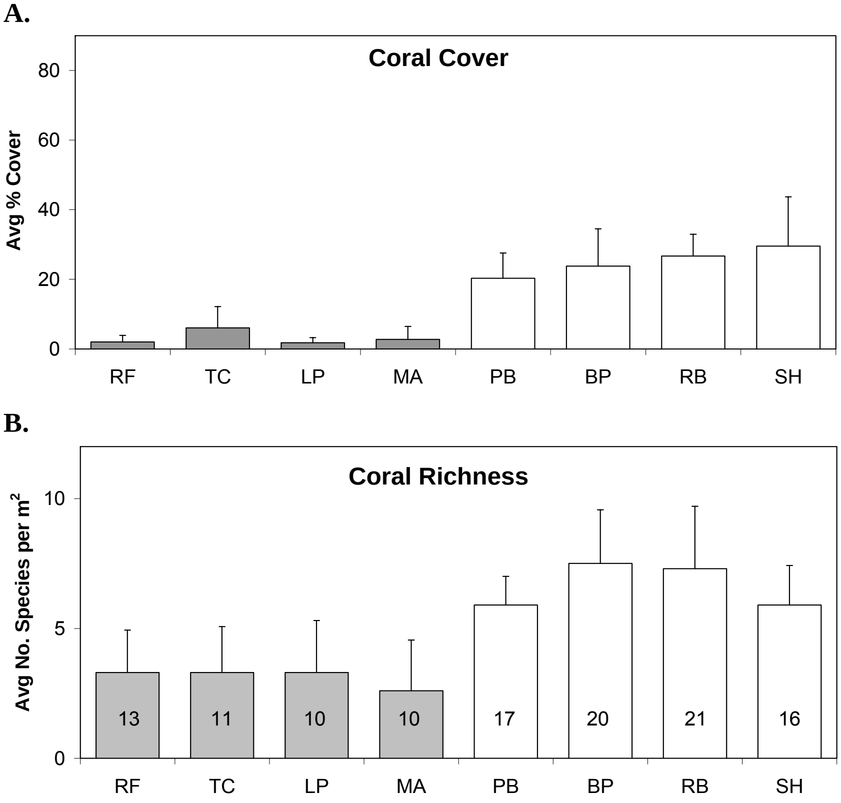


Figure 7. Coral abundance and richness at damaged sites (gray columns) and non-impact sites (white columns). **A.** Average percent cover of corals. **B.** Average coral richness (cumulative number of coral species observed at each site also indicated). Error bars show standard deviation. See Table 1 for site codes.

Comparison of corals from damaged and non-impact areas (Table 2) also showed that differences in the amount of cover varied by coral species. At non-impact sites, *Montastraea annularis* dominated (50.9 %) coral communities, followed by *Porites astreoides* (13.1 %), *M. franksi* (9.2 %), *M. faveolata* (8.7 %), *Agaricia agaricites* (7.6 %), *P. porites* (3.0 %), *M. cavernosa* (2.3 %), and *Siderastrea siderea* (0.5 %). The remaining 19 species (Table 2) collectively accounted for 4.8 % of coral cover (Fig. 8).

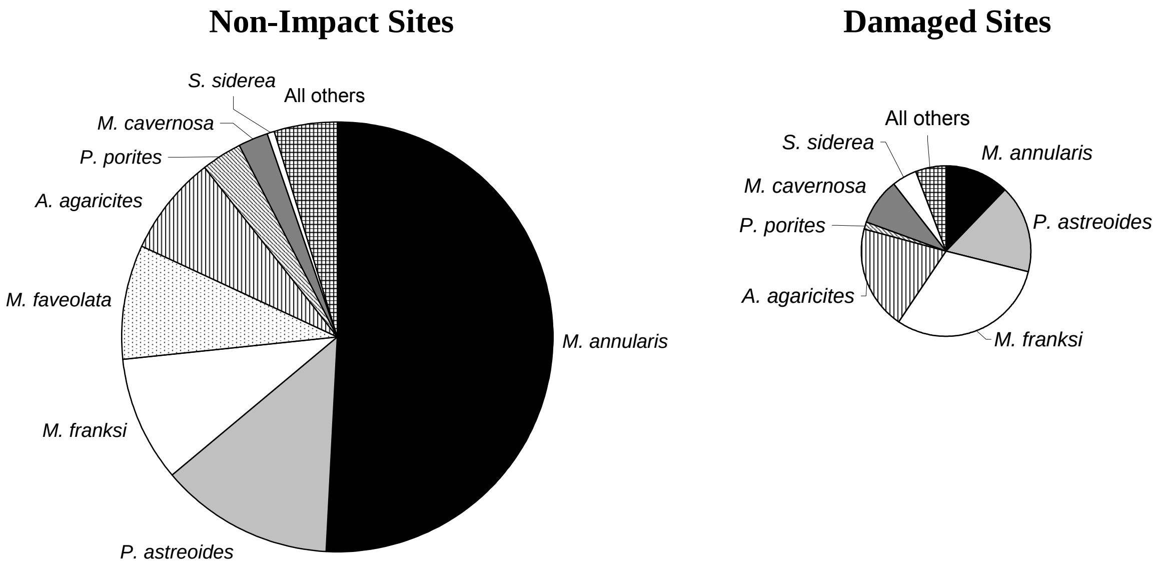
Table 2. Frequency and percent cover of corals at damaged and non-impact sites.

		Damaged Sites			Non-Impact Sites		
		Frequency	Percent Cover (per m^2)		Frequency	Percent Cover (per m^2)	
Species	Family	(n = 40)	Avg.	St.Dev.	(n = 40)	Avg.	St.Dev.
Montastraea annularis	Faviidae	27.5%	0.39	0.81	92.5%	12.77	11.04
Porites astreoides	Poritidae	52.5%	0.52	1.15	95.0%	3.28	2.45
Montastraea franksi	Faviidae	35.0%	0.95	1.99	57.5%	2.31	2.84
Agaricia agaricites	Agariciidae	57.5%	0.62	1.03	100.0%	1.90	1.55
Montastraea faveolata	Faviidae	2.5%	0.01	0.03	42.5%	2.18	3.75
Montastraea cavernosa	Faviidae	32.5%	0.28	0.87	35.0%	0.58	1.29
Porites porites	Poritidae	15.0%	0.04	0.12	47.5%	0.74	1.13
Siderastrea siderea	Siderastreidae	37.5%	0.14	0.24	17.5%	0.12	0.36
Colpophyllia natans	Faviidae	0.0%	-	-	10.0%	0.23	0.94
Diploria labyrinthiformis	Faviidae	5.0%	0.02	0.07	7.5%	0.14	0.50
Meandrina meandrites	Meandrinidae	5.0%	0.02	0.08	10.0%	0.12	0.46
Millepora alcicornis	Milleporidae	5.0%	0.03	0.16	32.5%	0.10	0.19
Stephanocoenia intersepta	Astrocoeniidae	15.0%	0.08	0.26	10.0%	0.03	0.13
Agaricia sp.	Agariciidae	0.0%	-	-	7.5%	0.09	0.38
Agaricia lamarki	Agariciidae	0.0%	-	-	5.0%	0.08	0.44
Madracis decactus	Pocilloporidae	10.0%	0.02	0.06	22.5%	0.06	0.13
Scolymia sp.	Mussidae	2.5%	0.003	0.02	10.0%	0.07	0.39
Madracis mirabilis	Pocilloporidae	0.0%	-	-	7.5%	0.07	0.35
Porites furcata	Poritidae	0.0%	-	-	5.0%	0.06	0.32
Favia fragum	Faviidae	5.0%	0.01	0.02	20.0%	0.04	0.13
Agaricia fragilis	Agariciidae	0.0%	-	-	7.5%	0.03	0.12
Eusmilia fastigiata	Caryophylliidae	0.0%	-	-	7.5%	0.03	0.12
Mycetophyllia ferox	Mussidae	0.0%	-	-	2.5%	0.02	0.13
Mycetophyllia lamarckiana	Mussidae	0.0%	-	-	5.0%	0.02	0.07
Mycetophyllia aliciae	Mussidae	0.0%	-	-	2.5%	0.01	0.09
Diploria strigosa	Faviidae	0.0%	-	-	2.5%	0.01	0.08
Millepora complanata	Milleporidae	2.5%	0.01	0.05	2.5%	0.003	0.02
Isophyllastrea rigida	Mussidae	2.5%	0.01	0.03	0.0%	-	-

Corals are ranked in decreasing order of average percent cover (all sites combined).

At damaged reef sites, average percent cover of *Montastraea annularis* was reduced by 97 % and *M. faveolata* was almost eliminated (Table 2). Coral community composition was restructured (see Fig. 8) such that the dominant corals were *M. franksi* (30.4 %), *A. agaricites* (19.8 %), *P. astreoides* (16.7 %), *M. annularis* (12.3 %), *M. cavernosa* (8.9 %), and *S. siderea* (4.6 %). Compared to non-impact sites, all coral species had lower average percent cover at damaged sites except for *S. siderea* and *Stephanocoenia intersepta*.

Figure 8. Average coral species composition at damaged sites (below, right) and non-impact sites (below, left). Pie charts are scaled 7:1 to show the relative difference in percent coral cover between damaged and non-impact sites.

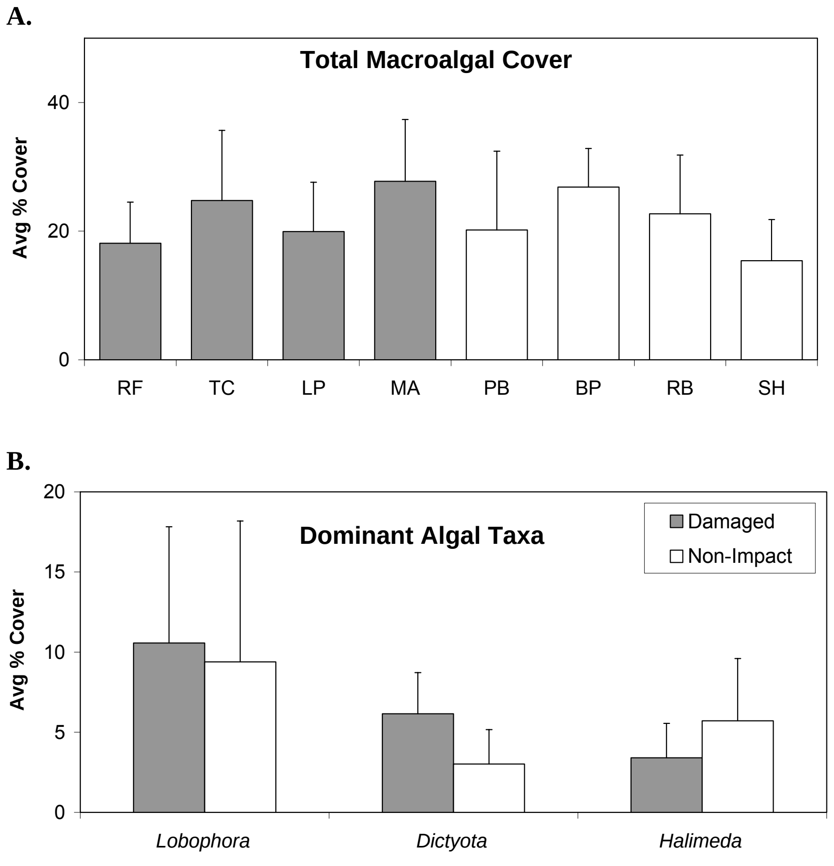


Macroalgae

Total cover by macroalgae was comparable between damaged and non-impact sites (Fig 9A). On average, percent algal cover was 21.3 ± 9.5 % at non-impact sites and 22.7 ± 9.3 % at damaged sites. These differences were not significant (*t*-test, $t = 0.65$, $p = 0.52$). Fourteen taxa (species or nominal taxa) of macroalgae were observed in this study. Over 87 % of macroalgal cover was contributed by three genera: *Lobophora*, *Dictyota*, and *Halimeda.* Each was observed with a frequency > 90 %. Also relatively abundant were encrusting coralline algae (4.8 %) and the filamentous blue-green algae, *Schizothrix calcicola* (2.6 %). The remaining genera (*Galaxaura*, *Ceramium*, *Jania*, *Udotea*, *Valonia*, *Ventricaria*, *Neomeris* and unidentified macroalga) were less frequent and less abundant, collectively contributing 5.6 % to observed macroalgal coverage.

Abundance of the three predominant algal genera were compared between damaged and non-impact sites (Fig. 9B). The percent cover of *Lobophora* (exclusively *L. variegata*) was similar between areas: 10.6 ± 7.3 % at damaged sites and 9.4 ± 8.8 % at non-impact sites (*t*-test, $t = 0.66$, $p = 0.51$). However, the average percent cover by *Dictyota* was greater at damaged sites (6.2 ± 2.6 %) than at non-impact sites (3.0 ± 2.1 %; *t*-test, $t = 5.95$, $p < 0.001$). Average percent cover by *Halimeda* was greater at non-impact sites (5.7 ± 3.9 %) than at damaged sites (3.4 ± 2.2 %; *t*-test assuming unequal variance, $t = -3.30$, $p = 0.002$). The author notes that three species (*H. goreaui*, *H. opuntia*, and *H. copiosa*) accounted for most observations ascribed to the taxon *Halimeda*.

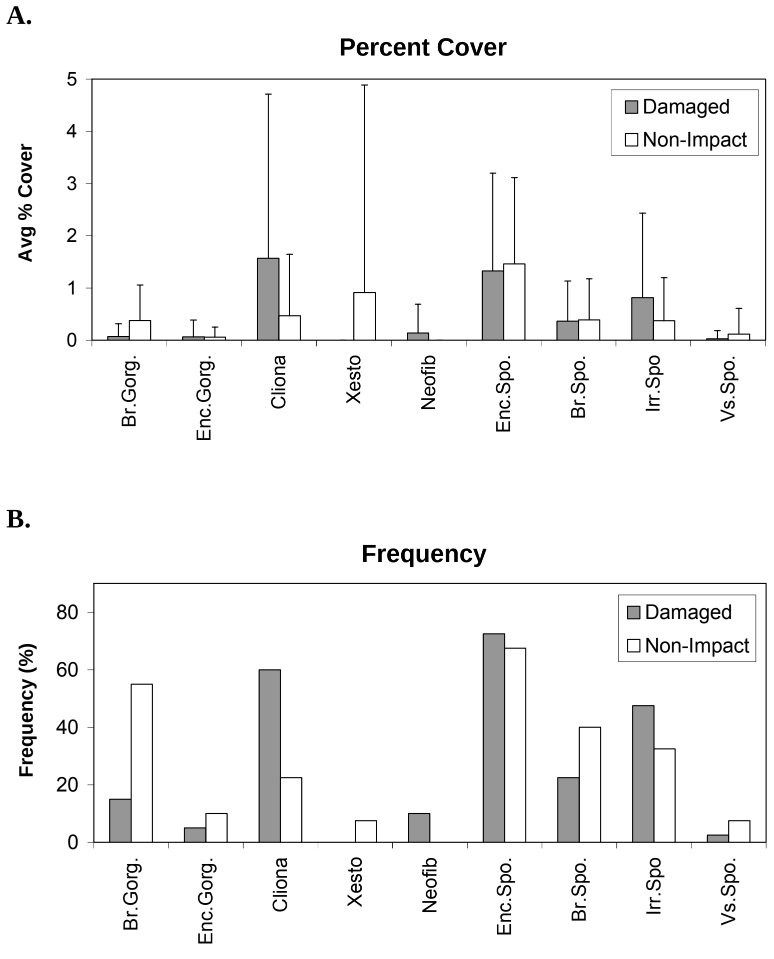
Figure 9. Percent cover of macroalgae at damaged sites (gray columns) and non-impact sites (white columns). **A.** Total cover of all macroalgae. See Table 1 for site codes. **B.** Cover of the three dominant taxa of macroalgae, *Lobophora*, *Dictyota* and *Halimeda*. Site data were pooled by impact group. Error bars show standard deviation.



Other Invertebrates

Gorgonians and sponges were the only taxa which contributed substantially to "other invertebrates" within benthic communities (i.e., recorded at > 0.1 % cover in quadrats). Collectively, sponges and gorgonians contributed about equally to average percent cover at damaged sites (4.4 ± 3.4 %) and at non-impact sites (4.2 ± 4.5 %). Examination of the composition of gorgonians and sponges indicated that there were several differences between damaged and non-impact areas (Fig. 10). Branching gorgonians (primarily *Pseudopterogorgia* sp.) had higher percent cover (Fig. 10A) and were more frequent (Fig. 10B) at non-impact sites. The giant barrel sponge, *Xestospongia muta*, was observed with greater frequency at non-impact sites (Fig. 10B). At damaged sites, the encrusting/boring sponges of the genus *Cliona* had higher percent cover (Fig. 10A) and were more frequently observed (Fig. 10) than at non-impact sites.

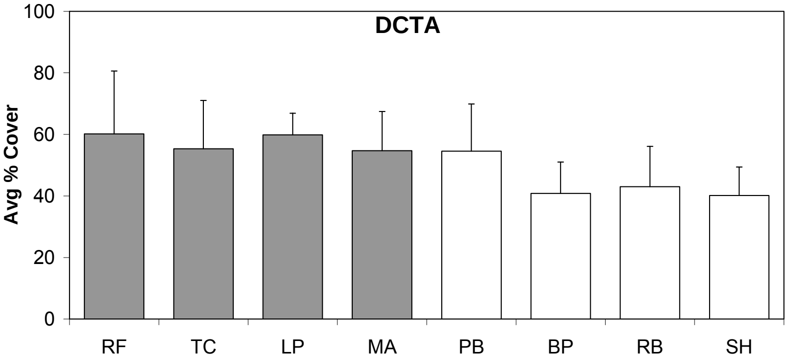
Figure 10. Abundance of gorgonians and sponges observed at damaged sites (gray columns) and non-impact sites (white columns). Site data were pooled by impact group. **A.** Average percent cover. Error bars show standard deviation. **B.** Frequency of observation (40 replicate quadrats per area). Abbreviations are as follows: Br.Gorg. = branching gorgonian, Enc.Gorg. = encrusting gorgonian, Cliona = sponge of the genus *Cliona*, Xesto = *Xestospongia muta*, Neofib = *Neofibularia nolitangere*, Enc.Spo. = encrusting sponge, Br.Spo. = branching sponge, Irr.Spo. = irregular/erect sponge, Vs.Spo. = vase sponge.



Dead Coral with Turf Algae

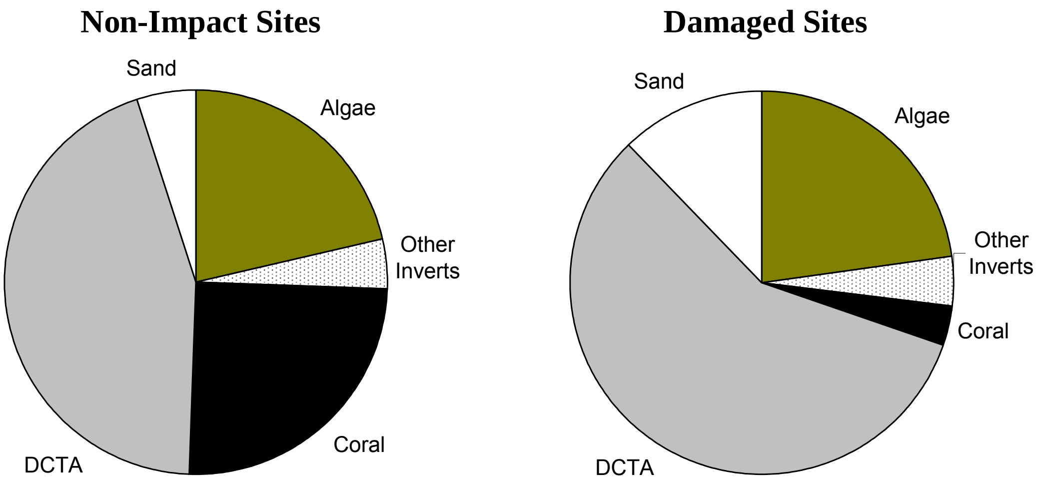
Among the primary biotic categories used for scoring benthic communities in this study, Dead Coral with Turf Algae (DCTA) dominated biotic cover at all sites (Fig. 11). Percent cover by DCTA was significantly greater (*t*-test, $t = 4.17$, $p < 0.001$) at damaged sites (57.5 ± 14.5 %) than at non-impact areas (44.6 ± 13.1 %).

Figure 11. Average percent cover of dead coral with turf algae (DCTA) at damaged sites (gray columns) and non-impact sites (white columns). Error bars show standard deviation. See Table 1 for site codes.



A comparison of the average contributions by each of the primary biotic categories (corals, algae, gorgonians & sponges, DCTA) to benthic community structure is shown in Figure 12 for damaged and non-impact sites. Among sites, the biotic cover of hard substrate (sand is also shown in Figure 12) by macroalgae was approximately equal between damaged and non-impact sites. Similarly, average cover by gorgonians & sponges was comparable between damaged and non-impact areas. However, large differences between damaged and non-impacted areas were seen for coral cover, DCTA cover, and sand (Fig. 12). At damaged sites, the large decline in coral cover is accompanied by an increase in DCTA cover and, to a lesser extent, an increase in sand cover.

Figure 12. Comparison of benthic community composition between damaged areas (below, right) and non-impacted areas (below, left). Average percent cover is shown for the four primary biotic categories observed. Site data are pooled by impact group. Average cover of sand (an abiotic category representing softbottom substrates) is also shown. DCTA = Dead Coral with Turf Algae, Other Inverts = sponges, gorgonians and other non-scleractinian invertebrates.

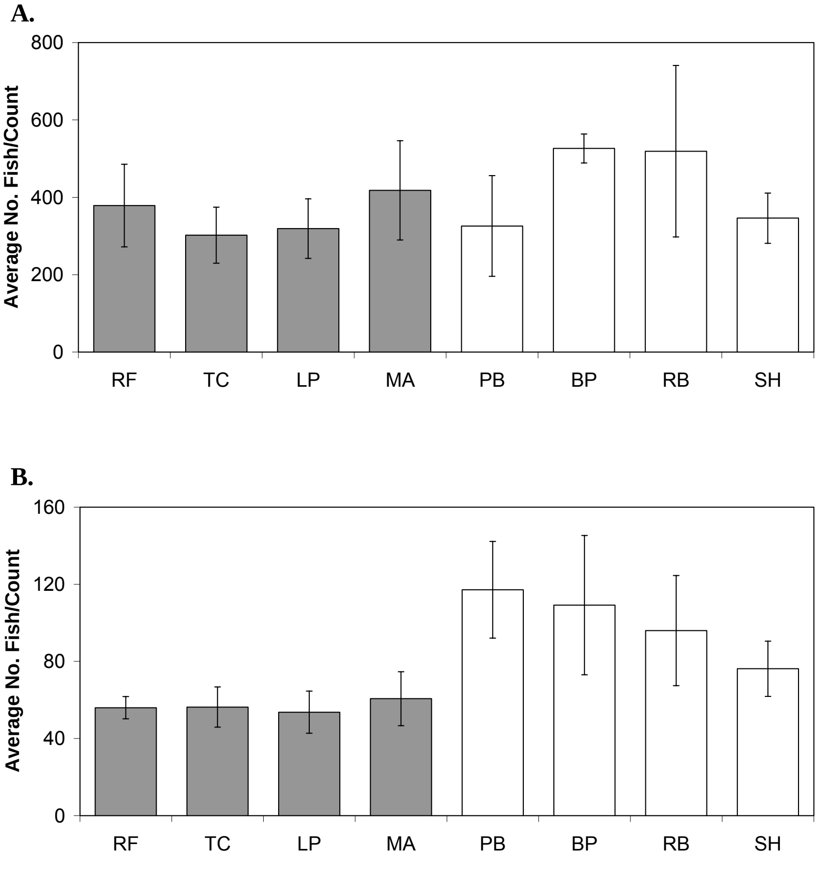


Fish Assemblages

Fish assemblages were assessed with a total of 48 point counts. Divers recorded a total of 18,813 fish representing 82 species from 29 families (Appendix 5). More fish were observed at non-impact sites (10,305 fish) than at impact sites (8,508 fish).

Average fish abundance at each site is shown in Figure 13. When data were pooled, average abundance at non-impact sites (429.4 ± 157.3 fish/count) was greater than average abundance at damaged sites (354.5 ± 103.6 fish/count) although this difference was not significant (*t*-test, *t* = -1.947, p = 0.058, Fig. 13A). After excluding the five most common species (see below), average abundance at non-impact sites (99.6 ± 29.9 species/count) was greater than average abundance at damaged sites (56.7 ± 10.3 species/count, Fig. 13B). This difference was significant (*t*-test, *t* = -6.65, p < 0.001).

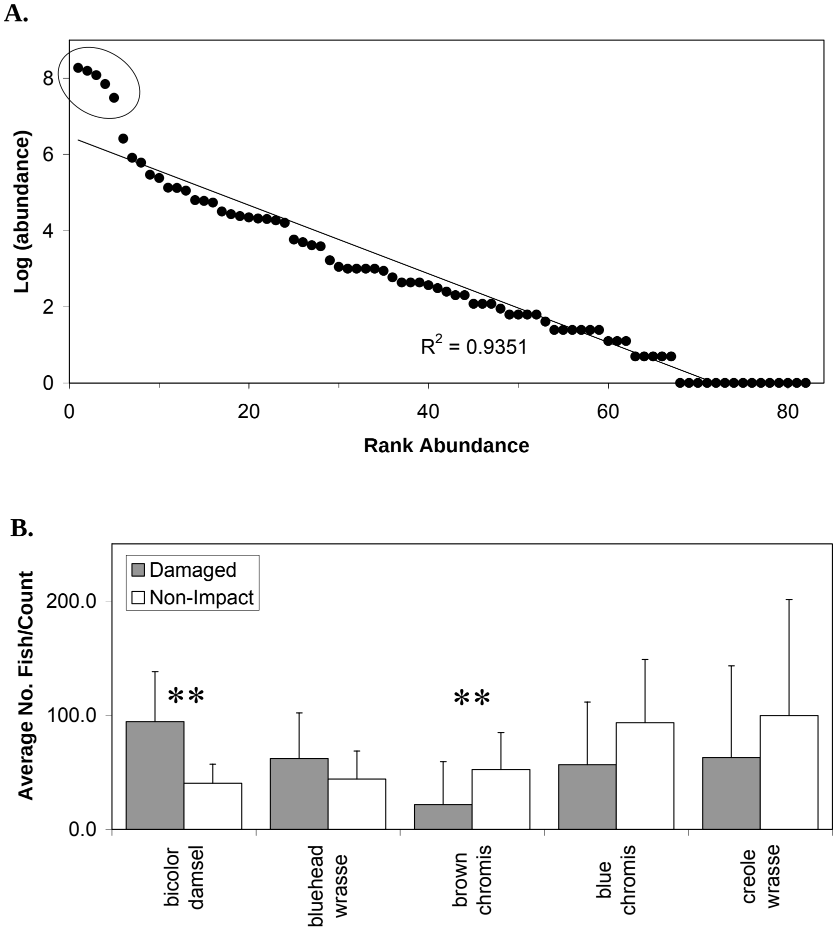
Figure 13. Fish abundance at damaged and non-impacted sites. **A.** Average abundance for all fish species observed. **B.** Average fish abundance after excluding the five most common fish species (creole wrasse, blue chromis, bicolor damselfish, bluehead wrasse and brown chromis). Error bars show standard deviation. Sites are coded as damaged (gray columns) or non-impact (white columns). See Table 1 for site codes.



Fish assemblages were dominated by the following five species, ranked in order of decreasing total abundance: creole wrasse (*Clepticus parrae*), blue chromis (*Chromis cyanea*), bicolor damselfish (*Stegastes partitus*), bluehead wrasse (*Thalassoma bifasciatum*), and brown chromis (*Chromis multilineata*). Together, the five most common species accounted for over 80 % (15,062 fish) of all observations (Table 3). Examination of specific abundance patterns revealed a general log-linear relation on rank abundance (Fig. 14A) which indicated that these five species were also somewhat exceptional in terms of abundance. Therefore, they were examined separately from the remaining fish assemblage. Collectively, planktivore abundance at damaged sites (297.8 ±

99.2 fish/count) and non-impact sites (329.8 ± 156.3 fish/count) was not significantly different (*t*-test, *t* = -0.844, p = 0.403). When analyzed individually, however, abundance differences were apparent for two species. At damaged sites, a significant increase in abundance was observed for bicolor damselfish (*t*-test, *t* = 5.640, p < 0.0001) and a significant decrease was observed for brown chromis (*t*-test, *t* = - 3.03, p < 0.004). Abundance of creole wrasse, bluehead, and blue chromis were not significantly different between damaged and non-impact areas.

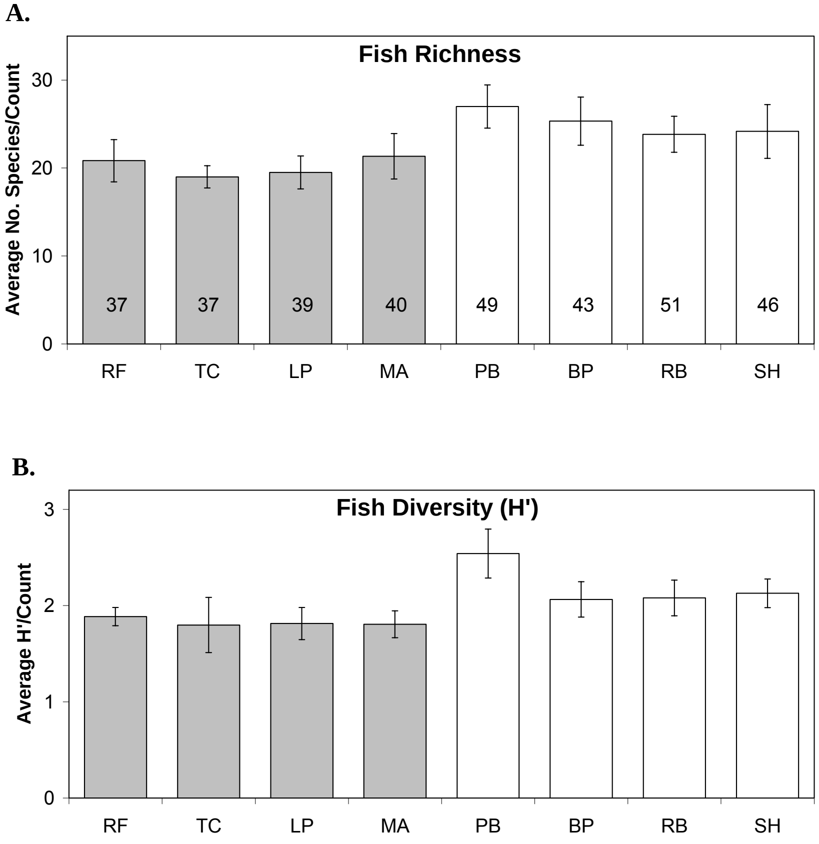
Figure 14. Analysis of abundance trends in the five most commonly observed fish species in this study. **A.** Rank abundance of all fish taxa plotted against natural logarithm of abundance. The five most common species (circled group at upper left) deviated from the general log-linear abundance trend observed for other species. **B.** Average abundance of the five most commonly observed species at damaged sites (gray columns) and non-impacted sites (white columns). Error bars show standard deviation. Asterisks indicate significant differences between pairs.



Average species richness of fish assemblages at each site is shown in Figure 15A. Average richness was higher at non-impact sites (25.1 ± 2.7 fish/count) than at damaged sites (20.2 ± 2.2 fish/count). Average richness was significantly different between groups (*t*-test, *t* = -6.89, p < 0.001). Cumulative number of species was also higher at non-impact sites (*t*-test, *t* = -4.73, p < 0.003). On average, the cumulative number of fish species observed at non-impact sites (47.3 species/site) was greater than that observed at damaged sites (38.3 species/site). Of 82 species observed during the study, 71 species were observed at non-impact sites and 56 were observed at damaged sites.

Average fish diversity (Shannon-Weaver H') is shown in Figure 15B. Average diversity, expressed as H' observed per replicate count, was higher at non-impact sites (2.20 ± 0.27) than at damaged sites (1.83 ± 0.18). Observed differences were significant (*t*-test, *t* = -5.69, p < 0.001).

Figure 15. Fish species richness and diversity at damaged sites (gray columns) and non-impacted sites (white columns). **A.** Average richness (average number of fish species observed from six replicate counts). Cumulative number of species observed per site is shown (inset). **B.** Average Shanon-Weaver diversity (average H' value from six replicate counts). Error bars show standard deviation. See Table 1 for site codes.



A comparison of fish species composition between damaged and non-impact sites is shown in Table 3. Observed differences were explored further by calculating the specific differences in abundance (Fig. 16). Large differences in abundance (> 1 standard deviation from average Δ abundance) are seen for 13 species. Relative to non-impact sites, the following species showed lower abundance in damaged habitats: brown chromis (*Chromis multilineata*), threespot damselfish (*S. planifrons*), french grunt (*Haemulon flavolineatum*), mackerel scad (*Decapterus macarellus*), graysby (*Cephalopholis cruentatus*), boga (*Inermia vittata*), mahogany snapper (*Lutjanus mahogoni*) and schoolmaster (*L. apodus*). Mackerel scad and boga were observed at only one site (sites RB and BP, respectively). The following species showed higher abundance in damaged sites: bicolor damselfish (*S. partitus*), yellowhead wrasse (*Halichoeres garnoti*), coney (*Cephalopholis fulvus*), tobaccofish (*Serranus tabacarius*) and harlequin bass (*S. tigrinus*).

Patterns of spatial distribution within and between impact groups were also examined (not shown). Six species showed evidence of restricted distribution between damaged and non-impact sites. Trumpetfish (*Aulostomus maculatus*), sergeant major (*Abudefduf saxatilis*), fairy basslet (*Gramma loreto*), whitespotted filefish (*Cantherhines macrocerus*), and caesar grunt (*Haemulon carbonarium*) were observed at most non-impact sites and not at damaged sites. Tobaccofish (*Serranus tabacarius*) were observed at most damaged sites but not at non-impact sites. These spatial patterns, together with observation on abundance, are summarized in Table 4.

Figure 16. Differences in species abundance patterns between damaged and non-impacted areas. Delta (abundance) was calculated from habitat-pairs for each species using ln(x+1) transformed data. Data are presented in rank order of average abundance (pooled data) and shown relative to average delta (-0.152) calculated from the entire fish assemblage (solid line). Dashed lines show 1 and 2 standard deviations. Note that a positive value of delta abundance indicates increased abundance in damaged habitats and a negative value indicates decreased abundance in damaged habitats. Species are abbreviated as follows: Ccru = *Cephalopholis cruentatus*, Cful = *Cephalopholis fulvus*, Cmul = *Chromis multilineata*, Dmac = *Decapterus macarellus*, Hfla = *Haemulon flavolineatum*, Hgar = *Halichoeres garnoti*, Ivit = Inermia vittata, Lapo = *Lutjanus apodus*, Lmah = *Lutjanus mahogoni*, Spar = *Stegastes partitus*, Spla = *Stegastes planifrons*, Stab = *Serranus tabacarius*, Stig = *Serranus tigrinus*.

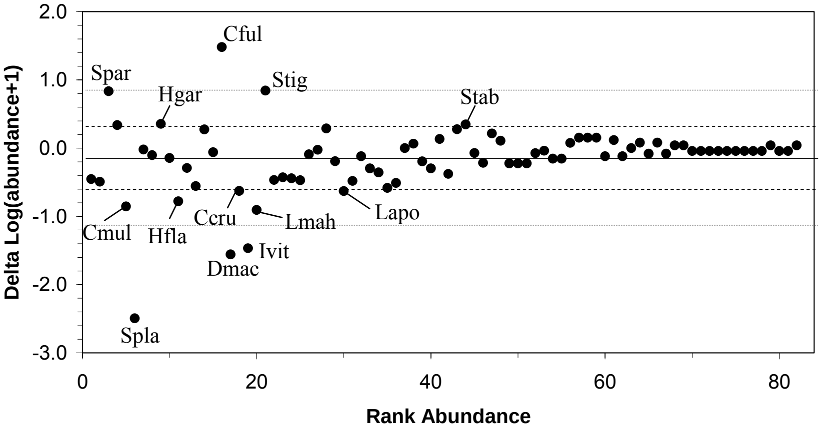


Table 3. Abundance of the 30 most common fish species at damaged and non-impact sites.

		Damaged Sites				Non-Impact Sites			
Common Name	Species	Total No.	Freq. (%)	Avg No. per Obs.	St.Dev	Total No.	Freq. (%)	Avg No. per Obs.	St.Dev
creole wrasse	*Clepticus parrae*	1,510	62.5%	62.9	80.2	2,390	79.2%	99.6	101.7
blue chromis	*Chromis cyanea*	1,361	91.7%	56.7	54.7	2,241	100.0%	93.4	55.5
bicolor damselfish	*Stegastes partitus*	2,264	100.0%	94.3	43.8	969	100.0%	40.4	16.7
bluehead wrasse	*Thalassoma bifasciatum*	1,491	95.8%	62.1	39.9	1,056	100.0%	44.0	24.6
brown chromis	*Chromis multilineata*	522	54.2%	21.8	37.5	1,258	100.0%	52.4	32.4
threespot damselfish	*Stegastes planifrons*	26	25.0%	1.1	2.3	582	100.0%	24.3	10.3
princess parrotfish	*Scarus taeniopterus*	183	100.0%	7.6	3.5	187	100.0%	7.8	2.5
redband parrotfish	*Sparisoma aurofrenatum*	153	95.8%	6.4	2.8	172	100.0%	7.2	2.5
yellowhead wrasse	*Halichoeres garnoti*	143	91.7%	6.0	3.5	93	91.7%	3.9	1.9
striped parrotfish	*Scarus iserti*	99	70.8%	4.1	4.4	118	87.5%	4.9	2.6
french grunt	*Haemulon flavolineatum*	44	87.5%	1.8	1.2	124	66.7%	5.2	11.5
longfin damselfish	*Stegastes diencaeus*	68	54.2%	2.8	4.5	99	62.5%	4.1	4.8
stoplight parrotfish	*Sparisoma viride*	50	79.2%	2.1	2.3	105	95.8%	4.4	2.1
ocean surgeonfish	*Acanthurus bahianus*	72	91.7%	3.0	2.5	49	79.2%	2.0	1.4
yellow goatfish	*Mulloidichthys martinicus*	57	25.0%	2.4	5.0	62	29.2%	2.6	6.7
coney	*Cephalopholis fulvus*	108	100.0%	4.5	1.6	6	16.7%	0.3	0.6
mackerel scad	*Decapterus macarellus*	0	0.0%	0.0	0.0	90	8.3%	3.8	16.4
graysby	*Cephalopholis cruentatus*	22	62.5%	0.9	0.9	62	91.7%	2.6	1.2
boga	*Inermia vittata*	0	0.0%	0.0	0.0	80	4.2%	3.3	16.3
mahogany snapper	*Lutjanus mahogoni*	12	8.3%	0.5	1.9	65	37.5%	2.7	6.0
harlequin bass	*Serranus tigrinus*	62	79.2%	2.6	2.0	13	33.3%	0.5	0.9
foureye butterflyfish	*Chaetodon capistratus*	23	45.8%	1.0	1.2	51	79.2%	2.1	1.5
blue tang	*Acanthurus coeruleus*	23	58.3%	1.0	1.0	48	91.7%	2.0	1.4
sharpnose puffer	*Canthigaster rostrata*	21	33.3%	0.9	1.5	46	79.2%	1.9	1.4
queen parrotfish	*Scarus vetula*	11	16.7%	0.5	1.3	32	66.7%	1.3	1.1
blackbar soldierfish	*Myripristis jacobus*	18	20.8%	0.8	2.0	22	33.3%	0.9	1.6
bar jack	*Caranx ruber*	18	41.7%	0.8	1.4	19	41.7%	0.8	1.1
longspine squirrelfish	*Holocentrus rufus*	24	58.3%	1.0	1.1	12	33.3%	0.5	0.8
rock beauty	*Holacanthus tricolor*	9	25.0%	0.4	0.7	16	20.8%	0.7	2.3
schoolmaster	*Lutjanus apodus*	0	0.0%	0.0	0.0	21	25.0%	0.9	1.8

Fish are ranked in order of decreasing total abundance (all sites combined).

Table 4. Abundance and distribution patterns of fish species affected by habitat damage.

Common Name	General Response to Damage	Δ Abundance*	Spatial Distribution** (No. of Sites) Damaged	Non-Impact
bicolor damselfish	strongly positive, abundance	0.835	4	4
brown chromis	negative, abundance	-0.854	4	4
threespot damselfish	strongly negative, abundance	-2.495	3	4
yellowhead wrasse	positive, abundance	0.356	4	4
french grunt	negative, abundance	-0.778	4	4
coney	strongly positive, abundance	1.482	4	3
graysby	negative, abundance	-0.626	4	4
mahogany snapper	strongly negative, abundance	-0.905	2	3
harlequin bass	strongly positive, abundance	0.843	4	4
schoolmaster	negative, abundance & spatial	-0.629	0	2
trumpetfish	negative, spatial	na	1	4
sergeant major	negative, spatial	na	0	4
fairy basslet	negative, spatial	na	0	4
tobaccofish	positive, abundance & spatial	0.348	3	0
whitespotted filefish	negative, spatial	na	0	3
caesar grunt	negative, spatial	na	0	3

Fish are ranked in order of decreasing average abundance (all site combined).

* Δ Abundance = Average abundance at damaged sites minus average abundance at non-impact sites calculated using ln(x+1)-transformed data. Values of Δ Abundance are reported only for 11 species which deviated from average assemblage values by > 1.0 standard deviation. Mackerel scad (*Decapterus macarellus*) and boga (*Inermia vittata*) were excluded due to infrequent observation.

** For analysis of spatial distribution patterns, six species were identified that showed restricted spatial distributions: ≥ 75 % frequency in damaged (or non-impact) sites but ≤ 25% in non-impact (or damaged) sites.

DISCUSSION

Declines in coral reef condition (Rogers and Beets 2001) and phase-shifts on Caribbean coral reefs (Hughes 1994) have recently focused attention on reef health and resiliency (Hughes et al. 2003). Anthropogenic stressors to Caribbean coral reefs have become so chronic that they may now impair the regeneration potential of reef systems (Nyström et al. 2000, McManus and Polsenberg 2004, Gardner et al. 2005). Thus, it has become increasingly important to understand the long-term response of reefs to different types of impacts. Results from this study offer insight into the medium-term (10-25 years) response of a coral reef and associated biota to physical destruction caused by anchoring. This study also provides local resource managers with a more accurate assessment of anchor damage to the Frederiksted Reef and a better description of unimpacted areas from the reef crest zone. As discussed below, these findings leave little doubt that anchoring on the Frederiksted Reef has altered the physical framework over a large area and that benthic and fish communities have been impacted.

I. Physical Impacts to the Reef

Anchors cause physical destruction of coral reefs by fracturing and leveling the reef framework, pulverizing or toppling carbonate structures, and further reducing carbonates to small rubble, debris or fine sediment (Jaap 2000). The magnitude of damage increases with the size of anchor and chain deployed. Deploying and retrieving the large (≥ 1 ton) anchors used by commercial vessels can deeply gouge the reef substrate creating permanent scars (e.g. Smith 1988, Rogers and Garrison 2001). Swinging of anchor chains may cause additional damage over an even larger area by crushing or toppling corals and sponges or dislodging benthic invertebrates (Jaap 2000, pers. obs.). On the Frederiksted Reef, abundant evidence for these types of anchoring impacts was observed. Measures of rugosity and vertical relief confirmed that structural complexity of the former reef crest zone had been greatly reduced. Impacted areas also had increased amounts of rubble and sand but less consolidated reef substrate.

The spatial extent of anchor damage to the Frederiksted Reef is large: 16.1 to > 21.2 hectares of contiguous damage. The towed-diver survey method used here was useful for identifying damaged reef areas in a preliminary manner, but the method was impractical for generating a high resolution map across the entire reef tract. Advanced mapping methods such as side scan sonar are needed to better delineate reef damage, as well as to gain a better understanding of the spatial, structural and bathymetric extent of the Frederiksted Reef System.

II. Benthic Communities

Anchoring impacts to coral communities were readily apparent. Live corals were sparse at damaged sites and comprised far fewer species. Compared to non-impact areas, there was a tremendous decrease (> 97 %) in the abundance of *Montastraea annularis* – the predominant reef building coral of the Caribbean (Knowlton and Weil 1994). In adjacent areas < 1 km to the north, *M. annularis* is the most abundant species in the reef crest zone and contributes most of the reef framework. Branching corals were also rare or absent from damaged sites. Corals from damaged areas were typified by small, encrusting or hemispherical growth forms such as *Montastraea franksi*, *Siderastrea siderea*, *Stephanocoenia intersepta*, *Porites astreoides* and *Agaricia agaricites*. Jaap (2000) considered the latter two corals to be pioneering species which recover at impact sites within eight to ten years. While these pioneer species provides some evidence for coral recovery, the observations indicate that the largest, slow-growing massive corals (e.g. *M. annularis*, *M. faveolata* and *Colpophyllia natans*) which were greatly impacted by anchor damage have shown little sign of re-growth at damaged sites.

In addition to scleractinian corals, anchoring may kill or dislodge sponges and gorgonians (Jaap 2000, Rogers and Garrison 2001). Data from the Frederiksted reef indicate that anchoring has reduced the abundance of some sponges - particularly large, slow growing species such as *Xestospongia muta*. However, encrusting sponges of the genus *Cliona* were more common in damaged habitats, presumably as an opportunistic response. Branching gorgonians were also less abundant in damaged habitats. Jaap (2000) predicts an ecological succession with a replacement over time of algal turfs (see below) by gorgonians, sponges and stony corals. *Pseudopterogorgia* is among the first octocorals to colonize damaged sites (Jaap 2000). At the Frederiksted Reef, however, *Pseudopterogorgia* occured in low abundance at damaged sites. Observations of invertebrates from damaged sites imply that these areas are in an early phase of recovery. Conditions for invertebrate recruitment may be unfavorable due to loose rubble and sand. Or, alternatively, foraging of microcarnivorous fishes such as wrasses may have reduced recruitment or survivorship of invertebrate larvae and juveniles (Ebersole 2001).

On Jamaican coral reefs, a sharp decline in coral cover was accompanied by a large increase in cover by fleshy macroalgae, or a phase shift (Hughes 1994). Such coral-algal phase shifts represent alternate ecological states which may persist indefinitely (Knowlton 1992, Hughes 1994, Knowlton 2004). Physical damage to coral reefs can cause phase shifts. For example, Hatcher (1984) observed a phase shift from coral to algal dominance at a ship grounding site on the Great Barrier Reef. Given the large reduction in coral cover caused by anchoring on the Frederiksted Reef, a shift to dominance by fleshy macroalgae might be predicted. However, results from this study do not support the inference that a coral-algal phase shift has occurred at damaged sites. Total cover by macroalgae was seen to be comparable between damaged and non-impact sites. Among macroalgal taxa observed, *Lobophora variegata* predominated but its abundance was similar at damaged and non-impact areas. *Dictyota* (fleshy brown algae) was relatively more abundant at damaged sites while *Halimeda* (less palatable calcareous green algae) was more common at non-impact sites. This pattern may be attributed to differential fish grazing pressure between damaged and nonimpact sites.

Although frondose or fleshy macroalgae did not proliferate at damaged sites, cover by turf algae *did* increase in disturbed areas. The reduction in live coral cover was accompanied by an increase in carbonate surfaces covered with turf-forming algae. Filamentous and turf-forming algae are typically the first recruits to reef surfaces following a major disturbance (Jaap 2000). The persistence of algal turfs at impact sites (instead of replacement by macroalgae) may be indicative of unfavorable growth conditions for macroalgae. Unstable substrata at disturbed sites may favor the growth of low, turf-like algal forms. Alternatively, foraging by resident herbivorous fishes or territorial damselfish activities may favor turf algae by preventing development of a frondose macroalgal flora (Hixon 1997).

Despite the passage of 10-25 years, the foregoing information on benthic community structure collectively indicates that areas damaged by anchoring off Frederiksted are still in an early phase of recovery: there has been little re-growth of the major reef building corals, gorgonian abundance remains low, species of slow growing sponges are rare, and turf algae predominates on carbonate surfaces. Coral reef recovery is known to be impeded by the presence of unstable, shifting substrata (rubble and debris) at impact sites which acts to prevent colonization and survival of coral recruits (Jaap 2000, Fox et al. 2003). On the Frederiksted Reef, it is likely that a preponderance of rubble and sand in impacted areas have slowed recovery from anchor damage.

III. Fish Assemblages

Fish assemblages at impacted sites were depauperate. The most striking difference in fish assemblage structure was a sharp reduction in diversity: damaged areas had approximately 20 % fewer species. Fish assemblages at damaged areas also showed reduced abundance. Unlike the benthic community, which is directly impacted by anchoring through physical disruption or mechanical destruction, changes in mobile fish assemblages must arise indirectly as a consequence of habitat disruption. Reef fish diversity is strongly and positively affected by substrate complexity (Risk 1972, Gladfelter and Gladfelter 1978, Luckhurst and Luckhurst 1978, Gratwicke and Speight 2005). It is likely that diversity of fish assemblages declined as a consequence of the physical reduction in habitat structural complexity at Frederiksted anchoring sites. However, fish diversity is also positively related to coral cover (Nemeth et al. 2003). Since both complexity and total coral cover were reduced by anchor damage, these data do not allow distinguishing between the two explanations.

In principle, habitat destruction could indirectly alter fish assemblages through a number of different mechanisms (see Adams 2001 and references therein), including 1) reduced larval recruitment to damaged reef areas, 2) altered movement patterns of juvenile and/or adult stage fishes which result in reduced immigration into, or increased emmigration away from, damaged sites, 3) increased mortality rates at damaged sites due to predation and competition, or 4) some combination of these factors. It was not the intent of this study to elucidate which mechanism(s) accounts for assemblage change. However, as discussed below, the variety of interspecific responses observed suggests that a satisfactory explanation for assemblage change may require invoking multiple mechanisms.

Habitat damage appeared to have inconsistent effects upon abundance of planktivorous fishes. Planktivores were highly abundant at all sites and the total (collective) abundance of the five most common species – all primarily planktivores - was similar between damaged and non-impact sites. This suggests that, as a trophic group, planktivore abundance may depend more upon favorable foraging opportunities afforded by currents associated with the shelf-break (Hobson 1991) than upon quality of reef habitat. However, among these five planktivores the abundance of two species (bicolor damselfish and brown chromis) differed between damaged and non-impact areas. Bicolor damselfish showed a positive population response. This may have been caused by reduced predation on bicolor damselfish at damaged sites due to refuge provided by the unique habitat architecture (predominantly rubble substrate) of these areas (Nemeth 1998). Alternatively, bicolor damselfish may have been released from space competition due to exclusion of threesport damselfish (see below) from damaged habitats (Robertson 1996). Brown chromis showed a negative population response to impact, perhaps due to the reduced availability of nightime shelter at damaged sites. These observations suggest that anchor damage impacts to fish assemblages may be manifested in a variety of different species-specific responses.

Exclusive of highly abundant planktivores, examination of the remaining fish assemblages showed that fish abundance was negatively affected by habitat damage, with total abundance reduced by about 43 % at damaged sites. For example, the threespot damselfish, *Stegastes planifrons*, was very common at unimpacted sites (observed in 100 % of surveys) but was observed infrequently (25 % of surveys) and at far lower abundance (> 95 % reduction) at damaged sites. This loss of fish abundance and assemblage diversity may also equate to reduced fisheries productivity of the Frederiksted Reef System. At least three recreationally and commercially important fish species had lower abundance at damaged sites: graysby (*Cephalopholis cruentata*), mahogany snapper (*Lutjanus mahogoni*), and schoolmaster (*L. apodus*) showed 65 %, 81 % and 100 % reductions in abundance at damaged sites.

It is tempting to propose a simple model of taxonomic attenuation to explain the decline in fish diversity corresponding with habitat damage (i.e., loss of habitat equals loss of species). Strict exclusion of reef-associated species might be predicted at reef habitats where benthic communities are sufficiently altered or where topographic complexity is largely eliminated. In this study, however, the spatial distribution patterns for most taxa were broad, and few species showed evidence of exclusions from damaged habitats. The composition of fish assemblages from damaged and non-impact sites showed broad overlap. Most of the differences between assemblages arose from changes in modal abundance and frequency, rather than from exclusion of species from a certain habitat. Thus, a simple subtractive model for fish assemblage change will not sufficiently explain abundance and spatial distribution patterns. Ebersole (2001) reached a similar conclusion in his study of fish assemblages from ship grounding sites in the Florida Keys.

The spatial distribution data did suggest that a small number of infrequently observed species were more common at damaged sites (e.g. tobaccofish, yellowhead jawfish and sargassum triggerfish). The presence of these non-reef species at damaged sites likely reflects a species preference for mixed rubble and sand substrates. This implies that, in some respects, anchor damage has altered the substrate sufficiently to create a different type of habitat in the former reef crest zone.

Species-specific patterns were often quantitative changes in abundance rather than exclusive restrictions to one or the other habitat type. For example coney (*Cephalopholis fulva*) and graysby (*C. cruentata*) were observed in both damaged and non-impact sites, but the two species exhibited opposite responses to habitat damage in terms of their abundance. Both coney and graysby are generalized serranid predators on natural reefs. Coney are more common in low-relief habitats on St. Croix (Toller 2002, Toller 2005) and graysby tend to inhabit high profile reefs with substantial topographic relief (DeLoach 2004). Given the marked simplification of habitat structure at damaged sites, opposite population responses by these two species was not entirely surprising. However, the strongly positive population response by coney to anchor damage (15-fold more abundant at damaged sites) was unexpected. The positive response of coney populations to reduced habitat complexity may reflect a strong habitat preference by this species. Alternatively, a favored prey item (e.g. bicolor damselfish) may be more abundant in damaged habitats, or the coney may be released from threat of predation in low-relief habitats. Given the importance of coney to the local commercial and recreational fishery (Bolden 1994), this finding deserves further study.

Among the various habitats which occur in near shore waters of the Caribbean, fish assemblages usually reach their greatest diversity in the fore-reef zone (Gratwicke and Speight 2005). On the Frederiksted Reef System, fish assemblages of the reef crest zone are quite diverse (Toller 2005) and are known to rival the highest diversities reported for the island of St. Croix (Nemeth et al. 2003, Kendall et al. 2005). Reduction or elimination of habitat structure on the Frederiksted Reef, and from the reef crest zone in particular, may cause a significant loss of fish biodiversity.

IV. Prognosis for Recovery

What is the time course for coral reef recovery from anchor damage on the Frederiksted Reef? Results from this study indicate that the damaged section of the Frederiksted Reef has recovered little during a 10 to >25 year period. The length of time required for full recovery will depend upon rates of coral recruitment, survival and growth which are difficult to predict with precision. Observations on coral density from this study were used to calculate a rate of coral recovery under a best case scenario, assuming 1) all anchoring impacts occurred exactly ten years ago and there were no intervening impacts during ten years of coral growth, 2) coral density was initially reduced to near zero by impacts, and 3) coral growth has followed a uniform geometric expansion in bottom cover. Recovery rate calculations suggest that total coral cover will be restored after 40 years and recovery of *M. annularis*, the primary reef framework building coral, will require > 60 years. These recovery estimates underscore the protracted nature of anchoring impacts.

Comparison of recovery rates from the Frederiksted Reef to damage investigations conducted in other locations suggests that the above estimates are not unreasonable. In St. John, USVI, a reef that was impacted by cruise ship anchoring showed no signs of recovery after more than 10 years (Rogers and Garrison 2001). In Grand Cayman, Smith (1988) examined anchor damage from cruise ships and estimated that recovery periods would exceed 50 years. Jaap (2000) suggests that recovery of stony corals from ship groundings requires “several decades to a century.” Ebersole (2002) suggested that “hardgrounds” created by ship groundings in the Florida Keys may persist > 100 years.

Coral reef recovery is known to be slowed by natural and anthropogenic stressors (Nyström et al. 2000). If anchoring activities have effectively ceased on the Frederiksted reef, duration of the recovery period may still be further protracted due to human activities. In addition to physical destruction caused by anchoring of large vessels (IRF 1993a, b, this study), anthropogenic stressors continue to impact the Frederiksted Reef System (Toller 2005), including bypass discharges of raw sewage (Kaczmarsky et al. 2005), dredging (Toller pers. obs.), and sediment loading (IRF 1993b) [a general failure to recognize and mitigate reef impacts occurred because of serious misconceptions about the composition and spatial extent of this reef system (see Toller 2005)]. Elimination or reduction of these stressors should facilitate the reef recovery process.

In recent years, coral reef restoration techniques have been developed for rehabilitating or restoring damaged reef habitats (Edwards and Clark 1998). Some restoration success has been achieved on reefs damaged by ship groundings (Jaap 2000) and blastfishing (Fox et al. 2005). However, the economic and scientific merit deriving from restoration efforts are still a matter of some debate (Edwards and Clark 1998, Spurgeon and Lindahl 2000). In the case of the Frederiksted Reef, the sheer size of the area impacted by anchoring (> 21 hectares) will likely make restoration a prohibitively expensive option (see restoration cost estimates in Spurgeon and Lindahl 2000). Despite the extended time projected, the only economically reasonable alternative may be to allow recovery of the Frederiksted Reef to occur through natural processes.

IV. Recommendations

Anchor damage which has occurred on the Frederiksted Reef should serve as a valuable lesson which galvanizes efforts to effectively conserve and manage coral reef resources in the USVI. Federal and Territorial governmental agencies must collaborate to develop a strategy that will enable the economic growth of coastal communities such as Frederiksted while minimizing further loss of valuable natural coral reef resources. Future consideration for anchorage areas must strive to avoid direct physical impacts to coral reef habitats. When re-location of anchorages is impractical, single-point moorings should be utilized as the preferred alternative to anchoring. Interagency cooperation will be required to develop a plan for effective management of maritime activities which will protect all USVI reefs from anchor damage and ship groundings. This plan should incorporate the formation of a local accident response team to provide objective scientific assessments of coral reef damages which arise from future anchoring and ship grounding incidents.

Effective management will necessarily require better information on USVI coral reef resources. Knowledge of the spatial distribution of marine habitats (mapping studies such as Kendall et al. 2001) and trends through time (e.g. ecosystem monitoring programs) will be instrumental. However, the most important step will be to valuate coral reef resources based upon socio-economic lines (Cesar and Chong 2004). Placing real dollar figures on the value of coral reef resources will better enable scientists and policymakers to assess risks, address mitigation, and evaluate alternate management strategies. In the case of the Frederiksted Reef, if the potential for long-term habitat impacts and potential economic losses had been fully appreciated, anchor damage might have been mitigated or avoided altogether. This example should serve as a valuable reminder of our imperfect knowledge of the coastal ecosystems and the need for effective management practices of valuable marine resources.

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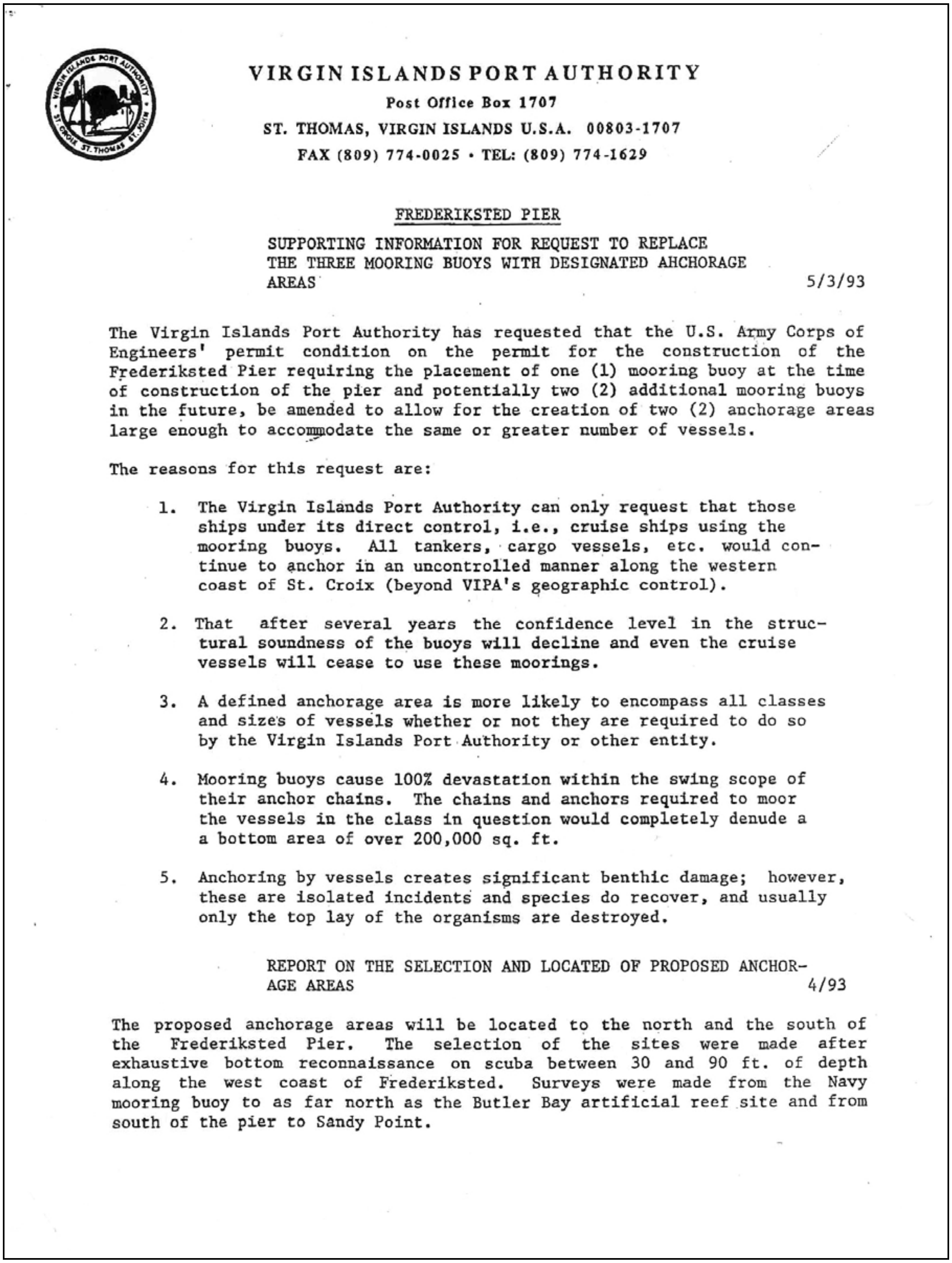
LIST OF TABLES AND FIGURES

Appendix 1. VIPA document regarding Frederiksted anchorage areas.



VIRGIN ISLANDS PORT AUTHORITY
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FREDERIKSTED PIER

SUPPORTING INFORMATION FOR REQUEST TO REPLACE THE THREE MOORING BUOYS WITH DESIGNATED AHCHORAGE AREAS 5/3/93

The Virgin Islands Port Authority has requested that the U.S. Army Corps of Engineers' permit condition on the permit for the construction of the Frederiksted Pier requiring the placement of one (1) mooring buoy at the time of construction of the pier and potentially two (2) additional mooring buoys in the future, be amended to allow for the creation of two (2) anchorage areas large enough to accommodate the same or greater number of vessels.

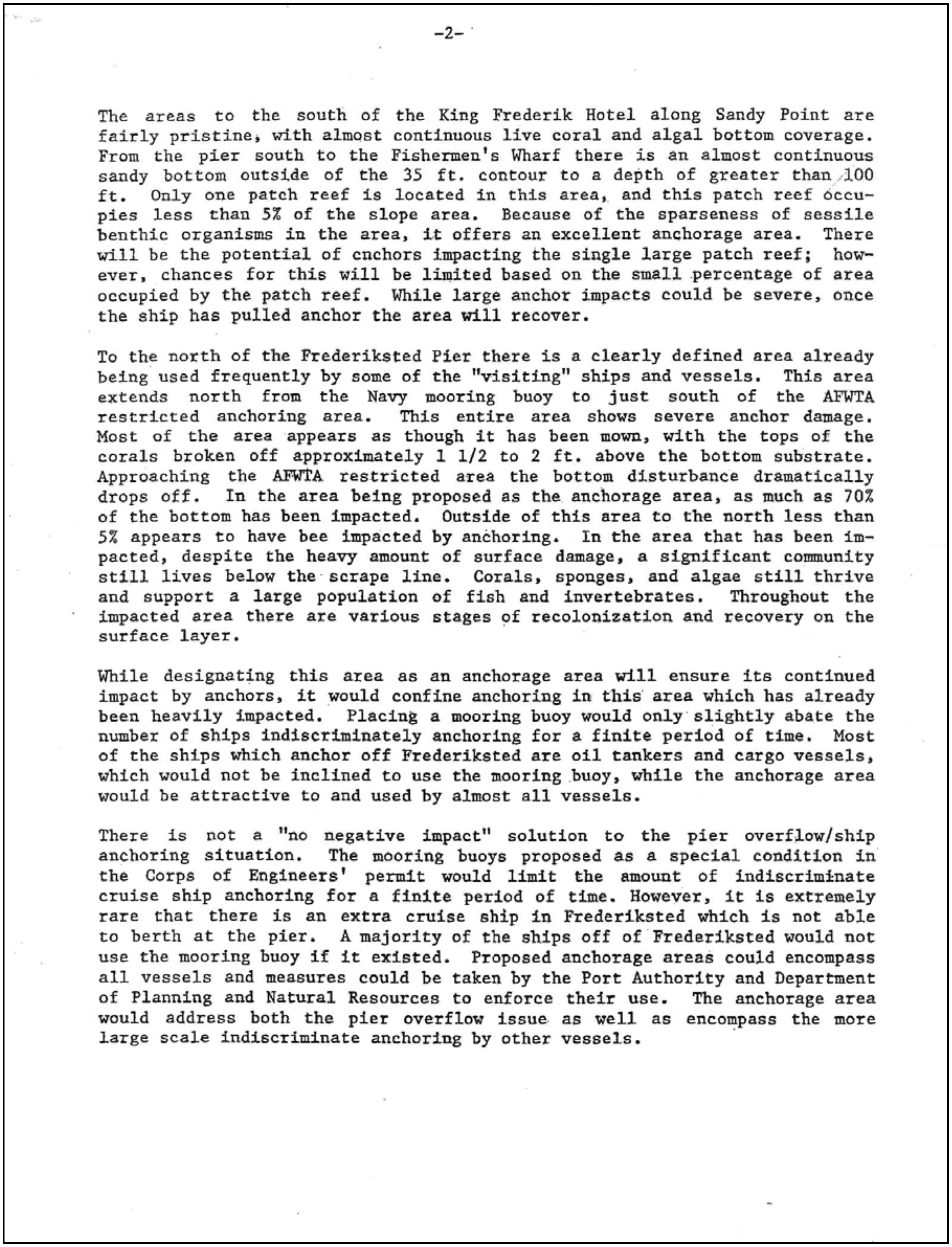
The reasons for this request are:

1. The Virgin Islands Port Authority can only request that those ships under its direct control, i.e., cruise ships using the mooring buoys. All tankers, cargo vessels, etc. would continue to anchor in an uncontrolled manner along the western coast of St. Croix (beyond VIPA's geographic control).
2. That after several years the confidence level in the structural soundness of the buoys will decline and even the cruise vessels will cease to use these moorings.
3. A defined anchorage area is more likely to encompass all classes and sizes of vessels whether or not they are required to do so by the Virgin Islands Port Authority or other entity.
4. Mooring buoys cause 100% devastation within the swing scope of their anchor chains. The chains and anchors required to moor the vessels in the class in question would completely denude a a bottom area of over 200,000 sq. ft.
5. Anchoring by vessels creates significant benthic damage; however, these are isolated incidents and species do recover, and usually only the top lay of the organisms are destroyed.

REPORT ON THE SELECTION AND LOCATED OF PROPOSED ANCHORAGE AREAS 4/93

The proposed anchorage areas will be located to the north and the south of the Frederiksted Pier. The selection of the sites were made after exhaustive bottom reconnaissance on scuba between 30 and 90 ft. of depth along the west coast of Frederiksted. Surveys were made from the Navy mooring buoy to as far north as the Butler Bay artificial reef site and from south of the pier to Sandy Point.

Appendix 1. continued.



The areas to the south of the King Frederik Hotel along Sandy Point are fairly pristine, with almost continuous live coral and algal bottom coverage. From the pier south to the Fishermen's Wharf there is an almost continuous sandy bottom outside of the 35 ft. contour to a depth of greater than 100 ft. Only one patch reef is located in this area, and this patch reef occupies less than 5% of the slope area. Because of the sparseness of sessile benthic organisms in the area, it offers an excellent anchorage area. There will be the potential of cnchors impacting the single large patch reef; however, chances for this will be limited based on the small percentage of area occupied by the patch reef. While large anchor impacts could be severe, once the ship has pulled anchor the area will recover.

To the north of the Frederiksted Pier there is a clearly defined area already being used frequently by some of the "visiting" ships and vessels. This area extends north from the Navy mooring buoy to just south of the AFWTA restricted anchoring area. This entire area shows severe anchor damage. Most of the area appears as though it has been mown, with the tops of the corals broken off approximately 1 1/2 to 2 ft. above the bottom substrate. Approaching the AFWTA restricted area the bottom disturbance dramatically drops off. In the area being proposed as the anchorage area, as much as 70% of the bottom has been impacted. Outside of this area to the north less than 5% appears to have bee impacted by anchoring. In the area that has been impacted, despite the heavy amount of surface damage, a significant community still lives below the scrape line. Corals, sponges, and algae still thrive and support a large population of fish and invertebrates. Throughout the impacted area there are various stages of recolonization and recovery on the surface layer.

While designating this area as an anchorage area will ensure its continued impact by anchors, it would confine anchoring in this area which has already been heavily impacted. Placing a mooring buoy would only slightly abate the number of ships indiscriminately anchoring for a finite period of time. Most of the ships which anchor off Frederiksted are oil tankers and cargo vessels, which would not be inclined to use the mooring buoy, while the anchorage area would be attractive to and used by almost all vessels.

There is not a "no negative impact" solution to the pier overflow/ship anchoring situation. The mooring buoys proposed as a special condition in the Corps of Engineers' permit would limit the amount of indiscriminate cruise ship anchoring for a finite period of time. However, it is extremely rare that there is an extra cruise ship in Frederiksted which is not able to berth at the pier. A majority of the ships off of Frederiksted would not use the mooring buoy if it existed. Proposed anchorage areas could encompass all vessels and measures could be taken by the Port Authority and Department of Planning and Natural Resources to enforce their use. The anchorage area would address both the pier overflow issue as well as encompass the more large scale indiscriminate anchoring by other vessels.

Appendix 2. GPS coordinates of features relating to the Frederiksted Reef study area.

Feature/Group	Coord. Name	GPS Position Latitude (N)	 Longitude (W)	Description/Comment
Permitted Anchorage Boundary				
North Anchorage				
	pt 1N	17° 43.170’	64° 53.502’	Reconstructed from the original ACOE permit text description using charted position of the Frederiksted Pier mooring (N17°42.823’, W64°53.366’) as a fixed reference point.
	pt 2N	17° 43.508’	64° 53.716’	
	pt 3N	17° 43.423’	64° 54.014’	
	pt 4N	17° 43.084’	64° 53.801’	
South Anchorage				
	pt 1S	17° 42.753’	64° 53.342’	Reconstructed positions (see above).
	pt 2S	17° 42.507’	64° 53.324’	
	pt 3S	17° 42.492’	64° 53.558’	
	pt 4S	17° 42.737’	64° 53.578’	
Marker Buoys for Anchorage Areas				
North Anchorage				
	A marker N	17° 43.571’	64° 53.684’	GPS coordinates were reported in a 1995 DFW memo by Aaron Adams. Coordinates were taken with handheld GPS unit (accuracy unknown).
	B marker N	17° 43.215’	64° 53.500’	
	C marker N	17° 43.228’	64° 53.693’	
	D marker N	17° 43.548’	64° 53.787’	
South Anchorage				
	A marker S	17° 42.706’	64° 53.322’	Positions from A. Adams (see above).
	B marker S	17° 42.452’	64° 53.339’	
	C marker S	17° 42.464’	64° 53.460’	
	D marker S	17° 42.678’	64° 53.434’	
	E marker S	17° 42.622’	64° 53.378’	
Underwater Tracking Range, Area A				
	Area A-1	17° 44.700’	64° 54.300’	No anchoring within triangular area bounded by 3 points. Reserved for use by the US Navy.
	Area A-2	17° 43.100’	64° 54.300’	
	Area A-3	17° 44.500’	64° 53.500’	
Sites of Fish and Benthic Surveys				
	RF	17° 43.101’	64° 53.448’	Rubblefield, damaged site
	TC	17° 43.209’	64° 53.570’	The Corner, damaged site
	LP	17° 43.310’	64° 53.671’	La Piedra, damaged site
	MA	17° 43.384’	64° 53.677’	Midank, impact site
	PB	17° 43.208’	64° 53.416’	Pauls Buoy, non-impact site
	BP	17° 43.642’	64° 53.688’	Black Point, non-impact site
	RB	17° 43.858’	64° 53.749’	Rainbow Reef, non-impact site
	SH	17° 44.049’	64° 53.715’	Sprat Hole, non-impact site
Frederiksted Reef				Approx. north and south boundaries of Frederiksted Reef (from NOAA Benthic Habitat Maps).
	north FRS	17° 44.865’	64° 53.871’	
	south FRS	17° 41.321’	64° 54.139’	
Miscellaneous Features				
	RC	17° 42.871’	64° 53.041’	Red Crane at base of Frederiksted Pier
	UTR	17° 44.442’	64° 53.482’	UTR command center at Estate Sprat Hall
	Navy Buoy	17° 43.063’	64° 53.579’	Mooring buoy for Navy ships and subs.

Appendix 3. Data for rugosity and vertical relief.

	Rugosity Index (RI) at Damaged Sites								Rugosity Index (RI) at Non-Impact Sites							
	Rubblefield (RF)		The Corner (TC)		La Piedra (LP)		Midank (MA)		Pauls Buoy (PB)		Black Point (BP)		Rainbow (RB)		Sprat Hole (SH)	
No.	D (m)	RI	D (m)	RI	D (m)	RI	D (m)	RI	D (m)	RI	D (m)	RI	D (m)	RI	D (m)	RI
1	3.20	1.56	3.90	1.28	4.64	1.08	4.23	1.18	2.07	2.42	1.98	2.53	1.89	2.65	2.19	2.28
2	3.80	1.32	3.93	1.27	3.60	1.39	3.79	1.32	1.90	2.63	2.41	2.07	1.55	3.23	3.35	1.49
3	3.50	1.43	3.82	1.31	3.66	1.37	3.99	1.25	3.13	1.60	1.81	2.76	1.73	2.89	2.79	1.79
4	4.20	1.19	3.90	1.28	4.09	1.22	3.98	1.26	2.35	2.13	2.18	2.29	1.74	2.87	2.44	2.05
5	4.08	1.23	3.51	1.42	3.40	1.47	4.12	1.21	3.03	1.65	2.65	1.89	2.27	2.20	2.69	1.86
6	4.20	1.19	3.60	1.39	3.98	1.26	3.66	1.37	2.70	1.85	2.16	2.31	1.92	2.60	2.37	2.11
7	4.24	1.18	3.59	1.39	4.40	1.14	3.90	1.28	2.40	2.08	3.44	1.45	2.25	2.22	2.81	1.78
8	3.86	1.30	3.24	1.54	4.10	1.22	3.66	1.37	2.75	1.82	2.26	2.21	1.58	3.16	1.06	4.72
9	4.05	1.23	3.52	1.42	4.11	1.22	3.95	1.27	2.34	2.14	2.17	2.30	2.65	1.89	1.43	3.50
10	4.88	1.02	3.70	1.35	3.92	1.28	3.99	1.25	1.90	2.63	2.54	1.97	2.30	2.17	2.11	2.37
Avg	4.00	1.26	3.67	1.37	3.99	1.26	3.93	1.28	2.46	2.09	2.36	2.18	1.99	2.59	2.32	2.39
StDev	0.46	0.15	0.22	0.09	0.37	0.12	0.18	0.06	0.44	0.37	0.45	0.36	0.36	0.45	0.68	0.98
Max	4.88	1.56	3.93	1.54	4.64	1.47	4.23	1.37	3.13	2.63	3.44	2.76	2.65	3.23	3.35	4.72
Min	3.20	1.02	3.24	1.27	3.40	1.08	3.66	1.18	1.90	1.60	1.81	1.45	1.55	1.89	1.06	1.49

	Estimated Vertical Relief at Damaged Sites (m)								Estimated Vertical Relief at Non-Impact Sites (m)							
	Rubblefield (RF)		The Corner (TC)		La Piedra (LP)		Midank (MA)		Pauls Buoy (PB)		Black Point (BP)		Rainbow (RB)		Sprat Hole (SH)	
No.	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max	Est. Avg	Est. Max
1	0.40	0.80	0.20	0.50	0.15	0.40	0.11	0.97	1.00	2.00	1.00	1.50	0.80	1.50	0.50	1.50
2	0.30	0.60	0.40	1.00	0.20	0.50	0.40	0.84	0.70	2.00	1.00	1.80	1.00	1.80	0.75	1.44
Avg	0.35	0.70	0.30	0.75	0.18	0.45	0.26	0.91	0.85	2.00	1.00	1.65	0.90	1.65	0.63	1.47

Rugosity Index (RI) was calculated as 5.0 m/D, where D = the linear distance covered by a 5.0 m chain when conformed to the substrate. Vertical Relief was visually estimated to the nearest cm (see text). Divers estimated average vertical relief (n=2 observations) and maximum vertical relief (n =2 observations) at each site.

Appendix 4A. Benthic data - Rubblefield (damaged site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	13.4	12.2	12.2	12.5	14.0	12.2	12.2	12.2	13.7	12.5	Avg	St.Dev	Count	%
Abiotic	reef /rock	50	2	18	44	60	14	20	17	80	0	30.5	26.6	9	90.0%
	rubble	50	37	21	44	30	79	77	82	15	97	53.2	28.6	10	100.0%
	sand	0	61	61	12	10	7	3	1	5	3	16.3	23.9	9	90.0%
	other	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0%
Corals	*Agaricia agaricites*	0.2	0.2	0.2	2.5	2.4		1.4	0.8		0.6	1.0	1.0	8	80.0%
	Diploria labyrinthiformis				0.4							0.4	-	1	10.0%
	Favia fragum					0.1						0.1	-	1	10.0%
	Madracis decactus							0.2				0.2	-	1	10.0%
	Millepora complanata						0.3					0.3	-	1	10.0%
	Montastraea annularis								0.1			0.1	-	1	10.0%
	Montastraea faveolata					0.2						0.2	-	1	10.0%
	Montastraea franksi			2.0								2.0	-	1	10.0%
	Montastraea cavernosa			0.2		0.3	0.1					0.2	0.1	3	30.0%
	Porites astreoides		0.3		0.2	3.1	0.2	0.1		0.1		0.7	1.2	6	60.0%
	Porites porites			0.1					0.1			0.1	0.0	2	20.0%
	Siderastrea siderea					0.4	0.2	0.8	0.3	0.3		0.4	0.2	5	50.0%
	Stephanocoenia intersepta								1.1	0.1		0.6	0.7	2	20.0%
	Subtotal Corals =	0.2	0.5	2.5	3.1	6.5	0.8	2.5	2.4	0.5	0.6	2.0	1.9	na	na
Algae	*Halimeda* sp.	3.5	0.6			4.9	1.4	0.5	3.9	3.6	2.0	2.6	1.6	8	80.0%
	Halimeda goreaui			1.5	3.0							2.3	1.1	2	20.0%
	Neomeris annulata	0.1								0.2		0.2	0.1	2	20.0%
	Udotea cyathiformis	0.1		0.2		0.2		0.2		0.5		0.2	0.2	5	50.0%
	Valonia/Ventricaria	0.1			0.1							0.1	0.0	2	20.0%
	Lobophora variegata	8.5	0.9	3.0	2.0	5.5	3.8	2.5	10.1	11.5	3.0	5.1	3.7	10	100.0%
	Dictyota sp.	7.9	7.2	5.0	10.0	5.4	10.2	9.0	9.8	6.3	7.0	7.8	1.9	10	100.0%
	Galaxaura sp.	0.2						0.1		0.1		0.1	0.1	3	30.0%
	Ceramium sp.				1.0	1.0		3.0		0.8	3.0	1.8	1.1	5	50.0%
	Calcareous/Encrusting Red				2.0			1.0			1.0	1.3	0.6	3	30.0%
	Schizothrix calcicola					1.0				1.0		1.0	0.0	2	20.0%
	Macro Algae, unidentified	8.8		0.1		0.2		1.0		0.7		2.2	3.7	5	50.0%
	Subtotal Algae =	29.2	8.7	9.8	18.1	18.2	15.4	17.3	23.8	24.7	16.0	18.1	6.4	na	na
Other Invertebrates	*Psuedopterogorgia* sp.			0.1								0.1	-	1	10.0%
	Erythropodium caribaeorum						0.5					0.5	-	1	10.0%
	branching gorgonian		1.4				0.2					0.8	0.8	2	20.0%
	Cliona sp.	2.4	1.0	7.0	3.5			0.5				2.9	2.6	5	50.0%
	Neofibularia sp.										0.8	0.8	-	1	10.0%
	encrusting sponge	0.5		0.5		0.5		0.5		1.0	1.9	0.8	0.6	6	60.0%
	branching sponge	1.8			2.2	2.0				3.2		2.3	0.6	4	40.0%
	irregular/lumpy sponge		0.3		0.8	0.3	1.6		0.3			0.7	0.6	5	50.0%
	Subtotal Other Inverts =	4.7	2.7	7.6	6.5	2.8	2.3	1.0	0.3	4.2	2.7	3.5	2.3	na	na
DCTA	Dead Coral with Turf Algae	65.9	27.1	19.1	60.3	62.5	74.5	76.2	72.5	65.6	77.7	60.1	20.5	10	100.0%

Appendix 4B. Benthic data - The Corner (damaged site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	14.0	13.7	14.0	14.0	13.7	13.4	13.1	13.4	13.4	13.7	Avg	St.Dev	Count	%
Abiotic	reef /rock	86	38	12	99	84	84	23	85	80	21	61.2	33.4	10	100.0%
	rubble	3	56	84	0	15	3	74	12	19	16	28.2	31.1	9	90.0%
	sand	10	6	3	1	1	6	3	3	1	63	9.7	18.9	10	100.0%
	other	1	0	1	0	0	7	0	0	0	0	0.9	2.2	3	30.0%
Corals	*Agaricia agaricites*	1.5	0.2		0.3	4.0	2.5			3.5		2.0	1.6	6	60.0%
	Diploria labyrinthiformis		0.2									0.2	-	1	10.0%
	Madracis decactus			0.2								0.2	-	1	10.0%
	Montastraea annularis	3.0			1.0	2.0	1.0		2.0			1.8	0.8	5	50.0%
	Montastraea franksi	9.0	2.0			5.5		0.5	3.5			4.1	3.3	5	50.0%
	Montastraea cavernosa		0.4						0.3			0.4	0.1	2	20.0%
	Porites astreoides	3.8	0.5			2.8			2.0	5.0		2.8	1.7	5	50.0%
	Porites porites									0.4		0.4	-	1	10.0%
	Scolymia sp.						0.1					0.1	-	1	10.0%
	Siderastrea siderea		0.8	0.8			0.4	0.2				0.6	0.3	4	40.0%
	Stephanocoenia intersepta	0.3								0.8		0.5	0.4	2	20.0%
	Subtotal Corals =	17.5	4.1	1.0	1.3	14.3	4.0	0.7	7.8	9.7	0.0	6.0	6.1	na	na
Algae	*Halimeda* sp.		2.0	3.0		4.0		3.0		9.0	1.5	3.8	2.7	6	60.0%
	Halimeda goreaui	2.5			0.5		3.0		7.0			3.3	2.7	4	40.0%
	Lobophora variegata	5.0	26.0	14.0		21.0	8.0	16.0	18.0	10.0	5.0	13.7	7.3	9	90.0%
	Dictyota divaricata		5.0			10.0	3.0	9.0		8.0	4.0	6.5	2.9	6	60.0%
	Dictyota sp.	1.0		9.0	6.0				8.0			6.0	3.6	4	40.0%
	Galaxaura sp.	2.0		0.8		0.5						1.1	0.8	3	30.0%
	Ceramium sp.				2.0							2.0	-	1	10.0%
	Jania sp.	0.5							0.3			0.4	0.2	2	20.0%
	Calcareous/Encrusting Red		0.2	1.5	2.5	2.0	0.5	3.0	0.5	1.0		1.4	1.0	8	80.0%
	Schizothrix calcicola	2.0			1.0				2.0	4.0		2.3	1.3	4	40.0%
	Subtotal Algae =	13.0	33.2	28.3	12.0	37.5	14.5	31.0	35.8	32.0	10.5	24.8	10.9	na	na
Other Invertebrates	branching gorgonian		0.5									0.5	-	1	10.0%
	encrusting gorgonian									2.0		2.0	-	1	10.0%
	Cliona sp.		1.0			0.5	0.5	0.6		2.0		0.9	0.6	5	50.0%
	encrusting sponge		5.0	7.0			0.3	1.0	1.0		3.0	2.9	2.7	6	60.0%
	branching sponge					1.5					1.3	1.4	0.1	2	20.0%
	irregular/lumpy sponge	1.5			3.5		7.5		2.3			3.7	2.7	4	40.0%
	Subtotal Other Inverts =	1.5	6.5	7.0	3.5	2.0	8.3	1.6	3.3	4.0	4.3	4.2	2.4	na	na
DCTA	Dead Coral with Turf Algae	58.0	50.2	60.7	82.3	45.2	67.3	63.7	50.2	53.3	22.2	55.3	15.7	10	100.0%

Appendix 4C. Benthic data - La Piedra (damaged site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	14.3	14.3	14.6	14.3	14.6	13.4	14.3	13.7	13.7	13.7	Avg	St.Dev	Count	%
Abiotic	reef /rock	75	39	95	10.5	84	14	75	48	78	17	53.6	31.9	10	100.0%
	rubble	10	56	3	65.5	10	63	5	49	2	60	32.4	28.2	10	100.0%
	sand	12	5	2	24	6	23	20	3	20	23	13.8	9.1	10	100.0%
	other	3	0	0	0	0	0	0	0	0	0	0.3	0.9	1	10.0%
Corals	*Agaricia agaricites*			1.0	0.1	0.3		0.2	0.2		0.1	0.3	0.3	6	60.0%
	Isophyllastrea rigida				0.2							0.2	-	1	10.0%
	Meandrina meandrites								0.5			0.5	-	1	10.0%
	Millepora alcicornis	1.0		0.3								0.7	0.5	2	20.0%
	Montastraea annularis			3.0							1.0	2.0	1.4	2	20.0%
	Montastraea franksi		1.2				1.0		1.1		1.5	1.2	0.2	4	40.0%
	Montastraea cavernosa				0.2	1.0			0.5		0.5	0.6	0.3	4	40.0%
	Porites astreoides					0.2		0.2	0.2	0.1	0.2	0.2	0.0	5	50.0%
	Porites porites			0.3				0.2				0.3	0.1	2	20.0%
	Siderastrea siderea			0.3	0.5	0.2	0.2		0.2		0.1	0.3	0.1	6	60.0%
	Subtotal Corals =	1.0	1.2	4.9	1.0	1.7	1.2	0.6	2.7	0.1	3.4	1.8	1.5	na	na
Algae	*Halimeda* sp.	5.0		6.0	2.0				1.5	3.0	2.0	3.3	1.8	6	60.0%
	Halimeda goreaui		2.0				0.8					1.4	0.8	2	20.0%
	Halimeda opuntia					6.0		2.0				4.0	2.8	2	20.0%
	Lobophora variegata	25.0	12.0	10.0	9.0	10.0	4.0	7.0	18.0	4.0	5.0	10.4	6.7	10	100.0%
	Dictyota divaricata			3.0		5.0		6.0				4.7	1.5	3	30.0%
	Dictyota sp.	7.0	4.5		7.5		7.0		3.0	2.0	8.0	5.6	2.4	7	70.0%
	Galaxaura sp.								0.2			0.2	-	1	10.0%
	Calcareous/Encrusting Red			3.0				3.0	2.0		2.0	2.5	0.6	4	40.0%
	Schizothrix calcicola			1.0		1.0						1.0	0.0	2	20.0%
	Subtotal Algae =	37.0	18.5	23.0	18.5	22.0	11.8	18.0	24.7	9.0	17.0	20.0	7.7	na	na
Other Invertebrates	*Psuedopterogorgia* sp.						0.5					0.5	-	1	10.0%
	Cliona sp.	2.0	17.5	2.0	0.5		0.5	0.3		5.0		4.0	6.2	7	70.0%
	Neofibularia sp.				0.4						1.0	0.7	0.4	2	20.0%
	encrusting sponge	1.0		2.0	1.0	0.5		0.3	0.7	0.5	1.5	0.9	0.6	8	80.0%
	branching sponge		1.0			1.0	0.5					0.8	0.3	3	30.0%
	irregular/lumpy sponge			1.0		0.5	1.0	3.0		1.0		1.3	1.0	5	50.0%
	Subtotal Other Inverts =	3.0	18.5	5.0	1.9	2.0	2.5	3.6	0.7	6.5	2.5	4.6	5.1	na	na
DCTA	Dead Coral with Turf Algae	47.0	56.8	65.1	54.6	68.3	61.5	57.8	68.9	64.4	54.1	59.9	7.0	10	100.0%

Appendix 4D. Benthic data - Midank (damaged site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	13.4	13.4	13.1	12.8	13.1	12.8	13.7	12.2	13.7	12.2	Avg	St.Dev	Count	%
Abiotic	reef /rock	32	69	48	37	30	45	85	72	97	24	53.9	25.2	10	100.0%
	rubble	64	21	37	55	30	52	6	23	3	74	36.5	24.2	10	100.0%
	sand	4	10	15	8	40	3	9	5	0	2	9.6	11.6	9	90.0%
	other	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0%
Corals	*Agaricia agaricites*							0.3	1.8		0.5	0.9	0.8	3	30.0%
	Favia fragum				0.1							0.1	-	1	10.0%
	Madracis decactus						0.2	0.2				0.2	0.0	2	20.0%
	Meandrina meandrites							0.1				0.1	-	1	10.0%
	Montastraea annularis	0.2				0.6	1.5					0.8	0.7	3	30.0%
	Montastraea franksi						0.8	2.7		6.7	0.5	2.7	2.9	4	40.0%
	Montastraea cavernosa						1.0	0.1		5.3	1.2	1.9	2.3	4	40.0%
	Porites astreoides					0.6	0.2	0.6	0.1	0.5		0.4	0.2	5	50.0%
	Porites porites								0.6			0.6	-	1	10.0%
	Stephanocoenia intersepta				1.0	0.1						0.6	0.6	2	20.0%
	Subtotal Corals =	0.2	0.0	0.0	1.1	1.3	3.7	4.0	2.5	12.5	2.2	2.8	3.7	na	na
Algae	*Halimeda* sp.	4.0	3.0		2.0	1.5	6.0	4.6	8.0	5.5	3.4	4.2	2.1	9	90.0%
	Halimeda goreaui			7.5								7.5	-	1	10.0%
	Neomeris annulata	0.2								0.1		0.2	0.1	2	20.0%
	Udotea cyathiformis			0.5								0.5	-	1	10.0%
	Lobophora variegata	13.0	16.0	26.0	8.0	10.2	22.0	2.7	20.0	17.0	10.0	14.5	7.1	10	100.0%
	Dictyota sp.	12.0	7.0	4.0	5.0	4.4	3.0	4.2	4.0	3.9	5.0	5.3	2.6	10	100.0%
	Galaxaura sp.	1.0					1.0	0.3		2.0	1.5	1.2	0.6	5	50.0%
	Ceramium sp.							1.5		8.3		4.9	4.8	2	20.0%
	Jania sp.										0.5	0.5	-	1	10.0%
	Calcareous/Encrusting Red	3.0	2.0	2.0	1.0		2.0		3.0		2.0	2.1	0.7	7	70.0%
	Schizothrix calcicola					1.0	1.0	0.8				0.9	0.1	3	30.0%
	Subtotal Algae =	33.2	28.0	40.0	16.0	17.1	35.0	14.1	35.0	36.8	22.4	27.8	9.6	na	na
Other Invertebrates	*Psuedopterogorgia* sp.								0.1			0.1	-	1	10.0%
	Cliona sp.	0.5		2.0	1.5	7.1	1.0	3.5		0.3		2.3	2.4	7	70.0%
	Neofibularia sp.					3.3						3.3	-	1	10.0%
	encrusting sponge	0.5	7.0	0.5	2.0		2.2	1.3	4.7	0.2	5.0	2.6	2.4	9	90.0%
	irregular/lumpy sponge				0.5	0.4	6.0	1.0		0.1		1.6	2.5	5	50.0%
	vase sponge			1.0								1.0	-	1	10.0%
	Subtotal Other Inverts =	1.0	7.0	3.5	4.0	10.8	9.2	5.8	4.8	0.6	5.0	5.2	3.2	na	na
DCTA	Dead Coral with Turf Algae	61.6	55.0	41.5	70.9	30.8	49.1	67.1	52.7	50.1	68.4	54.7	12.7	10	100.0%

Appendix 4E. Benthic data - Pauls Buoy (non-impact site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	8.8	9.1	8.5	8.2	8.8	8.5	8.5	9.1	9.8	9.1	Avg	St.Dev	Count	%
Abiotic	reef /rock	91	99	96	79.5	98	67.5	91	99.8	84	75	88.1	11.2	10	100.0%
	rubble	4	0	3	17.5	0	29	9	0	14	0	7.7	9.8	6	60.0%
	sand	5	1	1	3	2	3.5	0	0.2	1	25	4.2	7.5	9	90.0%
	other	0	0	0	0	0	0	0	0	1	0	0.1	0.3	1	10.0%
Corals	*Agaricia agaricites*	1.4	0.5	0.5	0.7	1.5	2.2	2.0	1.0	2.0	0.5	1.2	0.7	10	100.0%
	Agaricia lamarki			2.8								2.8	-	1	10.0%
	Agaricia sp.										0.3	0.3	-	1	10.0%
	Colpophyllia natans								0.8			0.8	-	1	10.0%
	Diploria labyrinthiformis							1.8				1.8	-	1	10.0%
	Diploria strigosa							0.5				0.5	-	1	10.0%
	Favia fragum									0.1		0.1	-	1	10.0%
	Madracis decactus						0.5					0.5	-	1	10.0%
	Millepora alcicornis			0.1								0.1	-	1	10.0%
	Montastraea annularis	23.0	27.5	21.0	17.0	0.5	4.0	7.5	4.0	5.5		12.2	9.9	9	90.0%
	Montastraea faveolata		3.0		0.8	2.0	4.8				15.0	5.1	5.7	5	50.0%
	Montastraea franksi		0.3			4.5		3.1	3.0		1.0	2.4	1.7	5	50.0%
	Montastraea cavernosa	0.8		0.3		3.5	1.5			1.4		1.5	1.2	5	50.0%
	Porites astreoides	1.2	3.5	0.8	0.4	3.5	0.8	5.2	0.5	3.5	1.0	2.0	1.7	10	100.0%
	Porites furcata						0.5			2.0		1.3	1.1	2	20.0%
	Porites porites	0.2			0.2	2.5		2.4				1.3	1.3	4	40.0%
	Siderastrea siderea						0.2					0.2	-	1	10.0%
	Subtotal Corals =	26.6	34.8	25.5	19.1	18.0	14.5	22.5	9.3	14.5	17.8	20.3	7.3	na	na
Algae	*Halimeda* sp.				1.5	10.0	2.0			5.0	1.0	3.9	3.7	5	50.0%
	Halimeda goreaui	1.5		6.0								3.8	3.2	2	20.0%
	Lobophora variegata	3.5	6.8		9.0	10.0	3.0	33.5	13.0	19.0	30.0	14.2	11.1	9	90.0%
	Dictyota sp.	0.2	2.0	2.0	2.5	7.0	2.5	4.5	8.0	0.5		3.2	2.7	9	90.0%
	Galaxaura sp.			0.2								0.2	-	1	10.0%
	Jania sp.						0.5	5.0				2.8	3.2	2	20.0%
	Calcareous/Encrusting Red								4.5			4.5	-	1	10.0%
	Schizothrix calcicola				1.0					2.0		1.5	0.7	2	20.0%
	Macro Algae, unidentified		4.5									4.5	-	1	10.0%
	Subtotal Algae =	5.2	13.3	8.2	14.0	27.0	8.0	43.0	25.5	26.5	31.0	20.2	12.3	na	na
Other Invertebrates	*Briarium* sp.			0.5								0.5	-	1	10.0%
	encrusting sponge						0.8		1.0		3.0	1.6	1.2	3	30.0%
	branching sponge			0.8								0.8	-	1	10.0%
	irregular/lumpy sponge			0.4	0.6	1.0					0.5	0.6	0.3	4	40.0%
	Subtotal Other Inverts =	0.0	0.0	1.7	0.6	1.0	0.8	0.0	1.0	0.0	3.5	0.9	1.1	na	na
DCTA	Dead Coral with Turf Algae	63.2	50.9	63.6	63.3	52.0	73.2	34.5	64.0	58.0	22.7	54.5	15.3	10	100.0%

Appendix 4F. Benthic - Black Point (non-impact site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	12.8	12.8	12.5	13.1	12.8	12.8	12.2	12.2	13.7	12.2	Avg	St.Dev	Count	%
Abiotic	reef /rock	86	70	93	99.7	91	95.5	85	79	100	92	89.1	9.4	10	100.0%
	rubble	13	11	6	0	9	0	11	4	0	7	6.1	5.0	7	70.0%
	sand	1	19	1	0.3	0	4.5	4	17	0	1	4.8	7.2	2	20.0%
	other	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0%
Corals	*Agaricia agaricites*	2.8	1.7	0.6	0.9	3.0	1.7	0.8	5.0	2.0	3.0	2.2	1.3	10	100.0%
	Agaricia fragilis			0.6					0.5			0.6	0.1	2	20.0%
	Colpophyllia natans			2.4								2.4	-	1	10.0%
	Eusmilia fastigiata						0.5	0.4				0.5	0.1	2	20.0%
	Favia fragum						0.1					0.1	-	1	10.0%
	Madracis decactus			0.4		0.1			0.1	0.2		0.2	0.1	4	40.0%
	Madracis mirabilis				0.1		0.3					0.2	0.1	2	20.0%
	Meandrina meandrites		2.6	0.2								1.4	1.7	2	20.0%
	Millepora alcicornis	0.1		0.4	0.3				0.1	0.3		0.2	0.1	5	50.0%
	Montastraea annularis	22.0		24.0	2.5	8.0	20.8	3.5	14.5	15.0	3.0	12.6	8.6	9	90.0%
	Montastraea faveolata					4.0		1.2		6.1		3.8	2.5	3	30.0%
	Montastraea franksi	3.5	4.0					6.5		4.5	2.8	4.3	1.4	5	50.0%
	Montastraea cavernosa					0.8		1.2		0.7		0.9	0.3	3	30.0%
	Mycetophyllia ferox		0.8									0.8	-	1	10.0%
	Mycetophyllia lamarckiana	0.2						0.4				0.3	0.1	2	20.0%
	Porites astreoides	2.0	3.8	4.0	1.1	6.5	7.9	4.0	3.0	4.3	4.5	4.1	2.0	10	100.0%
	Porites porites	0.8	1.6	2.0			4.6	1.5	2.0	0.3		1.8	1.4	7	70.0%
	Scolymia sp.								0.1	0.1		0.1	0.0	2	20.0%
	Siderastrea siderea			2.0				0.3				1.2	1.2	2	20.0%
	Stephanocoenia intersepta				0.1		0.1					0.1	0.0	2	20.0%
	Subtotal Corals =	31.4	14.5	36.6	5.0	22.4	36.0	19.8	25.3	33.5	13.3	23.8	10.7	na	na
Algae	*Halimeda* sp.	1.5	7.0	7.0	5.8	3.5	7.3	7.0	5.0	8.6	5.0	5.8	2.1	10	100.0%
	Halimeda opuntia				0.3							0.3	-	1	10.0%
	Valonia/Ventricaria						0.3					0.3	-	1	10.0%
	Lobophora variegata	23.0	18.0	11.0	25.0	13.0	16.3	13.0	7.0	6.5	17.0	15.0	6.1	10	100.0%
	Dictyota sp.	2.0	1.0	3.0	0.6	2.0	2.1	3.0	2.0	1.6	3.0	2.0	0.8	10	100.0%
	Galaxaura sp.	1.2	1.0	3.0	2.3	3.0	2.4	2.0		0.3	1.5	1.9	0.9	9	90.0%
	Calcareous/Encrusting Red	5.0	2.0	2.0		1.5		3.0	2.0			2.6	1.3	6	60.0%
	Schizothrix calcicola			2.0	1.5	2.0	1.5			1.0		1.6	0.4	5	50.0%
	Subtotal Algae =	32.7	29.0	28.0	35.5	25.0	29.9	28.0	16.0	18.0	26.5	26.9	6.0	na	na
Other Invertebrates	*Psuedopterogorgia* sp.	0.1	0.4		0.3	0.2	0.6	0.4	0.6			0.4	0.2	7	70.0%
	Cliona sp.		0.5					2.5				1.5	1.4	2	20.0%
	encrusting sponge	1.6	2.5	3.0	6.9	1.0	0.3	3.7	0.6	0.6	3.5	2.4	2.0	10	100.0%
	branching sponge			0.8		0.2			1.0			0.7	0.4	3	30.0%
	irregular/lumpy sponge	1.5	1.0		1.2		2.4					1.5	0.6	4	40.0%
	Subtotal Other Inverts =	3.2	4.4	3.8	8.4	1.4	3.3	6.6	2.2	0.6	3.5	3.7	2.3	na	na
DCTA	Dead Coral with Turf Algae	31.7	33.1	30.6	50.8	51.2	26.3	41.6	39.5	47.9	55.7	40.8	10.2	10	100.0%

Appendix 4G. Benthic data - Rainbow (non-impact site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	12.2	14.0	12.8	12.5	13.1	13.1	11.6	13.1	12.2	12.5	Avg	St.Dev	Count	%
Abiotic	reef /rock	98	92	80	77	98	96.5	87	97	96	94	91.6	7.7	10	100.0%
	rubble	1	0	16	20	0	0	10	0	1	5	5.3	7.5	6	60.0%
	sand	2	8	4	3	2	3.5	3	3	3	1	3.3	1.9	10	100.0%
	other	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0%
Corals	*Agaricia agaricites*	0.8	1.1	0.8	0.4	1.2	3.2	3.0	6.9	2.5	1.0	2.1	2.0	10	100.0%
	Agaricia fragilis				0.2							0.2	-	1	10.0%
	Agaricia lamarki	0.3										0.3	-	1	10.0%
	Agaricia sp.								0.8			0.8	-	1	10.0%
	Colpophyllia natans						0.5					0.5	-	1	10.0%
	Diploria labyrinthiformis						2.4	1.2				1.8	0.8	2	20.0%
	Eusmilia fastigiata		0.4									0.4	-	1	10.0%
	Favia fragum		0.1				0.2		0.2			0.2	0.1	3	30.0%
	Madracis decactus		0.4	0.2			0.1		0.3			0.3	0.1	4	40.0%
	Madracis mirabilis							2.2				2.2	-	1	10.0%
	Meandrina meandrites								1.4			1.4	-	1	10.0%
	Millepora alcicornis		0.1	0.2	0.1			0.4			0.8	0.3	0.3	5	50.0%
	Millepora complanata	0.1										0.1	-	1	10.0%
	Montastraea annularis	25.2	14.8		17.5	0.3	14.6	15.0	5.4	23.0	7.0	13.6	8.1	9	90.0%
	Montastraea faveolata		4.9		8.0		3.7		2.2		8.5	5.5	2.7	5	50.0%
	Montastraea franksi	1.9	5.2	10.5		2.1		4.0	2.0	1.2	11.0	4.7	3.9	8	80.0%
	Montastraea cavernosa				0.5	6.0	0.1					2.2	3.3	3	30.0%
	Porites astreoides		0.8	7.5	1.0	2.2	5.2	4.5	5.9	2.1	1.5	3.4	2.4	9	90.0%
	Porites porites			0.6	3.0		1.8		1.0		1.0	1.5	1.0	5	50.0%
	Scolymia sp.		0.1									0.1	-	1	10.0%
	Stephanocoenia intersepta						0.3					0.3	-	1	10.0%
	Subtotal Corals =	28.3	27.9	19.8	30.7	11.8	32.1	30.3	26.1	28.8	30.8	26.7	6.3	na	na
Algae	*Halimeda* sp.	3.3	10.6	4.0		2.2	8.0		8.0	7.8		6.3	3.1	7	70.0%
	Halimeda goreaui				3.0			2.0			6.0	3.7	2.1	3	30.0%
	Halimeda opuntia				1.0							1.0	-	1	10.0%
	Valonia/Ventricaria						0.1		0.2			0.2	0.1	2	20.0%
	Lobophora variegata	2.0	16.5	18.0	9.5	10.8	7.5	9.0	11.5	8.0	3.0	9.6	5.1	10	100.0%
	Dictyota sp.	4.4	5.7	3.0	2.0		8.6	5.0	4.8	3.3	3.0	4.4	2.0	9	90.0%
	Galaxaura sp.		3.2	1.0	5.0			0.5	2.5			2.4	1.8	5	50.0%
	Ceramium sp.		0.1	0.5		1.0			0.3			0.5	0.4	4	40.0%
	Jania sp.						1.2					1.2	-	1	10.0%
	Calcareous/Encrusting Red				3.0			2.0				2.5	0.7	2	20.0%
	Schizothrix calcicola		2.8	2.0			1.5	1.0			2.0	1.9	0.7	5	50.0%
	Macro Algae, unidentified		0.3				4.2		1.0		0.1	1.4	1.9	4	40.0%
	Subtotal Algae =	9.7	39.2	28.5	23.5	14.0	31.1	19.5	28.3	19.1	14.1	22.7	9.1	na	na
Other Invertebrates	*Psuedopterogorgia* sp.		0.5	0.1	0.2	1.0	0.5	0.2	0.8			0.5	0.3	7	70.0%
	Briarium sp.									1.0		1.0	-	1	10.0%
	branching gorgonian									3.0	0.2	1.6	2.0	2	20.0%
	Cliona sp.	5.3		0.5	0.4		2.5				3.0	2.3	2.0	5	50.0%
	encrusting sponge		3.9	1.0		0.3	3.7	1.0	1.2		2.8	2.0	1.5	7	70.0%
	branching sponge	0.6					0.2		0.1	0.1	0.5	0.3	0.2	5	50.0%
	irregular/lumpy sponge					4.3	1.0					2.7	2.3	2	20.0%
	vase sponge								2.8		1.5	2.2	0.9	2	20.0%
	Subtotal Other Inverts =	5.9	4.4	1.6	0.6	5.6	7.9	1.2	4.9	4.1	8.0	4.4	2.6	na	na
DCTA	Dead Coral with Turf Algae	54.1	20.5	46.1	42.2	66.6	25.4	46.0	37.7	45.0	46.1	43.0	13.2	10	100.0%

Appendix 4H. Benthic data - Sprat Hole (non-impact site).

	Quadrat No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Cover		Frequency	
Group	Depth (m)	10.1	9.8	9.4	10.7	9.4	9.8	10.7	9.4	10.1	9.1	Avg	St.Dev	Count	%
Abiotic	reef /rock	74	92	91	65	78	92	94.5	100	98.5	91	87.6	11.4	10	100.0%
	rubble	18	6	6	0	14	1	0	0	0	6	5.1	6.4	6	60.0%
	sand	8	2	3	35	8	7	5.5	0	1.5	3	7.3	10.1	9	90.0%
	other	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0	0.0%
Corals	*Agaricia agaricites*	1.5	2.0	0.8	2.1	1.0	2.5	0.8	0.4	3.0	7.0	2.1	1.9	10	100.0%
	Agaricia sp.									2.3		2.3	-	1	10.0%
	Colpophyllia natans								5.5			5.5	-	1	10.0%
	Favia fragum		0.1		0.1	0.8						0.3	0.4	3	30.0%
	Meandrina meandrites	0.4										0.4	-	1	10.0%
	Millepora alcicornis	0.5				0.5						0.5	0.0	2	20.0%
	Montastraea annularis	6.5	9.5	2.2	0.2	11.5	9.8	43.8	44.0	20.6	16.5	16.5	15.7	10	100.0%
	Montastraea faveolata	3.5	4.5	0.5			14.5					5.8	6.1	4	40.0%
	Montastraea franksi	2.5	7.0	4.5		3.0		4.2				4.2	1.8	5	50.0%
	Montastraea cavernosa	4.5		0.3		1.5						2.1	2.2	3	30.0%
	Mycetophyllia aliciae									0.6		0.6	-	1	10.0%
	Porites astreoides		8.5	3.5	3.7	4.0	6.4	1.0	1.1	1.9	9.0	4.3	3.0	9	90.0%
	Porites porites			3.0			0.2				1.0	1.4	1.4	3	30.0%
	Scolymia sp.									2.5		2.5	-	1	10.0%
	Siderastrea siderea			0.4	0.4					0.4	1.0	0.6	0.3	4	40.0%
	Stephanocoenia intersepta	0.8										0.8	-	1	10.0%
	Subtotal Corals =	20.2	31.6	15.2	6.5	22.3	33.4	49.8	51.0	31.2	34.5	29.6	14.1	na	na
Algae	*Halimeda* sp.	7.0			4.8			12.8		19.3		11.0	6.5	4	40.0%
	Halimeda goreaui		4.0	9.0		6.0	7.0		7.0		11.0	7.3	2.4	6	60.0%
	Udotea cyathiformis				0.2							0.2	-	1	10.0%
	Valonia/Ventricaria								0.4			0.4	-	1	10.0%
	Lobophora variegata			1.5			0.5					1.0	0.7	2	20.0%
	Dictyota sp.	1.0	2.0	7.0	2.9	6.0	3.0	1.3	2.0	4.2	2.0	3.1	2.0	10	100.0%
	Galaxaura sp.					2.0	0.5			0.2	0.5	0.8	0.8	4	40.0%
	Jania sp.								0.8			0.8	-	1	10.0%
	Calcareous/Encrusting Red					5.0	5.0		3.0	1.6	4.0	3.7	1.4	5	50.0%
	Schizothrix calcicola	0.5			0.1		0.1	8.0			1.0	1.9	3.4	5	50.0%
	Subtotal Algae =	8.5	6.0	17.5	8.0	19.0	16.1	22.1	13.2	25.3	18.5	15.4	6.4	na	na
Other Invertebrates	*Psuedopterogorgia* sp.	0.2	1.0				0.5				1.0	0.7	0.4	4	40.0%
	Briarium sp.						0.5					0.5	-	1	10.0%
	branching gorgonian				0.2					3.0		1.6	2.0	2	20.0%
	encrusting gorgonian									0.3		0.3	-	1	10.0%
	Cliona sp.		3.5		0.5							2.0	2.1	2	20.0%
	Xestospongia muta	9.0	4.0	23.5								12.2	10.1	3	30.0%
	encrusting sponge	1.0			0.4	3.0	4.5		2.2	1.9	3.0	2.3	1.4	7	70.0%
	branching sponge		0.5	2.5	3.2	1.0	0.5			0.7	3.0	1.6	1.2	7	70.0%
	irregular/lumpy sponge				0.2			0.2	0.6			0.3	0.2	3	30.0%
	vase sponge				0.3							0.3	-	1	10.0%
	Subtotal Other Inverts =	10.2	9.0	26.0	4.7	4.0	6.0	0.2	2.8	5.8	7.0	7.6	7.1	na	na
DCTA	Dead Coral with Turf Algae	53.1	51.4	38.3	45.8	46.7	37.5	22.5	33.0	36.2	37.0	40.1	9.2	10	100.0%

Appendix 5. List of fish species observed at each site (presence absence data).

				Site Code*					No. of
Species	RF	TC	LP	MA	PB	BP	RB	SH	Sites
Acanthurus bahianus	1	1	1	1	1	1	1	1	8
Acanthurus chirurgus			1		1				2
Acanthurus coeruleus	1		1	1	1	1	1	1	7
Aulostomus maculatus		1			1	1	1	1	5
Balistes vetula		1	1						2
Melichthys niger			1				1	1	3
Xanthichthys ringens			1	1					2
Bothus lunatus	1		1						2
Caranx latus		1							1
Caranx ruber	1	1	1		1	1	1	1	7
Decapterus macarellus							1		1
Chaetodon aculeatus					1			1	2
Chaetodon capistratus	1	1	1	1	1	1	1	1	8
Chaetodon ocellatus			1						1
Chaetodon striatus		1		1	1	1		1	5
Dasyatis americana					1				1
Cyclichthys antillarum							1		1
Fistularia tabacaria						1			1
Gramma loreto					1	1	1	1	4
Haemulon carbonarium						1	1	1	3
Haemulon chrysargyreum					1				1
Haemulon flavolineatum	1	1	1	1	1	1	1	1	8
Haemulon sciurus							1		1
Holocentrus adcensionis							1		1
Holocentrus rufus	1	1	1	1		1	1	1	7
Myripristis jacobus		1	1	1	1	1	1	1	7
Neoniphon marianus		1		1	1		1		4
Inermia vittata						1			1
Bodianus rufus	1		1	1	1	1	1	1	7
Clepticus parrae	1	1	1	1	1	1	1	1	8
Halichoeres garnoti	1	1	1	1	1	1	1	1	8
Halichoeres pictus		1						1	2
Thalassoma bifasciatum	1	1	1	1	1	1	1	1	8
Lutjanus apodus					1		1		2
Lutjanus mahogoni	1			1	1	1		1	5
Ocyurus chrysurus		1		1					2
Malacanthus plumieri	1					1			2
Cantherhines macrocerus					1	1		1	3
Cantherhines pullus							1	1	2
Mulloidichthys martinicus	1	1	1	1	1	1	1	1	8
Psuedupeneus maculatus	1	1	1	1	1			1	6
Gymnothorax funebris		1							1
Opistognathus aurifrons	1			1					2
Acanthostracion ploygonia						1		1	2
Lactophrys bicaudalis							1		1
Lactophrys triqueter	1	1		1		1			4
Holacanthus tricolor		1	1	1	1		1	1	6
Pomacanthus paru	1			1	1		1	1	5
Abudefduf saxatilis					1	1	1	1	4
Chromis cyanea	1	1	1	1	1	1	1	1	8
Chromis multilineata	1	1	1	1	1	1	1	1	8

Appendix 5. continued.

	Site Code*								No. of
Species	RF	TC	LP	MA	PB	BP	RB	SH	Sites
Microspathodon chrysurus								1	1
Stegastes diencaeus	1	1	1	1	1	1	1	1	8
Stegastes leucostictus	1		1	1	1	1	1	1	7
Stegastes partitus	1	1	1	1	1	1	1	1	8
Stegastes planifrons	1	1		1	1	1	1	1	7
Stegastes variabilis			1						1
Heteropriacanthus cruentatus					1				1
Scarus iserti	1	1	1	1	1	1	1	1	8
Scarus taeniopterus	1	1	1	1	1	1	1	1	8
Scarus vetula	1	1		1	1	1	1	1	7
Sparisoma atomarium	1					1	1		3
Sparisoma aurofrenatum	1	1	1	1	1	1	1	1	8
Sparisoma rubripinne					1				1
Sparisoma viride	1	1	1	1	1	1	1	1	8
Scomberomorus regalis		1		1	1		1		4
Cephalopholis cruentatus	1	1	1	1	1	1	1	1	8
Cephalopholis fulvus	1	1	1	1	1	1		1	7
Epinephelus guttatus	1		1	1	1		1		5
Hypoplectrus chlorurus	1					1	1	1	4
Hypoplectrus guttavarius							1		1
Hypoplectrus indigo							1		1
Hypoplectrus nigricans					1			1	2
Hypoplectrus puella		1	1	1	1	1	1	1	7
Hypoplectrus unicolor			1	1	1		1		4
Paranthias furcifer			1						1
Rypticus saponaceus					1				1
Serranus tabacarius	1	1	1						3
Serranus tigrinus	1	1	1	1	1	1	1	1	8
Sphyraena barracuda							1		1
Synodus intermedius						1	1		2
Canthigaster rostrata	1		1	1	1	1	1	1	7
Total No. Species	37	37	39	40	49	43	51	46	82

* See Table 1 for site codes.

Appendix 6A. Fish count data - Rubblefield (damaged site).

	Fish Count No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
creole wrasse	140	120	70	29	210	55	6	100.0%	624	104.00	66.29
bicolor damselfish	111	100	120	46	72	97	6	100.0%	546	91.00	27.36
bluehead wrasse	79	82	46	13	29	16	6	100.0%	265	44.17	30.47
princess parrotfish	19	8	7	2	6	5	6	100.0%	47	7.83	5.85
redband parrotfish	7	11	8	4	6	7	6	100.0%	43	7.17	2.32
coney	6	4	5	3	3	7	6	100.0%	28	4.67	1.63
ocean surgeonfish	10	5	8	1	2	2	6	100.0%	28	4.67	3.67
yellowhead wrasse	6	5	6	2	3	6	6	100.0%	28	4.67	1.75
blue chromis	0	40	11	105	59	11	5	83.3%	226	37.67	39.59
harlequin bass	2	2	4	2	0	3	5	83.3%	13	2.17	1.33
foureye butterflyfish	2	2	2	2	0	4	5	83.3%	12	2.00	1.26
graysby	1	1	0	2	1	2	5	83.3%	7	1.17	0.75
longfin damselfish	0	6	0	6	3	5	4	66.7%	20	3.33	2.80
striped parrotfish	6	2	2	0	10	0	4	66.7%	20	3.33	3.93
sharpnose puffer	2	2	0	0	5	2	4	66.7%	11	1.83	1.83
stoplight parrotfish	1	0	0	3	2	2	4	66.7%	8	1.33	1.21
blue tang	0	0	1	2	3	1	4	66.7%	7	1.17	1.17
tobacco fish	2	1	3	0	0	1	4	66.7%	7	1.17	1.17
bar jack	0	1	1	1	1	0	4	66.7%	4	0.67	0.52
brown chromis	0	20	0	140	115	0	3	50.0%	275	45.83	64.22
french grunt	0	0	0	2	2	2	3	50.0%	6	1.00	1.10
threespot damselfish	1	0	0	4	0	0	2	33.3%	5	0.83	1.60
greenblotch parrotfish	0	2	0	0	2	0	2	33.3%	4	0.67	1.03
sand tilefish	0	0	2	0	0	1	2	33.3%	3	0.50	0.84
spanish hogfish	1	0	0	2	0	0	2	33.3%	3	0.50	0.84
longspine squirrelfish	0	0	1	1	0	0	2	33.3%	2	0.33	0.52
smooth trunkfish	0	0	0	1	1	0	2	33.3%	2	0.33	0.52
spotted goatfish	0	1	1	0	0	0	2	33.3%	2	0.33	0.52
mahogany snapper	0	0	0	9	0	0	1	16.7%	9	1.50	3.67
yellow goatfish	0	0	0	0	7	0	1	16.7%	7	1.17	2.86
yellowhead jawfish	0	0	3	0	0	0	1	16.7%	3	0.50	1.22
queen parrotfish	0	2	0	0	0	0	1	16.7%	2	0.33	0.82
beaugregory	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
french angelfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
peacock flounder	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
red hind	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
yellowtail hamlet	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
Total No. Species =	17	22	20	24	22	20	37		2,272		
Total No. Fish =	396	418	302	383	543	230					

Appendix 6B. Fish count data - The Corner (damaged site).

	Fish Count No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
blue chromis	63	80	46	36	50	33	6	100.0%	308	51.33	17.66
bicolor damselfish	60	50	74	22	23	20	6	100.0%	249	41.50	23.05
princess parrotfish	8	4	7	6	7	13	6	100.0%	45	7.50	3.02
coney	2	2	3	7	6	4	6	100.0%	24	4.00	2.10
french grunt	2	2	3	1	4	2	6	100.0%	14	2.33	1.03
creole wrasse	0	30	5	250	200	200	5	83.3%	685	114.17	114.21
bluehead wrasse	55	20	42	20	0	27	5	83.3%	164	27.33	19.16
longfin damselfish	7	11	1	19	0	1	5	83.3%	39	6.50	7.48
redband parrotfish	4	2	5	7	0	3	5	83.3%	21	3.50	2.43
stoplight parrotfish	0	1	1	1	5	2	5	83.3%	10	1.67	1.75
yellowhead wrasse	9	4	12	0	0	6	4	66.7%	31	5.17	4.83
bar jack	0	1	1	0	6	3	4	66.7%	11	1.83	2.32
longspine squirrelfish	0	0	1	3	4	2	4	66.7%	10	1.67	1.63
ocean surgeonfish	2	1	1	0	0	1	4	66.7%	5	0.83	0.75
brown chromis	3	48	0	18	0	0	3	50.0%	69	11.50	19.20
yellow goatfish	0	16	0	15	12	0	3	50.0%	43	7.17	7.96
striped parrotfish	2	3	5	0	0	0	3	50.0%	10	1.67	2.07
barred hamlet	0	1	0	1	1	0	3	50.0%	3	0.50	0.55
graysby	1	1	1	0	0	0	3	50.0%	3	0.50	0.55
threespot damselfish	0	9	2	0	0	0	2	33.3%	11	1.83	3.60
rainbow wrasse	0	0	6	3	0	0	2	33.3%	9	1.50	2.51
queen parrotfish	2	0	0	0	6	0	2	33.3%	8	1.33	2.42
longjaw squirrelfish	0	1	6	0	0	0	2	33.3%	7	1.17	2.40
harlequin bass	2	0	0	0	0	3	2	33.3%	5	0.83	1.33
queen triggerfish	0	0	0	0	1	1	2	33.3%	2	0.33	0.52
rock beauty	0	0	0	1	1	0	2	33.3%	2	0.33	0.52
smooth trunkfish	1	0	1	0	0	0	2	33.3%	2	0.33	0.52
tobacco fish	1	0	0	0	0	1	2	33.3%	2	0.33	0.52
trumpetfish	0	0	1	1	0	0	2	33.3%	2	0.33	0.52
blackbar soldierfish	0	0	0	0	9	0	1	16.7%	9	1.50	3.67
banded butterflyfish	0	0	0	0	2	0	1	16.7%	2	0.33	0.82
foureye butterflyfish	0	0	0	0	2	0	1	16.7%	2	0.33	0.82
green moray	0	0	0	2	0	0	1	16.7%	2	0.33	0.82
cero mackerel	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
horse-eye jack	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
spotted goatfish	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
yellowtail snapper	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
Total No. Species =	19	20	21	18	18	18	37		1,813		
Total No. Fish =	226	287	224	413	340	323					

Appendix 6C. Fish count data - La Piedra (damaged site).

	Fish Count No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
bicolor damselfish	90	160	130	180	92	95	6	100.0%	747	124.50	38.70
bluehead wrasse	77	82	102	75	77	33	6	100.0%	446	74.33	22.57
princess parrotfish	9	13	7	6	6	9	6	100.0%	50	8.33	2.66
redband parrotfish	12	9	4	8	6	6	6	100.0%	45	7.50	2.81
yellowhead wrasse	13	5	8	2	7	8	6	100.0%	43	7.17	3.66
coney	6	5	4	6	6	4	6	100.0%	31	5.17	0.98
harlequin bass	4	8	2	3	4	5	6	100.0%	26	4.33	2.07
ocean surgeonfish	3	5	2	4	5	1	6	100.0%	20	3.33	1.63
french grunt	1	2	3	5	1	2	6	100.0%	14	2.33	1.51
blue chromis	13	25	66	0	42	54	5	83.3%	200	33.33	25.15
stoplight parrotfish	0	2	2	2	2	1	5	83.3%	9	1.50	0.84
blue tang	2	2	1	1	0	2	5	83.3%	8	1.33	0.82
striped parrotfish	11	5	2	0	2	0	4	66.7%	20	3.33	4.18
longspine squirrelfish	2	3	1	0	0	1	4	66.7%	7	1.17	1.17
spotted goatfish	1	1	1	0	1	0	4	66.7%	4	0.67	0.52
creole wrasse	0	30	80	70	0	0	3	50.0%	180	30.00	36.88
rock beauty	2	2	0	0	0	1	3	50.0%	5	0.83	0.98
brown chromis	18	2	0	0	0	0	2	33.3%	20	3.33	7.23
foureye butterflyfish	0	2	2	0	0	0	2	33.3%	4	0.67	1.03
bar jack	0	0	0	1	0	2	2	33.3%	3	0.50	0.84
graysby	0	0	1	2	0	0	2	33.3%	3	0.50	0.84
sargassum triggerfish	0	0	0	0	1	2	2	33.3%	3	0.50	0.84
spanish hogfish	0	0	2	0	0	1	2	33.3%	3	0.50	0.84
butter hamlet	0	0	0	0	1	1	2	33.3%	2	0.33	0.52
sharpnose puffer	1	0	0	0	1	0	2	33.3%	2	0.33	0.52
yellow goatfish	0	0	5	0	0	0	1	16.7%	5	0.83	2.04
black durgon	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
blackbar soldierfish	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
barred hamlet	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
beaugregory	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
cocoa damselfish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
creolefish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
doctorfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
longfin damselfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
peacock flounder	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
queen triggerfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
red hind	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
spotfin butterflyfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
tobacco fish	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
Total No. Species =	20	19	21	17	18	22	39		1,915		
Total No. Fish =	268	363	426	368	256	234					

Appendix 6D. Fish count data - Midank (damaged site).

	Fish Count No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
bicolor damselfish	150	120	138	138	76	100	6	100.0%	722	120.33	27.87
blue chromis	40	16	30	210	186	145	6	100.0%	627	104.50	85.97
bluehead wrasse	77	73	70	123	103	170	6	100.0%	616	102.67	38.87
striped parrotfish	4	6	3	9	11	16	6	100.0%	49	8.17	4.88
redband parrotfish	5	7	7	9	6	10	6	100.0%	44	7.33	1.86
princess parrotfish	8	8	7	5	4	9	6	100.0%	41	6.83	1.94
yellowhead wrasse	2	10	9	8	3	9	6	100.0%	41	6.83	3.43
coney	5	6	5	3	1	5	6	100.0%	25	4.17	1.83
ocean surgeonfish	4	2	2	2	3	6	6	100.0%	19	3.17	1.60
harlequin bass	2	4	4	5	1	2	6	100.0%	18	3.00	1.55
french grunt	1	2	2	1	2	2	6	100.0%	10	1.67	0.52
brown chromis	0	20	20	22	76	20	5	83.3%	158	26.33	25.69
stoplight parrotfish	0	2	1	5	10	5	5	83.3%	23	3.83	3.66
graysby	2	0	1	1	3	2	5	83.3%	9	1.50	1.05
blue tang	1	2	0	2	2	1	5	83.3%	8	1.33	0.82
banded butterflyfish	2	1	0	1	0	1	4	66.7%	5	0.83	0.75
longspine squirrelfish	0	1	0	2	1	1	4	66.7%	5	0.83	0.75
longfin damselfish	3	2	0	3	0	0	3	50.0%	8	1.33	1.51
blackbar soldierfish	0	0	0	3	2	2	3	50.0%	7	1.17	1.33
foureye butterflyfish	1	0	3	1	0	0	3	50.0%	5	0.83	1.17
butter hamlet	0	1	0	0	1	1	3	50.0%	3	0.50	0.55
threespot damselfish	0	0	0	0	5	5	2	33.3%	10	1.67	2.58
sharpnose puffer	0	0	0	4	4	0	2	33.3%	8	1.33	2.07
smooth trunkfish	0	2	0	1	0	0	2	33.3%	3	0.50	0.84
creole wrasse	0	0	0	0	21	0	1	16.7%	21	3.50	8.57
mahogany snapper	0	0	0	0	3	0	1	16.7%	3	0.50	1.22
yellowtail snapper	0	0	3	0	0	0	1	16.7%	3	0.50	1.22
beaugregory	0	0	0	0	2	0	1	16.7%	2	0.33	0.82
rock beauty	0	0	2	0	0	0	1	16.7%	2	0.33	0.82
spanish hogfish	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
yellow goatfish	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
barred hamlet	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
cero mackerel	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
french angelfish	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
longjaw squirrelfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
queen parrotfish	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
red hind	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
sargassum triggerfish	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
spotted goatfish	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
yellowhead jawfish	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
Total No. Species =	17	21	20	24	23	23	40		2,508		
Total No. Fish =	308	287	310	560	526	517					

Appendix 6E. Fish count data - Pauls Buoy (non-impact site).

	Transect No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
brown chromis	34	69	37	155	75	20	6	100.0%	390	65.00	48.96
bluehead wrasse	24	37	48	72	103	17	6	100.0%	301	50.17	32.34
bicolor damselfish	20	28	32	36	28	19	6	100.0%	163	27.17	6.65
blue chromis	28	22	28	20	34	31	6	100.0%	163	27.17	5.31
threespot damselfish	24	34	26	17	14	10	6	100.0%	125	20.83	8.82
french grunt	4	36	18	45	4	2	6	100.0%	109	18.17	18.44
longfin damselfish	9	5	7	8	9	20	6	100.0%	58	9.67	5.28
princess parrotfish	7	5	8	9	14	7	6	100.0%	50	8.33	3.08
redband parrotfish	5	7	7	3	6	8	6	100.0%	36	6.00	1.79
stoplight parrotfish	3	6	3	3	4	8	6	100.0%	27	4.50	2.07
yellowhead wrasse	3	3	6	4	2	5	6	100.0%	23	3.83	1.47
graysby	1	2	3	3	2	5	6	100.0%	16	2.67	1.37
blue tang	1	1	2	2	4	3	6	100.0%	13	2.17	1.17
creole wrasse	37	18	10	145	25	0	5	83.3%	235	39.17	53.36
striped parrotfish	4	8	5	4	8	0	5	83.3%	29	4.83	2.99
ocean surgeonfish	3	3	4	1	0	2	5	83.3%	13	2.17	1.47
sergeant major	2	1	0	2	2	4	5	83.3%	11	1.83	1.33
mahogany snapper	2	20	20	0	2	0	4	66.7%	44	7.33	9.85
schoolmaster	0	4	1	5	0	3	4	66.7%	13	2.17	2.14
sharpnose puffer	1	0	0	3	3	5	4	66.7%	12	2.00	2.00
foureye butterflyfish	0	2	1	4	2	0	4	66.7%	9	1.50	1.52
spanish hogfish	1	1	2	0	2	0	4	66.7%	6	1.00	0.89
trumpetfish	0	2	1	2	0	1	4	66.7%	6	1.00	0.89
beaugregory	0	1	1	5	0	0	3	50.0%	7	1.17	1.94
queen parrotfish	0	2	0	0	3	2	3	50.0%	7	1.17	1.33
harlequin bass	2	1	0	0	0	3	3	50.0%	6	1.00	1.26
blackbar soldierfish	0	3	0	0	1	1	3	50.0%	5	0.83	1.17
yellow goatfish	0	0	2	0	26	0	2	33.3%	28	4.67	10.48
bar jack	0	0	0	0	1	3	2	33.3%	4	0.67	1.21
red hind	1	0	0	0	3	0	2	33.3%	4	0.67	1.21
black hamlet	0	0	2	0	1	0	2	33.3%	3	0.50	0.84
cero mackerel	0	1	0	1	0	0	2	33.3%	2	0.33	0.52
longjaw squirrelfish	0	0	1	0	1	0	2	33.3%	2	0.33	0.52
redfin parrotfish	0	0	0	0	0	11	1	16.7%	11	1.83	4.49
smallmouth grunt	0	0	6	0	0	0	1	16.7%	6	1.00	2.45
spotted goatfish	0	0	0	0	0	3	1	16.7%	3	0.50	1.22
banded butterflyfish	0	0	0	2	0	0	1	16.7%	2	0.33	0.82
fairy basslet	0	0	0	2	0	0	1	16.7%	2	0.33	0.82
barred hamlet	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
butter hamlet	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
coney	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
doctorfish	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
french angelfish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
glasseye snapper	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
greater soapfish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
longsnout butterflyfish	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
rock beauty	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
southern stingray	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
whitespotted filefish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
Total No. Species =	23	29	27	26	27	30	49		1,955		
Total No. Fish =	217	324	282	554	379	199					

Appendix 6F. Fish count data - Black Point (non-impact site).

	Fish Count No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
blue chromis	225	85	120	157	95	175	6	100.0%	857	142.83	53.18
creole wrasse	100	200	70	135	230	90	6	100.0%	825	137.50	64.32
bluehead wrasse	65	91	58	39	57	28	6	100.0%	338	56.33	21.83
brown chromis	10	67	30	60	65	70	6	100.0%	302	50.33	24.55
threespot damselfish	28	42	26	27	45	35	6	100.0%	203	33.83	8.18
bicolor damselfish	27	35	30	47	16	25	6	100.0%	180	30.00	10.43
redband parrotfish	5	3	9	11	7	10	6	100.0%	45	7.50	3.08
princess parrotfish	8	7	5	8	4	8	6	100.0%	40	6.67	1.75
striped parrotfish	5	6	4	8	4	5	6	100.0%	32	5.33	1.51
yellowhead wrasse	4	3	8	5	5	6	6	100.0%	31	5.17	1.72
stoplight parrotfish	3	7	7	2	4	3	6	100.0%	26	4.33	2.16
ocean surgeonfish	3	2	2	2	2	2	6	100.0%	13	2.17	0.41
graysby	2	0	4	3	2	4	5	83.3%	15	2.50	1.52
queen parrotfish	1	2	2	2	0	2	5	83.3%	9	1.50	0.84
french grunt	1	0	2	1	1	1	5	83.3%	6	1.00	0.63
trumpetfish	0	1	1	1	1	1	5	83.3%	5	0.83	0.41
longfin damselfish	4	0	6	10	0	4	4	66.7%	24	4.00	3.79
sharpnose puffer	2	2	0	3	0	4	4	66.7%	11	1.83	1.60
barred hamlet	0	2	1	0	1	4	4	66.7%	8	1.33	1.51
foureye butterflyfish	2	0	2	2	2	0	4	66.7%	8	1.33	1.03
mahogany snapper	1	2	1	0	4	0	4	66.7%	8	1.33	1.51
blue tang	2	1	0	0	2	1	4	66.7%	6	1.00	0.89
longspine squirrelfish	0	1	1	0	1	3	4	66.7%	6	1.00	1.10
bar jack	1	2	1	0	0	0	3	50.0%	4	0.67	0.82
beaugregory	0	0	1	1	1	0	3	50.0%	3	0.50	0.55
yellow goatfish	0	0	0	0	20	11	2	33.3%	31	5.17	8.50
blackbar soldierfish	0	0	6	0	2	0	2	33.3%	8	1.33	2.42
sergeant major	0	0	4	2	0	0	2	33.3%	6	1.00	1.67
fairy basslet	0	0	2	2	0	0	2	33.3%	4	0.67	1.03
greenblotch parrotfish	0	0	2	0	2	0	2	33.3%	4	0.67	1.03
whitespotted filefish	2	2	0	0	0	0	2	33.3%	4	0.67	1.03
yellowtail hamlet	1	0	0	3	0	0	2	33.3%	4	0.67	1.21
caesar grunt	0	0	0	1	1	0	2	33.3%	2	0.33	0.52
boga	0	0	80	0	0	0	1	16.7%	80	13.33	32.66
banded butterflyfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
bluespotted cornetfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
coney	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
harlequin bass	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
honeycomb cowfish	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
sand diver	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
sand tilefish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
smooth trunkfish	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
spanish hogfish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
Total No. Species =	26	21	29	25	27	24	43		3,157		
Total No. Fish =	505	563	486	533	576	494					

Appendix 6G. Fish count data - Rainbow (non-impact site).

	Transect No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
creole wrasse	100	60	110	140	200	430	6	100.0%	1040	173.33	134.11
blue chromis	87	62	108	110	120	180	6	100.0%	667	111.17	39.57
brown chromis	69	70	22	70	30	110	6	100.0%	371	61.83	31.95
bicolor damselfish	42	38	41	30	70	55	6	100.0%	276	46.00	14.27
bluehead wrasse	41	11	19	20	23	72	6	100.0%	186	31.00	22.41
threespot damselfish	29	21	30	31	26	17	6	100.0%	154	25.67	5.57
princess parrotfish	9	10	10	4	3	8	6	100.0%	44	7.33	3.08
redband parrotfish	4	7	8	7	9	9	6	100.0%	44	7.33	1.86
striped parrotfish	3	9	5	6	5	6	6	100.0%	34	5.67	1.97
stoplight parrotfish	4	4	7	7	3	7	6	100.0%	32	5.33	1.86
yellowhead wrasse	4	7	4	3	2	5	6	100.0%	25	4.17	1.72
foureye butterflyfish	3	2	2	4	3	4	6	100.0%	18	3.00	0.89
graysby	2	2	2	4	2	4	6	100.0%	16	2.67	1.03
blue tang	2	2	1	2	1	3	6	100.0%	11	1.83	0.75
sharpnose puffer	1	1	1	3	0	4	5	83.3%	10	1.67	1.51
queen parrotfish	0	0	3	2	2	3	4	66.7%	10	1.67	1.37
ocean surgeonfish	4	3	2	0	0	0	3	50.0%	9	1.50	1.76
bar jack	0	0	2	3	0	3	3	50.0%	8	1.33	1.51
mackerel scad	0	0	0	10	80	0	2	33.3%	90	15.00	32.09
blackbar soldierfish	0	0	0	4	5	0	2	33.3%	9	1.50	2.35
schoolmaster	0	0	0	6	2	0	2	33.3%	8	1.33	2.42
greenblotch parrotfish	0	3	3	0	0	0	2	33.3%	6	1.00	1.55
beaugregory	1	0	0	0	0	3	2	33.3%	4	0.67	1.21
french grunt	0	2	2	0	0	0	2	33.3%	4	0.67	1.03
harlequin bass	1	0	2	0	0	0	2	33.3%	3	0.50	0.84
rock beauty	0	0	1	0	0	2	2	33.3%	3	0.50	0.84
barred hamlet	1	0	0	0	0	1	2	33.3%	2	0.33	0.52
longjaw squirrelfish	0	1	1	0	0	0	2	33.3%	2	0.33	0.52
yellowtail hamlet	0	0	1	0	1	0	2	33.3%	2	0.33	0.52
cero mackerel	0	0	0	0	2	0	1	16.7%	2	0.33	0.82
fairy basslet	0	2	0	0	0	0	1	16.7%	2	0.33	0.82
longfin damselfish	0	0	0	2	0	0	1	16.7%	2	0.33	0.82
longspine squirrelfish	0	0	2	0	0	0	1	16.7%	2	0.33	0.82
spanish hogfish	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
trumpetfish	0	0	0	0	0	2	1	16.7%	2	0.33	0.82
black durgon	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
bluestriped grunt	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
butter hamlet	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
caesar grunt	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
french angelfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
great barracuda	0	1	0	0	0	0	1	16.7%	1	0.17	0.41
indigo hamlet	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
orangespotted filefish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
red hind	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
sand diver	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
sergeant major	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
shy hamlet	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
spotted trunkfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
squirrelfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
web burrfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
yellow goatfish	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
Total No. Species =	21	23	27	25	24	23	51		3,116		
Total No. Fish =	409	320	391	472	593	931					

Appendix 6H. Fish count data - Sprat Hole (non-impact site).

	Transect No.										
Common Name	1	2	3	4	5	6	Ct.	Freq	Total No.	Avg No.	StDev
blue chromis	78	60	57	135	130	94	6	100.0%	554	92.33	33.89
bicolor damselfish	65	60	48	80	50	47	6	100.0%	350	58.33	12.82
bluehead wrasse	50	32	37	61	40	11	6	100.0%	231	38.50	16.98
brown chromis	30	30	24	30	41	40	6	100.0%	195	32.50	6.63
threespot damselfish	10	7	9	35	22	17	6	100.0%	100	16.67	10.60
princess parrotfish	12	9	8	9	8	7	6	100.0%	53	8.83	1.72
redband parrotfish	5	5	5	12	10	10	6	100.0%	47	7.83	3.19
blue tang	1	2	7	3	3	2	6	100.0%	18	3.00	2.10
sharpnose puffer	2	2	2	2	3	2	6	100.0%	13	2.17	0.41
stoplight parrotfish	4	0	3	1	6	6	5	83.3%	20	3.33	2.50
foureye butterflyfish	5	2	0	3	2	4	5	83.3%	16	2.67	1.75
graysby	3	0	3	4	2	3	5	83.3%	15	2.50	1.38
ocean surgeonfish	5	3	2	0	3	1	5	83.3%	14	2.33	1.75
striped parrotfish	2	5	8	8	0	0	4	66.7%	23	3.83	3.71
longfin damselfish	6	6	2	0	1	0	4	66.7%	15	2.50	2.81
yellowhead wrasse	4	3	4	3	0	0	4	66.7%	14	2.33	1.86
fairy basslet	2	0	0	2	2	2	4	66.7%	8	1.33	1.03
queen parrotfish	1	1	0	2	2	0	4	66.7%	6	1.00	0.89
blackbar soldierfish	4	0	0	2	2	0	3	50.0%	8	1.33	1.63
french grunt	2	0	1	0	0	2	3	50.0%	5	0.83	0.98
longsnout butterflyfish	2	2	0	0	0	1	3	50.0%	5	0.83	0.98
trumpetfish	2	1	0	0	2	0	3	50.0%	5	0.83	0.98
longspine squirrelfish	0	2	1	0	0	1	3	50.0%	4	0.67	0.82
yellowtail damselfish	0	0	1	0	1	1	3	50.0%	3	0.50	0.55
creole wrasse	0	200	90	0	0	0	2	33.3%	290	48.33	82.56
rock beauty	0	1	0	0	0	11	2	33.3%	12	2.00	4.43
banded butterflyfish	0	0	2	0	0	2	2	33.3%	4	0.67	1.03
barred hamlet	0	2	0	0	2	0	2	33.3%	4	0.67	1.03
coney	0	2	0	0	0	2	2	33.3%	4	0.67	1.03
bar jack	2	1	0	0	0	0	2	33.3%	3	0.50	0.84
harlequin bass	0	2	1	0	0	0	2	33.3%	3	0.50	0.84
spanish hogfish	1	0	0	0	2	0	2	33.3%	3	0.50	0.84
spotted goatfish	1	0	0	0	0	2	2	33.3%	3	0.50	0.84
honeycomb cowfish	0	1	0	0	0	1	2	33.3%	2	0.33	0.52
yellow goatfish	0	1	0	0	1	0	2	33.3%	2	0.33	0.52
mahogany snapper	0	0	0	13	0	0	1	16.7%	13	2.17	5.31
beaugregory	2	0	0	0	0	0	1	16.7%	2	0.33	0.82
black durgon	0	0	2	0	0	0	1	16.7%	2	0.33	0.82
black hamlet	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
caesar grunt	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
french angelfish	0	0	0	0	1	0	1	16.7%	1	0.17	0.41
orangespotted filefish	0	0	0	0	0	1	1	16.7%	1	0.17	0.41
rainbow wrasse	1	0	0	0	0	0	1	16.7%	1	0.17	0.41
sergeant major	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
whitespotted filefish	0	0	1	0	0	0	1	16.7%	1	0.17	0.41
yellowtail hamlet	0	0	0	1	0	0	1	16.7%	1	0.17	0.41
Total No. Species =	28	26	24	19	23	25	46		2,077		
Total No. Fish =	303	442	319	406	336	271					