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Validation of a Spawning Aggregation of Mutton Snapper and Characterization of the Benthic Habitats and Fish in the Mutton Snapper Seasonal Closed Area, St. Croix, U.S. Virgin Islands

Submitted to:
Caribbean Fishery Management Council
San Juan, Puerto Rico

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EXECUTIVE SUMMARY

This report describes the first study of the mutton snapper spawning aggregation within the Mutton Snapper Seasonal Closed Area (MSSCA), St. Croix, U.S. Virgin Islands and provides the first characterization of the habitat and habitat associated fish and invertebrate populations in the MSSCA.

Mutton snapper (*Lutjanus analis*) is highly prized by commercial and recreational fishers in the US Caribbean (Puerto Rico and the U.S. Virgin Islands) because of its good quality flesh and reports that it is seldom ciguatoxic. It is susceptible to targeted fishing by recreational and commercial fishers because it aggregates to spawn at predictable times and locations. Based largely on information provided by the Virgin Islands Department of Planning and Natural Resources, Division of Fish and Wildlife, the Caribbean Fishery Management Council (CFMC) and the Federal Government declared an area south of St. Croix seasonally closed from March 1 – June 30th commencing in 1993 to protect a spawning aggregation of mutton snapper south of St. Croix from fishing. In 1994, the Government of the U.S. Virgin Islands (USVI) followed with a similar declaration, resulting in a 2 nm sq. area seasonally closed to fishing. This area became the MSSCA. Owing to concerns about the status of the mutton snapper because of continued targeting of mutton snapper by fishers in the MSSCA during the closure, the CFMC in 2005 and the USVI in 2006 implemented a seasonal prohibition in federal and territorial waters, respectively, on the harvest of mutton snapper from April 1 – June 30th.

To document the mutton snapper spawning aggregation within the MSSCA on St. Croix, we conducted visual censuses using scuba divers from April to July 2009 and May to July 2010, hook and line catches from April to June 2009, and fisher interviews. Based on gonad maturity and the gonad somatic index of mutton snapper caught in the MSSCA and purchased on St. Croix in March 2009 and 2010 and July 2009, this species likely spawns in the vicinity of the MSSCA from April through July each year depending on the timing of the full moon. Individual fish are batch spawners, spawning repeatedly over a period of days or months.

The spawning aggregation of mutton snapper in or near the MSSCA appears to be fairly robust based on the high CPUE reported in this study. This is despite fairly heavy fishing pressure that continued until the seasonal prohibition on possession of mutton snapper in territorial and federal waters was implemented 2006. The skewed sex ratio of the catches (2.3 males:1 female), the result of a high proportion of small males, which start reproducing at a smaller size than females, may reflect high fishing pressure before the 2006 seasonal prohibition went into effect and the initial recovery of the population. Given the high female fecundity reported in this study, recovery may occur quickly if fishers continue to respect the seasonal possession prohibition and enforcement is adequate.

The actual site of the mutton snapper aggregation still needs to be confirmed. Divers were unable to detect any sign of a spawning aggregation within the MSSCA. Effort should be made to make visual dive inspections of the reefs near the Red Buoy site during the annual spawning period of mutton snapper. Also, visual dive inspections of reefs in this area at the spawning times of other species observed at the site would provide information about the importance of this site for these species and other species, for example, there have been reports of red hind spawning/aggregating in this area (Martinez pers. com.).

To verify the habitat mapped by Prada (2003) based on sidescan and multibeam data collected to Geophysics GPR, Inc. (2003) within the MSSCA, photo quadrats were used to describe the habitat. The deep reef slope, reported to once have high coral cover, experienced a sharp die off in the 2005 coral bleaching event and is now dominated by sponge, gorgonian and algal communities with low percent live coral cover. Live scleractinian coral cover was very low. Habitats such as COLI (Coral Limestone - a spur and groove coral community) and GOPL (gorgonian plain - actually a hillocky limestone hard bottom community with abundant gorgonians, sponges and corals - primarily dead coral heads), that had a strong 3D structure created by corals, only had a coral cover of 7.56% and 7.00% respectively. The *Montastrea annularis* species complex was the dominant coral taxa in both COLI and GOPL habitats. The dead coral skeletons in these habitats had high macro algal cover, primarily *Lobophora variegata*. In shallower habitats such as ALIN (Algae Invertebrate hard bottom),, *Sargassum* spp. was more common while *Dictyota* was most abundant in SAIN (Sand Invertebrates). In the most extensive habitats, the predominately shallow ALIN and SAIN, *Siderastrea siderea* was the most abundant coral. However, this species only covered 0.96% of the substrate in ALIN and 0.68% in SAIN. The current low coral cover in the MSSCA is largely a function of coral bleaching and disease. Coral bleaching in the USVI is related to higher than normal water temperatures, which in turn is related to global climate change.
.
An underwater temperature logger was used to monitor subsurface sea water temperatures on dives from April to July 2009 and from May to July 2010. Subsurface sea water temperatures were much warmer in 2010. The mean temperature in May 2010 was 1.61^{o}C warmer than 2009 and June 2010 was 0.91^{o}C warmer than June 2009. It is uncertain how long mutton snapper aggregations will continue to exist in the face of an altered habitat.

To describe the fish communities associated with each habitat within the MSSCA visual surveys of fish populations were conducting using roving and transect techniques. The MSSCA harbors a high diversity of fish species. The most abundant fish were the small blue head wrasse and bicolor damselfish. These are important forage fish for groupers and snappers. None of the larger grouper species such as the Nassau and goliath groupers and few of the large snapper and parrotfish (rainbow, midnight and blue) were observed. Surgeonfish comprised slightly over 30% of the maketable species recorded in transects. Carangids (jacks), scarids (parrotfishes), and holocentrids (squirrelfishes), were the next most abundant, comprising 17 - 19% of the marketable species recorded. The groupers (serranids) were the fifth most abundant taxa (7%), primarily because the coney were abundant in all habitats.

Only one lionfish was recorded in over 250 dives in 2009 and 2010 in the MSSCA and adjacent areas. However, ominously, the lionfish was detected on one of the last dives conducted for this project in July 2010. The timing of this sighting was consistent with the increasing numbers of lionfish being reported to the VI DPNR Division of Fish and Wildlife by commercial fishers and divers.

Searches were undertaken in the East End Marine Park on St. Croix for juvenile snapper and grouper, with a particular emphasis on searching for juvenile mutton snapper. Intensive searches were done in a variety of habitats in two bays, Chenay Bay on the north shore and Robin Bay on the south shore. Neither bay had high numbers of juvenile snapper and no juvenile grouper were recorded. Most of the juvenile snapper were yellowtail, lane and mahogany snapper. No mutton snapper juveniles were recorded. The highest number juvenile snappers was found along the eroded beachrock south of Frederiksted on the western shore of St. Croix. Schools of primarily lane snapper were present during a snorkel and dive in July 2010.

It is possible that the paucity of juveniles of *L. analis* and commercially important serranid species may be a function of the number of recruits available. Although *L. analis* is now seasonally protected during its peak spawning months and harvest and possession of *E. striatus* is prohibited, these management measures have only recently been implemented in both territorial and federal waters. The *L. analis* seasonal closure appears to be working well with no signs of sale of *L. analis* during the closure period.

Several recommendations for further research are provided at the end of this report. Of special note, further research to find the location of the spawning aggregation and obtain information on trends in the number, size, and sex ratio of fish in the aggregation should be conducted throughout the spawning season. As well, research as to whether mutton snapper males and females spawn in one or more months should be undertaken because it is important in determining the total number of fish in the aggregation.

CHAPTER 1

Mutton Snapper (*Lutjanus analis*) Spawning Aggregation in the Mutton Snapper Seasonal Closed Area, St. Croix, U.S. Virgin Islands

INTRODUCTION

Mutton snapper (*Lutjanus analis*) is highly prized by commercial and recreational fishers in the US Caribbean (Puerto Rico and the U.S. Virgin Islands) because of its good quality flesh (Delgado 2004) and reports that it is seldom ciguatoxic (Olsen and Wood 1984). It is often referred to as "virgin snapper" throughout the U.S. Virgin Islands and "sama" on St. Croix where there is a large Hispanic population. "Sama" is the local name for mutton snapper in Puerto Rico (Esteves-Amador 2005). It is also called mutton fish, "pargo", "pargo criollo", and "pargo cebadal" in other parts of the Caribbean (Delgado 2004). It is among the species managed in the Exclusive Economic Zone (EEZ) of the U.S. Caribbean by the Caribbean Fishery Management Council (CFMC) and has been designated an indicator species for Snapper Unit 3 (shallow water snappers) (SEDAR14-SAR2 2007). Snapper Unit 3 includes the gray (*L. griseus*), lane (*L. synagris*), dog (*L. jocu*), schoolmaster (*L. apodus*), and mahogany (*L. mahogoni*) snappers (CFMC and NOAA NMFS 2005). Snapper Unit 3 is not listed as overfished or undergoing overfishing by the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA NMFS) (SEDAR14-SAR2 2007).

Mutton snapper is on the International Union for the Conservation of Nature (IUCN) Redlist and was assessed as Vulnerable (applicable criteria: A2d, B1+2e ver.2.3) by Huntsman (1996). This designation means that mutton snapper are considered at high risk of extinction in the wild in the medium-term future. The criteria pertaining to mutton snapper are defined as follows:

> A2) "A reduction of at least 20%, projected or suspected to be met within the next ten years or three generations, whichever is longer, based on...."
>
> > "d) actual or potential levels of exploitation."
>
> "B) Extent of occurrence estimated to be less than 20,000km^2 or area of occupancy estimated to be less than 2000km^2, and estimates indicating any two of the following" (B1 and B2e pertain to mutton snapper).
>
> > B1 = "Severely fragmented or known to exist at no more than ten locations".
> >
> > B2 = "Continuing to decline, inferred, observed or projected, in any of the following:"
> >
> > > "e) number of mature individuals"

B1 is likely incorrect for this species, since mutton snapper range from Massachusetts to Brazil (Anderson 2002 cited in SEDAR14-SAR2 2007) and are apparently genetically homogeneous throughout the northern Caribbean and Florida (Gold pers. com.). Also, mutton snapper are not severely fragmented and certainly exist at more than ten locations. The IUCN assessment is over 14 years old and needs to be updated.

Mutton snapper reproduce by gathering seasonally into spawning aggregations at predictable times and locations (Erdman, 1976, Claro and Lindeman 2003, Esteves-Amador 2005, Heyman and Kjerfve 2008). Spawning aggregations of snapper and grouper are vulnerable to targeted fishing by recreational and commercial fishers (Anon. 2004, Beets 1987, CFMC 1993, Claro et al. 2001, Claro and Lindeman 2003, Beets and Friedlander 1992, Nemeth 2005). Targeted fishing of spawning aggregations in the US Virgin Islands (USVI) occurred in the 1960's and 1970's resulting in the loss of a Nassau grouper (*Epinephelus striatus*) aggregation on St. Croix by 1971 and a sharp decline in an aggregation of this species off St. Thomas in 1975-1976 (Olsen and LaPlace 1978) with the eventual loss of the aggregation in the 1980's. Fishers on St. Thomas also targeted a red hind (*E. guttatus*) aggregation in the vicinity of the Nassau grouper aggregation. Loss of the Nassau grouper spawning aggregation focused the attention of fishers and territorial and federal fisheries management agencies on the importance of protecting aggregations and resulted in seasonal area closure of the red hind (*E. guttatus*) spawning aggregation south of St. Thomas in 1989 (CFMC 1993). A similar seasonal closure for red hind was instituted on Lang Bank, St. Croix (CFMC 1993 and CFMC and NOAA NMFS 2005).

There has been only one reported extinction of shallow water snapper spawning aggregations by fishing. Craig (1966 (abstract seen) cited by Graham et al. 2008), reported the loss of a mutton snapper spawning aggregation in Long Cay, Belize. However, there is other evidence targeted fishing of spawning aggregations has caused the decline of some snapper species, including mutton snapper (Claro et al. 2001, Matos-Caraballo et al. 2006, Graham et al. 2008, Claro et al. 2009). A significant decline in catches of mutton snapper was reported by Puerto Rican fishers (Matos-Caraballo et al. 2006). In Cuba, the highest catches of mutton snapper were often obtained during the reproductive period (April to August) with the peak spawning months of May and June accounting for 35-40% of the annual catch of this species (Claro et al. 2009). Catches of mutton snapper in Cuba were stable until the early 1990's when there were drastic reductions in catches attributed to: 1) a reduction of commercial fishing effort owing to a national crisis that reduced the availability of fishing supplies and gear and 2) the development of an intense subsistence fishery in the Archipelago Sabana-Camaguey that targeted mutton snapper among other species. In 1997-98, catches increased to nearly former levels, but then again declined. Since 1998, annual catches have been slowly declining and were more variable compared to the years prior to 1990 (Claro et al 2009).

In 1986, Tobias (referenced in CFMC 1993) wrote a brief report describing fishing on a mutton snapper spawning aggregation on the southwest of St. Croix. The CFMC (1993) reported the following information about the aggregation:

> Based on information obtained from commercial fishermen and the Division of Fish and Wildlife, U.S.V.I. records from 1981, mutton snapper have been harvested for more than 20 years from the spawning aggregation. The

> aggregation area is located between 2.1 and 3.2 nautical miles southwest of Long Point in 10 to 27 fathoms of water. Most commercial fishing occurs at night by handline fishermen in outboard-powered vessels less than 6 m in length; however, fish traps and most recently gill nets have been used to harvest mutton snapper in this area. Weather permitting, more than 30 fishing vessels can be seen nightly for one week after the full moon during the months of March through June. Fishing effort is most heavily concentrated at depths of 10 to 15 fathoms. Commercial landings indicate that mutton snapper have been fished to the extent that production from the aggregation is declining; catches have been reduced from >500 lbs per boat to <100 lbs per boat for the highliners. Average individual weights have decreased from 10 lbs to 5 lbs during the period reported.

According to the CFMC (1993), several dives were conducted by the USVI DPNR/Division of Fish and Wildlife and researchers in the fishing area during daylight hours, but no aggregation was observed. Dives were apparently limited to a depth of 15 fathoms (90ft or 27.4m). It was assumed that the aggregation site was in deepwater off the slope at 27 fathoms (162ft or 49.3m), deeper than the divers had dived. Based on fishing effort, the coordinates of the presumed aggregation area were determined.

In December 1993, the US Department of Commerce, based on the recommendation of the Caribbean Fishery Management Council (CFMC and NOAA NMFS 2005), implemented a seasonal closed area, the Mutton Snapper Seasonal Closed Area (MSSCA) to protect the spawning aggregation of mutton snapper in the southwest corner of St. Croix (58 FR 53145) (Fig. 1.1). Because only a portion of the spawning area occurred in federal waters, joint territorial and federal protection was essential to protect the spawning aggregation. In 1994, the USVI government established compatible regulations within their area of jurisdiction to establish a seasonally closed area deemed adequately sized to protect the mutton snapper spawning aggregation (SEDAR14 SAR2 2007, Garcia-Moliner 2009). The joint efforts of the two governments established an annual seasonal closed area for mutton snapper from March 1 to June 30.

The mutton snapper spawning aggregation within and outside the MSSCA was targeted by St. Croix fishers for many years, even after the implementation of the prohibition on fishing within the MSSCA. Enforcement of fishing inside the MSSCA was difficult because fishers often targeted the aggregation at night. Some fishers legally fished the aggregation, fishing outside the western boundary of the MSSCA during the spawning season (pers. com.). Fish were apparently drawn to the chum used in the line fishing technique for snappers both inside and outside the MSSCA. In order to increase compliance and improve enforcement, the U.S Department of Commerce in 2005 (50CFR622.33(a)(7)) and USVI Government in 2006 (VIRR 9A 316-14 (c)) implemented regulations to prohibit possession of mutton snapper during the presumed peak spawning months, April 1 to June 30, each year in federal and territorial waters.

Latitude	Longitude
17°37.8' N	64°53.0' W
17°39.0' N	64°53.0' W
17°39.0' N	64°50.5' W
17°38.1' N	64°50.5' W
17°37.8' N	64°52.5' W

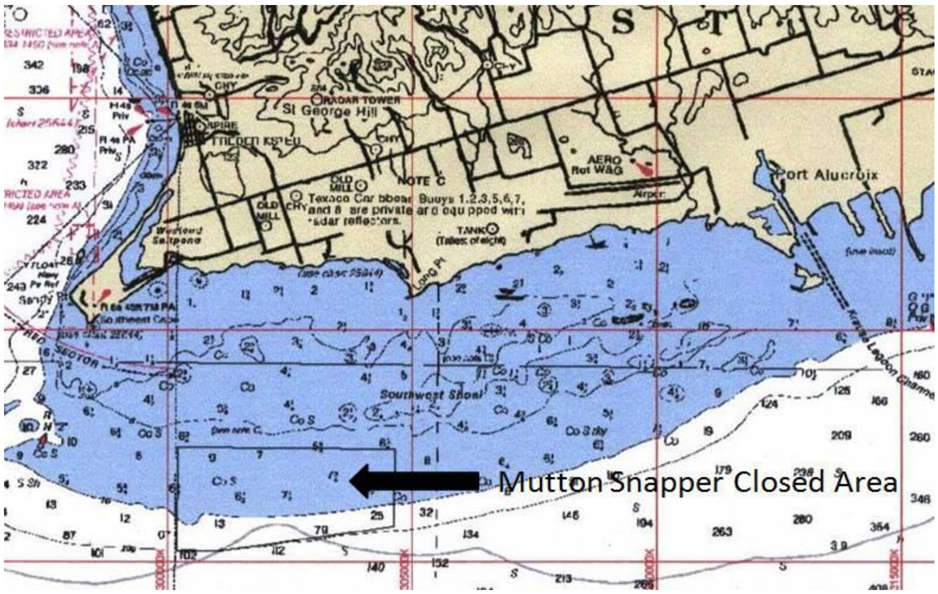


Figure 1.1 Location of the Mutton Snapper Seasonal Closed Area (MSSCA) in the southwest corner of the St. Croix shelf, including latitude and longitude.

The St. Croix spawning aggregation is one of only two confirmed spawning aggregations for mutton snapper in the U.S. Caribbean. The other is Abril la Sierra in southwestern Puerto Rico (Ojeda-Serrano et al. 2007). Ojeda-Serrano et al. (2007) listed the locations of another 26 potential spawning sites for mutton snapper around Puerto Rico based on interviews with fishers. They recommended that these sites be field verified. Fishers on St. Croix have indicated that there may be a spawning site on the northeast shelf edge based on seasonal catches of mutton snapper in this area and a fisher on St. Thomas has indicated a spawning aggregation on the southern shelf south of St. Thomas/St. John (pers. com.).

NOAA National Marine Fisheries Service (NMFS) Southeast Data, Assessment, and Review (SEDAR) 14 Review Workshop (2007) recommended monitoring spawning aggregations for density (abundance indices) and population parameters such as sex ratio and size of fish. Partnership with fishers to conduct research was also strongly endorsed by SEDAR14-SAR2 (2007). USVI fishers have often expressed dissatisfaction with the lack of monitoring of the status of spawning aggregations after seasonal closures have been put in place. Management of species by seasonally closing spawning areas to all fishing and prohibiting possession of a species during spawning periods can have profound socio-economic effects, especially in the short term, because of the high catch per unit effort (CPUE) of high value fish that occurs when spawning aggregations are fished. The goal of protecting fish spawning aggregations is to protect reproductive individuals when they are most vulnerable to ensure adequate recruitment to the fishery. Monitoring to determine the effectiveness of regulations will confirm if the goals are being met.

This study was conducted to provide information on the status of the *Lutjanus analis* spawning aggregation on the southwestern insular shelf of St. Croix, U.S. Virgin Islands, verify the spawning period for this species, and provide life history information.

MATERIALS AND METHODS

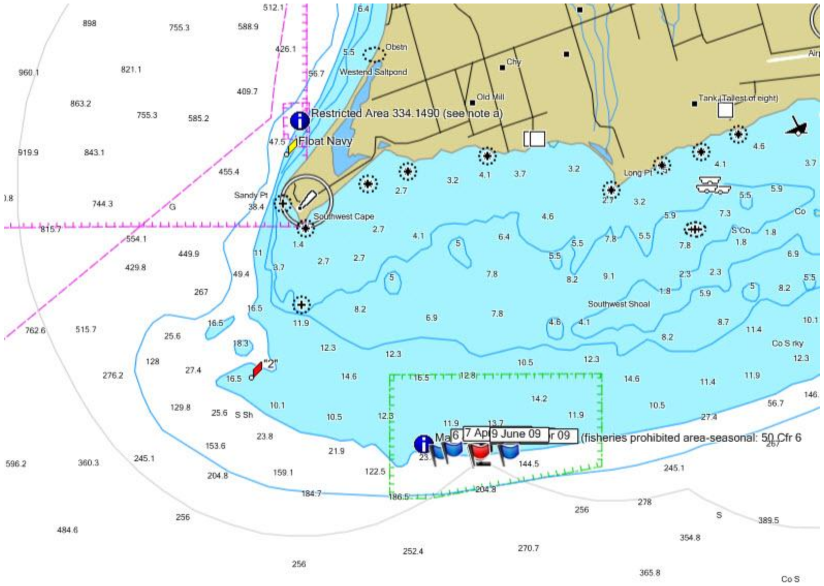
Fishing Dates and Methods

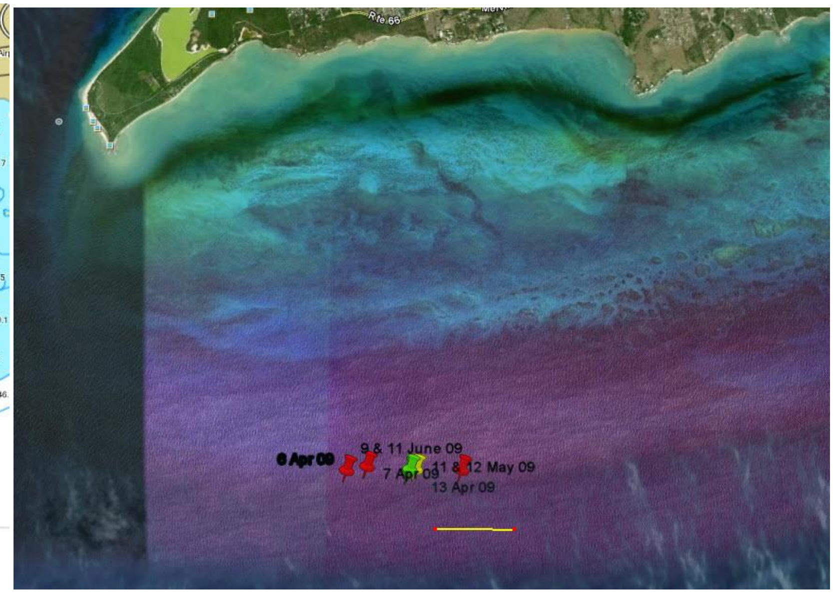
Spawning in *Lutjanus analis* has been recorded around full moon in the spring and early summer in the Caribbean (CFMC 1993, Claro et al. 2009, Matos-Caraballo et al. 2006). Anon. (2004) recorded spawning of *L. analis* 4 - 13 days after full moon. In the USVI, fishers targeted spawning aggregations of mutton snapper primarily from March to June (CFMC 1993). Fishing for *L. analis* in this study was conducted in 2009 around the full moon in April, May, and June inside the MSSCA (Table 1.1) at sites provided by fishers and Carlos Farchette, former VI DPNR Chief of Enforcement (Fig. 1.2). Fishing was conducted from an anchored boat by experienced St. Croix fishermen as well as scientific personnel each fishing day. Fishing commenced at dusk at approximately 18:15h in April, 18:30h in May and 19:00h in June and continued until about half the monthly permitted quota of 30 fish was caught. The number of hours spent fishing varied depending on CPUE. The latest we fished was 23:30h on nights no or few *L. analis* were caught. Since, only five fish were caught in April, the quota for May was increased to make up for the April shortfall.

Table 1.1 Days fished for *Lutjanus analis* in the Mutton Snapper Seasonal Closed Area in relation to full moon (0 = date of full moon, numbers refer to days before (-) or after full moon). Sampling days are marked with an X and in bold.

Day of month	April Sampling days	Full moon	May Sampling days	Full moon	June Sampling days	Full moon
6	**X**	**-3**		-3		-1
7	**X**	**-2**		-2		0
8		-1		-1		1
9		0		0	**X**	**2**
10		1		1		3
11		2	**X**	**2**	**X**	**4**
12		3	**X**	**3**	**X**	**5**
13	**X**	**4**		4		6

Fishing was done using hand lines with primarily single J hooks (hook size 7 - 8) and 60 - 200 lb test line. Weights were used only occasionally. Lines were baited with round robin (*Decapterus sp.*) (Fig. 1.2) and ballyhoo (*Hemiramphus brasiliensis*). A fluorescent light was attached to the top of the center console to help attract fish and allow fishers to see what they were doing. Chumming with cut up bait (primarily ballyhoo) started shortly before fishing commenced and continued periodically during fishing. Fishing line was paid out into the current until it was near the bottom.





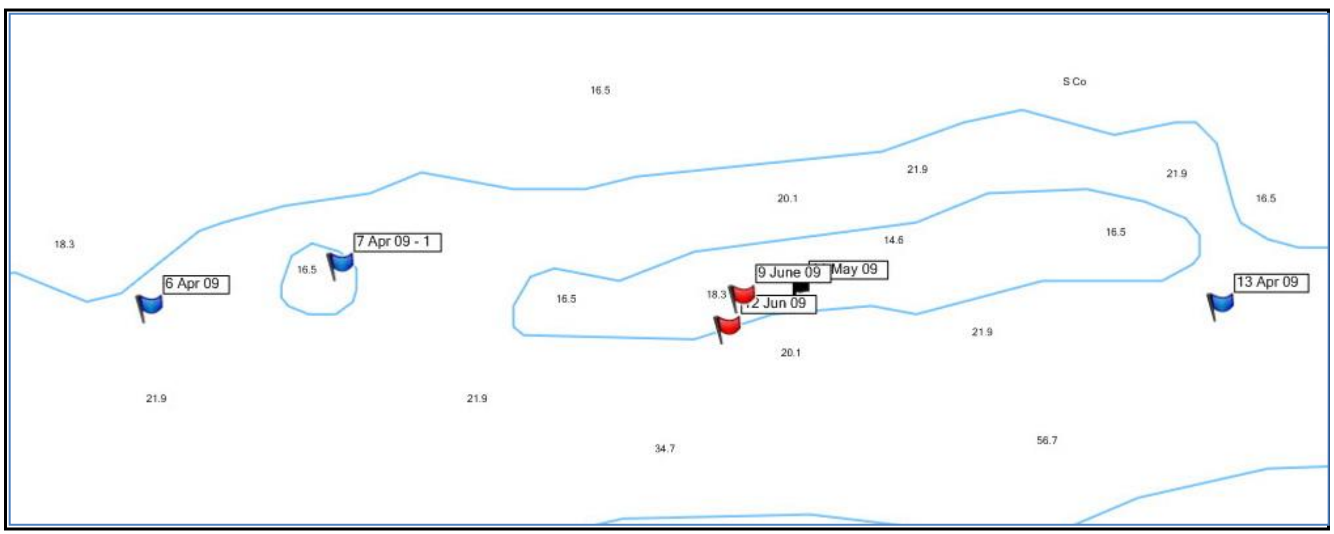


Figure 1.2. Location of fishing sites in the Mutton Snapper Seasonal Closed Area, St. Croix, U.S. Virgin Islands. Garmin MapSource image (top left) - blue flags - April 09 sites, black flag, May 09 site, red flags June 09 sites. Google Earth image (top right) - red flags - April 09 sites, yellow flag May 09 site, green flags June 09 sites. MapSource image (left) more detailed view of fishing sites.


Figure 1.2. Gerson Martinez uses a cast net to catch bait fish (left). Some of the baitfish used were caught in shallow water off the south shore of St. Croix prior to fishing (right).

***Scuba Diving Searches for* Lutjanus analis**

In May and June 2009 and May, June, and July 2010, divers searched for mutton snapper along and adjacent to the insular shelf edge primarily within the MSSCA. In 2010, searches were also conducted to the west of the MSSCA and near the red marker buoy at the southwest corner of the St. Croix shelf commencing mid-afternoon. In May and June 2009, several dives were conducted about an hour prior to fishing from the fishing boat, which was anchored at the fishing site (anchor had retrieval system that allowed the anchor to be recovered by the crown in order to minimize damage to the substrate). In 2010, some dives commenced at sites successfully fished in 2009 and at sites known by local fishers as excellent fishing sites for *L. analis*. Diver searches were conducted at depths of 20-35m and lasted 50-60 min. Two or three divers spaced about


Figure 1.3. Gerson Martinez (left) and Dr. Norman Quinn (right) searching for mutton snapper spawning aggregation in the MSSCA on the outer shelf.

7m apart swam at a constant speed and surveyed an area approximately 10m wide while towing a surface buoy (Fig. 1.3). A Garmin GPS map 67Cx on the boat was used to track the divers. Representative dive tracks are shown in Fig. 1.4.

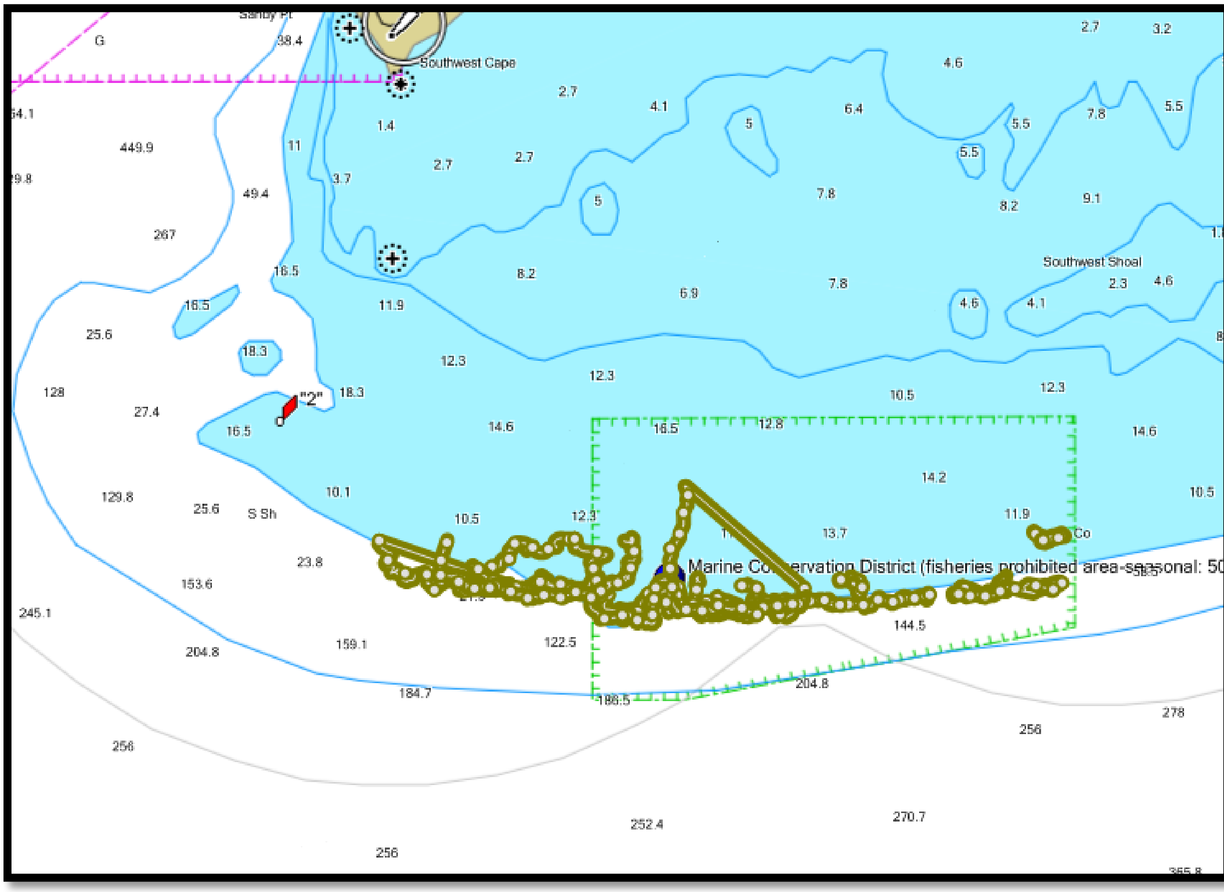


Figure 1.4. Garmin MapSource map showing some of the mutton snapper search tracks within and to the west of the Mutton Snapper Seasonal Closed Area (outlined in green).

Fish Abundance Assessment by Fishing Effort

Fishing was conducted from an anchored 7m local fishing boat. In May and June, the fishing site was marked each month by a buoy anchored to the bottom and fishing was conducted in the same area each night. The anchor and buoy were removed at the end of fishing each month. To determine fishing effort, the number of lines in the water, start and finish time for fishing and number of individuals of each species of fish caught were recorded for each fishing date. Only mutton snapper were retained in catches for analysis.

Biometric Analysis

Mutton snapper were purchased from fishers in March and July 2009 and March 2010, before and after the seasonal closure. In 2009, mutton snapper was also caught during the each month of the seasonal closure (April, May and June). Each fish was weighed using a Pesola 5kg mechanical scale or an AWS 20kg digital scale. Fork length (FL) was measured using a tape measure or a Picket 76mm plastic fish measuring board. Fish purchased in March 2009 were frozen and analyzed after thawing. Length decreases after freezing. Consequently, the length of frozen fish was adjusted based on the difference in fork length of four fish measured and weighed before and after freezing. Fish caught or purchased after March were not frozen and were analyzed within 24 hours of sampling.

Sex Determination

Fish were dissected, sex determined and gonads removed, photographed and weighed (Fig. 1.5). Ovaries and representative samples of testes were fixed in 70% isopropyl alcohol or 70% ethanol. If the sex could not be determined macroscopically, gonads were fixed for future microscopic analysis. Fixed gonads were analyzed under a binocular microscope to determine sex. Immature ovaries were distinguished from immature testes by the presence of ovigerous folds with oogonia (visible as small translucent spherules). Early maturing ovaries contained at least a few oocytes including larger translucent (previtellogenic oocytes) and opaque spherules (vitellogenic oocytes). Larger immature ovaries had a visible lumen. Testicular tissue appeared amorphous under the microscope and no lumen was present. No histological analysis was carried out. However, the binocular microscopic analysis of the gonads follows descriptions of histological staging criteria in the literature (Domeier et al. 1996, SEDAR15A-SAR3 2008).

Figure 1.5. Mutton snapper were measured, weighed (Liam Carr), and dissected to remove gonads, stomachs and provide genetic samples.

Fecundity and Oocyte Size Distribution

Fish purchased from fishers in March 2009 were frozen and then thawed prior to analysis. Fish caught in April, May, June, and July 2009 in the MSSCA were immediately placed on ice after capture (or purchase in July) and processed within 24 hrs. Gonads were removed from both male and female fish and weighed. Two subsamples of each mature female gonad were removed, one from the central portion of each of the paired ovaries. The subsamples were weighed and the gonads and subsamples fixed and stored in 70% isopropyl alcohol for further analysis.

Oocyte Size Distribution

The diameter of all eggs (oogonia and oocytes) from at least one subsample per gonad was measured using an ocular micrometer. A minimum of 100 eggs were counted in each subsample.

Fecundity

All eggs (oocytes) with a diameter of approximately $\geq$ 0.35mm were counted in all subsamples analyzed. Oocytes $\geq$ 0.35 mm appeared to be Vtg3 oocytes (large vitellogenic oocytes) and early stages of OM (oocyte maturation showing GVM - germinal vesicle migration) (Brown-Peterson et al. 2009) based on the relative size of oocytes (GVM could not be detected using a binocular microscope). Vtg3 oocytes indicate that the gonad has entered the Spawning Capable phase and are precursors to GVM. Fecundity was estimated using the following equation:

$$F_{xy} = (GW_x/SW_{xy}) \times N_{xy}$$

F = fecundity of ovary x, subsample y; GW_x = total weight of gonad x; SW_{xy} = subsample weight of ovary x, subsample y; and N_{xy} = number of eggs in ovary x, subsample y (modified from Gundersen et al. 1999).

The coefficient of variation of representative paired subsamples was calculated to obtain an estimate of variation in the egg counts between subsamples:

$$CV = (std \times 100\% / F_{mean})$$ F_{mean} is the mean fecundity std = standard deviation

Otoliths, Diet, and Genetic Samples

Otoliths were removed, dried, placed in labeled envelopes, and stored. Liam Carr, a Ph.D. student at Texas A&M, is currently working with an undergraduate student, Lance Massey, under the supervision of Dr. W. Heyman, analyzing the otoliths (Fig. 1.7) to determine the age of the fish sampled. They prepared an abstract for the 63rd Gulf and Caribbean Fisheries Institute Meeting, November 2010 (abstract provided in Appendix 1), but were unable to complete the analyses in time for the meeting. As of January 11, 2011, they have analyzed 64 of the 156

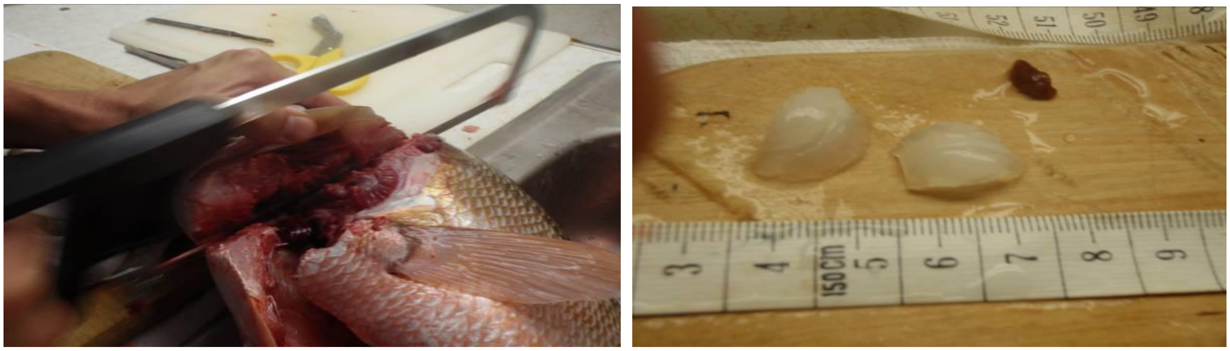


Figure 1.7. Otoliths were removed by cutting through the head just behind the operculum. The large, paired otoliths are shown in the right photo.

otoliths. They anticipate completing the otolith analysis by April 30, 2011. They will provide copies of all published papers associated with this grant will be provided to the CFMC and the NOAA Coral Reef Conservation Grant Program.

Stomachs were removed, frozen and provided to Dr. Richard Nemeth, University of the Virgin Islands, for his research on fish diets. He will provide copies to the CFMC of any published papers related to this data.

Tissue samples of *L. analis* were provided to Hector Rivera (St. Croix) who was collecting samples for Dr. John R. Gold, Texas A&M University and to Dr. Gold via Dr. Nemeth for his studies of *L. analis* population structure and phylogenetics. Dr. Gold is finalizing a manuscript describing genetic variation among populations of *L. analis* from St. Croix, St. Thomas, the east and west coasts of Puerto Rico, and the Florida Keys (Carson et al. ms). A draft was provided for review in January 2011. The manuscript is not yet finalized. Results suggest that *L. analis* can be subdivided into a number of demographic stocks similar to *L. griseus* (Gold et al. 2009), *L. synagris* (Gold et al. ms, Karlsson et al 2009), and *L. campechanus* (Saillant et al. 2010).

RESULTS

Catch Results in the Mutton Snapper Seasonal Closed Area

Fifteen species of fish were caught within the Mutton Snapper Seasonal Closed Area (MSSCA) (Table 1.2) during three fishing trips in April ((48 fishing hrs) (fishing hrs = hrs fished x number of fishers)), two in May (11 fishing hrs), and three in June (13.75 fishing hrs) 2009. Only three species were caught in all three months: *Lutjanus analis* (mutton snapper), *Ocyurus chrysurus* (yellowtail snapper), and *Carnax latus* (horse-eye jack). Four species of snapper were caught (Table 1.2) but only *L. analis* and *O. chrysurus* were caught in large numbers. The fishing technique used was one commonly used in the US Virgin Islands to target mutton snapper and yellowtail snapper, and these were the species that were the most abundant in the catches.

The catch rate for mutton snapper in the MSSCA was highest in May and June (Table 1.2, Fig. 1.8). In April, fishing was done on three nights, two nights before the full moon and one night after the full moon (Table 1.1). Only five mutton snapper were caught in April, and only on fishing nights before the full moon. Four of the five fish caught were mature and one was maturing. No fish were caught four days after full moon in April, even though 13 mutton snapper were caught in less than three hours on the 4th day after full moon in June. All sites fished were within the outer portion of the MSSCA. The sites fished in April were different from the sites fished in May and June (Fig. 1.2), which may have affected catch success. In the latter months, the sites fished were adjacent to a "bridge" connecting two reefs separated by a sand channel. "Bridges" are known by fishers to concentrate fish migrating from shallow to deepwater and vice versa. In July, Gerson Martinez (pers. com.), fished within the MSSCA but was unable to fish the location we had fished in May and June because it was occupied by another fisher. He did not catch any mutton snapper and it is unknown if the fisher occupying the May/June fishing location caught any mutton snapper.

Mutton snapper catch per unit effort (CPUE), based on number of individuals caught, was highest in May and June (Fig. 1.8). Mutton snapper CPUE in May was more than twice that of June and 50 times that of April. The seasonal CPUE for mutton snapper, based on weight, was similar to CPUE, based on numbers: April CPUE = 0.41kg, May CPUE = 13.27kg, and June = 5.78kg. In contrast, yellowtail snapper catches exceeded mutton snapper catches in April 2009, but declined by two-thirds in May and June 2009 (Table 1.2). The total CPUE, based on number of individuals, for species other than mutton snapper, was similar in all months. Total CPUE, including mutton snapper, increased by 600% May and 300% June compared to April because of the high catches of mutton snapper (Table 1.2).

The fishing gear used did not target bottom dwelling fish. However, a few individuals of three species of serranids and a holocentrid (*Holocentrus* sp.) were caught (Table 1.2). The serranids caught were the smaller species commonly targeted by fishers on St. Croix. All the species in the catches, except the reef shark (*Carcharhinus perezii*), were recorded in the fish surveys in this study (Chapter 3).

The maximum size of male mutton snappers exceeded female mutton snapper caught in the MSSCA between April and June 2009 (male = 660 mm (25.98in), 5.73kg (12.63lb); female =

635mm (25in.), 5.0kg (11.02lb)). The mean weight of all mutton snapper caught in the MSSCA in April, May and June 2009 was 2.49 kg or 5.49 lbs (N=94, SE = 1.23). The average weight of female fish (N = 29, 3.094 kg or 6.82 lbs) was significantly larger than males (N = 65, 2.218 kg or 4.89 lbs) (MS Excel T-test $_{\text{assuming unequal variances}}$ = 3.42, df = 52, P = >0.001). Weight of fish caught in May and June 2009 was compared for each sex separately. There was no difference in the weight of either male or female fish between months (Female: T-test = 0.41, df = 19, $P_{\text{one tail}}$ =0.344); Male: T-test = -1.5, df = 24, P = >0.07).

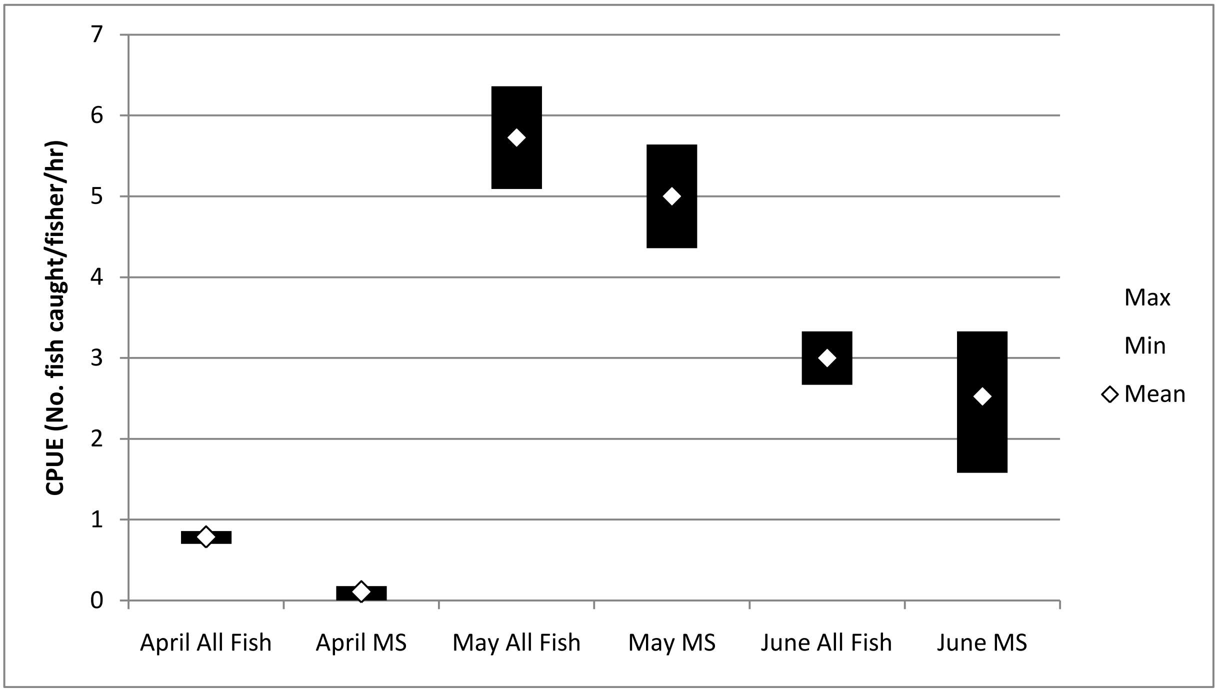


Figure 1.8. Mean CPUE (catch per unit effort based on number of fish caught $fisher^{-1}$ hr^{-1}) for all fish and *Lutjanus analis* (MS) caught in the Mutton Snapper Seasonal Closed Area in 2009 during the three months of the seasonal closure. Number of fishing days/fish caught per month: April = 3 days/5 fish, May = 2/59, June = 3/31. Black bars indicate maximum and minimum CPUE on different fishing days.

Table 1.2. Summary of the number and CPUE (number of fish caught per fisher per hour fishing) of fish caught in the Mutton Snapper Seasonal Closed Area in the spring of 2009.

			Number of fish caught each month in 2009						
			April		**May**		**June**		
Family	**Species**	**Common Name**	**No. fish**	**No. fish caught per fisher per fishing hr**	**No. fish**	**No. fish caught per fisher per fishing hr**	**No. fish**	**No. fish caught per fisher per fishing hr**	**Total no. fish**
Balistidae	*Balistes vetula*	Queen triggerfish	0	0.00	1	0.09	0	0.00	1
Belonidae		Needlefish	0	0.00	1	0.09	0	0.00	1
Carangidae	*Caranax latus*	Horse-eye jack	4	0.08	2	0.18	1	0.07	7
Carcharhinidae	*Carcharhinus perezii*	Reef shark	1	0.02	0	0.00	0	0.00	1
Echeneidae	*Echeneis* sp.	Remora	0	0.00	0	0.00	1	0.07	1
Holocentridae	*Holocentrus* sp.	Squirrelfish	1	0.02	0	0.00	0	0.00	1
Lutjanidae	*Lutjanus analis*	Mutton snapper	5	0.10	56	5.09	31	2.25	92
	Lutjanus apodus	Schoolmaster snapper	1	0.02	0	0.00	0	0.00	1
	Lutjanus jocu	Dog snapper	1	0.02	1	0.09	0	0.00	2
	Ocyurus chrysurus	Yellowtail snapper	31	0.65	3	0.27	3	0.22	37
Muraenidae	*Gymnothorax moringa*	Spotted moray	0	0.00	0	0.00	2	0.15	2
Rhincodontidae	*Ginglymostoma cirratum*	Nurse shark	0	0.00	0	0.00	1	0.07	1
Serranidae	*Cephalopholis cruentatus*	Graysby	0	0.00	0	0.00	1	0.07	1
	Cephalopholis fulvus	Coney	1	0.02	0	0.00	0	0.00	1
	Epinephelus guttatus	Red hind	0	0.00	1	0.09	1	0.07	2
Sphyraenidae	*Sphyraena barracuda*	Barracuda	0	0.00	0	0.00	1	0.07	1
	Total including mutton snapper		45	0.94	65	5.91	42	3.05	152
	Total excluding mutton snapper		40	0.83	9	0.82	11	0.80	60

Red Buoy Site

Several dives were conducted at a reef 1km southwest of the red buoy marking the St. Croix shelf edge for shipping. The reef lies in territorial waters. During four dives on 2 May 2010 (4 days after full moon), large schools of *Lutjanus cyanopterus* (cubera snapper) (Fig. 1.9), *Chaetodipterus faber* (Atlantic spadefish) (Fig. 1.10), *Trachinotus falcatus* (permit), *Caranx crysos* (blue runner), and a smaller school of crevalle jack (*Caranx hippos*) (Fig. 1.11) were observed and photographed. On the last dive, about an hour before dusk, about 200 *Lutjanus analis* (mutton snapper) were observed by Gerson Martinez forming an aggregation over sand adjacent to the reef; no spawning was observed. Because of the low light levels, depth and distance the fish were from the divers, they were not able to be photographed. On two dives conducted on 29 May 2010 (2 days after full moon), only one large school of fish (>50 fish), *Aluterus schoepli* (orange filefish), was observed on the reef.

Figure 1.9. Large school of cubera snapper (*Lutjanus cyanopterus*) at Nicky's reef, St. Croix.

Figure 1.10. School of Atlantic spadefish (*Chaetodipterus faber*) hovering in water column at Nicky's reef, St. Croix.

Figure 1.11. Schools of fish and conch at Nicky's reef near the Red Buoy. Starting top left moving clockwise: queen conch (*Strombus gigas*) amassing at the foot of the reef at a depth of 45m, permit (*Trachinotus falcatus*) showing black spot spawning coloration (Anon. 2004), blue runner (*Caranx crysos*), crevalle jack (*Caranx hippos*), and blue runner (*Caranx crysos*).

Reproductive Aspects

Sex Ratio

Lutjanus analis are gonochoric based on the parameters provided for describing *L. griseus* a gonochoric species by Domeier et al. (1996): the similarity in the size of males and females at sexual maturation, the overlap in size frequency distribution of the sexes, and the absence of any evidence of sexual transition. Males were over twice as abundant as females (Table 1.2) in May and June 2009 catches in the MSSCA. In April, females were more abundant than males but the sample size was small.

Table 1.2 Ratio of number of male to number of female *Lutjanus analis* caught in Mutton Snapper Seasonal Closed Area during the area and seasonal closures in 2009.

Month	Male	Female	Sex Ratio
April	2	3	0.7
May	43	16	2.7
June	21*	10	2.0
Total	66	29	2.3

*One fish was bitten in half during capture on hook and line, but the testes were still attached.

Gonad Somatic Index

The gonad somatic index (GSI - gonad weight (g)*100/weight of fish (g)) for *L. analis* was determined for fish purchased in March 2009 and 2010 and July 2009 and for fish caught in the MSSCA in April, May and June. The maximum GSI for all females sampled was 5.61 (caught 9 June 2009) and males 5.49 (caught 12 May 2009). The highest GSI values were in April, May and June for both sexes (Table 1.3, Fig. 1.12). GSI was lower and more variable in July (fish were purchased from fishers and not caught in the MSSCA). This was the only month in which a female was found with a spent gonad. This female was sampled on July 18 which was 11 days after full moon. GSI for females was lowest in March 2009 and 2010 when the proportion of small fish was higher. Male GSI was very low in March 2009 with the two largest males purchased (462mm and 475mm FL) having a GSI of 0.10 and 0.27, respectively. Even the one large female purchased (599mm FL) had a GSI of only 0.42. Female GSI and FL was smaller in 2010 compared to 2009 although the GSI was similar. A much larger number and size range of males was sampled in 2010 (N = 14, 513 - 598mm FL) with a GSI range of 0.13 (513mm FL) - 2.08 (542mm FL). The difference in GSI between years for males was likely a function of the proportionally larger sample size in March 2010 (Table 1.3), since the mean number of days before the April 9, 2009 / March 30, 2010 full moons that fish were sampled was greater in 2010 (-18 days) than in 2009 (-4 days).

Table 1.3 The monthly mean GSI and standard error (SE) for males (♂) and females (♀) and mean fork length (FL) (mm) and range of FL of *Lutjanus analis*. April to June fish were caught in the MSSCA. March and July fish were purchased from fishers and smaller fish were targeted.

	March '09		**April '09**		**May '09**		**June '09**		**July '09**		**March '10**	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
N	2	4	3	2	16	43	10	20	4	3	5	14
GSI	0.28	0.12	2.94	2.14	3.04	2.86	3.12	2.98	1.82	0.93	0.47	1.38
(SE)	(0.14)	(0.05)	(0.46)	(1.86)	(0.22)	(0.21)	(0.37)	(0.30)	(0.75)	(0.24)	0.13	0.23
FL	493	427	615	555	539	472	525	503	601.5	628	453	497
(range)	(386-599)	(369-475)	(590 - 635)	(490-620)	(410 - 633)	(367 - 600)	(393-625)	(375-660)	(550 - 653)	(605-644)	(340-513)	(373-598)

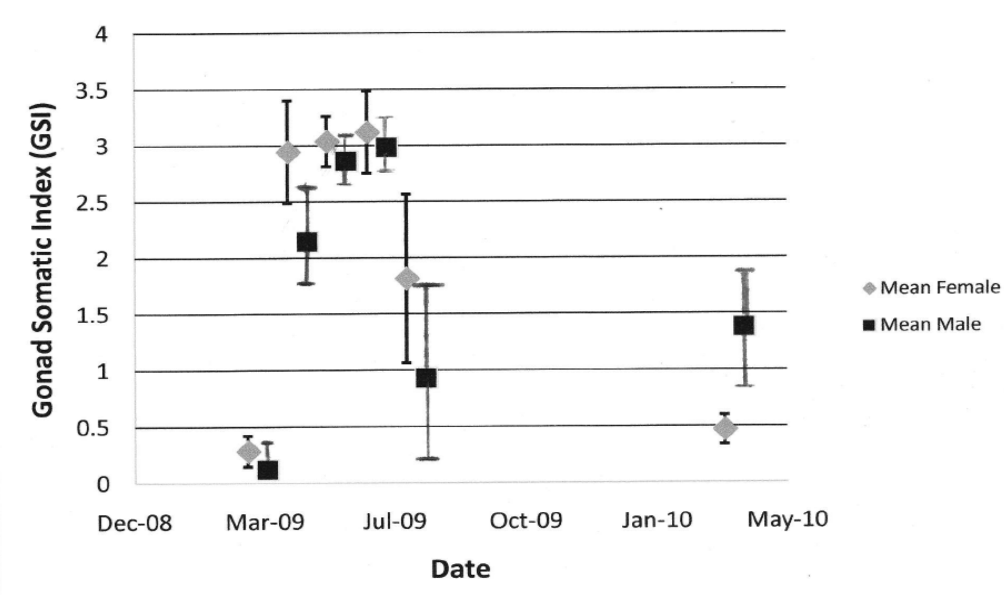


Figure 1.12. *Lutjanus analis* - Mean gonad somatic index (GSI) (gonad weight (g)*100/weight of fish (g)) with Standard Error bars. See Table 1.3 for the number of fish sampled on each date.

The size range (FL) of all reproductive females sampled was 393 - 635 mm. A linear regression of GSI versus FL for females caught April - June 2009 explained only .09% of the variance in GSI (Fig. 1.13). There was no significant difference in GSI versus fork length ($P = 0.879$), indicating that the amount of energy an individual fish expended on gonad production does not increase or decrease with fork length, within the size range sampled.

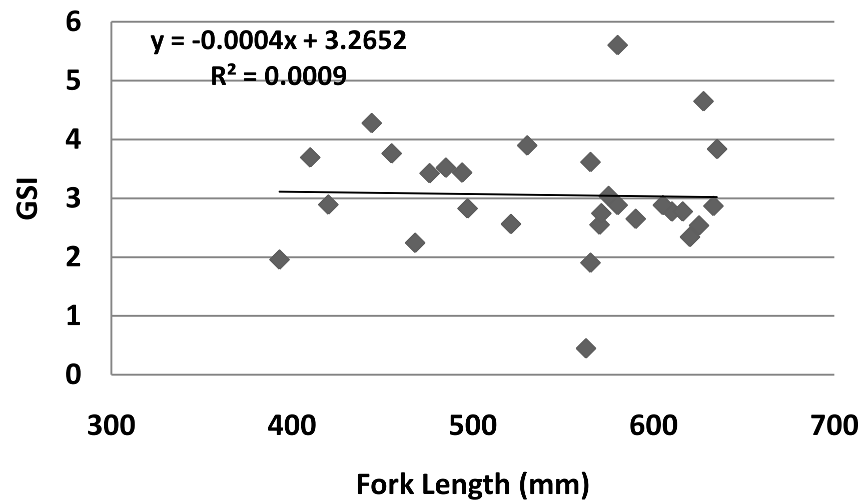


Figure 1.13. *Lutjanus analis* ♀: Linear regression of GSI based on fork length (N = 29).

The size range (FL) of all reproductive males sampled was 367 - 660 mm (GSI 2.25 and 2.11, respectively). A linear regression of GSI versus FL for males caught April - June 2009 explained only 4% of the variance in GSI (Fig. 1.14). There was no significant difference in GSI versus FL (P = 0.103).

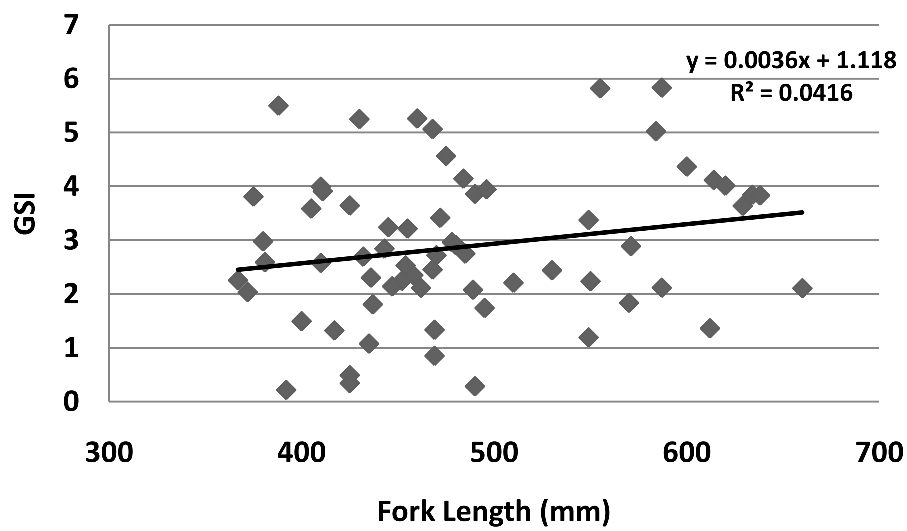


Figure 1.14. *Lutjanus analis* ♂: Linear regression of GSI based on fork length (N = 65).

Size at the Onset of Reproduction

Fish caught in April through June 2009 ranged in size (FL) from 367 - 660mm: mean size of males was 484mm FL (range 367 to 660mm, N = 65) and females 542mm FL (range 393 to 653mm, N = 29). Although more than twice as many males were caught as females, a size frequency analysis of female and male fork length shows that proportionally more large female fish were caught than large males fish (Figs. 1.15). Though the actual number of large fish (≥525 mm FL) was similar for both males and females, 20 and 19 respectively.

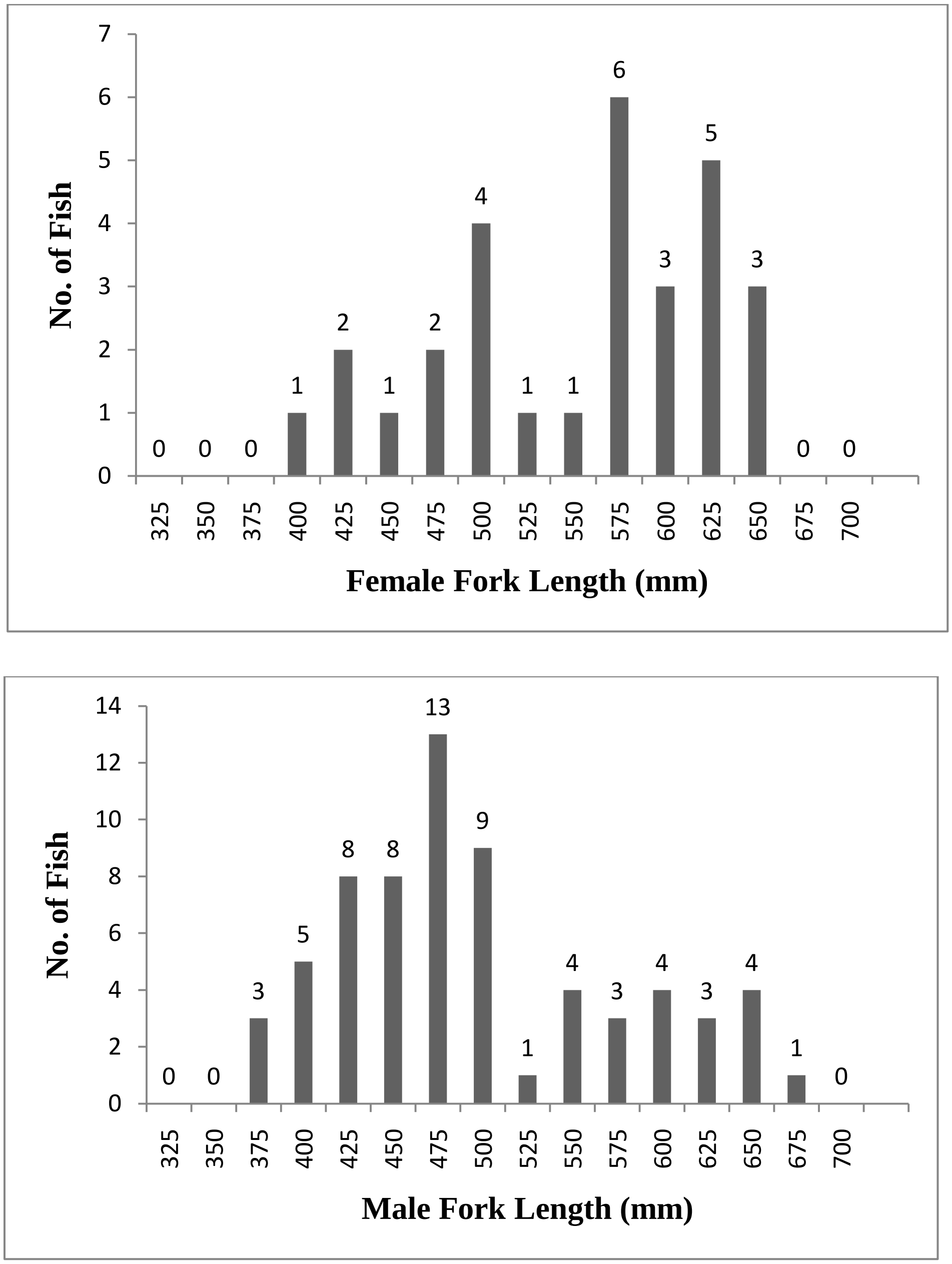


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Figure 1.15 Length frequency of analysis of female (a) and male (b) mutton snapper (*Lutjanus analis*) caught in the Mutton Snapper Seasonal Closed Area in April, May and June 2009.

The smallest mature or maturing fish sampled was 393mm FL for females (caught 11 Jun 09, GSI 1.96) and 410mm FL (caught 12 May 09, GSI 3.7). For males the smallest mature or maturing fish was 367mm FL (caught 11 May 09, GSI 2.25). Ten male fish ≤410 FL were caught in May and June 2009. Nine of these ten fish were mature or maturing and had GSI values ranging from 1.49 - 5.45; one (caught 11 June 09, FL 392mm) was immature (GSI 0.22).

Because of the relatively small sample size, data from males and females were combined to determine the length at first maturity, which "is conventionally the size at which 50% of the population attains an advanced stage of gonad development ($L_{m50\%}$)" (Ungaro 2008). Size at L_{m50} was approximately 390mm (Fig. 1.16). Given the small sample size and variation in maturity with size, the 95% confidence limit for the size at first maturity was large (330 - 410mm), particularly for the lower bound.

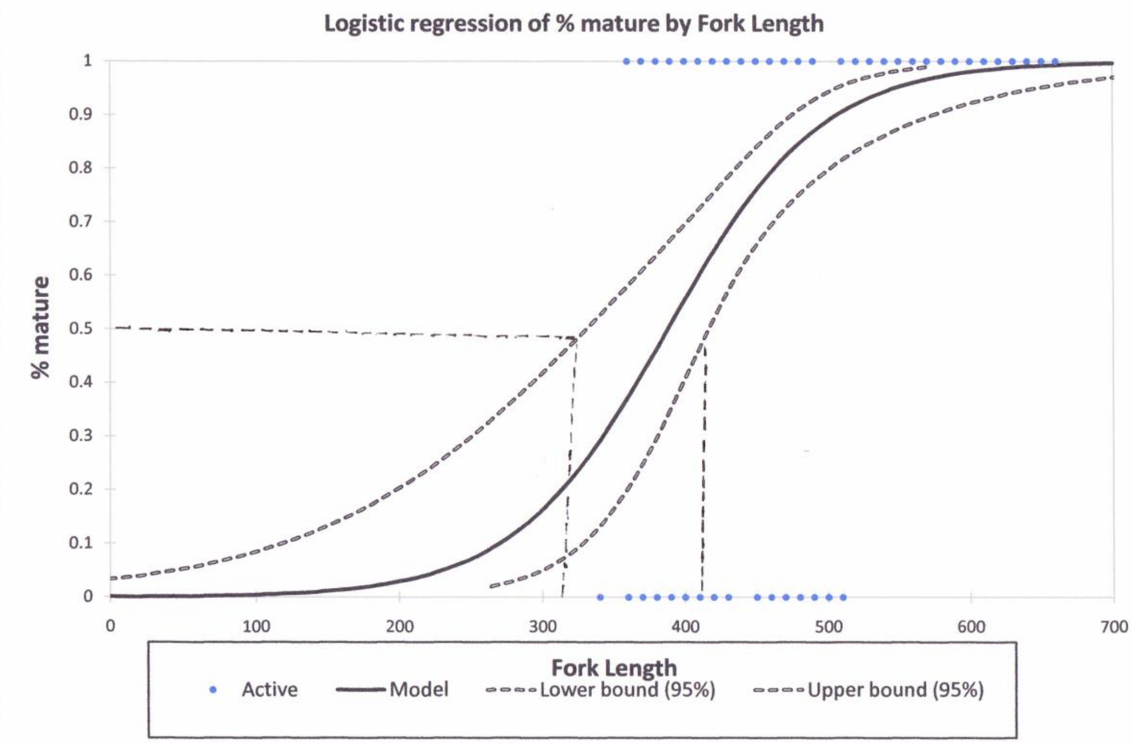


Figure 1.16. Estimated size of first maturity of mutton snapper (*Lutjanus analis*) using logistic regression (N = 129) based on all fish caught (male and female) in the MSSCA and purchased from fishers on St. Croix in 2009 and 2010.

Length Weight Relationship

The length weight relationship for male and female *Lutjanus analis* collected between 24 March 2009 and 20 March 2010 was calculated using a power regression (Fig. 1.17) ($P<0.001$). The equations for males and females differ only slightly and explain almost 98% of the variation.

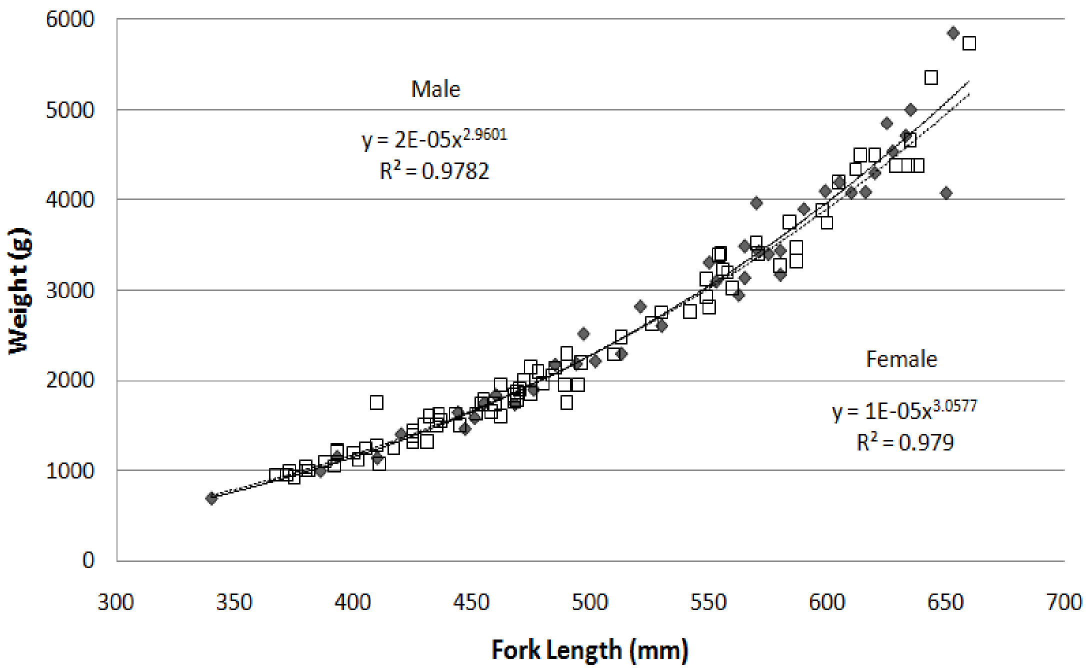


Figure 1.17. Length weight relationship for male (open squares, black line) and female (black diamonds, dashed line) *Lutjanus analis.* N: ♀ = 41, ♂ = 85.

Fecundity and Egg Size Distribution

Based on the egg size distribution in gonads from fish sampled from March to July 2009 (Fig. 1.18 and 1.19), mutton snapper:

1. Are batch spawners - eggs are released in batches over a period of days or months with only a portion of yolked oocytes spawned in each batch (Murua and Saborido-Rey 2003),

2. Possibly have indeterminate fecundity - number of eggs produced in a spawning season is not fixed before the onset of spawning - unyolked eggs continue to mature and be spawned during the spawning season (Murua and Saborido-Rey 2003)

3. Have asynchronous oocyte development - oocytes present in all stages of development without dominant populations (Murua and Saborido-Rey 2003), producing successive batches of oocytes multiple times during the spawning season.

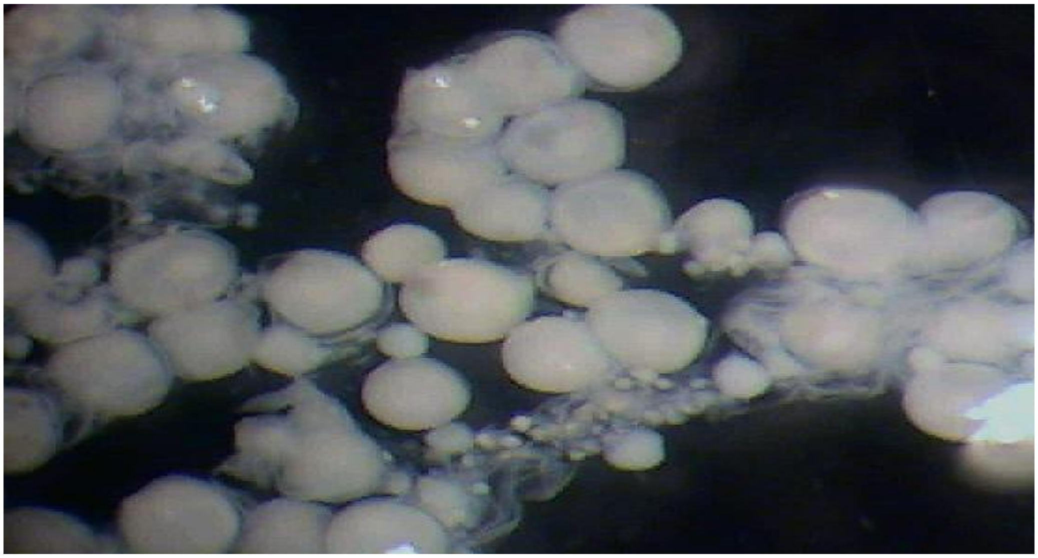


Figure 1.18. Sample from an ovary of a *Lutjanus analis* caught 11 May 2009 showing size range of eggs. The Largest eggs are approximately 0.5 mm diameter. The small eggs, part of the oogonia net, range in size from 0.06 - 0.1 mm.

Egg size distribution changed over time (Fig. 1.19). In March 2009, the largest, most developed egg sizes were absent, while they were present in May, June and July 2009. Eggs measured from fish caught in the first week of July, had an almost even distribution of egg sizes compared to March, May and June when the majority of gonads were small. The one female fish sampled on July 18th, 11 days after full moon, had few large eggs and the ovary was flaccid (spent) (Fig. 1.19).

Fecundity increases with increasing female size. MS Office Excel 2007 was used to fit linear trendlines to the data with R^2 values $\geq$70% (Fig. 1.20).

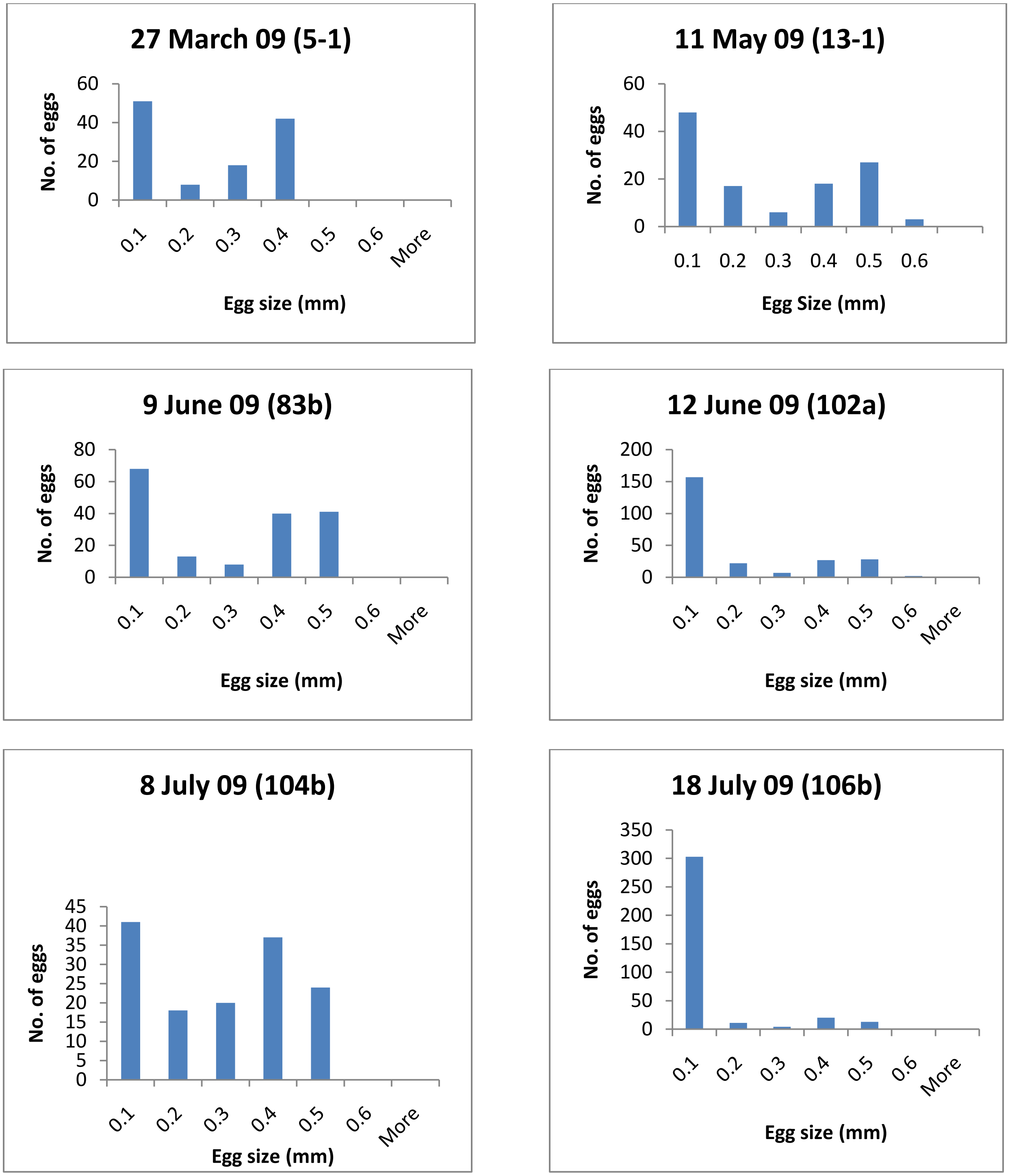


Figure 1.19. Egg size distribution from subsamples (sample # in parentheses) of representative ovaries of *Lutjanus analis* from 27 March to 18 July 2009 showing asynchronous oocyte development over time.

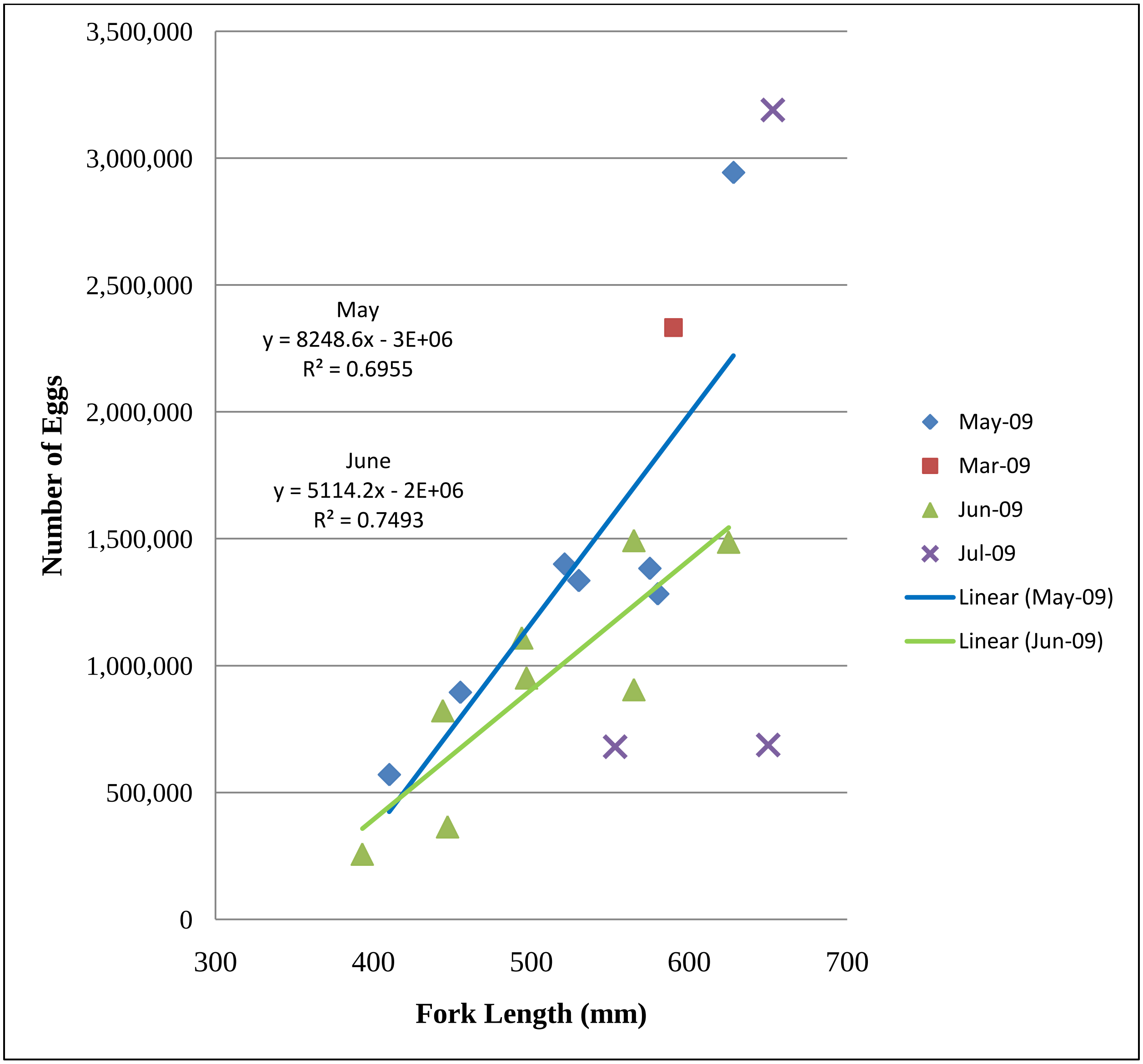


Figure 1.20. Fecundity of *Lutjanus analis* by fork length by month. Linear trend lines, the equation for the trend lines, and R^2 values are shown for May and June 2009. There were insufficient data for trendlines for March 2009 and July 09. No mature females were sampled in March 2010.

DISCUSSION

The MSSCA (Mutton Snapper Seasonal Closed Area) has been under territorial and federal government management since 1993/1994. In 2003, CRCP funds were used to obtain high resolution bathymetry and map the habitat of the MSSCA (Geophysics GPR International, Inc. 2003, Prada 2003) in order to describe the habitat within the protected area and identify geomorphological features that may attract the mutton snapper spawning aggregation. In 2009, funding was provided by the CRCP to the CFMC to carry out this study, which was the first attempt to determine the location of the mutton snapper (*Lutjanus analis*) spawning aggregation in the MSSCA and to verify the continued existence and status of the aggregation.

Historically, the mutton snapper spawning aggregation in the southwest of St. Croix has been targeted by fishers. With the implementation of the MSSCA in 1994 and the seasonal prohibition on landing mutton snapper in 2006, fishing on this spawning aggregation has ceased. While fishers on St. Croix understand the need for protecting fish spawning aggregations, they have expressed concern about the loss of income from the seasonal prohibition on fishing for mutton snapper and the prohibition of fishing in the MSSCA. Fishing on aggregations is highly lucrative. A local high-liner (pers. com.) related that he had caught 103 mutton snapper in just one night of fishing on the aggregation (his personal best). At an average size of about 5.5lbs (based on mean weight of May 2009 catch in this study), his estimated total catch was 567lb. Assuming a price of $6 per lb (low end of the price range for snapper), the fisher could have made $3,400 from just one night of fishing. Given that he likely fished the aggregation more than one night in a month and more than one month in a year, a significant portion of his annual income may have been derived from fishing the aggregation. Given the income loss to fishers on St. Croix, especially after implementation of the seasonal closure in 2006, it was important to obtain information on the status of the aggregation and on life history parameters of mutton snapper that used in stock assessments, status determinations, and assessing the vulnerability of the species to fishing pressure.

Spawning Season

Mutton snapper spawning has been recorded from February to September in the Caribbean (Table 1.4). Spawning months vary with location. They also vary annually depending on when full moon falls in the month. For example, the peak spawning period was May and June in Cuba (Paris et al. 2005, Claro et al. 2009), March to May in Puerto Rico (Ojeda-Serrano et al. 2007), March through May if the full moon falls after the middle of the month and April to June if the full moon falls before the middle of the month in Belize (Graham et al. 2008), and May and June on St. Croix, USVI (this study). While fish were not sampled in August or September (months spawning was recorded in Cuba), it is unlikely that they spawn in these months on St. Croix. The declining GSI in males and females in July (Figure 1.11 and Table 1.3) and the occurrence of a spent ovary in a female purchased from a fisher on July 18, 2009, 11 days after full moon, suggested that the annual spawning cycle was at or near its end in July in St. Croix.

The reported spawning days in relation to lunar phase varies greatly (Table 1.5). Some of the variation depends on when fishing occurs and/or gonads are macroscopically determined to be ripe. For example, Graham et al. (2008) reported fishing for mutton snapper in Belize occurred over 10-16 days before and after full moon while Claro and Lindeman (2003) reported fishing from two to three days before full moon to the three-quarter lunar phase. In this study high CPUE of reproductively mature fish occurred from 2 - 5 days after the full moon (Table 1.5). These were the only days we fished during the peak spawning months of May and June, so it is likely that high catches could have occurred both earlier and later in the lunar phase.

Table 1.4: Representative studies showing the geographic variation in the months with documented spawning (macroscopic gonad observations, gonad somatic index (GSI), microscopic and histological analyses, field spawning observations, fisher interviews) of *Lutjanus analis* in the Caribbean and Florida. Months with documented spawning are shown with an x. "X's" in bold and capitals indicate peak spawning months.

Location	Feb	March	April	May	June	July	August	Sept
Cuba[1]		x	x	**X**	**X**	x	x	
Cuba[2]			x	X	X	x	x	x
Puerto Rico[3]			x	x	x			
Puerto Rico[4]		**X**	**X**	**X**	x			
LaParguera, PR[5]			**X**					
Belize[6]	x	X	X	X	X	x		x
Gladden Spit, Belize[7]		x	X	X	x	x		
Gladden Spit, Belize[8]		x	X	X	X			
US Caribbean[9]		**X**	**X**	**X**	x			
Tequesta, Florida[10]			**x**	**X**	X			
Florida Keys[10]				**X**	X			
Florida[11]		**x**	**x**	**X**	X	x		
NE Caribbean[12]	x	**x**	**x**	**x**	x	x		
St. Croix, VI[13]			x	**X**	**X**	x		

[1]Claro et al. (2001) and Claro et al. (2009)
[2]Claro et al. (2003). Summary of all sites - spawning months varied among sites
[3] Matos-Caraballo et al. (2006)
[4]Ojeda-Serrano et al. (2007) - based on fisher interviews
[5]Esteves-Amador (2005) - only monitored fisher catches of mutton snapper in April 2003
[6]Heyman and Kjerfve (2008) spawning months based on direct visual observations by divers of spawning and inferences from a variety of indirect evidence
[7]Anon. (2004)
[8]Graham et al. (2008) based on Table 2 in publication - peak months varied among years with timing of full moon. Peak spawning occurring in only two of the three months marked in any year.
[9] CFMC and NOAA (2005)
[10]SEDAR15A-SAR3 (2008) - authors inferred spawning months from GSI and histological analysis of gonad maturity stages
[11] Burton (2002) cited in SEDAR15A-SAR3 (2008) inferred from GSI
[12]Erdman 1976
[13]This study

Claro and Lindeman (2003) reported that snappers appeared to be batch spawners, with individual females releasing several egg batches over a 5 to 10 day period during only one month. They designate mutton snapper as Type A species vs Type D species. Oocytes of Type A species mature at different rates while all oocytes of Type D species "mature at once but ovulate at different rates" (p. 102) (Claro and Lindeman 2003). The results of study support the designation of mutton snapper as a Type D species, however, see the discussion on fecundity below.

Table 1.5: Days spawning documented for mutton snapper (*Lutjanus analis*) in relation to lunar phase. Nf = no fishing due to bad weather. Capitalized x's indicate reports of peak spawning/ catch periods.

Location	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
LaParguera, PR[1] (April 2003)			x	Nf	Nf	Nf	Nf	x	x	X	x	x					
Gladden Spit, Belize[2]								x	x	x	x	x	x	x	x	x	x
Gladden Spit, Belize[3]		x	x	x	x	x	x	x	x	x	x						
Cuba[4]	x	x	x	x	x	x	x	x	x	x	x						
Not reported[5]										X	X						
Cuba[6]	x	x	x	x	x	x	x	x	x	x	x						
St. Croix, USVI (April, May and June 2009)[7,8]	x	x				X	X	X	X								

[1]Esteves-Amador (2005) based on commercial fish catches
[2]Anon. (2004)
[3]Heyman and Kjerfve (2008)
[4]Claro (1981) cited in Esteves-Amador (2005)
[5]Garcia-Cagide et al. (2001) cited in SEDAR15A-SAR3 (2008)
[6]Claro and Lindeman (2003)
[7]Based on catches in MSSCA. Fishing was not conducted more than five days after the full moon because the permitted catch limit in the MSSCA was always reached by then.
[8]April was the only month that we fished for mutton snapper on days prior to the full moon. Three days before full moon only one mutton snapper caught (mature female) and 11 yellowtail snapper. Two days before full moon four mutton snapper (one maturing male and three mature females) and 9 yellowtail snapper caught. Four days after full moon in April no mutton snapper and nine yellowtail snapper caught. Four of five fish caught had mature gonads.

Spawning Aggregation Location

Domeier et al. (1996) and Heyman and Kjerfve (2008) reported that mutton snapper were shelf-break spawners. Heyman and Kjerfve (2008) observed mutton snapper aggregating at a depth of 32 - 37m at the shelf edge of Gladding Spit, Belize and releasing gametes 23-25m below the surface. Divers observed actual spawning of mutton snapper four times between May and August between 13:00 - 16:30, 3 to 8 days after full moon (Heyman and Kjerfve 2008).

Within the MSSCA, we did not observe any spawning behavior or increase in mutton snapper abundance while diving during the spawning season. We conducted searches from mid-afternoon to dusk after full moon during April, May, June and July in 2009 and 2010 on both the shelf edge and on both sides of the sand channel immediately north of the shelf-edge reef. Dives were conducted at depths of 20 - 34 m. We also conducted a number of dives while anchored at fishing sites. At the fishing sites we dived from the anchored boat in the late afternoon just prior to dusk and just prior to putting fishing lines in the water. We were surprised to encounter so few mutton snapper on dives in general, but especially on dives conducted at fishing sites. Typically, less than 30 minutes after divers climbed in the boat in May and June 2009 mutton snapper were rapidly caught by fishers. In one instance, fishers started chumming while divers were in the water, but divers did not see any mutton snapper. Dives were done as unobtrusively as possible with only 2-3 divers in the water at one time. Possibly, fish were attracted to the chum and light on the boat while migrating to or from a spawning aggregation in deeper water than divers could observe (depth range of mutton snapper is 5 - 86m in Puerto Rico (Esteves-Amador 2005) with the greatest depth of 151m reported by Roe (1975) cited in SEDAR14-SAR2 (2007) in the Carolinas) or to a site outside the MSSCA.

Weber and Brown (2008a, b) conducted a six-year study of spawning aggregations at sites around St. Croix with the assistance of local fishermen. They dived a number of sites within and to the west of the MSSCA around full moon during peak spawning months of the mutton snapper: April and May 2005. They also dived this area in January 2003, February 2004, and March 2003 and 2005 before, during and after full moon. Despite conducting dives during the spawning months for mutton snapper, the only aggregation of mutton snapper that they found was at a single site in the southwest corner of the St. Croix shelf, west of the MSSCA. They labeled this a schooling only aggregation, not a spawning aggregation. They did not document spawning aggregations or schools of mutton snapper at any of 73 sites surveyed around St. Croix.

The most likely location of the spawning aggregation in the area of the MSSCA is the SW corner of St. Croix. This corner has geomorphological characteristics of mutton snapper spawning sites at other locations, *i.e*. a promontory close to a sharp bend in the shelf (Anon. 2004). In contrast, the shelf edge of the MSSCA has no promontory nor is it near a sharp bend in the shelf. The shelf edge is characterized by a fairly straight line of spur and groove reefs without an obvious promontory/projection (Quinn and Kojis 2010, Chapter 2 of this study) that characterizes many aggregation sites in the Atlantic (Anon. 2004).

If mutton snapper do not aggregate to spawn in the MSSCA, but near the Red Buoy Reef, then mutton snapper appear to be vulnerable to fishing several km from an aggregation site based on our high catch rates within the MSSCA.

Status of the Mutton Snapper Aggregation

While no aggregation was detected in the MSSCA on St. Croix during dives conducted in 2009 and 2010, the high CPUE of mutton snapper in May and June 2009 and the high GSI values from

March through July indicated that mutton snapper still aggregate to spawn within or in the vicinity of the MSSCA and, based on the CPUE (number of fish caught fisher^{-1} hr^{-1}), likely do so, in fairly large numbers. A comparison of the CPUE (weight based, kg fisher^{-1} hr^{-1}) in the peak spawning months of May and June between Gladden Spit and this study, indicates that the St. Croix aggregation is relatively healthy. The average monthly CPUE at Gladden Spit ranged from 2.4 -5.2kg fisher^{-1} hr^{-1}, while the CPUE in this study ranged from 10.1 - 14.4kg fisher^{-1} hr^{-1}. However, differences in fishing need to be taken into account. Graham (pers. com.) noted that fishers at Gladden Spit fish during the day. She thought that this may affect the CPUE because mutton snapper spawn in mid-afternoon and may not take the hook when they are spawning. She thought that they may bite better at dusk and night when we fished (this study). Also, Graham et al. (2009) included changing of fishing stations, baiting time (not including bait search), and travel and anchoring time in hrs fished, though travel time was short. Of these items, only baiting time was included in the CPUE calculations for this study. The mean fishing time at Gladden Spit ranged from 12.4 to 17.8 hrs day^{-1} compared to 1.5 to 2 hrs day^{-1} in this study. Graham et al. (2008) included the majority of fishing effort at Gladden Spit in their mean CPUE. Our CPUE was limited to our efforts with no competition from other fishers and we fished for a limited period of time, stopping once our quota was reached.

Since the implementation of the seasonal possession prohibition, it appears fishing pressure on mutton snapper during the spawning season and on the aggregation in the vicinity of the MSSCA has been curtailed. We saw no other boats fishing at night in the vicinity of the MSSCA on the nights that we fished for mutton snapper in 2009. Nor did we see fishing vessels in the southwest corner of the shelf in 2010 when we carried out diver searches for mutton snapper in the mid-afternoon to early evening after the full moon in May, June and July.

In July 2010, no mutton snapper were present at the LaReine fish market. Fishers stated in July that they forgot about fishing for mutton snapper and, even though snappers may aggregate to spawn in July, fishers likely have not traditionally targeted the aggregation and continue not to do so during this month. Fishers may not target the aggregation in July because mutton snapper may only aggregate in July in significant numbers when the full moon falls in the late in the last lunar quarter of June or in the first quarter of July. Thus, fishing success in July may be highly variable among years. Also, July may be last month spawning occurs and the number of fish spawning may be too few to make it worth their while. If individual mutton snapper spawn throughout the spawning season, then, in the past, fishing at the earlier in the spawning season may have significantly reduced the number of fish and, in combination with July being the end of the spawning season, may have resulted in a low CPUE.

Size at Onset of Reproduction

Thompson and Munro (1983) suggested, based on length distributions of catches, that most lutjanids exhibit sexually dimorphic growth rates and sizes at maturity. However, their data were limited or inconclusive for most lutjanid species. A number of studies have since confirmed that female mutton snapper mature at a larger size than males (Table 1.6, this study). The mean size of female mutton snapper in catches were significantly larger than males at Gladden Spit, Belize (female mean FL - 554mm, male mean FL = 523mm) (Graham et al. 2008) and St. Croix (female mean FL - 542mm, male mean FL = 484mm) (this study). Peak female fork length frequency distribution of fish caught during the period of the mutton snapper spawning aggregation were similar at both Gladden Spit, Belize (560-650mm FL) (Graham et al. 2008) and St. Croix (575-650mm FL). Maximum size however was larger at Gladden Spit (910mm FL) than this study (635mm FL). The peak size frequency distribution of males occurred at a larger size at Gladden Spit than in this study (510-600mm FL and 425-500mm FL, respectively). In both studies, males represented both the maximum and minimum sizes recorded in fish spawning aggregation catches: Gladden Spit - 180 - 960mm FL, this study - 367 - 660mm FL.

There could be a several of reasons for the smaller maximum and mean size of females and males on St. Croix compared to Gladden Spit. The smaller number of fish sampled in this study (n = 65) compared to Graham et al.'s (2008) study(n = 4,096) reduced the chance of catching very large fish on St. Croix and the catch may not accurately represent the size frequency distribution on St. Croix. However, mutton snapper in the St. Croix aggregation may be smaller on St. Croix because of intense fishing pressure on the population throughout the year and historical fishing on the aggregation itself. Fishing on the aggregation was not fully curtailed until 2006 when the seasonal prohibition on possession went into effect. It is also possible, given St. Croix's relative isolation from other insular shelves, that the smaller size of mutton snapper on St. Croix may be a characteristic of the population, especially if there is evidence that it is genetically distinct (Carson et al. ms).

Size and age at maturity of mutton snapper has been estimated at a number of locations (Table 1.6) Female size at maturity (L_{m50}) ranges from 353mm TL_{max} (maximum total length) for females in Florida to 574mm TL (total length) in Cuba (Table 1.6). Figuerola and Torres (2001) reported that all males and females mature at 43.1 cm and 45cm FL, respectively. There may be a number of reasons for the differences in size at L_{m50} at different locations:

1) population (genetic) differences at different geographic locations,
2) more rapid growth rates in warmer water and/or where food abundant resulting in larger size at L_{m50} (although it appears from Table 1.6 that in all locations age increases concomitant with size at L_{m50}),
3) differences in methodology in determining maturity, e.g. histologic vs microscopic vs. macroscopic methods, and
4) greater fishing pressure at some locations resulting in selection that results in fish reproducing at smaller sizes.

Maximum Length and Age

Maximum length of mutton snapper in the US Caribbean varied between years and location, ranging from 540 to 790mm FL between the years 1983 and 2006 in Puerto Rico and 460 to 780mm FL in the US Virgin Islands (SEDAR14-SAR2 2007). The maximum length of mutton snapper caught in this study was 660mm FL.

The only age-length study done in the US Caribbean was in Puerto Rico by Figuerola and Torres (2001). They determined that the maximum age of the mutton snapper to be 17 years. Mason and Manooch (1985) reported a maximum age of 14 yrs based on a 824mm TL fish from the east coast of Florida. Other studies in Florida, reported that mutton snapper live much longer. Burton (2002 cited by SEDAR14-SAR2 2007) and SEDAR15A-SAR3 (2008) reported a maximum age of 29 yrs in south of Fort Pierce, Florida, and 40 years in Tequesta and Marathon, Florida, respectively.

Table 1.6: Mutton snapper (*Lutjanus analis*) size and age at maturity various locations. FL = fork length. TL = total length.

Location	**Male/Female combined**		**Male**		**Female**	
	L_{m50} (mm)	**Age (yr)**	**Lm_{50} (mm)**	**Age (yr)**	**L_{m50} (mm)**	**Age (yr)**
Puerto Rico[1]			330 FL		414 FL ca. 459 TL_{max}	
Cuba[2]	~500 FL	~5	530 FL		545 FL	
Florida (Tequesta and Marathon, Florida Keys[3]					353 TL_{max}	2.07
Unidentified location[4]					402 TL	3.71
Cuba SW, NW[5]	500 FL				520 FL ca. 574 TL_{max}	5.5
Unidentified location[6]	402 SL					
Hatchery stock obtained in Florida[7]		3	375-465 TL		450-470 TL	
St. Croix, US Virgin Islands[8]	~390 FL (range ca. 330 - 410 mm)					

[1]Figuerola and Torres (2001)
[2]Claro et al. (2001)
[3]SEDAR 15A SAR3 (2008)
[4]SEDAR15A-SAR3 (2008)
[5]Claro and Lindeman (1981) cited in Froese and Pauly (2007)
[6]SEDAR14-SAR2 (2007) - Rojas (1960 cited by Druzhinin 1970)
[7]Watanabe 2001
[8]This study

Sex Ratio

The male:female sex ratio of mutton snapper in catches from Gladden Spit was nearly equal (1:1.2), while in St. Croix males caught in the MSSCA were more than twice as abundant as females (2.3:1). This may be a function of the high fishing pressure on the St. Croix spawning aggregation in the recent past. Absolute numbers of male and female fish of larger sizes ≥525mm were similar on St. Croix (20 males to 22 females, sex ratio = 1:1.1). Since females mature at a larger size than males, smaller females may be as abundant as smaller males on St. Croix, but may not yet have recruited to the spawning aggregation. Fishing pressure on the spawning aggregation and on this species throughout the USVI has been reduced since 2006. We hypothesize that female fish will recruit to the spawning aggregation in future years and the sex ratio will equilibrate.

Fecundity

Individual female mutton snapper produce large numbers of eggs (Table 1.7). Watanabe (2001) reported that fecundity values range from 186,500 to 603,00 eggs kg^{-1} for fish 2.3-2.27kg, respectively. Wild caught fish (this study) in the same size range had estimated fecundity values ranging from 500,425 eggs kg^{-1} (2.19kg fish) to 496,345 eggs kg^{-1} (2.82kg). The largest number of eggs kg^{-1} in this study was 648,972 eggs in a 4.54kg fish caught on May 11 2009.

Watanabe (2001) observed one egg size group (mean egg diameter = 0.382 mm, range = 225 - 475 mm FL) in an ovarian biopsy of a 3yr old hatchery reared female (460mm FL) and suggested that the unimodal egg distribution indicated that females release eggs only once during the spawning season. Garcia-Cagide et al. (1994) and Claro and Lindeman (2003) reported that individual female mutton snapper are batch spawners, releasing eggs a number of times in a single month, but spawning only one month each year. Given the long mutton snapper spawning season and the wide range of egg sizes in gonads of mutton snapper sampled in March through the beginning of July 2009 on St. Croix, individual females are more likely batch spawners that spawn more than one month in a spawning season, similar to predictions for gray snapper (Bortone and Williams 1986).

Table 1.7: Number of eggs produced by female mutton snapper (*Lutjanus analis*).

# of Eggs	Size of Female (mm)	Location	Reference
1,365,975	512 FL		Rojas (1960) cited in Bortone and Williams (1986)
1,355,000			Thompson and Munro (1983) cited in SEDAR15A - SAR3
373,000 - 1,400,000		South Atlantic	Stevens (2004) citing Barbieri and Colvocoresses (2003)
534,781	460 FL	Three year old hatchery reared female from Florida induced to spawn	Watanabe (2001)
256,943 - 3,189,777*	393 - 653 FL	St. Croix, U.S. Virgin Islands	This study

*Number of eggs $\geq$0.35mm in ovary. Eggs did not appear to be hydrated. Watanabe (2001) reported that the mean diameter of eggs one hour after fertilization was 0.783mm (range = 0.725 to 0.875mm).

If an individual mutton snapper female spawns in two or more months in a single spawning season, the number of eggs produced per female could double, triple, etc., depending on the length of the spawning season and the number of months the female spawns. Clearly more work needs to be done to clarify the annual spawning frequency of both male and female mutton snappers to determine not only individual female fecundity but to accurately estimate the size of the spawning population. Both these factors are important in determining the status of the stock and developing management measures.

Conclusions

The spawning aggregation of mutton snapper in or near the MSSCA appears to be fairly robust based on the high CPUE reported in this study. This is despite fairly heavy fishing pressure that continued until the seasonal prohibition on possession of mutton snapper in territorial and federal waters 2006 went into effect. The skewed sex ratio of the catches, a result of a high proportion of small males, which start reproducing at a smaller size than females, may reflect high fishing pressure before 2006 and the initial recovery of the population. Given the high female fecundity reported in this study, recovery may occur quickly if fishers continue to respect the seasonal possession prohibition and enforcement is adequate.

The actual site of the mutton snapper aggregation still needs to be confirmed. Effort should be made to make visual dive inspections of the reefs near the Red Buoy site during the annual spawning period of mutton snapper. Also, visual dive inspections of reefs in this area at the spawning times of other species observed at the site would provide information about the importance of this site for these species and other species, for example, there have been reports of red hind spawning/aggregating in this area (Martinez pers. com.).

LITERATURE CITED - CHAPTER 1

Anderson, W.D. 2002. Lutjanidae. Pp. 1479-1504 In: Carpenter, K.E. (Ed.) The Living Marine Resources of the Western Central Atlantic. Volume 2: Bony Fishes. Part 2 (Opistognathidae to Molidae), sea turtles and marine Mammals. FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5. 2002. Rome, FAO, 2127 pp.

Anon. 2004. Reef Fish Spawning Aggregation Monitoring Protocol for the Meso-American Reef and the Wider Caribbean, Ver. 2.0. <http://collaborations.wcs.org/Portals/3/pdfs/Spawning_Aggregation_Monitoring_Protocol_4_July_2004_%5B1%5D.pdf>. Downloaded January 13, 2011.

Barbieri L, Colvocoresses JA (2003) Southeast Florida reef fish abundance and biology. Five-year final report to the Department of Interior by the Florida Marine Research Institute, St. Petersburg.

Beets, J. 1987. Profile of a collapsing fishery: V. Proceedings of the Conference on Fisheries in Crisis. J. deGraaf and D. Moore, eds. St. Thomas, USVI.

Beets, J. and A. Friedlander. 1992. Stock analysis and management strategies for red hind, *Epinephelus guttatus,* in the U.S.V.I. *Proceedings of the 42nd Gulf and Caribbean Fisheries Institute.* **42**: 66-79.

Bortone, S.A. and J.L. Williams. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) -- gray, lane, mutton, and yellowtail snappers. U.S. Fish. Wildl. Serv. Biol. Rep. 82(11.52). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp.

Burton, M.L. 2002. Age, growth and mortality of mutton snapper, *Lutjanus analis*, from the east coast of Florida, with a brief discussion of management implications. Fish. Res. 59(1-2):31-41.

Burton ML, KJ Brennan, RC Munoz and RO Parker Jr. 2005. Preliminary evidence of increased spawning aggregations of mutton snapper (Lutjanus analis) at Riley's Hump two years after establishment of the Tortugas South Ecological Reserve. Fish Bull 103:404-410.

Brown-Peterson, NJ, DM Wyanski, F. Saborido-Rey, BJ Macewicz, and S.K. Lowerre-Barbieri. (ms). A standardized terminology for describing reproductive development in fishes.

CFMC. 1993. Amendment 2 to the Fishery Management Plan for the Shallow-water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands. Caribbean Fishery Management Council, San Juan, PR. 564 pp.

CFMC and NOAA NMFS 2005. Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act. Caribbean Fishery Management Council, San Juan, PR.

Carson, E.W., E. Saillant, M.A. Renshaw, N.J. Cummings, and J.R. Gold. ms. Population structure, connectivity, and effective size of mutton snapper (*Lutjanus analis*) in the Caribbean Sea and northern Gulf of Mexico.

Claro R. 1981. Ecologia y ciclo de vida del pargo criollo, Lutjanus analis (Cuvier), en la plataforma cubana. Informacion Cientifica Tecnica, Academia de Ciencias de Cuba. 186:1-83.

Claro, R. J.A. Baisre, K.C. Lindeman, and J.P. Garcia-Arteaga. 2001. Cuban fisheries: historical trends and current status. In: Ecology of the Marine Fishers of Cuba (R. Claro, K.C. Lindeman, L.R. Parenti, eds.). Smithsonian Institution Press, Washington, D.C. pp. 194:219.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. *Gulf. Carib. Res.* **14**: 91-106.

Claro, R., Y. Sadovy de Mitcheson, K.C. Lindeman, and A.R. Garcia-Cagide. 2009. Historical analysis of Cuban commercial fishing effort and the effects of management interventions on important reef fishes from 1960-2005. Fish Res. **99(1**): 7-16.

Craig, A.K. 1966. Geography of fishing in British Honduras and adjacent coastal waters. Coastal Studies Laboratory Louisiana State University, Baton Rouge. Abstract and 1st page downloaded 18 Jan 2011.

Delgado, P. 2004. The U.S. Caribbean Region, Wetlands and Fish: A Vital Connection, Fish, Crustaceans, and Mollusks Found in U.S. Caribbean Wetlands. NOAA National Marine Fisheries Service, Silver Spring, MD. 89 pp.

Domeier, M.L., C. Koenig and F. Coleman. 1996. Reproductive biology of the grapy snapper (Lutjanidae: Lutjanus griseus) with notes on spawning for other western Atlantic lutjanids. In: F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos and D. Pauly, eds. Biology, Fisheries and Culture of Tropical Groupers and Snappers. ICLARM Conf. Proc. 48:189-201.

Druzhinin, A.D. 1970. The range and biology of snapper (fam. Lutjanidae). J. Ichthyol. 10:715-735.

Erdman, D.S. 1976. Spawning patterns of fishes from the northeastern Caribbean. Cont. Serv. Esp. VIII (2):1-36.

Esteves-Amador, R.F. 2005. Dispersal of Reef Fish Larvae from Known Spawning Sites in LaParguera. MSc. Thesis, University of Puerto Rico, Mayaquez, Puerto Rico. 53 pp.

Figuerola, M., D. Matos-Caraballo and W. Torres. 1998. “Maturation and Reproductive Seasonality of Four Reef Fish Species in Puerto Rio.” Proc. Gulf Carib. Fish. Inst. 50: 938-968.

Figuerola-Fernandez, M. and W. Torres-Ruiz. 2001. Aspectos de la biologia reproductiva de la sama (Lutjanus analis) en Puerto Rico y recommendaciones para su manejo. Departmento de recursos naturales y ambientales area de recursos vivientes negociado de pesca y vida silvestre laboratorio de investigaciones pesqueras.

Froese R. and D. Pauly. 2007. FishBase. Electronic source document available at www.fishbase.org.

García-Cagide, A., R. Claro and B.V. Koshelev. 1994 Reproducción. p. 187-262. In R. Claro (ed.) Ecología de los peces marinos de Cuba. Inst. Oceanol. Acad. Cienc. Cuba. and Cen. Invest. Quintana Roo (CIQRO) México.

Garcia-Moliner, Graciela. 2009. Quick reference to the fishing regulations history in the US Caribbean. SEDAR Caribbean Data Workshop, January 26-29, 2009. Caribbean Fishery Management Council, San Juan, PR. 12 pp.

Geophysics GPR International, Inc. 2003. Marine Habitat Mapping Offshore St. Thomas & St. Croix US Virgin Islands EEZ, Final Report to the CFMC. Volume 2. pp. 21.

Gold, J.R., E. Saillant, N.J. Cummings, and M.S. Renshaw. ms. Genetic divergence and effective size among lane snapper (*Lutjanus synagris*) in U.S. waters of the Western Atlantic.

Gold, Jr., E. Saillant, N.D. Ebelt and S. Lem. 2009. Conservation genetics of gray snapper (*Lutjanus griseus*) in U.S. waters of the northern Gulf of Mexico and Western Atlantic Ocean. Copeia **2**:277-286.

Graham, R.T., R.Carcamo, K.L. Rhodes, C.M. Roberts and N. Requena. 2008. Historical and contemporary evidence of a mutton snapper (*Lutjanus analis* Cuvier, 1828) spawning aggregation fishery in decline. Coral Reefs. 27:311-319. Downloaded 18 Jan 2011. DOI 10.107/200338-007-0329-4.

Gundersen, A.C., O.S. Kjesbu, K.H. Nedreaas, and A. Stene. 1999. Fecundity of Northeast Arctic Greenland halibut (Reinhardtius hippoglossoides). J. Northw. Atl. Fish. Sci. 25:29-36.

Heyman, W.D. and B. Kjerfve. 2008. Characterization of transient multi-species reef fish spawning aggregations at Gladden Spit, Belize. Bull. Mar. Sc. **83(3**): 531-551.

Huntsman, G. 1996. *Lutjanus analis*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Downloaded on **09 January 2011**.

Karlsson, S., E. Saillant and J.R. Gold. 2009. Population structure and genetic variation of lane snapper (*Lutjanus synagris*) in the northern Gulf of Mexico. Mar. Biol. **156**:1841-1855.

Mason, D.L. and C.S. Manooch III. 1985. Age and growth of mutton snapper along the east coast of Florida. Fish. Res. 3:93-104 (abstract).

Matos-Caraballo, D., M. Cartagena-Haddock and N. Pena-Alvarado. 2006. Portrait of the fishery of mutton snapper, *Lutjanus analis*, in Puerto Rico during 1988-2001. Proceedings of the 57st Gulf and Caribbean Fisheries Institute. 57: 343-356.

Munro, J.L. 2005. The assessment and management of Caribbean coral reef fisheries. Proc. of Gulf and Caribbean Fisheries Institute. 58:1-19.

Murua, H. and F. Saborido-Rey. 2003. Female reproductive strategies of marine fish species of the North Atlantic. 33:23-31.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Mar Ecol. Prog. Ser.* **286**: 31-97.

Ojeda-Serrano, E., R. Appeldoorn, and I. Ruiz-Valentin. 2007. Reef fish spawning aggregations of the Puerto Rican shelf. Caribbean Coral Reef Institute. Puerto. University of Puerto Rico. 31 pp.

<http://www.sefsc.noaa.gov/sedar/download/S14RD51%20CCRI%20SpawnAgg%20ID.pdf?id=DOCUMENT> downloaded 10 January 2011.

Olsen, D.A. and J.A. LaPlace. 1978. A study of a Virgin Islands grouper fishery based on a breeding aggregation. *Proceedings of the 31st Gulf and Caribbean Fisheries Institute* **31**: 130-144.

Olsen, D.A. and R.S. Wood. 1984. Ciguatera in the Eastern Caribbean. Marine Fisheries Review. 46(1):13-18.

Paris, C.B., R.K. Cowen, R. Claro, K.C. Lindeman. 2005. Larval transport pathways from Cuban snapper (Lutjanidae) spawning aggregations based on biophysical modeling. Mar. Ecol. Prog. Ser. 296:93-106.

Roe, R. 1975. Distribution of snappers and groupers in the Gulf of Mexico and Caribbean Sea as determined from exploratory fishing. Proceedings: Colloquium on snapper-grouper fishery resources of the Western Central Atlantic Ocean. Florida Sea Grant Program Rep. No. 17, pp. 129-164.

Rojas, L.E. 1960. Estudios estadisticos y biologicos sobre el pargo criollo, Lutjanus analis. Cent. Invest. Pesq. Notas sobre Invest. 2. 16 pp.

Quinn, N.J. and B.L. Kojis. 2010. Habitat description of the St. Croix, U.S. Virgin Islands south coast Mutton Snapper (*Lutjanus analis*) Conservation Area. *Proceedings of the 62nd Gulf and Caribbean Fisheries Institute* **62**: 59-68.

Saillant, E., S.C. Bradfield and J.R. Gold. 2010. Genetic variation and spatial autocorrelation among young-of-the-year red snapper (*Lutjanus campechanus*) in the northern Gulf of Mexico. ICES Journal of Mar. Sc. **67**:1240-1855.

SEDARI4-SAR2 (Southeast Data, Assessment Review 14 - Stock assessment Report 2). 2007. SEDAR 14: Stock Assessment Report 2: Caribbean Mutton Snapper. North Charleston, SC 194 pp.

SEDAR15A-SAR3 (Southeast Data, Assessment Review 15A - Stock Assessment Report 3). 2008. South Atlantic and Gulf of Mexico Mutton Snapper. South Atlantic Fishery Management Council, Charleston, SC. 410 pp.

Stevens, M.M. 2004. Commercially important Gulf of Mexico/South Atlantic snappers (red snapper, vermillion snapper, yellowtail snapper, with minor reference to gray snapper, mutton snapper, and lane snapper). Seafood Watch, Seafood Report, Monterey Bay Aquarium. Final Rpt. April 20, 2004. 29pp.

Thompson, R. and J.L. Munro. 1983. In: Caribbean Coral Reef Fishery Resources, 2nd ed. (J.L. Munro, ed.). ICLARM, Manila, Philippines. 276 pp.

Ungaro, N. 2008. Field manual on macroscopic identification of maturity stages for the Mediterranean fishery resources. GCP/PER/ITA/MSM-TD-21. MedSudMed Technical Documents No.21:34 pp.

Watanabe, W.O. 2001. Species Profile: Mutton Snapper. SARC Publication No. 275. 11 pp.

Webber, J.L. and J. Brown. 2008a. Spawning Aggregations: A Six-year Study in Saint Croix, USVI (2003 - 2008). Unpublished booklet prepared by The Nature Conservancy Southeast Caribbean Program, Saint Croix, USVI. 28 pp.

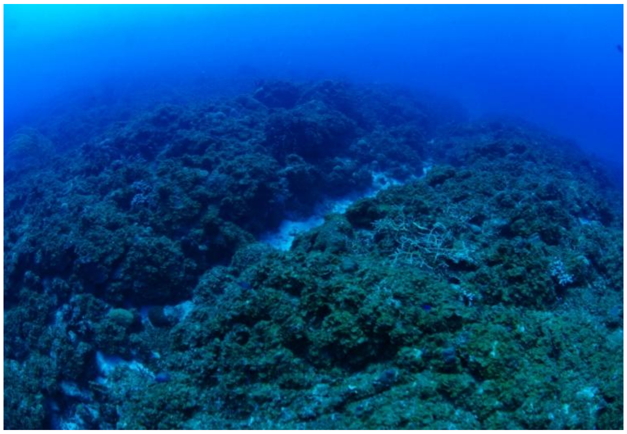
Webber, J.L. and J. Brown. 2008b. Using lessons learned from six years of reef fish spawning aggregation site validation, collaboration, and outreach in St. Croix, USVI.

APPENDIX 1

Abstract submitted by Liam Carr to Gulf and Caribbean Fishery Institute for poster presentation at meeting in Venezuela in 2010. Poster was not submitted.

Age-frequency distributions of a protected mutton snapper (*Lutjanus analis*) aggregation following 17 years of protection

Snappers have historically been a n important economic stock for the U.S. Virgin Islands, annually contributing nearly 4% of total landings by weight prior to seasonal closures set in place to prevent stock collapse. Evidence of depleted mutton snapper (*Lutjanus analis*) stocks in St. Croix led the Caribbean Fisheries Management Council into developing the Mutton Snapper Seasonal Area Enclosure (MSSAE) in 1993. The MSSAE closes fishing off at a historical fish spawning aggregation (FSA) site, during the March-June mutton snapper spawning season. Between March 2009 and June 2010, 139 mutton snapper were collaboratively harvested with St. Croix fishers within the MSSAE from an anchored fishing vessel at coordinates provided by local fishers. From this sample, 61 otoliths were collected and analyzed to develop age-frequency distributions, an important tool for creating growth curves and examining population structures. This analysis is part of the first effort since the MSSAE was enacted for gauging how successful management programs have been over the past 17 years for rebuilding local mutton snapper stocks. Researchers determined that the sampled population had a mean age of 6.5 ± 1.8 yrs, with a mode of 7 yrs. Additional analyses on length-frequency and weight-frequency distributions, along with examinations of gonadal conditions, provide preliminary evidence that the MSSAE's historical FSA site remains active, although the size of the spawning population continues to be difficult to assess.



CHAPTER 2

Habitat Description of the St. Croix, U.S. Virgin Islands Mutton Snapper Seasonal

INTRODUCTION

The Mutton Snapper Seasonal Closed Area's (MSSCA) northern boundary is located approximately 4km off the south-western point of the island of St. Croix, U.S. Virgin Islands (USVI) (Fig. 2.1). The MSSCA lies north and south of the edge of the insular platform (approximately 25m contour) and is 4.5km long and 2.2km wide with depths from 12m to >200m (the shelf outer slope) (Fig. 2.2). Figure 2.3 is a bathymetric image of the MSSCA to depths of >50m showing the high rugosity of the southern half of the MSSCA and the steep drop off at the edge of the shelf.

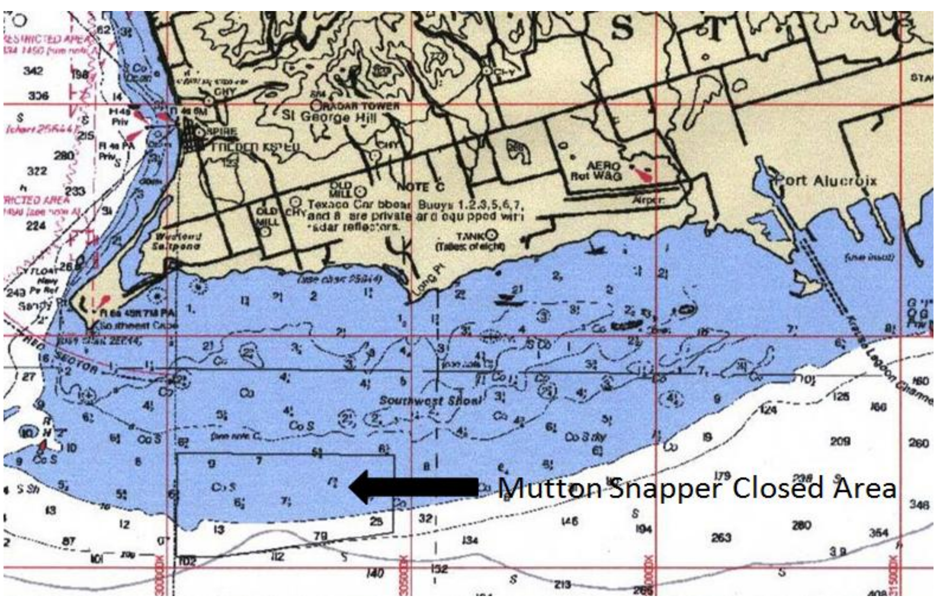


Figure 2.1. Mutton Snapper Closed Area off St. Croix, USVI (see Fig. 1.1 for coordinates).

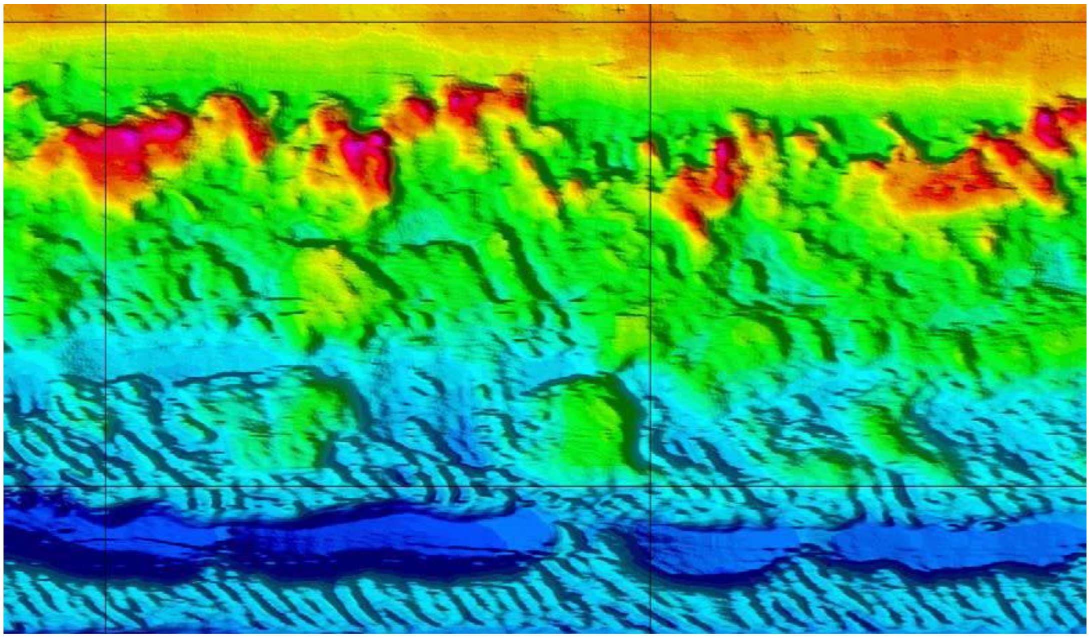


Figure 2.2. Example color bathymetry near the edge of the island shelf in the MSCA (GPR 2003). The red / orange colors represent depth around 12-18m with the dark blue colors represents depths 25-30m.

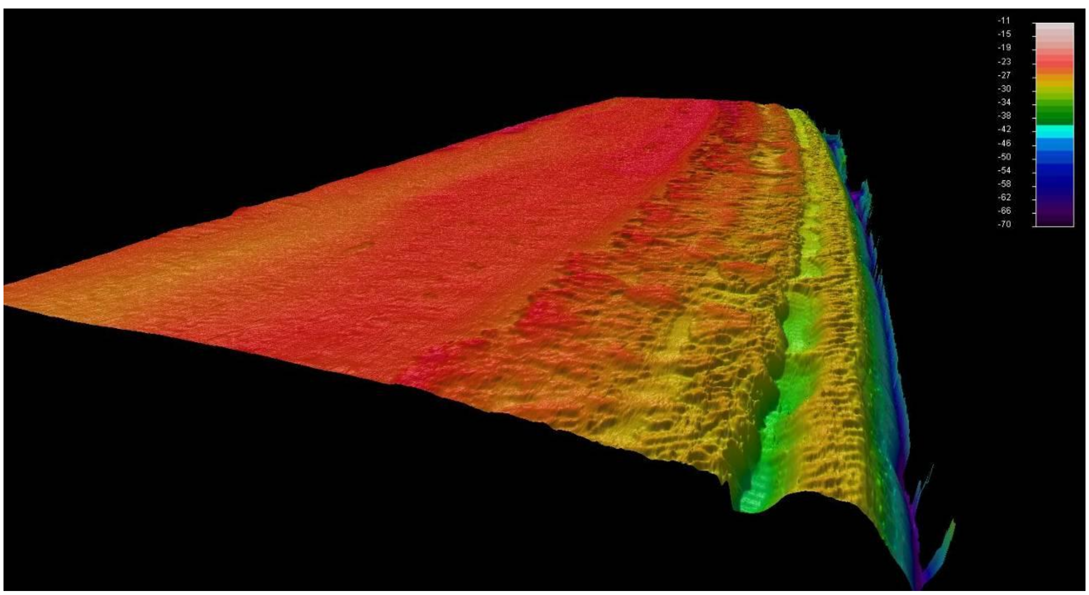


Figure 2.3. Multi-beam side scan sonar image of Mutton Snapper Closed Area (GRP 2003). The red / orange colors represent depths of 12-18m with yellow representing depths of 25-30m and green depths of around 25-30m. The depth legend on the chart is not entirely accurate for shallower depths according to GRP (2003).

Some interesting topography was present in SSS images just before the outer reef on the southern shelf edge. Although no spawning aggregations were observed during ten dusk dives in April – June 2009, 65 ripe *Lutjanus analis* males and 30 ripe females were caught in a habitat similar to that depicted in Figures 2.2, 2.3 and 2.4 showing flat sandy moats separating raised reefs.

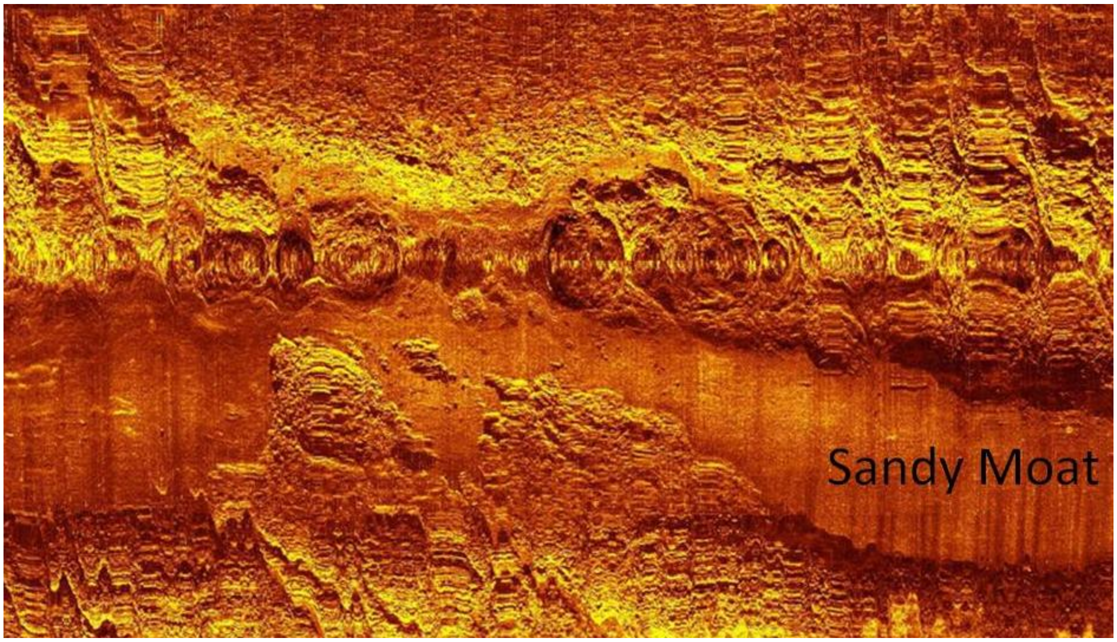


Figure 2.4. Side scan sonar mosaic showing sandy moat between two reefs (after Prada 2003). The reef to the south was the last reef before the shelf edge slope. The habitat depicted in this image is similar to the site where many reproductively mature *Lutjanus analis* were caught from April – June 2009.

Using mosaics in geotiff format from Side Scan Sonar (SSS) imagery processed at 0.2m resolution, Prada (2003) generated detailed benthic habitat maps (Fig. 2.5) through visual interpretation and delineation. Rivera (et al 2005) used SSS to detect fish aggregations in three MPAs. Fish aggregations in the MSSCA were significantly smaller than fish aggregations at the Marine Conservation District off St Thomas and the Lang Bank closed area off St Croix (Rivera et al 2005).

Prada (2003), however, was unable to provide an estimation of habitat classification accuracy of the maps for the MSSCA because of a lack of in water verification. GOPL and ALIN were two of the major habitat types in the MSSCA. She consequently considered that their classification may need correction and recommended that additional ground truth information be collected for the full set of habitats in order to:

- better classify SSS mosaics not having distinct echo-returns nor sharp boundaries as observed, for instance at the Gorgonian Plain (GOPL) habitats, and
- be able to estimate map accuracy for the Algae with Invertebrates (ALIN) habitat type.

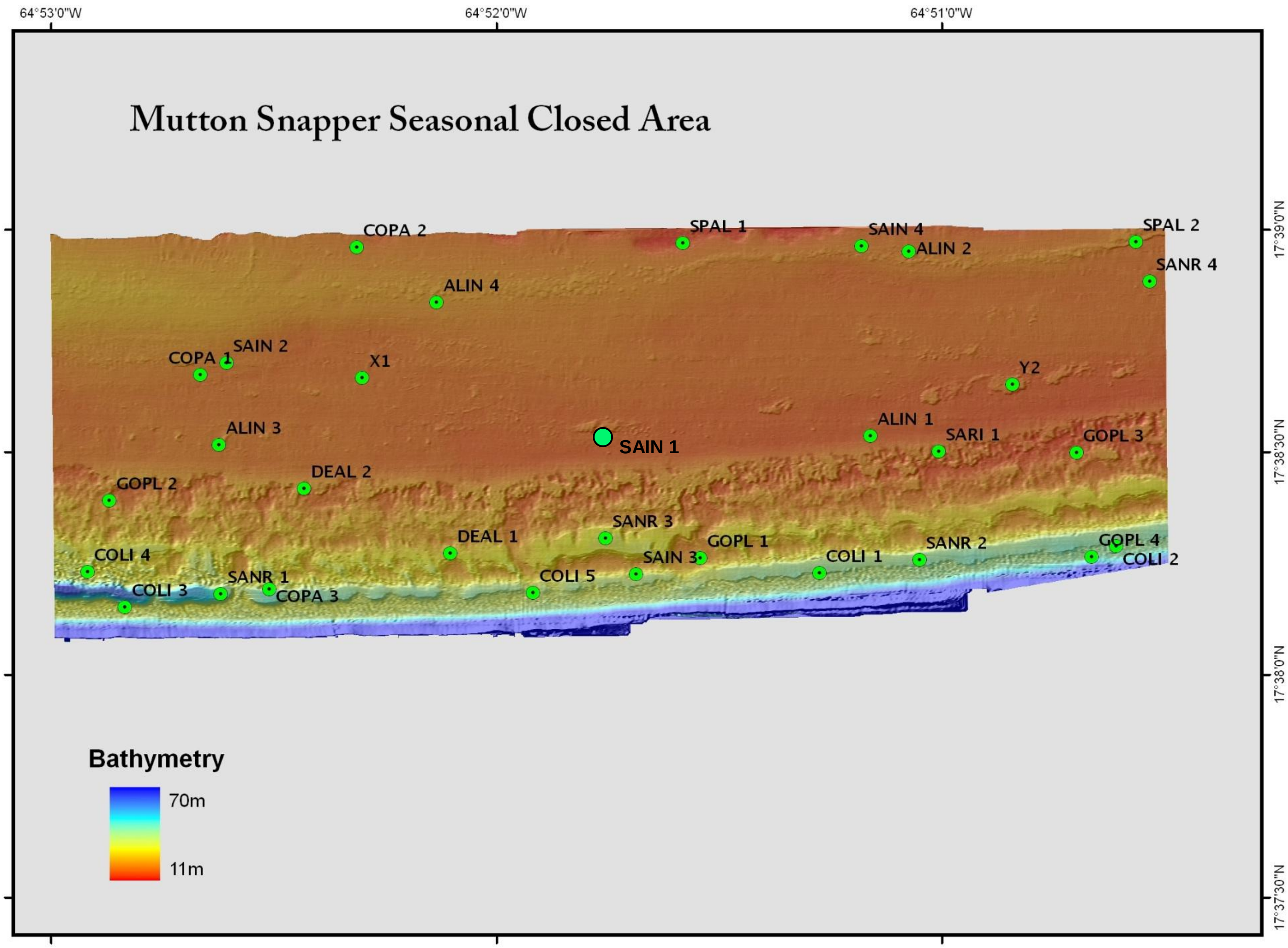


Figure 2.5. Mutton Snapper Seasonal Closed Area showing topographic relief and depth. The benthic sites sampled are marked.

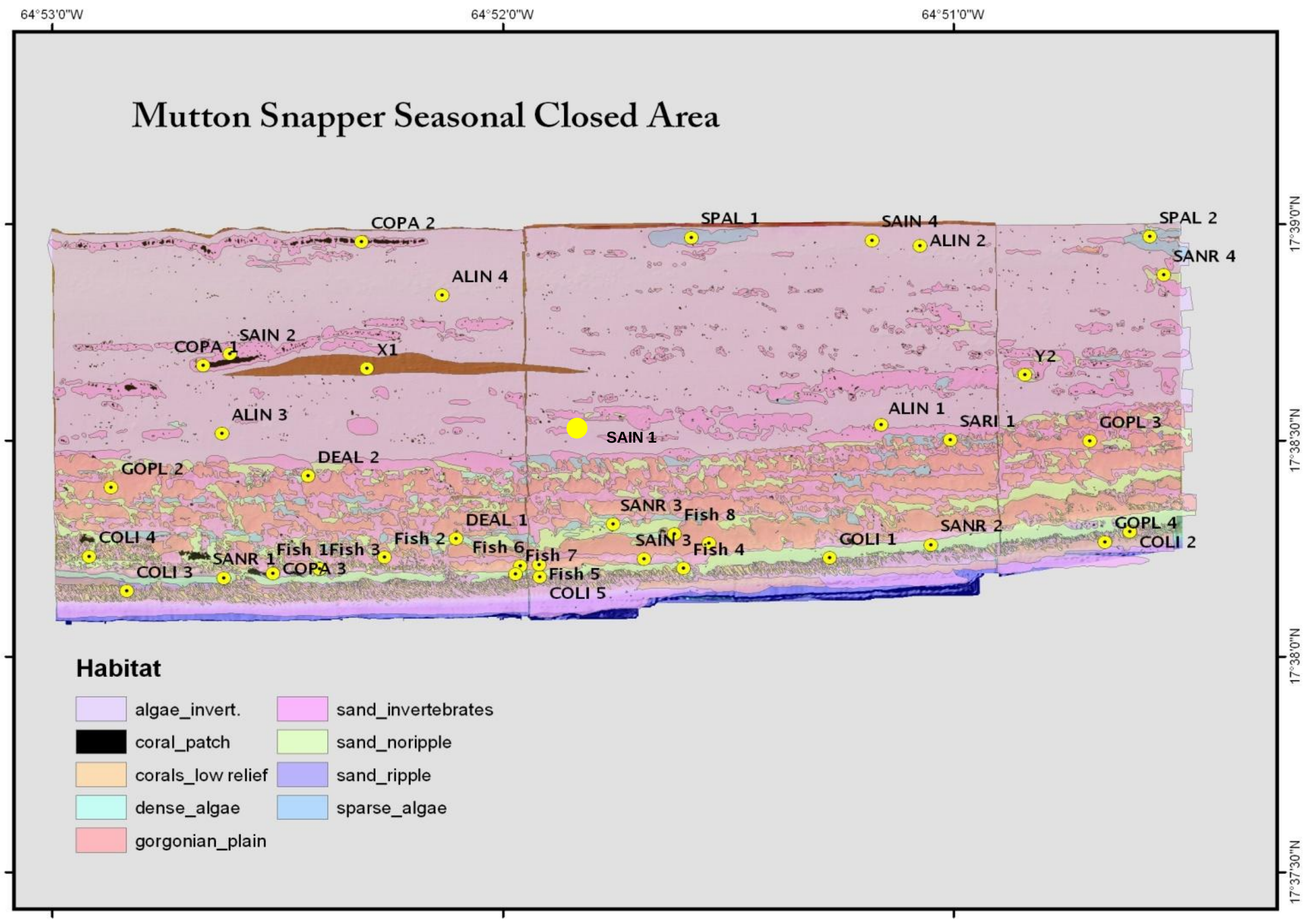


Figure 2.5. Classification of benthic habitats in MSSCA (provided by J. Blondeau from images provided by Prada 2003) with sites sampled.

Prada's (2003) habitat descriptions (Table 2.1) were derived from SSS and multi-beam data within the MSSCA. These habitats were defined by Prada (2003) using modifications of the scheme created by NOAA for the shallow waters of Puerto Rico and U.S. Virgin Islands (NOAA-NOS 2001). Having more detailed habitat information, will not only benefit future users with more accurate maps, but also will allow complete habitat definitions.

Knowledge of the spatial distribution patterns of habitat is essential information for scientists and managers in order to maintain important Essential Fish Habitat within areas under legal protection and conservation (Prada 2003). The purpose of this effort was to provide detailed in water verification of the classifications with metrics of dominant fauna / flora and substrate types and to characterize the temperature variation during the period of spawning.

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The MSSCA comprises 692.4ha. The specific area of each of the benthic habitats as determined by Prada (2003) is listed in Table 2.2. In some cases the distinction between the habitats is clear, while in other cases the change is gradual so the values should be considered approximate.

Table 2.1. Hierarchical classification scheme developed by Prada (2003) to generate detailed habitat maps around the USVI. The table lists the benthic habitats found in the MSSCA. Description of the Habitat Codes follows.

Meta Community	Community	Sub-community	Habitat Types	Habitat Codes
Coral and gorgonians on consolidated sediments	Corals	Coral Patch	Coral Patch	COPA
		Coral Low Relief	Coral Limestone	COLI
	Gorgonians	Plains	Gorgonian Plains	GOPL
Submerged Aquatic Vegetation on unconsolidated sediments	Macro-algae	Algae on Sand	Dense Algae	DEAL
			Sparse Algae	SPAL
			Algae and Invertebrates	ALIN
Bare or mixed invertebrates on unconsolidated sediments	Sand	Coarse Sand	Sand Invertebrates	SAIN
			Sand No Ripple	SANR
			Sand Ripple	SARI

Table 2.2. Total area (ha) of benthic habitats for the MSSCA (after Prada 2003)

	COPA	COLI	GOPL	ALIN	DEAL	SPAL	SAIN	SANR	SARI	Total
Total (ha)	4.7	15.6	102.9	341.3	2.8	13.6	162.9	48.2	0.4	692.4
% area	0.68%	2.25%	14.86%	49.29%	0.40%	1.96%	23.53%	6.96%	0.06%	

METHODS - BENTHIC SURVEY

Using an on board GPS device, a lead line with a float attached was tossed upon reaching the coordinates for each site. Divers then descended the line to the bottom and deployed the transect tape, usually in a radial pattern from the lead. Twenty quadrats ($0.25m^2$) were photographed using an Olympus SW1030 digital camera along at least five 20m transect lines at each of the habitats described by Prada (2003) within the MSSCA. The sampling protocol assessed benthic composition using CPCe 3.6 software (Kohler and Gill 2006), habitat type, and coral health. The photos were classified into substrate categories and percent cover of nine substrate categories calculated. Corals, gorgonians, and some algae were identified to species or genus. Diseases and bleaching of hydrocoral and scleractinian coral colonies within the quadrat were recorded.

RESULTS – BENTHIC SURVEY

A brief description of each habitat type found is presented below along with a sample of the Side Scan Sonar (SSS) imagery representative of the image/habitat variability. Each SSS image sample from (Prada 2003) is shown at the scale 1:1000 and represents an area of 625m^2 (0.0625ha). A summary table (Table 2.3) of the CPCe analysis shows the distribution of the benthic categories across habitats. Detailed summary descriptive statistics for each benthic category at each site in each habitat is listed in Appendices - Chapter 2 (A2), Tables A2-2.1 – A2-2.9. Detailed summary descriptive statistics for corals, gorgonians and algae at each site in ALIN, COLI, GOPL and SAIN habitat is list in Tables A2-3.1 – A2-3.10.

Table 2.3. Comparison of the percentage of invertebrate and substrate cover habitat classifications (Prada 2003) in the MSSCA. More detail for each site in each habitat is available in Tables A2-2.1 – A2-2.9. Tables A2-3.1 – A3.10 contain descriptive statistics for corals, gorgonians and algae in selected habitats.

	COPA	COLI	GOPL	DEAL	SPAL	ALIN	SAIN	SANR	SARI
Coral	5.25	7.56	7.00	0.15	0.85	2.19	2.30	0.16	0.30
Gorgonian	0.75	3.87	3.43	0.00	0.00	0.09	0.48	0.00	0.00
Sponge	6.80	16.20	12.74	1.98	3.55	6.29	6.96	6.40	1.65
Zooanthids	0.00	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Macro algae	33.90	26.16	17.69	1.33	19.73	23.70	22.18	4.94	1.25
Turf Algae & Other Live	2.25	20.99	14.85	5.83	40.94	50.79	29.68	22.91	14.70
Dead coral	36.35	16.72	10.40	1.90	0.38	0.34	2.23	2.14	0.00
Coralline algae	7.90	3.35	1.66	0.03	0.13	0.58	0.08	0.10	0.00
Diseased coral	0.00	0.11	0.05	0.00	0.00	0.00	0.04	0.09	0.00
Sand, rubble, etc.	6.80	5.01	32.19	88.8	34.43	16.03	36.08	63.26	82.10
# sites surveyed for each habitat	1	5	4	2	2	4	4	4	1
Area Sampled m^2	25	125	100	50	50	100	100	100	25

Using the Agglomerative Hierarchical Clustering (XLSTAT 2010) analysis on the CPCe benthic categories by habitat matrix (Table 2.3), classifying Pearson correlation coefficients and agglomerating using weighted pair-group averages resulted in the clusters in Figure 2.6. At the 0.85 similarity level there are four major clusters. The first clusters are coral reef on consolidated sediments (COLI, COPA), coral and gorgonians on plains with a large amount of rubble (GOPL). The next clusters are on unconsolidated sediments ALIN, SPAL and SAIN are characterized by the large amount of macroalgae while SANR, DEAL and SARI are macroalgae depauperate, having the least macroalgae of all habitats.

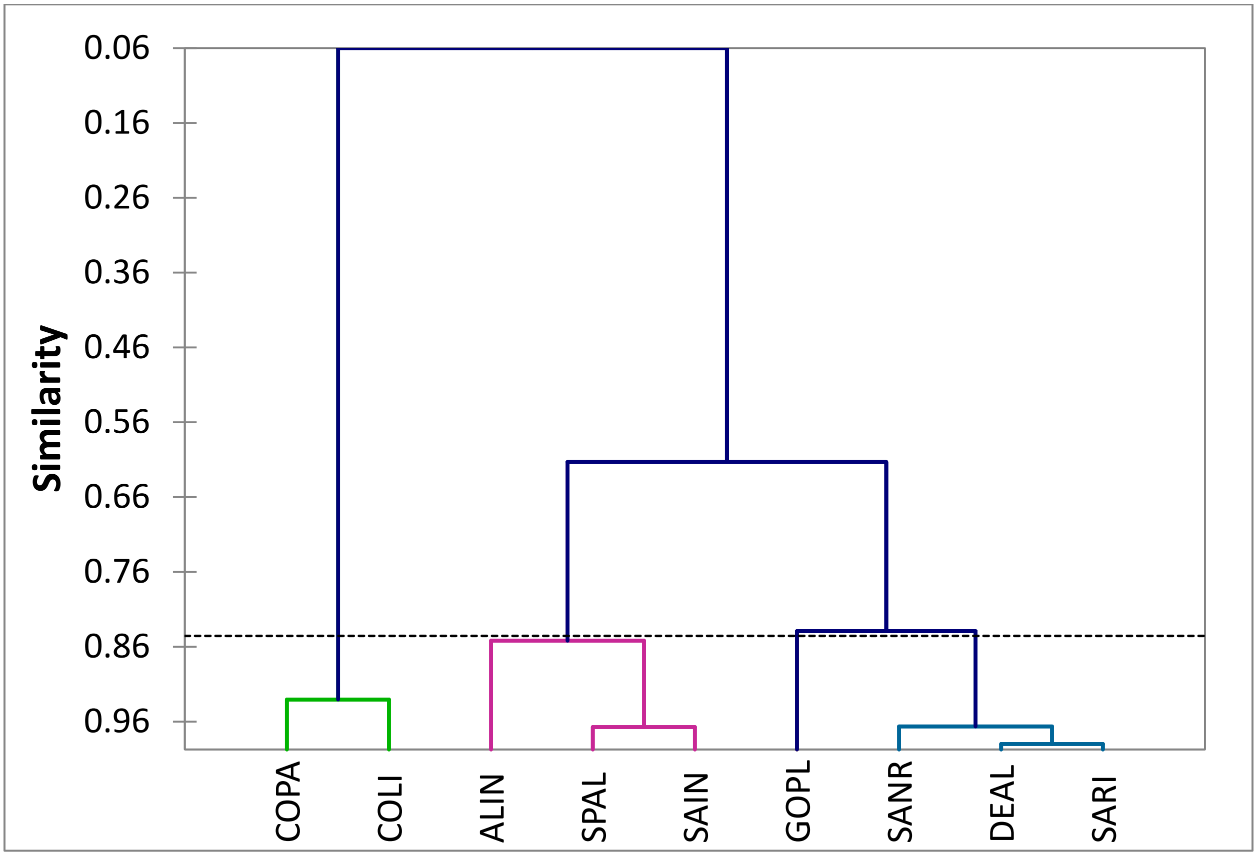


Figure 2.6. Dendrogram of CPCe benthic categories by habitat matrix, classifying using Pearson correlation coefficients and agglomerating using weighted pair-group averages. Dotted line represents truncation into four major clusters at 0.85 similarity.

Prada (2003) Habitat Type - Submerged Aquatic Vegetation on Unconsolidated Sediments

ALIN - Algae with Invertebrates

Algae with Invertebrates (ALIN) was surveyed at four sites in 2009 and 2010. ALIN is a flat carbonate pavement habitat with a thin veneer of sand and turf algae, with some cyanobacteria, collectively representing 66.82% of the substrate (Table 2.3). It is the largest habitat (341.3ha) with only 2.19% live coral cover with no diseased coral. *Clypeaster rosaceus* individuals were common at some sites, both as live individuals and dead tests (Fig. 2.7). Macroalgae (primarily *Saragassum, Lobophora* and some *Dictyota*) covered 23.70% of the substrate. The relief is uniformly flat except for occasional shallow depressions, some with holes and coral rubble; scattered heads of dead and living coral; and a few gorgonians and sponges.

Figure 2.7. ALIN 1 - *Clypeaster rosaceus* test.

Figure 2.8 are SSS images of ALIN from Prada (2003). The middle image (b) does not look similar to the other images (a, c). No details were given by Prada (2003) as to why these images were considered representative of ALIN. The end images (a, c) show a light / dark banding pattern while image b appears to show more relief. This could represent the variation in algal cover and rugosity between ALIN habitats as exhibited in (Fig. 2.9 and Fig 2.10).

a b c

Figure 2.8. Side Scan Sonar images (Prada 2003) of ALIN generally show few features.

Figure 2.9. ALIN 2 site in July 2, 2009 showing the sandy bottom interspersed with algal clumps, sponges and small coral heads.

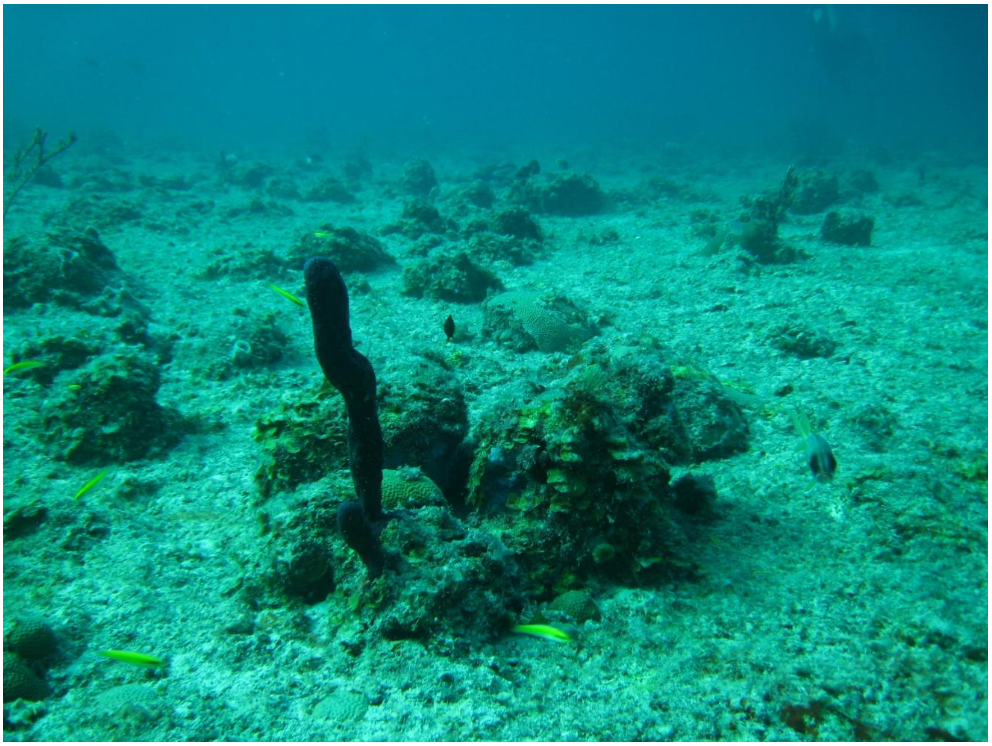


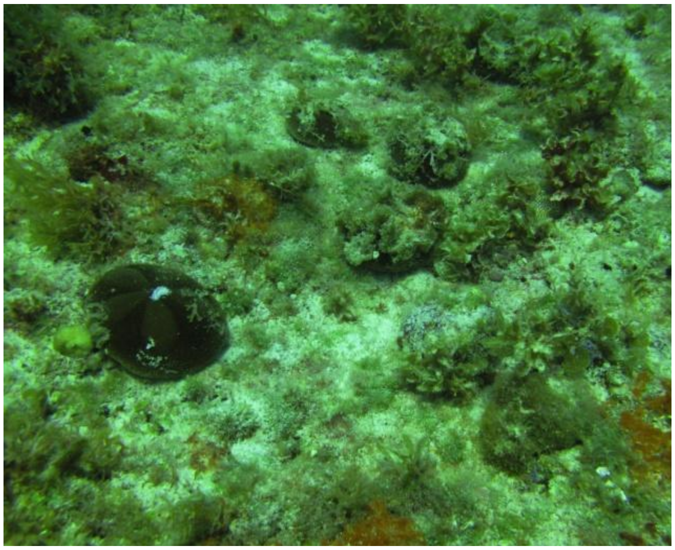
Figure 2.10. Variation in ALIN habitat mapped by Prada (ALIN 1 - June 20, 2009) is demonstrated in this photo by the lack of macro algae on the flat, hardbottom substrate. Macroalgae primarily was found on dead coral in this variation of ALIN habitat.

SPAL - Sparse Algae

SPAL covers only a relatively small area of the MSSCA. Prada (2003) described SPAL (Sparse Algae) as similar to ALIN except that ALIN had more invertebrates, which gave additional structure to the habitat. Both SPAL and ALIN were dominated by a combination of macro and turf algae (includes cyanobacteria) (ALIN - 74.49% algae: 23.70% macro algae, 50.79% turf algae; SPAL - 60.67% algae: 19.73% macro algae, 40.94% turf algae – Table 2.3). Both habitats only had a small amount of live coral with ALIN having >2 times the coral cover of SPAL: ALIN 2.19% and SPAL 0.85%. The mean density of sponges was also greater in ALIN, but this was due to a single ALIN site that had several large barrel sponges (*Xestospongia muta*).

The irregular sea urchin, *Clypeaster rosaceus*, was common, camouflaged among the algae and the occasional shallow ledges and solution holes with rubble provided habitat for octopus and small to medium size fish (Fig. 2.11 a, b). The surface consists of areas of algae mixed with shallow sand patches, small primarily dead coral heads, occasional sponges with the bottom dominated by turf algae and patches of macroalgae (*Sargassum*, *Lobophora* and *Dictyota*) (Fig. 2.12). The habitat did not have distinct boundaries. SPAL is another hard bottom habitat with generally little vertical relief and is very similar to ALIN (Fig. 2.13).

A



B

Figure 2.11. SPAL 1 - *Clypeaster rosaceus* were abundant (left) in this habitat. Sand channels with ledges added some rugosity to an otherwise two dimensional, flat habitat (right).

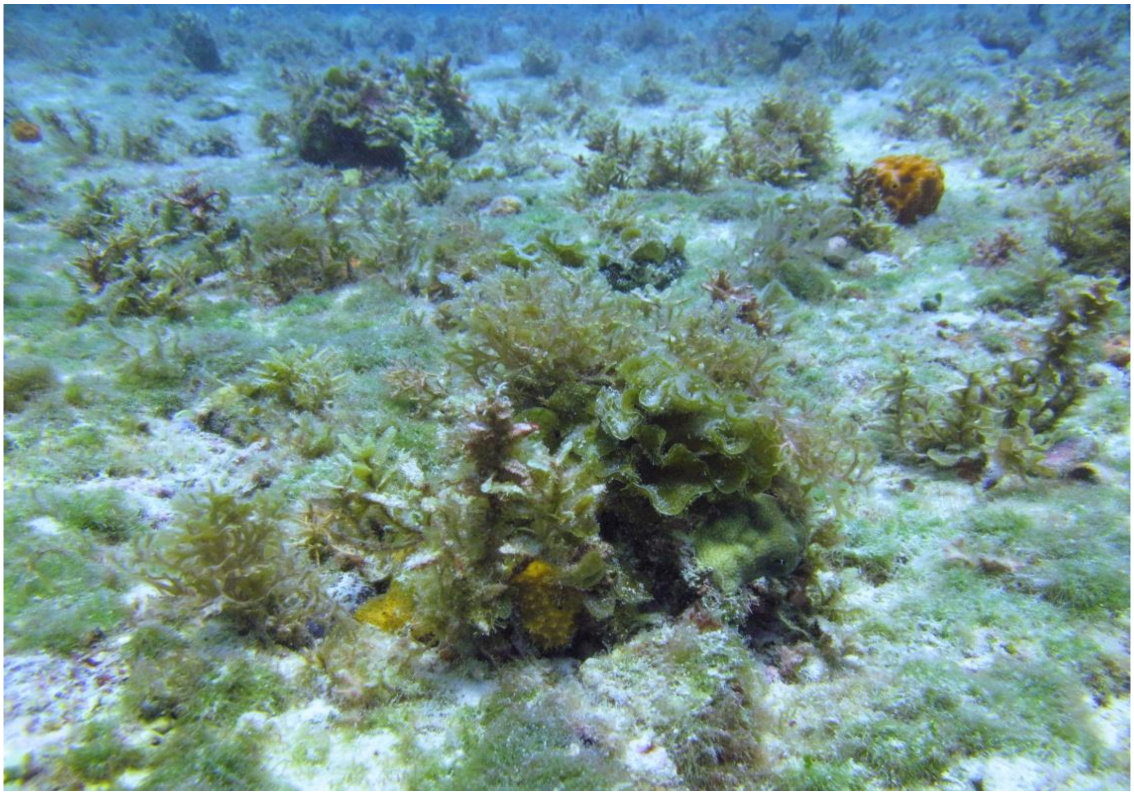
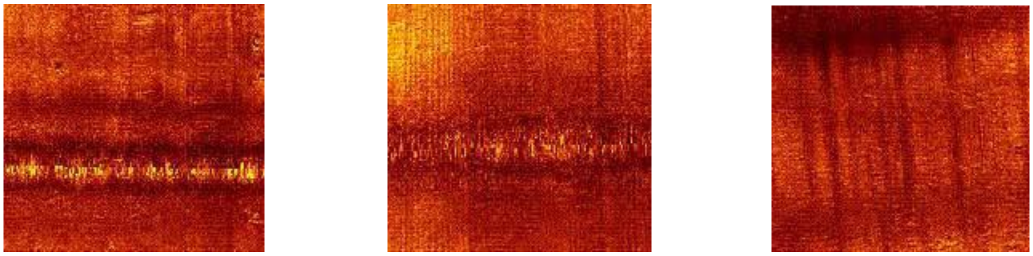


Figure 2.12. Close up of SPAL site showing high cover of macro and turf algae.

Figure 2.13. SPAL habitat showing lack of vertical relief, no live gorgonians, a solitary vase sponge and dense cover of macro and turf algae.

The uniformity of the habitat observed in 2009 / 2010 did not support Prada's observation (2003) that the light and dark banding in the SSS images were associated with algae and sand patterns (Fig. 2.14 a, b, c). We suggest that the SSS images may be placing greater importance on the reflective nature of the substrate rather than the thin veneer of live biota.

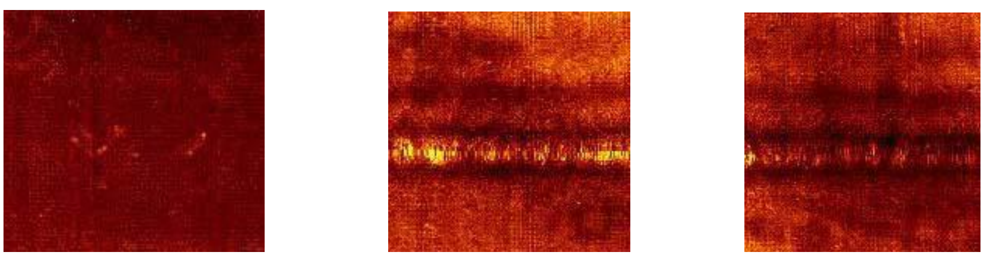


a b c

Figure 2.14. Prada (2003) suggested that the dark and light bands in the side scan sonar images corresponded to the algae and sand respectively.

DEAL - Dense Algae

Prada (2003) considered that Dense Algae (DEAL) was characterized by dense fleshy algae patches which resulted in a dark and uniform side scan sonar return (Fig. 2.15). No suggestion was given by Prada (2003) to explain the banding observed.



a b c

Figure 2.15. SSS images from Prada (2003) show the uniform dark signal (a) which was interpreted as dense algae.

DEAL habitat consisted mainly of sand (63.26%) followed by turf algae/ cyanobacteria (22.91%) (Fig. 2.16, Table 2.3). Scattered primarily dead coral heads and some dead branches of *A. cervicornis* branches provided low relief (Fig. 2.17). The percent coral cover based on 4000 points from 200 quadrats (50m^2) was 0.15%. Sand is at least 13cm deep in some places and is covered in many places with either tufts of brown cyanobacteria with dead white bases or brown, yellow or blue green cyanobacteria film. Some live green algae and the calcareous remains of *Halimeda*, were present, but live macro algae was rare (1.33% cover). The predominance of sand in the site (63.25%) makes it effectively indistinguishable from SANR (sand 88.80%, Table 2.3).

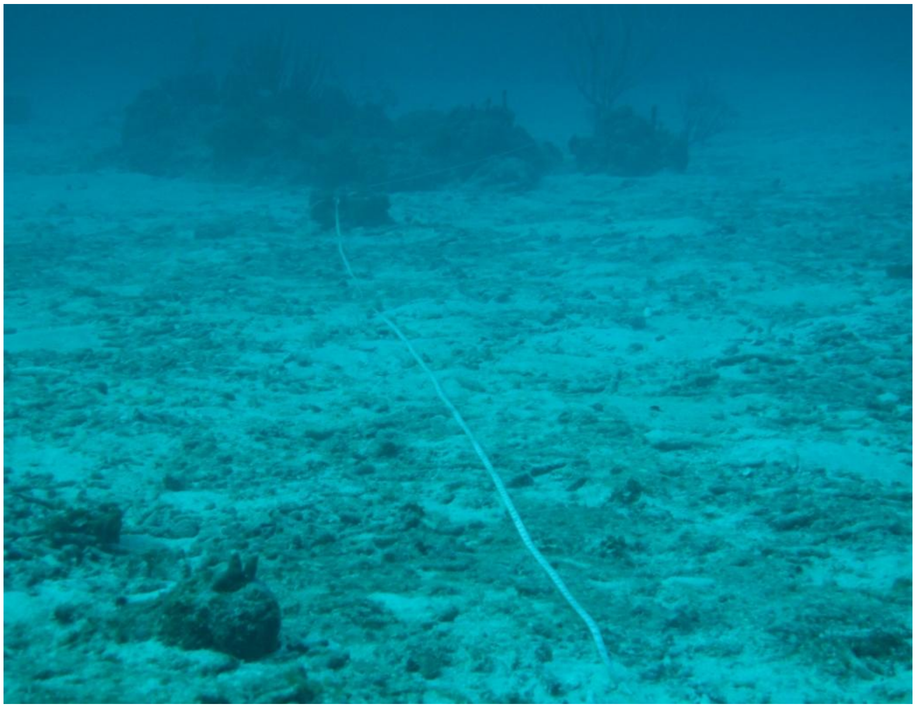


Figure 2.16. 2009 photo showing DEAL habit devoid of dense meadows of fleshy algae.

Figure 2.17. Coral rubble and remnants of *Acropora cervicornis* on the sandy bottom in DEAL in 2009.

Prada (2003) Habitat Type - Bare or Mixed Invertebrate on Unconsolidated Sediments

SANR - Sand No Ripple

Sand No Ripple (SANR) was a flat, sand substrate, with low relief rocks, rubble (63.26%, Table 2.3) and small sponges (6.40%) (Fig. 2.18). SANR were biogenetic sandy channels between two linear coral limestone reef systems (COLI) or between COLI and GOPL habitats. Sand was generally deeper toward center of the channel with pavement along edges. Small to medium sized coral rubble was scattered on the sand, particularly along the edges of the channels where *Strombus gigas* were found (Fig. 2.19). Turf algae / cyanobacteria also covered large areas, 22.91% (Table 2.3, Fig. 2.20).

Figure 2.18. SANR is dominated by a sandy substrate with sporadic patches of turf algae / cyanobacteria and small clumps of limestone.

Figure 2.19. Queen conch, *Strombus gigas*, was commonly observed in SANR.

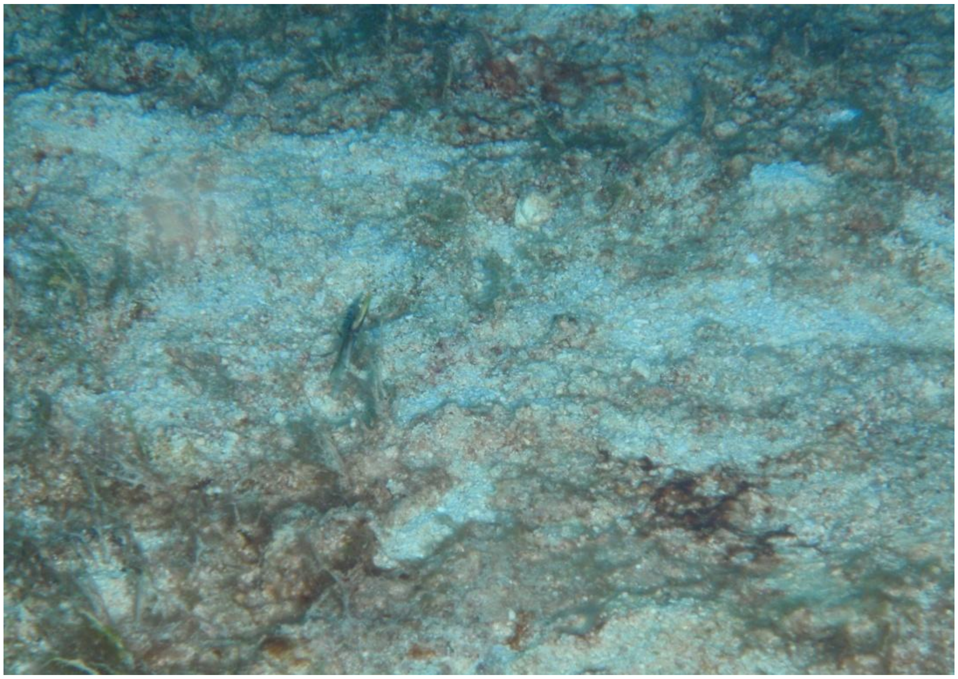
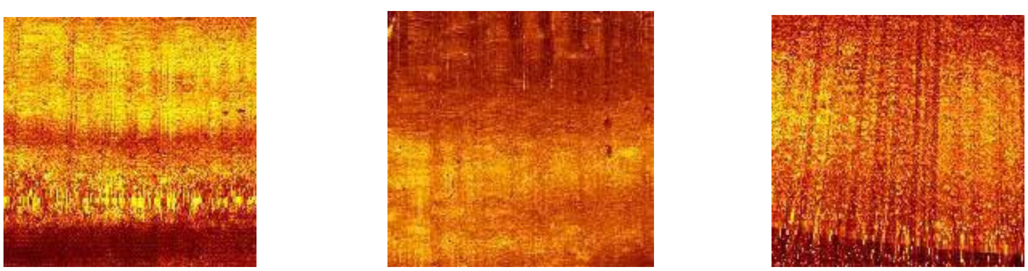


Figure 2.20. Film of cyanobacteria covers much of SANR and DEAL habitats.

Dead coral covered 2.14% of the bottom. Of the 0.16% live coral sampled over half of it (0.09% of the total cover sampled; Table 2.3) was diseased. The habitat is similar to SAIN but without abundant invertebrates which function to increase habitat structure. The dominant biota is turf algae / cyano-bacteria (22.91%). Prada (2003) offers no explanation for the obvious variation in light intensity SSS (Fig. 2.21 a, b) or for the distinctive uniform discontinuities in Fig. 2.21c considering that the habitat was termed Sand No Ripple.



a b c

Figure 2.21. Prada (2003) notes that the lack of large macro invertebrates in SANR results in a lack of habitat complexity and strong continuous reflections from the sand.

SAIN - Sand Invertebrates

The habitat termed sand invertebrates (SAIN) was described by Prada (2003) as coarse biogenic sand on unconsolidated sediments with sparse coral (2.30%) and gorgonian colonies (0.48%) (Table 2.3). We found that the habitat was primarily consolidated sediments with a thin veneer of sand with scattered sand patches where the sand was relatively deep (36.08%) (Fig. 2.22).

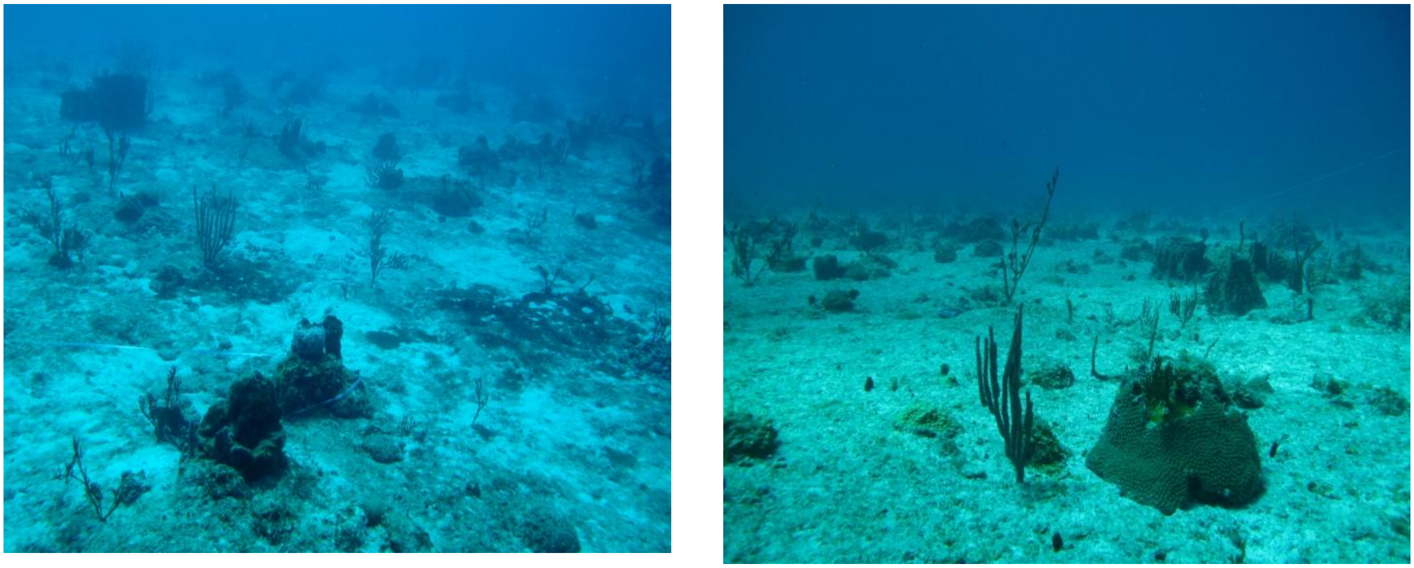
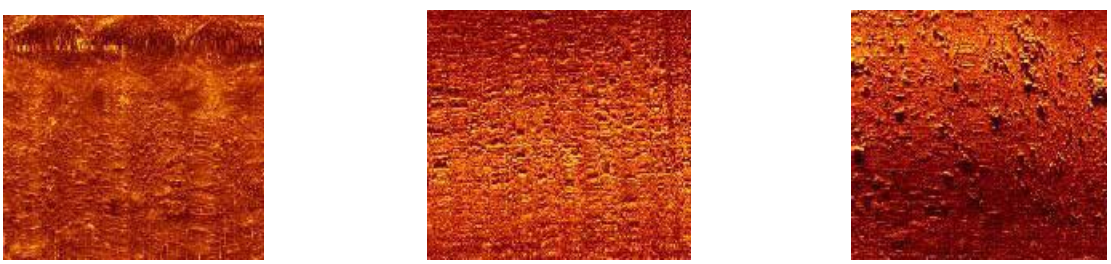


Figure 2.22. SAIN habitat had sandy patches over pavement with occasional gorgonians, sponges, and live and dead coral heads.

Unlike SANR, SAIN contained a diverse invertebrate community which increased habitat structure as see on the SSS images (Fig. 2.23). Prada (2003) considered that the SSS pattern was characterized by its strong and continuous reflection from the sand. We suggest that consolidated sediment would reflect a stronger signal than unconsolidated sediment like sand.



a b c

Figure 2.23. Side Scan Sonar images show irregularities caused by invertebrate and limestone clumps.

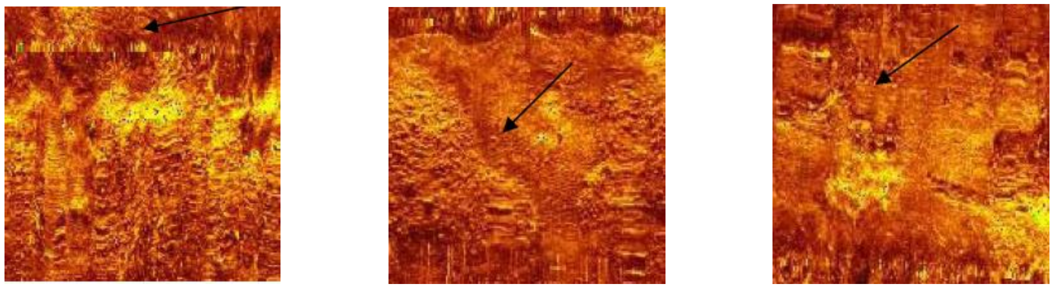
SARI - Sand Ripple

Sand Ripple (SARI) habitat was the smallest in area (0.4ha) of the habitats. Prada (2003) characterized SARI as small biogenetic sand patches. Sand comprised 82.10% of the cover (Table 2.3). Patches of SARI habitat were only large enough for a few 20m transects. The sand was commonly less than 10cm deep over the limestone pavement (Fig. 2.24). Turf algae / cyanobacteria were the dominant biota (14.70%, Table 2.3). Some coral rubble – old branches of *A. cervicornis* and & dead “coral heads” of primarily *Montastrea annularis* (complex) are scattered throughout in the habitat.

Gorgonian Plains (GOPL) habitat was adjacent and there was a clear division between the two habitats (Fig. 2.25) which is evident by the sharp pattern changes on SSS images (Fig. 2.26).

Figure 2.24. Sand and *Acropora cervicornis* rubble dominant SARI habitat in 2009. The adjacent GOPL habitat can be seen in the background.

Figure 2.25. Sharp interface between SARI habitat on the right and GOPL habitat on the left.



a b c

Figure 2.26. Sand with ripple marks but had distinct discontinuities in the SSS imagery (Prada, 2003). Arrows undefined in Prada.

Coral and Gorgonians on Consolidated Sediments

COLI - Coral Limestone

Prada (2003) noted that Coral Limestone (COLI) was divided by sand channels, which is commonly called “spur and groove” (Fig. 2.27). She also noted that it had a high vertical relief that exceeded 10m in some regions (Fig. 2.28). Over 78.8% of the substrate was covered with live biota. Although COLI had the highest percentage of live coral cover (7.56%, Table 2.3) and coralline algae (*Porolithon pachydermum*) (3.35% of the substrate) of the habitats within the MSSCA, coral and coralline algae cover were still considered low.

The reef was not considered healthy and showed signs of stress. Coral disease was not prevalent. Only 1.5% of the live coral was diseased and only about 1.1% was considered “recently killed coral”. This suggests that while coral mortality owing to disease was occurring, there was no major disease outbreak during the sampling period. However, it was clear that coral cover had been much higher in the past as "dead coral" covered 16.72% of the substrate. The category "dead coral” was defined as substrate with obvious coral structure that was not recently killed but had not been eroded or covered with algae. The live coral in COLI had either died several years ago or had slowly died over several decades. Although there was extensive dead coral, coral plates that overhung the sand channels between reefs were still in place (Figs. 2.27, 2.29), suggesting that mortality had been relatively recent and insufficient time had passed for storms and/or boring organisms to erode and dislodge them. Also, gaps in the reef had not filled with sediment, coral rubble, or biota.

While coral diversity was high in this habitat, coral cover was currently, and apparently historically, dominated by the *Montastrea annularis* species complex Table A2-3.1). This was evident from the preponderance of fragments of live *M. annularis* on the large hemispherical and the plate-like coral heads that dominated the COLI reefs and the hemispherical shape and relatively smooth surface (*i.e.* lack of ridges characteristic of *Colpohyllia* and *Diploria* colonies) of totally dead colonies (Fig. 2.30). Hemispherical and plate-like *M. annularis* overhung the grooves forming ledges. It is likely that the decline in coral cover has been occurring over a long period and events such as the 1993 (Quinn and Kojis 1999), 1998, and the 2005 coral bleaching episodes and accompanying disease-related mortality have been the main contributors to this decline.

Sponges were the dominant animal in the habitat, comprising 16.20% of the substrate cover (Table 2.3). Macro algae, primarily *Lobophora variegata*, extensively covered the dead coral substrate.

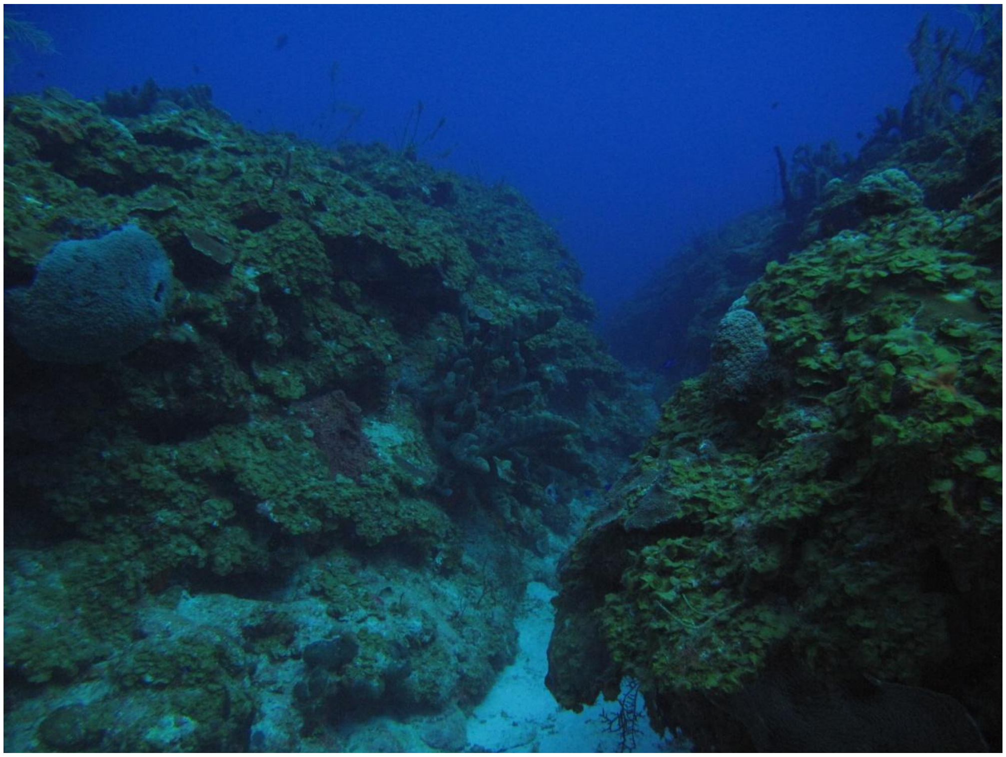


Figure 2.27. Deep groves between limestone spurs were characteristic of coral limestone habitat.

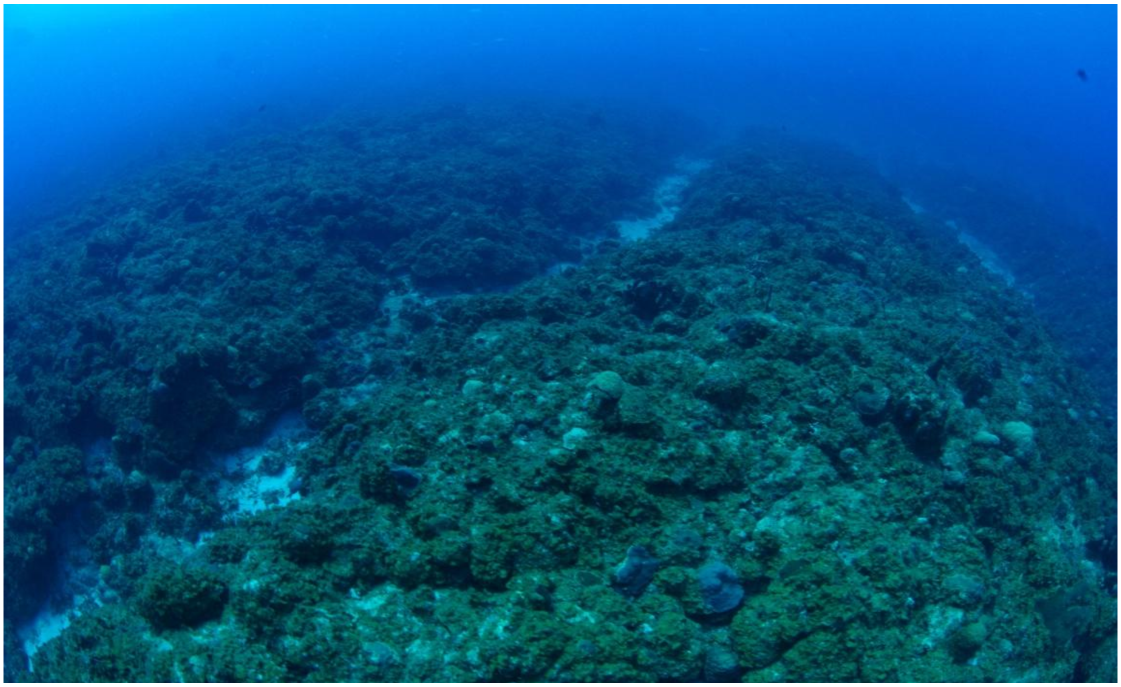


Figure 2.28. The high relief of the coral limestone (COLI) habitat is visible in this photograph.

Figure 2.29. The edge of reef with coral colonies overhanging sand channel, creating ledges.

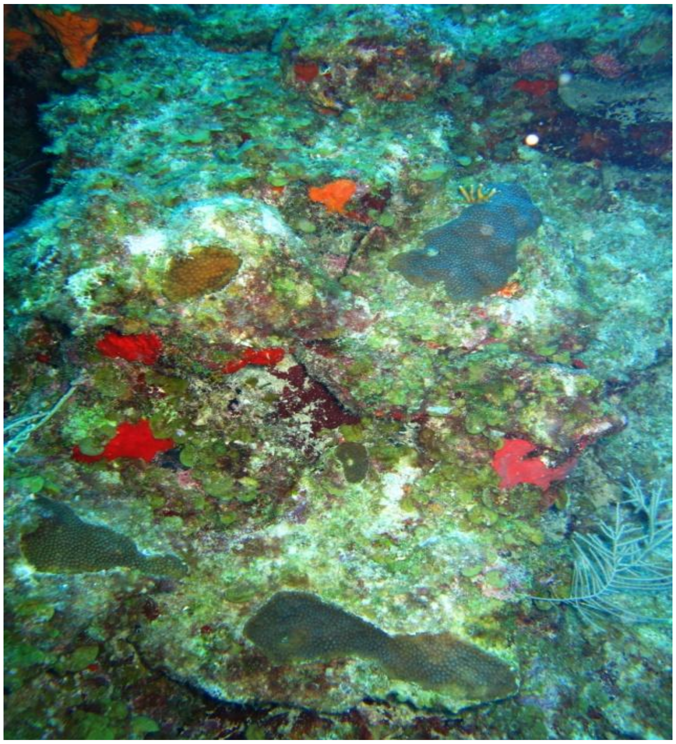
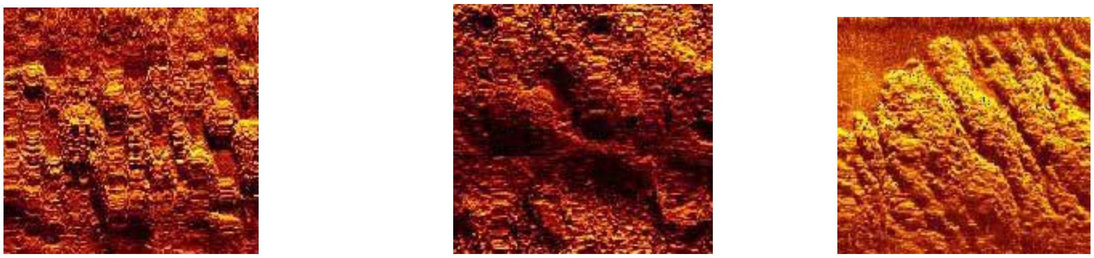


Figure 2.30. *Montastrea annularis* species complex coral head showing live fragments with partial mortality of the coral colony.

The "spur and groove" relief and structural complexity is evident in SSS imagery (Fig. 2.31). The structural complexity of the reef provides a lot of shelter for many species of fish.



a b c

Figure 2.31. The high vertical relief in the coral limestone habitat is easily recognized in the side scan sonar images. The characteristic "spur and groove" is very apparent in image c.

COPA - Coral Patch

Coral Patch was a small habitat of continuous corals and was considered similar to Coral Limestone habitat (COLI) in 2002 (Prada 2003) (Figure a, b). In 2009 / 2010 no COPA habitat was detected in areas labeled COPA on Prada's (2003) habitat maps in the northern half of the MSSCA (COPA 1 and 2). The habitat at COPA 1 and 2 (Fig. 2.32) was surrounded by SAIN and ALIN habitat on Prada's map. The habitat seen during dives at representative GPS coordinates for COPA in these two areas was flat pavement with sand (6.80%) and macro algae (33.90%, Table 2.3) with occasional large *Xestospongia muta* and many smaller sponges (6.80%, Table 2.3).

COPA 1 and 2 habitats were similar to Algae and Invertebrates (ALIN) or Sparse Algae (SPAL). Large, shallow depressions filled with coral rubble and sand occurred throughout the habitat. These depressions have ledges along the edges and provide shelter for lobsters and several species of fish (Fig. 2.33). The subsurface strata may be different from the surrounding habitat resulting in the different acoustic signal Prada observed. The habitat has either changed drastically since Prada (2003) did her field work or was misidentified. Therefore, we have excluded it from further analysis.

The COPA 3 site that we surveyed was a deeper water site located within COLI habitat. The site we surveyed was identical to the surrounding COLI habitat. However, in 2009, during a diver search for mutton snapper, COPA habitat was observed. This COPA habitat was within or adjacent to COLI habitat and was similar to COLI except for the lack of grooves for a couple hundred meters.

COPA had high relief with a sharp boundary in SSS images (Fig. 2.34 a, b, c). We hypothesize that the solution holes (Fig. 2.35) in the substrate created the distinct boundaries in the SSS images. A variety of fish including squirrelfish and French and white grunts congregate in these depressions during the day.

Figure 2.32. Habitat observed at GPS coordinates for COPA 1 in June 2010. This habitat was a fairly flat carbonate pavement with a thin veneer of sand, which was dominated by algae with occasional sponges and dead and living coral heads.

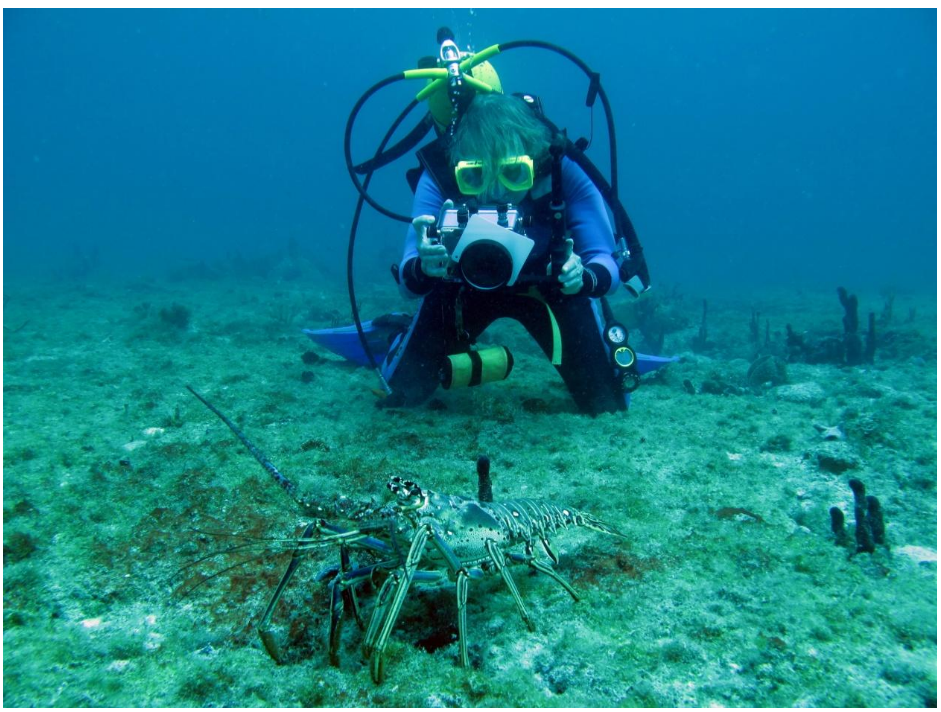


Figure 2.33. Spiny lobster being photographed in the COPA habitat as it leaves its den in the depression at the right middle of the photograph (August 2009).

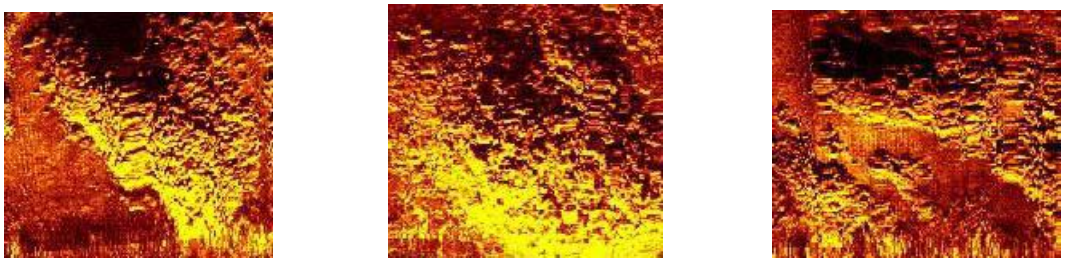


Figure 2.34. Side Scan Sonar of COPA from Prada (2003). The authors consider the sharp boundaries to probably be the solution pit ledges.

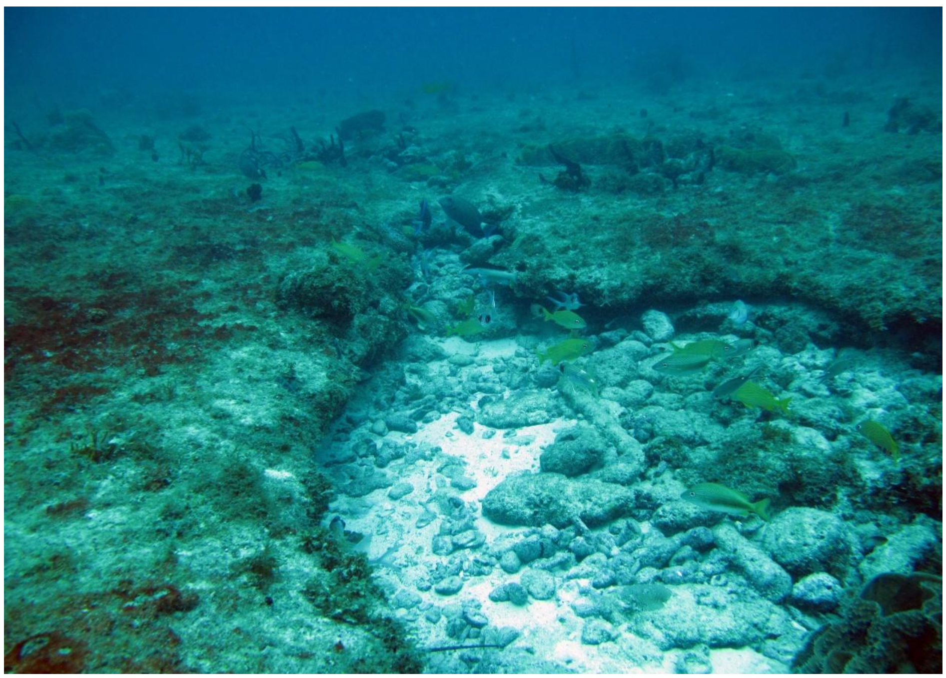


Figure 2.35. Pavement in sites designated COPA by Prada (2003) is disrupted by these depressions which are often have ledges around their perimeter and contain sand and coral rubble (photograph June 1, 2010).

GOPL - Gorgonian Plain

Gorgonian Plain (GOPL) was the third most abundant habitat in the MSSCA with 102.9 ha. Prada (2003) described this habitat as "flat and extensive areas covered by gorgonian colonies mixed with scleractinian corals." She noted that GOPL habitats in the USVI had a higher percentage of scleractinian corals compared to La Parguera, Puerto Rico. She also noted that this habitat did not have a distinct boundary with adjacent habitat.

In contrast, we found that this was a distinctive habitat at the sites we surveyed. This habitat often had considerable vertical relief and usually consisted of large carbonate mounds with corals, gorgonians and sponges scattered over the surface (Figs. 2.36). These mounds rose above surrounding SPAL, ALIN, DEAL and SANR habitats. Vertical relief of GOPL habitat was highest just north of COLI habitat, but declined as to the north. GOPL rises could have been part of a series of ancient reefs that paralleled the shelf edge. The inner reefs (GOPL habitat) may have declined as sea level rose and flooded the shelf making the habitat inimical to scleractinian coral survival. It is not clear, why, today, this habitat lacks evidence of extensive coral cover similar to COLI.

GOPL may give an impression of pavement where this habitat is extensive. However, the edges of this habitat always showed a sharp rise above the surrounding substrate (Fig. 2.37). GOPL habitat was covered mostly by macroalgae (17.69%), sponges (12.74%), turf algae / cyanobacteria (14.85%), live coral (7.00%) and gorgonians (3.43%) (Table 2.3). *Lobophora variegata* was the dominant macro algae and *Dictyota* was the subdominant macro algae in the shallower GOPL sites. Gorgonians were as abundant in GOPL as they were in COLI (3.87%). The presence of dense invertebrate communities and limestone rocks cause the regular patterned SSS image in Fig. 2.38. About 32.19% of the substrate was sand or rubble. GOPL had the second highest occurrence of coralline algae (1.66%). Only 0.05% of the live coral was diseased (Fig. 2.39). A relatively large, healthy population of *Acropora cervicornis* about 10m x 15m was observed at 18m in July 2010 (Fig. 2.40). There were no sign of predation or disease in the population.

Figure 2.36. GOPL habitats were distinct from adjacent habitats (GOPL 3, photo May 5, 2010).

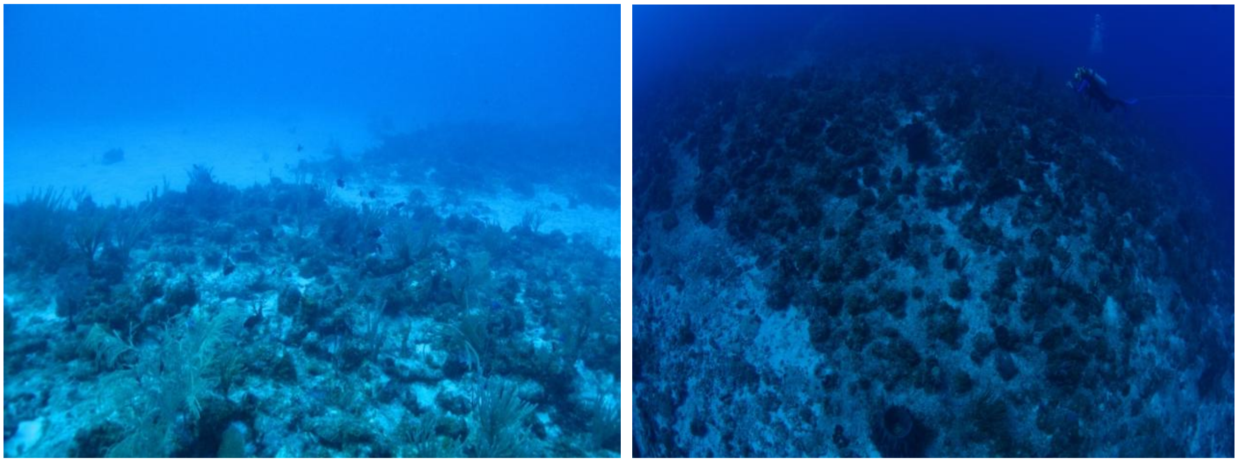
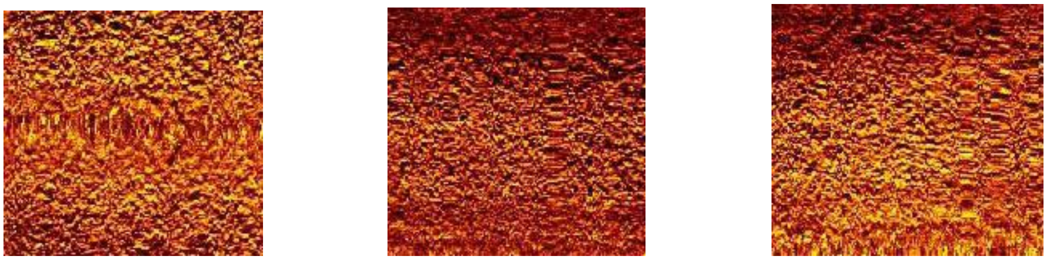


Figure 2.37. Sponges and gorgonians stand out among the macroalgae covering the dead coral colonies in GOPL 1 (left, June 26, 2009). Dense invertebrate populations and limestone rocks characterized GOPL (right, April 30, 2010).



a b c

Figure 2.38. According to Prada (2003) GOPL (gorgonian plain) did not present a distinct boundary with its adjacent habitats.

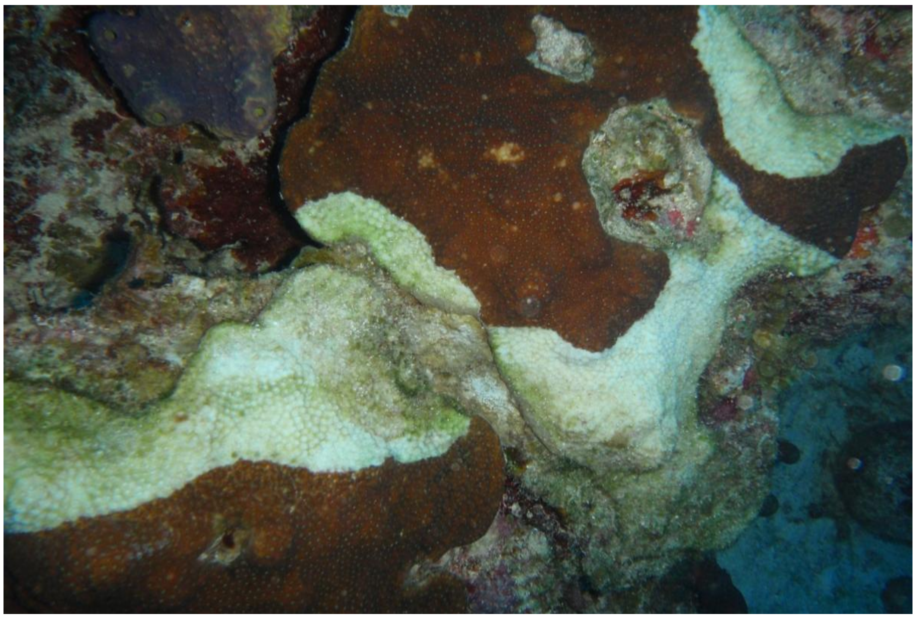


Figure 2.39. White plague disease on *Montastrea annularis* at GOPL 4 (July 2, 2009).

Figure 2.40. Healthy population of *Acropora cervicornis* in GOPL (May 30, 2010), depth 13m.

The lionfish, *Pterois volitans*, an invasive species to the Caribbean from the Pacific Ocean (Snyder and Burgess 2007), was observed for about 5 min. in GOPL habitat at 18m in July 2010 during a mutton snapper search dive (Fig. 2.41). The fish showed no defensive behavior and did not try to seek shelter. This was the only individual observed during the surveys. It was not killed owing to lack of equipment for killing or collecting when initially sighted and the inability to find it again at end of the dive when G. Martinez searched for it with spearfishing gear. Several *Ginglymostoma cirratum*, (nurse shark) were observed at several habitats in both years (Fig. 2.42). This was the only shark species observed.

Figure 2.41. The lionfish, *Pterois volitans* (~SL 15cm), an invasive species, observed in GOPL at 18m (July 2010).

Figure 2.42. A nurse shark (*Ginglymostoma cirratum*), ~1.5m TL, observed cruising over GOPL habitat (GOPL 3, May 5, 2010). Note the ubiquitous consolidated substrate with shallow sand pockets, coral rubble, gorgonians, sponges and dead/live coral heads.

DISCUSSION - BENTHIC SURVEY

Mean percent cover for the fauna / flora and substrate and depth for each survey site and each habitat is found in Appendicies - Chapter 2 Tables A2.2.1 - A2.2.9 covering a total of 675m^2. Live scleractinian coral cover was very low. Habitats such as COLI and GOPL (Table A2.2.3) that had a strong 3D structure created by corals only had a coral cover of 7.56% and 7.00% respectively. The *Montastrea annularis* species complex was the dominant coral taxa in both COLI and GOPL (Table A2-3.4) habitats. Similarly, at a mesophotic coral reef on nearby St. Thomas (Smith et al 2010) *M. annularis* was also the dominant coral, though coral cover was higher on the mesophotic reefs (23% vs. 7% in COLI in the MSSCA on St. Croix).

The dead coral skeletons COLI and GOPL had high macro algal cover, primarily *Lobophora variegata*. In shallower habitats such as ALIN *Sargassum* spp. were more common (Table A2-3.7) while *Dictyota* was most abundant in SAIN (Table A2-3.9). In the largest habitat, the predominately shallow ALIN and SAIN habitats, *Siderastrea siderea* was the most abundant coral. However, this species only covers 0.96% of the substrate (Table A2-3.6) in ALIN and 0.68% in SAIN (Table A2-3.8).

Coral cover in similar habitats outside the MSCA had been around 30% prior to the 2005 bleaching event (T. Smith, pers. com.). Work by Adey et al (1981) on the southern St. Croix reefs only investigated inshore shallow reefs. Their closest site to the MSSCA, Airport Reef, was sampled to a depth of only 7m. Unlike the more eastern reefs that they sampled, no *Acropora palmata* was observed. The percent coral cover was 17.2%, with 69% macroalgae, 14% sand and 0.1% coralline algae. While not stating the reefs were overfished, they noted that studies involving fish (Randall 1963, 1967) and urchins (Sammarco et al. 1974) had demonstrated that herbivores were not only capable of lowering algal biomass but they also can create an environment that favors algal species with high rates of growth over the other, slow growing macroalgae which are better space competitors. They further noted that larger fleshy benthic algae, with more rapid growth rates than coral, are quite capable of out competing corals and coralline algae for space, and that without the effects of grazing, reefs could not develop their carbonate structure.

Adey et al (1981) reported over 100 species of algae in the algal turfs in the shallow reefs at the east end of St. Croix. A relatively few species of blue-green algae dominated the turf. The taxonomy has changed and the Phylum is now referred to as Cyanobacteria.

The very thin layer of sand over hard bottom led Prada (2003) to misidentify the Meta Community for SAIN, SPAL and ALIN as "unconsolidated sediments" from the side scan signal. This Meta Community should be renamed SAV on consolidated sediments. DEAL is also a hard bottom habitat, but with more sand. Prada described GOPL as flat areas covered mostly by gorgonian and sponge colonies and without a distinct boundary with adjacent habitats. In fact, this habitat often had considerable vertical relief and usually consisted of extensive carbonate mounds with corals, gorgonians and sponges scattered over the surface. GOPL appears to be the remnants of a relict reef system once likely similar to COLI. The underlying surface of the relict GOPL reef has been smoothed by infilling of interstices and erosion of the surface. It provides a hard, angular settlement surface for larvae and as a result has a relatively high cover of sponges, gorgonians, and corals compared to the flat, hard bottom habitats, i.e. ALIN, SPAL, SAIN and DEAL.

WATER TEMPERATURE ON ST. CROIX

INTRODUCTION

Water temperature is an important driver of reef health and reproductive timing in invertebrates and possibly fish. Water temperature data were collected during this the main spawning months of *Lutjanus analis*.

MATERIALS AND METHODS - TEMPERATURE

A ReefNet brand underwater temperature logger, attached to a diver, was used to measure subsurface sea water temperatures every 10 seconds during dives in May and June 2009 and May, June and July 2010. The temperature logger automatically recorded water temperature at preset intervals once it was immersed to 3m. Subsurface sea water temperatures were measured during several dives to depths ranging from 10-28m. The monthly mean was calculated from observations starting at least 5 min into the dive. A detailed analysis of temperature variation is beyond the scope of this report.

RESULTS - TEMPERATURE

The mean temperature in May 2009 was 27.7°C (N = 8) and was 28.4°C in June 2009 (N = 3). The temperature range in May was only about 0.2°C while it ranged nearly 0.8°C in June. Heavy rains in June 2009 resulted in the discharge of freshwater at a depth of 22 - 28m at SANR 5 (sand channel behind the outer shelf edge reef, COLI) creating a cooler, lower salinity layer (Fig. 2.43). The increase in temperature from May to June was consistent with ten years of subsurface sea water temperature observations from a reef in St. Thomas, USVI (Quinn and Kojis 2003).

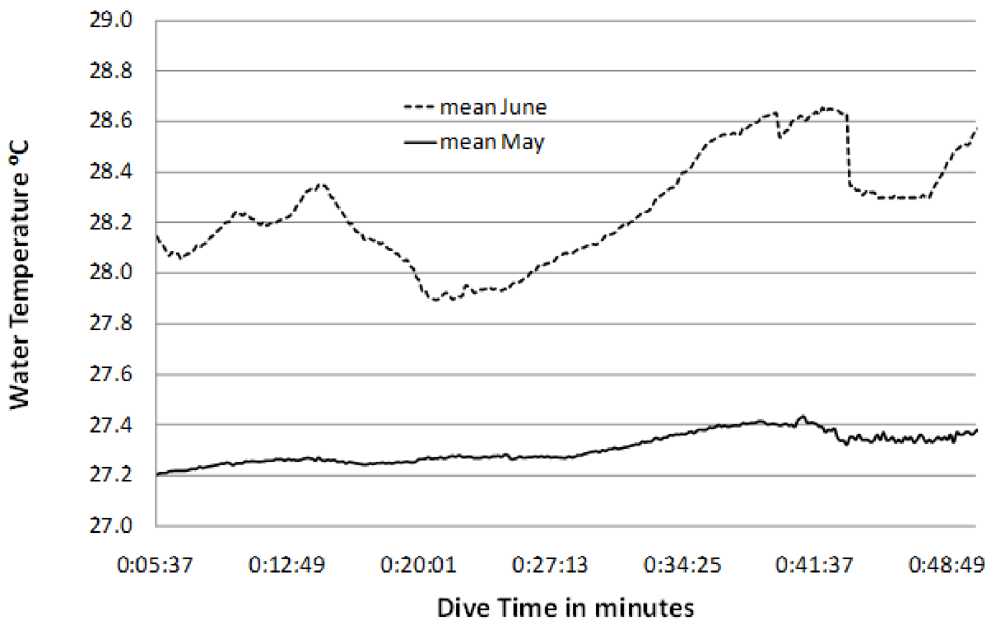


Figure 2.43. Mean subsurface sea water temperature during dives in May 2009 (N=8) and June 2009 (N=3).

Subsurface sea water temperatures were much warmer in 2010. The mean temperature in May 2010 was 28.31^{o}C (N = 5), 29.22^{o}C in June 2010 (N = 4) and 29.40^{o}C in July 2010 (N=3). May 2010 was 1.61^{o}C warmer than 2009 and June 2010 was 0.91^{o}C warmer (Fig. 2.44). As expected, temperature varied slightly with depth.

Table 2.4. Mean monthly subsurface seawater temperature in the MSSCA in 2009 and 2010.

Date	Temperature ^{o}C	Difference ^{o}C
May-09	27.30	
May-10	28.91	1.61
Jun-09	28.31	
Jun-10	29.22	0.91
Jul-10	29.40	

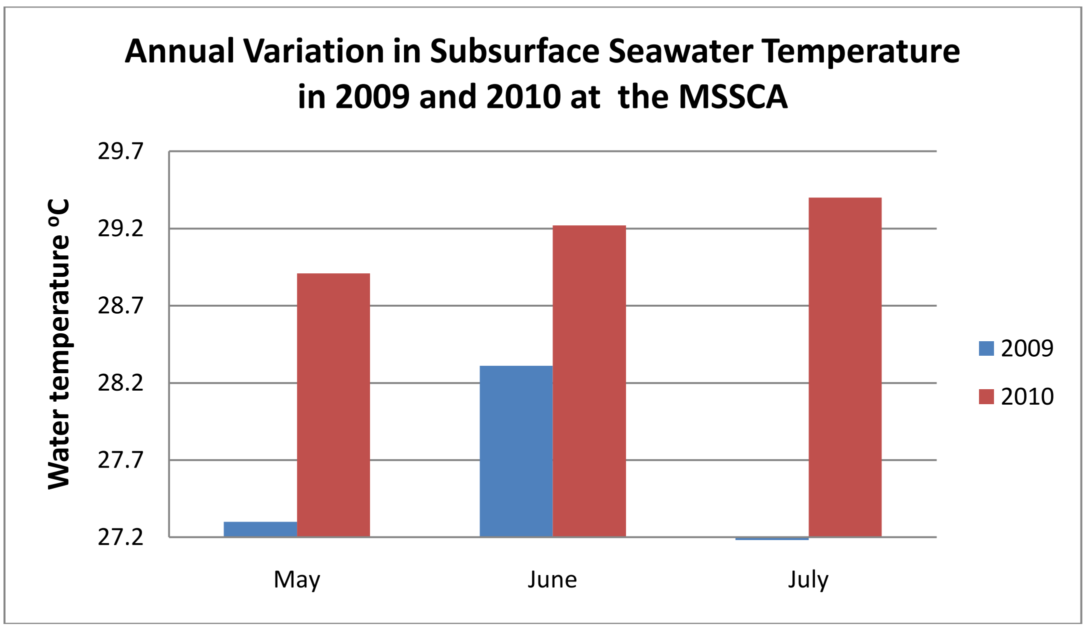


Figure 2.44. Subsurface sea water temperatures warmer in 2010 during the period of closure.

DISCUSSION - TEMPERATURE

Variations in mean monthly water temperature between 2009 and 2010 did not appear to affect the timing of the onset of spawning. The presence of immature gonads in *Lutjanus analis* caught in March 2009 and 2010 suggests that the increased water temperature in 2010 had not altered the timing of gonad development in 2010. However, the effects of sustained increases in water temperature on fish populations are unknown and require further study if fisheries management policy is going to adapt to climate change.

No bleaching of corals was observed during dives from April to early August 2009 and during May to July 2010. Bleaching would not be expected, even with the higher water temperatures in 2010, during these months. Corals historically have bleached, even in warmer years, primarily in September and October.

To protect coral reef habitat, especially because of its importance to fisheries, the Caribbean Fishery Management Council (CFMC) banned bottom tended fishing gear (traps, bottom long lines, etc.) in the MSSCA. However, the USVI, which has jurisdiction over most of the MSSCA has not followed suit. It would behoove the USVI to also ban bottom tended gear within at least a portion of the MSSCA under its jurisdiction. The seaward or southern half of the MSCA contains the remnants of magnificent reef structures which, over time, might recover from the 2005 bleaching event which affected all Virgin Islands reefs (Miller et al 2006, Rothenberger et al 2008).

Nearly thirty years ago Adey et al (1981) observed that the surest approach to maintaining natural conditions is to prohibit all land and water use in the neighborhood of the reef. However, this statement is less true in 2010. While local impacts to reefs can certainly degrade or destroy reefs, regional and global factors are having more of an impact on reefs today. The current low coral cover in the MSSCA is largely a function of coral bleaching and disease, perhaps assisted by the components in dust blowing from Africa. Coral bleaching in the USVI is related to higher than normal water temperatures, which in turn is related to global climate change. Bleaching stresses corals and makes them more susceptible to disease (Miller et al 2006).

LITERATURE CITED - CHAPTER 2

Adey, W.H., C.S. Rogers, R.S. Steneck and N.H. Salesky. 1981. The south St. Croix reef: A study of reef metabolism as related to environmental factors and an assessment of environmental management. Department of Conservation and Cultural Affairs, Government of the Virgin Islands. 74p.

Adey, W.H., W. Gladfelter, J. Ogden and R. Dill. 1977. Field Guidebook to the reefs and reef communities of St. Croix, Virgin Islands. *3rd International Symposium on Coral Reefs*. 52p.

Geophysics GPR International, Inc. 2003. Marine Habitat Mapping Offshore St. Thomas & St. Croix US Virgin Islands EEZ, Final Report to the CFMC. Volume 2. pp. 21.

Herzlieb, S., E. Kadison, J. Blondeau and R.S. Nemeth. 2006. Comparative assessment of coral reef systems located along the insular platform south of St. Thomas, US Virgin Islands and the relative effects of natural and human impacts. *Proc 10th International Coral Reef Symposium* 4-2:1144-1151.

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

Kojis, B.L. and N.J. Quinn. 2010. Validation of a Mutton Snapper (*Lutjanus analis*) spawning aggregation off St. Croix, U.S. Virgin Islands. *Proceedings of the 62nd Gulf and Caribbean Fisheries Institute* 62: 279-285.

Miller, J., R. Waara, E. Muller and C.S. Rogers. 2006. Coral bleaching and disease combine to cause extensive mortality on reefs in U.S. Virgin Islands. *Coral Reefs* 25(3): 418-426.

Smith, T.B., J. Blondeau, R.S. Nemeth, S.J. Pittman, J.M. Calnan, E. Kadison and J. Gass. 2009. Benthic structure and cryptic mortality in a Caribbean mesophotic coral reef bank system, the Hid Bank Marine Conservation District, U.S. Virgin Islands. *Coral Reefs* 29:289-308.

Prada, M. 2003. Delineation of benthic habitats from side scan sonar mosaics from the Marine conservation District, St. Thomas, Lang Bank and Mutton Snapper Closed Area in St. Croix, U.S. Virgin Islands. Report to Caribbean Fishery Management Council, October 2003. Note: Side scan images depicting habitat types are taken from Prada 2003. pp 23.

NOAA-NOS 2001. Benthic habits of Puerto Rico and the U.S. Virgin Islands, National Oceanic and Atmospheric Administration.

Quinn, N.J. and B.L. Kojis. 1999. Subsurface seawater temperature variation and the recovery of corals from the 1993 coral bleaching event in waters off St Thomas, US Virgin Is. *Bulletin of Marine Science* 65(1):201-214.

Quinn, N.J. and B.L. Kojis. 2003. Variation in subsurface seawater temperature off Discovery Bay, Jamaica and the U.S. Virgin Islands. *International Journal of Tropical Biology & Conservation / Revista de Biología Tropical* 51(4):181-187.

Randall, J. 1963. An analysis of the fish populations of artificial and natural reefs in the Virgin Islands. *Carib. J. Sci*. 3:31-47.

Randall, J. 1967. Food habits of the reef fishes of the West Indies. Studies *in Tropical Ocean-*

ography, Inst. of Marine Sci., Univ. of Miami. 5:665-847.

Rivera, J.A., M.C. Prada, J.-L. Arsenault, G. Moody and N. Benolt. 2005. Detecting fish aggregations from reef habitats mapped with high resolution side scan sonar imagery. NMFS PAP 5:88-104. website:http://www.sefsc.noaa.gov/sedar/download/S14RD11%20Rivera%20Carib% 20Reef%20Sonar%202005.pdf?id=DOCUMENT

Rothenberger, P., et al. 2008. The state of coral reef ecosystems of the U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS 11. Silver Spring, MD. 522 pp.

Sammarco, P., J. Leighton and J. Ogden. 1977. Grazing and control of coral reef community structure by *Diadema antillarum* Philippi (Echinodermata:Echinoides): a preliminary study. *Journ. of Mar. Res.* 32:47-53.

Snyder, D.B. and G.H. Burgess. 2007. The Indo-Pacific red lionfish, *Pterois volitans* (Pisces: Scorpaenidae), new to Bahamian ichthyofauna. *Coral Reefs* 26:(1):175.

APPENDICIES CHAPTER 2

Appendix 1 - Abstract 63rd Gulf and Caribbean Fisheries Institute Meeting

Age-frequency distributions of a protected mutton snapper (*Lutjanus analis*) aggregation following 17 years of protection

LIAM CARR and BARBARA LOUISE KOJIS

Snappers have historically been an important economic stock for the U.S. Virgin Islands, annually contributing nearly 4% of total landings by weight prior to seasonal closures set in place to prevent stock collapse. Evidence of depleted mutton snapper (*Lutjanus analis*) stocks in St. Croix led the Caribbean Fisheries Management Council into developing the Mutton Snapper Seasonal Area Enclosure (MSSAE) in 1993. The MSSAE closes fishing off at a historical fish spawning aggregation (FSA) site, during the March-June mutton snapper spawning season. Between March 2009 and June 2010, 139 mutton snapper were collaboratively harvested with St. Croix fishers within the MSSAE from an anchored fishing vessel at coordinates provided by local fishers. From this sample, 61 otoliths were collected and analyzed to develop age-frequency distributions, an important tool for creating growth curves and examining population structures. This analysis is part of the first effort since the MSSAE was enacted for gauging how successful management programs have been over the past 17 years for rebuilding local mutton snapper stocks. Researchers determined that the sampled population had a mean age of 6.5 ± 1.8 yrs, with a mode of 7 yrs. Additional analyses on length-frequency and weight-frequency distributions, along with examinations of gonadal conditions, provide preliminary evidence that the MSSAE's historical FSA site remains active, although the size of the spawning population continues to be difficult to assess.

Appendix 2 - Summary of Benthic Habitat Analysis: Benthic Categories

Table A2-2.1 – Descriptive statistics of benthic categories by site in Algae and Invertebrates (ALIN) habitat.

Transect Name	**ALIN 1**	**ALIN 2**	**ALIN 3**	**ALIN 4**			
Number of frames	100	100	100	100			
Total points	2000	2000	2000	2000			
MAJOR CATEGORY	**% of Transect**	**% of Transect**	**% of Transect**	**% of Transect**	**Mean**	**Std. Dev**	**Std. Error**
Coral	3.55	0.25	4.10	0.55	2.11	1.99	1.00
Gorgonians	0.05	0.00	0.05	0.10	0.05	0.04	0.02
Sponges	16.90	5.00	3.90	2.95	7.19	6.53	3.26
Zoanthids	0.00	0.00	0.05	0.00	0.01	0.03	0.01
Macro algae	8.50	28.25	27.05	31.75	23.89	10.45	5.23
Turf algae	70.00	11.00	62.95	9.00	38.24	32.74	16.37
Dead coral	0.35	0.25	0.05	0.75	0.35	0.29	0.15
Coralline algae	0.10	1.25	0.05	2.15	0.89	1.01	0.50
Diseased corals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand, pavement, rubble	0.55	54.00	1.80	52.75	27.28	30.15	15.07
Sum	100.00	100.00	100.00	100.00			
depth m	12.80	13.90	14.90	15.80			

Table A2-2.2 – Descriptive statistics of benthic categories by site in Sand and Invertebrates (SAIN) habitat.

TRANSECT NAME	**SAIN 1**	**SAIN 2**	**SAIN 3**	**SAIN 4**	**Total**		
Number of frames	100	100	100	100	400		
Total points	1600	1600	1600	1600	6400		
MAJOR CATEGORY	**% of Transect**	**% of Transect**	**% of Transect**	**% of Transect**	**Mean**	**Std Dev.**	**Std. Error**
Coral	2.25	4.30	2.10	0.55	2.30	1.54	0.77
Gorgonians	0.00	0.80	1.10	0.00	0.48	0.56	0.28
Sponges	6.05	11.50	7.40	2.90	6.96	3.56	1.78
Zoanthids	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macro algae	9.05	17.75	6.60	55.30	22.18	22.60	11.30
Turf algae	82.10	6.85	1.05	28.70	29.68	36.92	18.46
Dead coral	0.10	0.50	8.30	0.00	2.23	4.06	2.03
Coralline algae	0.10	0.05	0.15	0.00	0.08	0.06	0.03
Diseased corals	0.00	0.00	0.15	0.00	0.04	0.08	0.04
Sand, pavement, rubble	0.35	58.25	73.15	12.55	36.08	35.10	17.55
Sum	100.00	100.00	100.00	100.00			
depth m	13.40	13.70	22.30	13.90			

Table A2-2.3 - Descriptive statistics of benthic categories by site in Sand No Ripple (SANR) habitat.

TRANSECT NAME	**SANR 1**	**SANR 2**	**SANR 3**	**SANR 4**	**Total**		
Number of frames	100	100	100	100	400		
Total points	2000	2000	2000	2000	8000		
Major Category	**% of transect**	**% of transect**	**% of transect**	**% of transect**	**Mean**	**Std. Dev.**	**Std. Error**
Coral	0.20	0.05	0.05	0.35	0.16	0.14	0.07
Gorgonians	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sponges	7.20	14.55	1.50	2.35	6.40	5.99	2.99
Zoanthids	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macroalgae	4.35	1.75	0.40	13.25	4.94	5.78	2.89
Turf algae / cyanobacteria	27.10	30.00	2.20	32.35	22.91	13.97	6.99
Dead coral with algae	0.05	0.00	8.15	0.35	2.14	4.01	2.01
Coralline algae	0.00	0.00	0.05	0.35	0.10	0.17	0.08
Diseased corals	0.00	0.00	0.30	0.05	0.09	0.14	0.07
Sand, pavement, rubble	61.10	53.65	87.35	50.95	63.26	16.62	8.31
Sum	100.00	100.00	100.00	100.00			
depth m	29.90	25.60	21.30	13.70			

Table A2-2.4 – Descriptive statistics of benthic categories by site in Sparse Algae – (SPAL) habitat.

TRANSECT NAME	SPAL 1	SPAL 2	Total		
Number of frames	100	100	200		
Total points	2000	2000	4000		
MAJOR CATEGORY	**% of transect**	**% of transect**	**Mean**	**Std. Dev.**	**Std. Error**
Coral	1.15	0.55	0.85	0.42	0.30
Gorgonians	0.00	0.00	0.00	0.00	0.00
Sponges	4.56	2.55	3.55	1.42	1.00
Zoanthids	0.00	0.00	0.00	0.00	0.00
Macro algae	15.90	23.55	19.73	5.41	3.82
Turf algae/cyanobacteria	76.34	5.55	40.94	50.06	35.39
Dead coral	0.05	0.70	0.38	0.46	0.32
Coralline algae	0.00	0.25	0.13	0.18	0.13
Diseased corals	0.00	0.00	0.00	0.00	0.00
Sand, pavement, rubble	2.00	66.85	34.43	45.86	32.42
Sum	100.00	100.00			
depth m	11.00	15.24			

Table A2-2.5 – Descriptive statistics of benthic categories by site in Sand Ripple (SARI) habitat.

TRANSECT NAME	**SARI**
Number of frames	100
Total points	2000
MAJOR CATEGORY	**% of transect**
Coral	0.30
Gorgonians	0.00
Sponges	1.65
Zoanthids	0.00
Macro algae	1.25
Turf algae/cyanobacteria	14.70
Dead coral	0.00
Coralline algae	0.00
Diseased corals	0.00
Sand, pavement, rubble	82.10
Sum	100.00
depth m	11.00

Table A2-2.6 – Descriptive statistics of benthic categories by site in Dense Algae (DEAL) habitat.

TRANSECT NAME	**DEAL 1**	**DEAL 2**	**Total**		
Number of frames	100	100	200		
Total points	2000	2000	4000		
Major Category	**% of transect**	**% of transect**	**Mean**	**Std.**	**Std Error**
Coral	0.05	0.25	0.15	0.14	0.10
Gorgonians	0.00	0.00	0.00	0.00	0.00
Sponges	2.45	1.50	1.98	0.67	0.48
Zoanthids	0.00	0.00	0.00	0.00	0.00
Macroalgae	2.40	0.25	1.33	1.52	1.08
Turf algae, cy bacteria	10.95	0.70	5.83	7.25	5.13
Dead coral with algae	0.00	3.80	1.90	2.69	1.90
Coralline algae	0.00	0.05	0.03	0.04	0.03
Diseased corals	0.00	0.00	0.00	0.00	0.00
Sand, pavement, rubble	84.15	93.45	88.80	6.58	4.65
Sum	100.00	100.00			
Depth m	19.9	16.5			

Table A2-2.7 - Descriptive statistics of benthic categories by site in Coral Patch (COPA) habitat**.**

TRANSECT NAME	**COPA 3**
Number of frames	20
Total points	400
MAJOR CATEGORY	**% of Transect**
Coral	5.25
Gorgonians	0.75
Sponges	6.80
Zoanthids	0.00
Macro algae	33.90
Turf algae	2.25
Dead coral	36.35
Coralline algae	7.90
Diseased corals	0.00
Sand, pavement, rubble	6.80
Sum	100.00
depth m	21.3

Table A2-2.8 - Descriptive statistics of benthic categories by site in Coral Limestone (COLI) habitat**.**

TRANSECT NAME	**COLI 1**	**COLI 2**	**COLI 3**	**COLI 4**	**COLI 5**	**Total**		
Number of frames	20	20	20	20	20	100		
Total points	400	400	400	400	400	2000		
MAJOR CATEGORY	**% of transect**	**% of transect**	**% of transect**	**% of transect**	**% of transect**	**Mean**	**Std. Dev.**	**Std Error**
Coral	5.46	7.45	9.90	8.25	6.75	7.56	1.66	0.74
Gorgonians	2.00	2.65	8.20	1.75	4.75	3.87	2.69	1.20
Sponges	18.38	15.50	6.30	21.05	19.75	16.20	5.90	2.64
Zoanthids	0.04	0.00	0.20	0.00	0.00	0.05	0.09	0.04
Macro algae	28.75	35.15	17.40	25.25	24.25	26.16	6.50	2.90
Turf algae / cyanobacteria	34.83	22.00	2.00	11.60	34.50	20.99	14.35	6.42
Dead coral	0.13	7.25	51.75	24.45	0.00	16.72	21.97	9.83
Coralline algae	0.00	9.45	2.30	5.00	0.00	3.35	3.98	1.78
Diseased corals	0.04	0.05	0.40	0.05	0.00	0.11	0.16	0.07
Sand, pavement, rubble	10.38	0.50	1.55	2.60	10.00	5.01	4.79	2.14
Sum	100.00	100.00	100.00	100.00	100.00			
depth m	17.10	25.60	22.60	19.80	22.50			

Table A2-2.9 - Descriptive statistics of benthic categories by site in Gorgonian Plain (GOPL) habitat**.**

TRANSECT NAME	**GOPL 1**	**GOPL 2**	**GOPL 3**	**GOPL 4**	**Total**		
Number of frames	100	100	100	100	400		
Total points	2000	2000	2000	2000	8000		
MAJOR CATEGORY	**% of transect**	**% of transect**	**% of transect**	**% of transect**	**Mean**	**Std. Dev**	**Std. Error**
Coral	5.85	5.15	5.30	11.70	7.00	3.15	1.57
Gorgonians	1.80	3.30	2.60	6.00	3.43	1.82	0.91
Sponges	10.05	11.55	17.20	12.15	12.74	3.10	1.55
Zoanthids	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macro algae	17.55	4.95	8.80	39.45	17.69	15.44	7.72
Turf algae / cyanobacteria	35.20	9.00	12.05	3.15	14.85	14.06	7.03
Dead coral	0.10	12.20	11.90	17.40	10.40	7.32	3.66
Coralline algae	0.00	0.90	0.00	5.75	1.66	2.76	1.38
Diseased corals	0.00	0.15	0.05	0.00	0.05	0.07	0.04
Sand, pavement, rubble	29.45	52.80	42.10	4.40	32.19	20.84	10.42
Sum	100.00	100.00	100.00	100.00			
depth m	16.2	13.70	12.20	31.6			

Appendix 3 - Summary of Benthic Habitat Analysis: Coral Species

Table A2-3.1 - Mean percent cover of coral species (±SE) (N=5) in the COLI habitat. Species are listed in order of abundance.

	Mean % Cover	**SE**
Montastrea annularis	2.71	0.84
Porites astreoides	1.24	1.21
Montastrea cavernosa	1.14	0.73
Millepora alcicornis	0.75	0.52
Siderastrea siderea	0.48	0.33
Porites porites	0.23	0.16
Meandrina meandrites	0.16	0.09
Acropora cervicornis	0.14	0.09
Agaricia agaricites	0.06	0.05
Colpophyllia natans	0.06	0.04
Eusimilia fastigiata	0.05	0.03
Diploria strigosa	0.03	0.02
Madracis mirabilis	0.02	0.02
Stephanocoenia michelini	0.02	0.02
Diploria labyrinthiformis	0.01	0.01
Porites divaricata	0.01	0.01
Scolymia cubensis	0.01	0.01

Table A2-3.2 - Mean percent cover of gorgonian genera (±SE) (N=5) in the COLI habitat. Genera are listed in order of abundance.

	Mean % Cover	**SE**
Pseudopterogorgia	1.59	0.41
Muricea	0.60	0.14
Eunicea	0.34	0.24
Plexaurella	0.27	0.15
Pseudoplexaura	0.18	0.03
Gorgonian	0.10	0.10
Briareum	0.02	0.02
Pterogorgia	0.02	0.02
Plexaura	0.01	0.01

Table A2-3.3 - Mean percent cover of algal genera (±SE) (N=5 in the COLI habitat. Genera are listed in order of abundance.

	Mean % Cover	**SE**
Lobophora	21.63	1.76
Wrangelia	1.72	1.72
Dictyota	0.79	0.21
Halimeda	0.26	0.07
Amphiroa	0.02	0.01
Sargassum	0.02	0.02

Table A2-3.4 - Mean percent cover of coral species (±SE) (N=4) in the GOPL habitat. Species are listed in order of abundance.

	Mean % Cover	**SE**
Montastrea annularis	8.75	3.26
Millepora alcicornis	4.40	1.23
Siderastrea siderea	3.90	1.22
Montastrea cavernosa	3.00	1.44
Montastrea faveolata	2.70	2.40
Porites astreoides	2.25	1.23
Meandrina meandrites	0.75	0.57
Agaricia agaricites	0.60	0.49
Diploria strigosa	0.55	0.55
Porites porites	0.15	0.15
Colpophyllia natans	0.15	0.06
Mycetophyllia danaana	0.15	0.15
Mycetophyllia ferox	0.15	0.15
Porites divaricata	0.15	0.10
Dichocoenia stokesii	0.10	0.10
Madracis mirabilis	0.10	0.06
Colpophyllia natans	0.05	0.05
Diploria clivosa	0.05	0.05
Stephanocoenia michelini	0.05	0.05

Table A2-3.5 - Mean percent cover of gorgonian genera (+SE) (N=4) in the GOPL habitat. Genera are listed in order of abundance.

	Mean % Cover	**SE**
Pseudopterogorgia	1.43	0.61
Plexaurella	1.38	0.51
Eunicea	0.25	0.15
Gorgonian	0.14	0.14
Muricea	0.14	0.08
Pseudoplexaura	0.08	0.06
Briareum	0.01	0.01
Pterogorgia	0.01	0.01

Table A2-3.6 - Mean percent cover of coral species (+SE) (N=4) in the ALIN habitat. Species are listed in order of abundance.

	Mean % Cover	**SE**
Siderastrea siderea	0.96	0.35
Montastrea cavernosa	0.34	0.19
Millepora alcicornis	0.31	0.10
Montastrea annularis	0.21	0.16
Porites astreoides	0.13	0.08
Stephanocoenia michelini	0.10	0.05
Meandrina meandrites	0.05	0.04
Diploria labyrinthiformis	0.03	0.02
Porites divaricata	0.03	0.03
Porites porites	0.03	0.03
Eusimilia fastigiata	0.01	0.01

Table A2-3.7 - Mean percent cover of algal genera (+SE) (N=4) in the ALIN habitat. Genera are listed in order of abundance.

	Mean % Cover	SE
Sargassum	11.74	1.83
Lobophora	6.68	1.47
Dictyota	4.41	0.88
Amphiroa	0.74	0.07
Halimeda	0.09	0.04
Padina	0.03	0.03
Schizothrix	0.03	0.02

Table A2-3.8 - Mean percent cover of coral species (+SE) (N=4) in the SAIN habitat. Species are listed in order of abundance.

	Mean % Cover	SE
Siderastrea siderea	0.68	0.24
Millepora alcicornis	0.54	0.18
Montastrea cavernosa	0.45	0.32
Porites astreoides	0.14	0.07
Montastrea annularis	0.10	0.09
Meandrina meandrites	0.09	0.08
Colpophyllia natans	0.08	0.05
Diploria labyrinthiformis	0.05	0.05
Colpophyllia natans	0.04	0.02
Dichocoenia stokesii	0.03	0.02
Diploria strigosa	0.03	0.03
Madracis mirabilis	0.03	0.03
Porites porites	0.03	0.03
Eusimilia fastigiata	0.01	0.01
Millepora squarrosa	0.01	0.01
Scolymia cubensis	0.01	0.01
Stephanocoenia michelini	0.01	0.01

Table A2-3.9 - Mean percent cover of algal genera (±SE) (N=4) in the SAIN. Genera are listed in order of abundance.

	Mean % Cover	**SE**
Dictyota	10.98	1.19
Lobophora	7.16	1.60
Wrangelia	3.66	2.20
Turbinaria	0.13	0.05
Sargassum	0.11	0.09
Halimeda	0.11	0.07
Liagora	0.01	0.01
Schizothrix	0.01	0.01

CHAPTER 3

Habitat Focused Fish Surveys in the Mutton Snapper Seasonal Closed Area

INTRODUCTION

The Mutton Snapper Seasonal Closed Area (MSSCA) was initially created to protect a *Lutjanus analis* (mutton snapper) spawning aggregation during the known spawning season by prohibiting fishing in the MSSCA for four months of the year (March 1 - June 30). Subsequently, with the approval of the SFA Amendment (CFMC and NMFS 2005), which amended the Spiny Lobster and Reef Fish Fishery Management Plans in 2005, all bottom tended gear, including bottom long lines, gill and trammel nets, and pots or traps, was prohibited on coral or hard bottom habitat within the MSSCA year round (50 CFR 622.33). The latter regulatory provision was adopted to protect essential fish habitat (EFH). EFH is defined in the Magnuson-Stevens Act as "those waters and substrate necessary for spawning, breeding, feeding or growth to maturity" (CFMC 1998). The MSSCA met the criteria for EFH because it was presumed to contain habitat necessary for the spawning and breeding of the mutton snapper (*Lutjanus analis*) and, likely, other species of fish as well.

In order to characterize the distribution and abundance of fish species within the habitats identified by Prada (2003) in the MSSCA, roving fish and fish transect surveys were conducted in each habitat. Also, the presence and life stage (juvenile, subadult and adult) of mutton snapper were recorded.

MATERIALS AND METHODS

Fish surveys were conducted in eight of the nine the benthic habitats identified by Prada (2003). One habitat, COPA (Coral Patch), comprising < 5 ha total area within the MSSCA could not be uniquely identified. Chapter 2 of this study characterizes these habitats. Habitat was identified using Prada's habitat maps created in Arc View GIS. Latitude and longitude coordinates for specific habitat sites identified by the authors were provided by Jeremiah Blondeau of the University of the Virgin Islands using Prada habitat map database and Arc View GIS. The number of sites surveyed in each habitat was a function of the abundance of that habitat within the MSSCA (see Chapter 2 of this study).

To ensure that divers were conducting fish surveys in the identified habitat, a Garmin WAAS enabled GPSmap 76Cx was used to locate habitats based on habitat locations on Prada's habitat maps and coordinates provided by Blondeau. When the specified coordinates were located using the GPS, a weight with dive flag attached to a rope was dropped from the boat to mark the habitat. Roving fish surveys and fish transect surveys were all carried out in the vicinity of the marked area. Most surveys were carried out in the morning between 7:00 and 11:00 am in June and July 2009. A few surveys were conducted in 2010 during May and June in mid-afternoon from about 2:30 - 5:00 pm.

Note: Common names for fish in the following text, tables and appendices are based on Humann (undated).

Fish and Caribbean Spiny Lobster and Queen Conch Transects

At each site, a total of five 20m transects were laid haphazardly on the substrate within the habitat to record benthos (see Chapter 2) and fish populations within specific habitat types. A total area of $400m^2$ was surveyed for fish at each site. One to four sites were surveyed for each habitat type. More sites were surveyed in habitats comprising more of the area of the MSSCA. All fish two meters each side of each transect were identified to species and numbers of individuals counted. The recording diver stopped every five meters along the transect line and recorded the fish observed. Most blennies, gobies, and other very small fish were not recorded. Most of these species are cryptic and it would have been time consuming and difficult to accurately count them. Fish census surveys were primarily conducted by Dr. Barbara Kojis.

Counts of *Acanthurus bahianus* (ocean surgeonfish) and *A. chirurgus* (doctorfish) in both transects and roving fish surveys (see below) were combined because the two species are primarily distinguished underwater by the presence of body bars in *A. chirurgus*. However, these bars can be "quite faint" according to Humann (undated). Acanthurids with bars were seldom seen during transects. Because *A. chirurgus* is commonly seen in fishers catches (*A. chirugus* body bars were clearly seen in dead surgeonfish in fisher's coolers), we suspected that *A. chirurgus* was not being accurately counted underwater.

Lobsters (*Panulirus argus*) were also recorded in transects. Lobsters are found under ledges and in crevasses. They can be difficult to find unless a concerted effort is made to look in every crack and crevasse. Given the limited bottom time, especially in deeper sites, and the large number holes in COLI (Coral Limestone - deepwater coral reef habitat), *P. argus* presence and abundance in most habitats is likely under-represented in this study.

Roving Fish Censuses

At each site, one to three roving fish counts were conducted for 15 minutes. When more than one fish count was conducted at a site, they were usually done on different days. Divers swam in a slow steady fashion around an imaginary outer circumference of the study site and in the vicinity of the site marker, recording species and number of fish observed. Divers were instructed to record fishes within the marked habitat. However, this was difficult for habitat characterized by small sand patches such as SARI (see Chapter 2) or sand channels surrounded by COLI and GOPL habitats (see Chapter 2) and bisected by limestone/coral "bridges", which served as super highways for fish, e.g. SANR habitat. Divers were also instructed not to count small species in the roving fish censuses, (i.e. blennies, gobies, pomacentrids, small species of pufferfish, and all wrasses except the three larger wrasses listed in the CFMC reef fish FMP: puddingwife (*Halichoeres radiatus*), hogfish (L*achnolaimus maximus*) and Spanish hogfish (*Bodianus rufus*). When schools of fish were encountered, the number of fish in the school was estimated.

Roving fish censuses were conducted primarily by Liam Carr, Texas A&M University, and Gerson Martinez, commercial fisher, St. Croix.

Fish Biodiversity

Habitat biodiversity was compared using the Shannon Diversity Index (H'). H' takes into account the number of species and the evenness (relative abundance) of the species. Values increase when there are more unique species or the numbers of individuals of each species are similar (greater evenness).

RESULTS

A total of 132 species (not including species only identified to family or genus unless it was clear that the species was unique, e.g. only species recorded in family or genus) and 24,225 individual fish were recorded (Tables A3-1.1 and A3.1.2) . Of these 21,564 individual fish were included in analyses (see Materials and Methods for rationale): 107 species and 13,417 individuals (Table 3.1) in benthic transects and 87 species and 8,147 individuals in roving fish surveys (Table 3.2). Most of the species removed from the analyses were species inconsistently recorded in the roving fish survey (small wrasses, damselfish, etc.) and, therefore, omitted so that comparisons could be more accurately made between habitats. The mean number of species per site and individuals 100m^{-2} in each habitat for the benthic transect method ranged from 16 - 31.6 and 42 - 176.9, respectively (Table 3.1). Only one lionfish (*Pterois volitans*) was observed (in July 2010) in the MSSCA in over 250 diver hours from April 2009 to July 2010.

In the transect surveys Coral Limestone (COLI) and Gorgonian Plain (GOPL) had the most species and individuals in the benthic transect surveys with an average of 31.6 and 26.5 species per site and 176.9 and 170.4 individuals 100m^{-2} (Table 3.1), respectively. Sand Ripple (SARI) had the fewest species and individuals 100m^{-2}. Dense Algae (DEAL - hard bottom with some sand) had the greatest biodiversity (H') and SAIN (Sand with Invertebrates - hard bottom with some sand) had the least. The Coral Patch (COPA) habitat identified by Prada (2003) was not recognized *in situ* (see Chapter 2) and will not be considered in the subsequent analysis.

Table 3.1. Summary of fish transect data in the Mutton Snapper Seasonal Closed Area. Prada (2003) habitat types in column headers are described in Chapter 2.

	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL
Total # individuals	2406	3537	478	2726	2315	809	168	978
# individuals 100m^{-2}	150.4	176.9	59.8	170.4	144.7	50.6	42.0	122.3
Total # species	39	61	29	52	42	42	16	29
Mean # species site^{-1}	18.3	31.6	19.5	26.5	19.5	19.3	16	21
Shannon Diversity Index (H')	2.41	3.16	3.45	3.11	2.20	3.26	2.40	2.95
# Lobster	1	2	0	0	0	0	0	0
Number of sites surveyed	4	5	2	4	4	4	1	2

In the roving fish surveys (Table 3.2), DEAL had the highest mean number of individuals recorded, owing to two schools of scads recorded by surveyors. COLI had the highest mean number of species and biodiversity (H') (Table 3.2). SANR had the lowest mean number of individuals and the second lowest number of species after ALIN. SANR is primarily a sand habitat with coral rubble around its periphery. ALIN is a flat, pavement habitat with algae and scattered macro-invertebrates.

Lobsters were very rare and were only present in Algae Invertebrates (ALIN) and Coral Limestone (COLI) (Table 3.1). However, as noted above, lobsters are cryptic and the focus of the surveys was fish species. Intensive searches in cracks and crevasses (lobster habitat) were not conducted. It is likely that lobsters, especially juvenile lobsters, are present in the hard bottom habitats (DEAL, GOPL, SARI, SPAL), which have cracks, crevasses, and ledges, preferred by juvenile and adult lobsters, as well as sponges and algae covered coral heads preferred by newly settled lobsters.

Table 3.2. Summary of roving fish surveys in the Mutton Snapper Seasonal Closed Area. Prada (2003) habitat types in column headers are described in Chapter 2.

	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL
Total # individuals	1233	1489	1064	1302	1028	820	200	1011
Mean # individuals survey^{-1} (SD)	176.10 (119.08)	186.61 (52.64)	354.67 (288.70)	217.00 (145.77)	205.6 (97.88)	102.50 (60.08)	200.0	252.75 (271.22)
Total # species	34	57	29	43	38	43	17	27
Mean # species survey $^{-1}$ (SD)	12.28 (3.20)	23.0 (3.2)	18.67 (2.52)	17.83 (5.42)	17.80 (4.97)	14.50 (3.29)	17	12.75 (4.57)
# roving surveys	7	8	3	6	5	8	1	4
Shannon Diversity Index (H')	3.20	4.19	3.53	3.71	3.65	3.79	3.05	2.46

Habitat Overview

Using the Agglomerative Hierarchical Clustering (XLSTAT 2010) analysis of the fish species recorded in transects by habitat (fish abundance was standardized by 100m^{-2} and only species comprising >1% of total were included), we correlated the fish with habitats using Pearson correlation coefficients and then agglomerated the habitats using weighted pair-group averages, which resulted in the clusters shown in Figure 3.1. At the 0.80 similarity level there are three major clusters. The first cluster is coral reef on consolidated sediments (COLI, GOPL) characterized primarily by the presence or absence of parrotfishes: princess, striped and stoplight; the black durgon; French grunt; blackbar soldierfish; and blue chromis. The second cluster is comprised of ALIN, SPAL and SAIN, which were flat pavement habitats (SAV on consolidated sediments), are characterized primarily by the yellowhead wrasse, spotted goatfish, bridled goby, slippery dick, bicolor damselfish, queen triggerfish, sand tilefish, and yellowhead jawfish. SANR, DEAL and SARI, the third cluster comprise two unconsolidated sediment habitats (SANR and SARI) and DEAL, which is more of a consolidated sediment habitat but has pockets of deep sand. Fish characterizing these habitats primarily include the bluehead wrasse, coney, longspine squirrelfish, squirrelfish, three species of surgeonfish, brown chromis, banded butterfly fish, redband parrotfish, foureye butterfly fish and rock beauty.

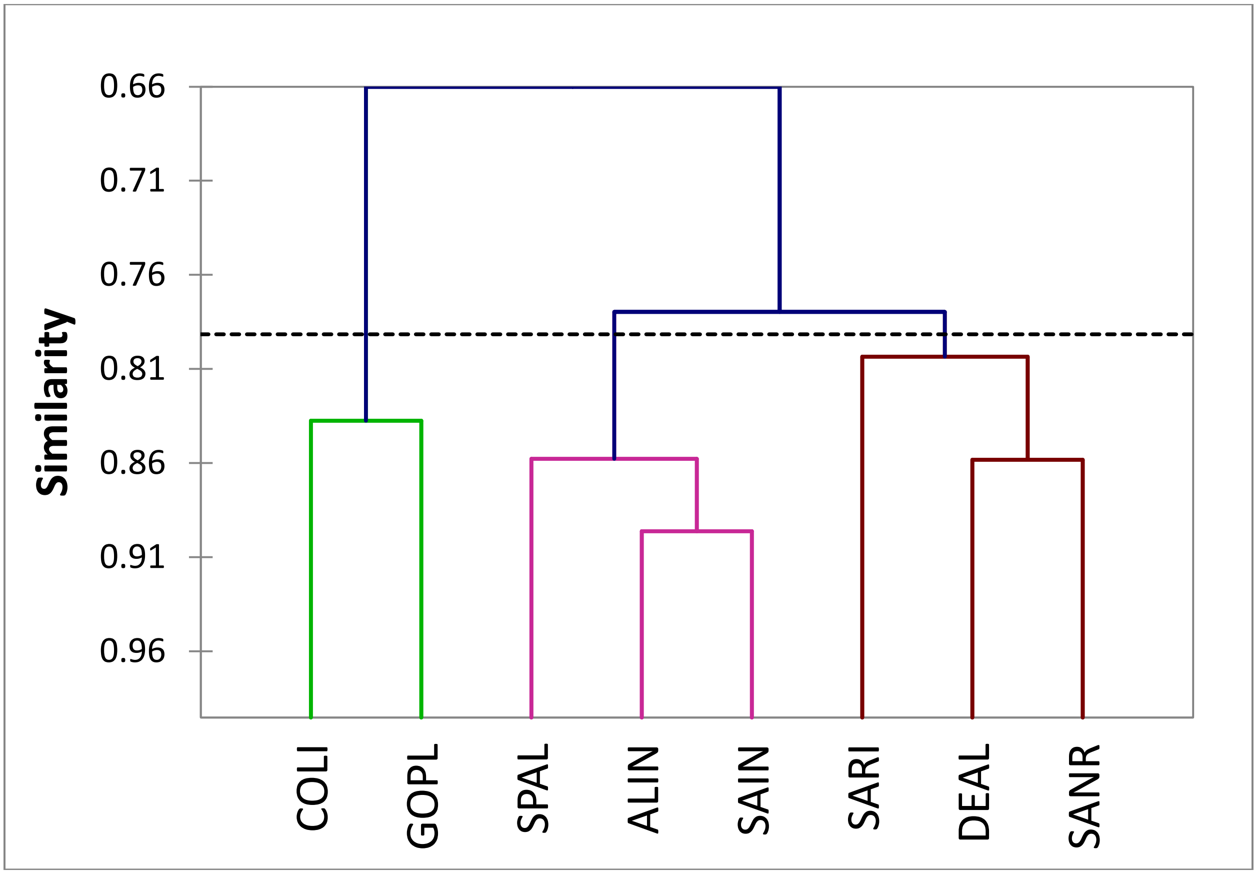


Figure 3.1. Dendrogram of habitats using Agglomerative Hierarchical Clustering (XLSTAT 2010). Pearson correlation coefficients were used to correlate fish species distribution and abundance with habitat and habitats were agglomerated using weighted pair-group averages. The dotted line divides the habitats into three major clusters at 0.80 similarity.

Habitat Summaries

ALIN - Algae Invertebrates

ALIN is a hard bottom habitat with sponges and small to medium sized coral heads, which are mostly dead and covered in macroalgae and small sessile invertebrates, and some gorgonians. Crevasses and shallow solution holes partially filled with sand and coral rubble were distributed throughout the habitat and, along with the larger invertebrates, provide shelter for small and medium sized fish.

Fish Surveys – Transects

A variety of small wrasses, pomacentrids, and serranids were recorded in transects in ALIN habitat (Appendices Chapter 3 (A3) Table A3-1.1). Two species, *Thalassoma bifasciatum* (bluehead wrasse) and *Eupomacentrus partitus* (bicolor damsel fish), comprised a total of 75.4% of the fish recorded in this habitat using transect methodology (Table A3-2.1). Only a few species targeted by fishers were recorded in transects in this habitat. These were primarily grazers (ocean/doctor surgeonfish (comprising 1.9% of individuals recorded), redband parrotfish) (0.7%), princess parrotfish (0.2%), redtail parrotfish (<0.1%), yellowtail parrotfish (<0.1%)), the longspine squirrelfish (1.9%), and a pelagic baitfish, the round scad, locally known as "round robin" (4.2%). Only two predator species targeted by fishers, the coney (0.8%) and barracuda (<0.1%) were recorded.

Roving Fish Census

A total of 32 species and 1,234 individuals were recorded in the four sites surveyed (Table A3-2.2). The schooling *Decapterus punctatus* (25.1% of individuals recorded) was the most abundant fish observed in the roving censuses (Table A3-2.1). Doctor/ocean surgeon fish were the second most abundant species comprising 22% of individuals recorded. Twenty-three species targeted by fishers were recorded, including surgeonfish, parrotfish, angelfish, squirrelfish, queen triggerfish, barracuda, filefish, goatfish, and trunkfish. Eight species, seven of which were commercial fisheries species, comprised almost 90% of the individuals recorded. One large mutton snapper was recorded.

COLI - Coral Limestone

This habitat is comprised of primarily dead, algae covered coral forming spurs and groove reefs (see Chapter 2). These reefs were historically dominated by corals, particularly the *Montastrea annularis* species complex. The habitat was still structurally complex and had the highest mean number of fish species and individuals per $100m^{-2}$ in the transect surveys (Table 3.1) and the highest mean number of species and highest biodiversity (H') in the roving surveys (Table 3.2). Sixty-one species of fish were recorded in the transect surveys and 57 in the roving surveys.

Fish Surveys – Transects

Blue chromis (*Chromis cyanea),* (32.57%), bluehead wrasse (*Thalassoma bifasciatum)* (24.77%) and bicolor damselfish (*Eupomacentrus partitus*) (11.70%) comprised almost 70% the fish recorded in COLI transects (69.04%) (Table A3-2.3). The princess parrotfish (*Scarus taeniopterus*) was the most abundant commercial species (6.33% of total). Nine species, of which three were commercial species, comprised almost 90% of the individuals recorded.

Roving Fish Census

The black durgon (*Melichthys niger*) (16.52%), princess parrotfish (*Scarus taeniopterus*) (16.45%) and ocean/doctor surgeonfish (*Acanthurus chirurgus/bahianus*) were the most abundant fish in the roving census, comprising 44.53% of the total (Table A3-2.4) Seventeen species made up almost 90% of the individuals recorded, At least 14 of which are marketable fish on St. Croix. Among the species comprising the 90% were two groupers, the small coney

(*Cephalopholis fulvus* - 3.63% of individuals recorded) and graysby (*Epinephelus cruentatus* - 1.81%), and one snapper, the mahogany snapper (*Lutjanus mahogoni* - 1.75%). Two mutton snapper (*L. analis*) were recorded comprising 0.13% of fish recorded in a total of 8 roving surveys conducted in this habitat.

DEAL - Dense Algae

DEAL is a hard bottom habitat with primarily a thin layer of sand with macroalgae and scattered invertebrates. It has deeper, coral rubble filled, sand pockets in depressions scattered throughout the habitat. The larger invertebrates (coral heads, sponges, and gorgonians), crevasses, ledges and depressions provide habitat for small fish and limited habitat for larger species.

Fish Surveys – Transects

Nine species made up 90% of the fish recorded (Table A3-2.5) in this habitat. Only two were marketable fish: *Caranx ruber* and the baitfish *Decapterus punctatus* comprising 10.67% and 10.46% of the recorded fish, respectively. The ubiquitous bicolor damselfish was the most abundant comprising 27.82% of fish recorded. The sand burrowing yellowhead jawfish, *Opistognathus aurifrons* was the second most abundant species comprising 15.27%. Its high relative abundance indicated that this habitat had extensive areas of deeper sand, even though it is primarily a hard bottom habitat. DEAL had the highest biodiversity (H' = 3.45) (Tables 3.1 and A3-2.5).

Roving Fish Census

The French grunt, *Haemulon flavolineatum* (20.43%), black durgon, *Melichthys niger* (19.77%), doctor/ocean surgeonfish, *Acanthurus chirurgus/bahianus* (15.63%), and coney, *Cephalopholis fulvus* (7.06%), comprised 62.90% of the fish recorded (Table A3-2.6). A total of 25 commercially marketable species were recorded, including seven species of parrotfish, which comprised 10.44% of the fish recorded (Table A3-2.6).

GOPL - Gorgonian Plain

Fish Surveys – Transects

The ubiquitous bluehead wrasse, *Thalassoma bifasciatum*, and bicolor damselfish, *Eupomacentrus partitus*, comprised more than half the fish recorded in the benthic transects in the GOPL habitat (Table A3-2.7). Ten species comprised nearly 90% of the individuals recorded. Of these three were species that are commercially caught on St. Croix: doctor/ocean surgeonfish, *Acanthurus chirurgus/bahianus* (5.10% of individuals recorded); princess parrotfish, *Scarus taeniopterus* (3.74%); and coney, *Cephalopholis fulvus* (1.39%).

Roving Fish Census

Acanthurus chirurgus/bahianus was the most abundant fish (25.04% of individuals recorded) of the 43 species recorded in the six roving surveys in GOPL (Table A3-2.8). The black durgon, *Melichthys niger* (19.82%), and the coney, *Cephalopholis fulvus* (7.3%), were the next most abundance species. These three species comprise more than half the individual fish counted.

Twelve species make up nearly 90% of individual fish counted and include ten commercially harvested species.

SAIN - Sand Invertebrates

SAIN is flat, hard bottom habitat with a layer of sand and algae with scattered invertebrates (live and dead coral heads, sponges, and a few gorgonians). This habitat does not support large numbers of commercial fisheries species.

Fish Surveys – Transects

Thalassoma bifasciatum (56.72%) was overwhelmingly the most abundant fish in these surveys. *Eupomacentrus partitus* (23.11%) was next most abundant and together with *T. bifasciatum* comprised 79.83% of the benthic survey total (Table A3-2.9).

Roving Fish Census

A total of 809 individuals and 42 species were observed in the roving survey (Table A3-2.10). The ocean/doctor surgeonfish, *Acanthurus chirurgus/bahianus* (31.23%),, black durgon, *Melichthys niger* (13.13%), French grunt, *Haemulon flavolineatum* (9.73%) comprised more than 50% of individuals counted in the roving fish censuses. Fourteen species comprised almost 90% of the individual fish recorded and included ten commercially important species (two of the smaller parrotfish species, three species of surgeonfish, the French grunt, the queen triggerfish, and two species of squirrelfish).

SANR - Sand No Ripple

SANR habitat is positioned between GOPL and COLI habitats. It is a deep sand habitat with coral rubble on its margins. Sand dwelling fish and small fish sheltering in and around coral rubble are the main resident species. Individuals and schools of larger species live on the periphery of the habitat, migrate along the edges of the habitat, and cross the habitat primarily where "bridges" of coral bisect the habitat.

Fish Surveys – Transects

The bluehead wrasse, *Thalassoma bifasciatum* (30.53%) and *Eupomacentrus partitus* (25.09%) comprised more than 50% of the individual fish recorded (Table A3-2.11). Ten species comprised nearly 90% of the individual fish recorded. Small wrasses, damselfish, jawfish, and gobies comprising nearly 83% of individual fish in the top ten species.

Roving Fish Census

Roving divers generally recorded and counted fish species not only in SANR habitat but also those that were associated with adjacent habitats (usually COLI and/or GOPL). In one case, the SANR sand channel was crossed by a raised carbonate "bridge" with corals, sponges, and gorgonians. These bridges are used as highways by fish (Gerson Martinez, pers. com.). Smaller fish, e.g. parrotfish, are known by fishers to avoid swimming over sand channels (SANR) to move from one habitat to the next or to migrate on to the shelf during the day and off the shelf at night. The diver recorded the fish streaming over the bridge.

The ocean/doctor surgeonfish, *Acanthurus chirurgus/bahianus* (30.37%), coney, *Cephalopholis fulvus* (9.51), and scad, *Decapterus* sp. (8.54%), all commercially marketable fish, were the most abundant fish in the roving fish censuses, comprising 48.41% of the 820 individuals recorded (Table A3-2.12).

SARI - Sand Ripple

This is a minor habitat in the MSSCA comprising only 0.4 ha. It is a shallow water (13 - 15m depth) SANR type of habitat with sand channels lying between low rises of GOPL habitat, almost like the grooves of an old spur and groove reef system. The relative shallowness of the habitat means that it is more susceptible to wave action than SANR resulting in sand ripples when seas are heavy. Coral rubble, primarily dead branches of *Acropora cervicornis*, are scattered on the sand within the habitat.

Fish Surveys – Transects

When SARI habitat and fish populations were surveyed using transects, only one or two transects could be conducted in each SARI "groove" because of the limited size of the SARI habitat at the site surveyed. *Thalassoma bifasciatum* (53.57%), *Eupomacentrus partitus* (14.29%) and *Opistognathus aurifrons* (10.71%) comprised 78.57% of the 168 individuals in these surveys (Table A3-2.13). Eight commercially marketed species were recorded, but they comprised a total of only 22 of the total individuals recorded. This site had a low biodiversity (H' - 2.40) and lowest number of individuals $100m^{-2}$.

Roving Fish Census

Only one roving fish census was conducted in this habitat. Because of the small size of the SARI habitat patches, divers inevitably incorporated fish inhabiting both SARI and the adjacent low-rise GOPL habitat in their censuses. *Acanthurus chirurgus/bahianus* (27.50%), *Melichthys niger* (25.50%) and *Holocentrus* sp. (9.50%) collectively comprised 62.50% of the roving fish census (Table A3-2.14). This was the least diverse habitat with Shannon Diversity Index of 3.05 (Tables 3.2 and A3-2.14) with only seven species comprising almost 90% of the individual fish recorded.

SPAL - Sparse Algae

SPAL is a hard bottom habitat with a thin covering of sand and algae. Like the other hard bottom habitats in the MSSCA it contains cracks, crevasses and depressions and widely scattered invertebrates (dead and live coral heads and sponges), which provide habitat, primarily for small species of fish and the juveniles of some larger species.

Fish Surveys – Transects

Eight species comprised just over 90% of individual fish recorded. Six of these were small parrotfish, wrasses and damselfish (Table A3-2.15). The other two species were the doctor/ocean surgeon (*Acanthurus chirurgus/bahianus*) and the redband parrotfish (*Sparisoma* *aurofrenatum*), which together comprised 6.54% of fish recorded. A total of eight of 29 species recorded, were commercially marketable species.

Roving Fish Census

Six species, all commercially marketable, comprised 90.77% of the individual fish recorded in this habitat (Table A3-2.16). The round scad, *Decapterus punctatus)* comprised 54.40% of individuals recorded. The other five species included three acanthurid species (two are combined in this study), the longspine squrrelfish, *H. rufus*, (10.68%), the French grunt, *H. flavolineatum*, (12.96%) and the redband parrotfish, *S. aurofrenatum* (3.26%). A total of twenty-two marketable species were recorded in this habitat.

Population Abundance of Marketable Fish

Marketable fish (MF) is defined in this study as fish commonly recognized as commercially saleable fish on St. Croix, U.S. Virgin Islands. Determination of MF was obtained from a list of port samples (McCarthy and Gedamke, 2009), a list of fishes retained in bycatch studies carried out by MRAG on St. Croix (Anon. 2009), and from discussions with St. Croix fishers (Martinez and Dailey pers. com.) (Table 3.3). Species that can be consumed, i.e. small pomacentrids and chaetodons, have been excluded from the analysis because they are not considered marketable because of their small size. Black durgon were omitted because the meat is considered tough and this species is seldom marketed. Creole-fish (*Paranthias furcifer*), Saragassum triggerfish (*Xanthichthys ringens*) and sand tile fish (*Malacanthus plumieri*) were also omitted because they are not commonly targeted on St. Croix.

The estimated relative abundance of the MF species in each family was calculated for each habitat using the benthic transect data (Table 3.4). Species in the five families, Acanthuridae (surgeonfishes) (30.88% - three MF), Carangidae (jacks and scads, 19.39% - four MF), Holocentridae (squirrelfishes) (17.20% - three MF), Scaridae (parrotfishes) (18.59% - seven MF), and Serranidae (7.72% - five MF).had the greatest estimated relative abundance totaling 93.79% of the MF families (Tables 3.3 and 3.5). The high relative abundance of groupers was a function of the high abundance of the coney (*Cephalopholis fulvus*) in most habitats. Lutjanids (six MF species - including *Lutjanus analis*) were not common and comprised only 0.13% of the MF species in the MSSCA (Table 3.5).

Fish were relatively more abundant (ratio of % fish to % habitat: >1) in rugose habitats (COLI and GOPL) than in the less rugose hard bottom and sand habitats (Table 3.5). The relative proportion of fish in most of the flat, hard bottom habitats was 0.74 - 0.94 (ALIN, DEAL, SAIN, and SPAL). The two unconsolidated sediment habitats (SANR and SARI) had relatively few fish (ratio of fish to habitat $\leq$0.33).

Table 3.3: List of the species recorded in this study that are marketable fish species on St. Croix. The determination of marketable species on St. Croix was based on advice of St. Croix fishers Gerson Martinez and Tom Daley, a list of species caught and retained by fishers on St. Croix (Table 14 in Anon. 2009) and a list of fishes with $\geq$300 individuals recorded from commercial port samples taken on St. Croix (McCarthy and Gedamke 2009).

Family	Scientific Name	Common Name	CFMC FMP Unit[1]
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	Surgeonfishes Unit
Acanthuridae	*Acanthurus bahianus and A. chirurgus*	Surgeon - Doctor and Ocean	Surgeonfishes Unit
Balistidae	*Balistes vetula*	Queen triggerfish[2]	Triggerfishes Unit
Balistidae	*Canthidermis sufflamen*	Ocean triggerfish	Triggerfishes Unit
Carangidae	*Caranx crysos*	Blue runner	Jacks Unit
Carangidae	*Caranx ruber*	Bar jack[3]	Jacks Unit
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	
Carangidae	*Decapterus sp.*	Scad	
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish	
Haemulidae	*Anisotremus virginicus*	Porkfish	Grunts Unit
Haemulidae	*Haemulon carbonarium*	Caesar grunt	Grunts Unit
Haemulidae	*Haemulon aurolineatum*	Tomtate	Grunts Unit[4]
Haemulidae	*Haemulon flavolineatum*	French grunt	Grunts Unit
Haemulidae	*Haemulon plumieri*	White grunt	Grunts Unit
Haemulidae	*Haemulon sciurus*	Bluestriped grunt	Grunts Unit
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	Squirrelfishes Unit
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	Squirrelfishes Unit
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish[2]	Squirrelfishes Unit
Labridae	*Bodianus rufus*	Spanish hogfish[2]	Wrasses Unit
Labridae	*Halichoeres radiatus*	Puddingwife (doesn't sell well)	Wrasses Unit
Lutjanidae	*Lutjanus analis*	Mutton snapper[2]	Snapper Unit 3
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper[2]	Snapper Unit 3
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper[2]	Snapper Unit 3
Lutjanidae	*Lutjanus synagris*	Lane snapper	Snapper Unit 3
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	Snapper Unit 4
Lutjanidae	*Rhomboplites aurorubens*	Vermillion snapper	Snapper Unit 1
Monacanthidae	*Aluterus scriptus*	Scrawled filefish[5]	Filefish Unit
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish[5]	Filefish Unit
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish[4,5]	

Family	Scientific Name	Common Name	CFMC FMP Unit[1]
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	Goatfish Unit
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	Goatfish Unit
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish	Boxfishes Unit
Ostraciidae	*Acanthstracion quadricornis*	Scrawled cowfish	Boxfishes Unit
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	Boxfishes Unit
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	Boxfishes Unit
Ostraciidae	*Lactrophrys trigonus*	Trunkfish	Boxfishes Unit
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	Angelfishes Unit
Pomacanthidae	*Holacanthus tricolor*	Rock Beauty[4]	Angelfishes Unit
Pomacanthidae	*Pomacanthus arcuatus*	Gray angelfish	Angelfishes Unit
Scaridae	*Scarus coeruleus*	Blue parrotfish	Parrotfishes proposed Unit 2
Scaridae	*Scarus taeniopterus*	Princess parrotfish	Parrotfishes proposed Unit 1
Scaridae	*Scarus vetula*	Queen parrotfish	Parrotfishes proposed Unit 1
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish[4]	Parrotfishes proposed Unit 1
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	Parrotfishes proposed Unit 1
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	Parrotfishes proposed Unit 1
Scaridae	*Sparisoma viride*	Stoplight parrotfish	Parrotfishes proposed Unit 1
Scombridae	*Scomberomorus maculatus*	Spanish mackerel	
Scombridae	*Scomberomorus regalis*	Cero	
Serranidae	*Cephalopholis fulvus*	Coney	Grouper Unit 3
Serranidae	*Epinephelus adscensionis*	Rock Hind	Grouper Unit 3
Serranidae	*Epinephelus cruentatus*	Graysby[4]	Grouper Unit 3
Serranidae	*Epinephelus guttatus*	Red hind	Grouper Unit 3
Sphyraenidae	*Sphyraena barracuda*	Great barracuda[3]	

[1] 50 CFR Part 622 - Table 2 of Appendix A to Part 622 - Caribbean Reef Fish - list of species of fish managed by the Caribbean Fishery Management Council.

[2] Frequent ciguatera poisoning occurs (Olsen 1988).

[3] High risk of ciguatera poisoning (Olsen 1988) though still fished and sold on St. Croix.

[4] Only large individuals marketable.

[5] Filefish are only occasionally sold. Customers are reticent to buy them because they consider them ugly fish. Sometimes fishers cut heads off to help sell fish.

[5] Species generally considered too small to sell but are commonly recorded in port samples.

Table 3.4: Number of individuals 100m^{-2} of marketable species in each commercially harvested family recorded in Mutton Snapper Seasonal Closed Area (MSSCA) habitats. See Table 3.3 for list of marketable species recorded in roving and transect fish surveys.

	ALIN	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**
Acanthuridae	2.88	4.75	0.88	10.38	7.75	1.06	1.75	4.13	33.58
Balistidae	0	0.05	0	0.31	0.13	0.19	0.25	0	0.93
Carangidae	6.31	0.10	12.63	0	0.06	0.19	0	0	19.29
Haemulidae	0	1.15	0	1.38	0	0	0	0	2.53
Holocentridae	3.25	2.85	0.63	2.50	2.75	1.19	1.00	2.13	16.3
Labridae	0.06	0.20	0	0.13	0.06	0.06	0	0	0.51
Lutjanidae	0	0.05	0	0.13	0	0	0	0	0.18
Monacathidae	0	0.35	0	0.19	0	0	0	0	0.54
Mullidae	0	1.2	0	0.6	0.38	0	0	0.5	2.68
Ostraciidae	0.063	0.1	0	0.25	0.06	0.13	0.25	0.13	0.983
Pomacanthidae	0.13	0.55	0	0.50	0.13	0.06	0	0.13	1.5
Scaridae	1.44	16.05	0.38	9.31	1.44	0.75	1.75	5.25	36.37
Serranidae	1.25	1.00	0.38	2.88	0.63	0.69	0.5	0	7.33
Sphyraenidae	0.06	0.15	0.13	0.06	0	0.06	0	0	0.46
Total fish 100m^{-2}	**15.44**	**28.55**	**15.03**	**28.62**	**13.39**	**4.38**	**5.50**	**12.27**	**123.18**

Table 3.5: Estimate of total number of marketable fish by family in the Mutton Snapper Seasonal Closed Area based on the number of fish 100m^{-2} and size of habitat. Table 3.3 lists the marketable species recorded in roving and transect surveys.

	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Percent of Total
Acanthuridae	98,294	9,643	246	106,810	126,248	5,109	70	5,617	352,037	30.88%
Balistidae	0	102	0	3,190	2,118	916	10	0	6,336	0.56%
Carangidae	215,360	203	3,536	0	977	916	0	0	220,992	19.39%
Haemulidae	0	2,335	0	14,200	0	0	0	0	16,535	1.45%
Holocentridae	110,923	5,786	176	25,725	44,798	5,736	40	2,897	196,081	17.20%
Labridae	2,048	406	0	1,338	977	289	0	0	5,058	0.44%
Lutjanidae	0	102	0	1,338	0	0	0	0	1,440	0.13%
Monacanthidae	0	711	0	1,955	0	0	0	0	2,666	0.23%
Mullidae	0	2,436	0	6,174	6,190	0	0	680	15,480	1.36%
Ostraciidae	2,150	203	0	2,573	977	627	10	177	6,717	0.59%
Pomacanthidae	4,437	1,117	0	5,145	2,118	289	0	177	13,282	1.17%
Scaridae	49,147	32,582	106	95,800	23,458	3,615	70	7,140	211,918	18.59%
Serranidae	42,663	2,030	106	29,635	10,263	3,326	20	0	88,043	7.72%
Sphyraenidae	2,048	305	36	617	0	289	0	0	3,295	0.29%
Total fish 100m^{-2}	527,070	57,957	4,208	294,500	218,123	21,112	220	16,687	1,139,881	100%
% Total fish	46.24%	5.08%	0.37%	25.84%	19.14%	1.85%	0.02%	1.46%	100%	
Habitat area (ha)	341.3	20.3	2.8	102.9	162.9	48.2	0.4	13.6	692.40	
% Total habitat	49.29%	2.93%	0.40%	14.86%	23.53%	6.96%	0.06%	1.96%	100%	
Relative fish abundance In proportion to habitat[1]	0.94	1.73	0.93	1.74	0.81	0.27	0.33	0.74		

[1]Ratio of % Total Fish to % Total habitat

DISCUSSION

Of the 132 species observed only eleven common species (occurrence >1%) were ubiquitous in the eight MSSCA habitats included in this analysis (Table A3-1.1). COLI and GOPL benthic transects had highest average number of species and individuals per site. These are the two habitats with the most rugosity.

The blue head wrasse (*Thalassoma bifasciatum*) and the bicolor damsel fish (*Eupomacentrus partitus*), recorded only in the transect surveys, were the most abundant fish and were ubiquitous throughout all the MSSCA habitats (Table A3-3.1). The numerical dominance of these two species is consistent with the findings of Garcia-Sais (2004), where they dominated the reef top habitat of Bajo de Sico (depth 25-30m). This was the shallowest habitat surveyed at Bajo de Sico. In this study, they were the 2nd and 3rd most abundant fish, respectively, in COLI (Coral Limestone) habitat of the MSSCA (depth 25 - 30m), the habitat most similar to the reef top at Bajo de Sico. Blue chromis (*Chromis cyanea*) was the most abundant species in COLI habitat and the sixth most abundant in the reef top habitat at Bajo de Sico. The blue chromis was uncommon on the wall, but the second most abundant species on the rhodolith reef at Bajo de Sico. Density of the bluehead wrasse and bicolor damselfish were much lower in COLI than the reef top at Bajo de Sico. Bluehead wrasse density was 43.8 $100m^{-2}$ at COLI and 148.3 $100m^{-2}$ at Bajo de Sico. Density of bicolor damselfish was 20.7 $100m^{-2}$ at COLI and 400 $100m^{-2}$ at the reef top at Bajo de Sico. In deeper habitats in Bajo de Sico such as the reef wall (30-40m) and the rhodolith reef (45-53m), the bluehead wrasse was less dominant, while still among the top five most abundant species, though its density fell off dramatically with depth (148.3 $100m^{-2}$ at 25-30m to 7.3 $100m^{-2}$ at 45-53m). The bicolor damselfish remained the first or second most abundant species in all habitats in Bajo de Sico with a density of 400 $100m^{-2}$ on the reef top (25-30m), 58.3 $100m^{-2}$ on the reef wall (30-40m) and 160 $100m^{-2}$ on the rhodolith reef (45-53m). All three species are planktivores and, along with other small species of wrasses (Labridae), gobies (Gobiidae), sea basses (Serranidae), and basslets (Grammatidae) provide an important food resource for juvenile and adult piscivorous and demersal predatory fish (Garcia-Sais, et al. 2004). Differences in abundance at these sites may relate to higher planktonic food availability at Bajo de Sico compared to COLI in the MSSCA and/or a higher number of predators at COLI. These hypotheses need to be tested.

Of the eleven ubiquitous species, six were marketable species: *Acanthurus chirurgus/bahianus*., *Cephalopholis fulvus*, *Holocentrus rufus*, *Haemulon flavolineatum*, *Mulloidichthys martinicus*, and *Scarus taeniopterus*. *Clepticus parrae* was the most habitat specific species of with >80 individuals, occurring only in COLI, and GOPL. The percentage of ubiquity for all species is given in Tables A3-1.1 and A3-1.2.

Commercially Harvested Fish Recorded in the MSSCA

Commercially harvested fish recorded in the MSSCA are discussed below in relation to their trophic level, their importance to the St. Croix commercial fishery, and their habitat distribution. Clavijo et al (1980), Randall (1967) and the Froese and Pauly (2007) were used to categorize fish families and species by general trophic level. Below we discuss selected families, including the most common, commercially important species recorded in transects and in port samples (McCarthy and Gedamke 2009). We assumed that the number of measured fish summed across all years and gears for St. Croix (McCarthy and Gedamke 2009) reflected their importance in the St. Croix fishery. We recognize that port sampling was not randomized among gears and fishers and that there have likely been changes in the relative abundance of species in catches over time, however, these data provide information on species that are important to the fishery.

Note: that while the percentage of marketable fish for each family is based only on the fish recorded in transects, the habitat distribution is based on both the roving fish census and transect techniques.

Carnivorous species

Eight families that are considered generalized carnivores or piscivorous species (Randall 1967) were recorded and were either commercially important, relatively common, and/or ecologically important because they are top predators. These eight families were the Carangidae (jacks), Holocentridae (squirrelfishes), Lutjanidae (snappers), Pomadasyidae (grunts), Rhincodontidae (nurse shark), Serranidae (groupers), Scombridae (mackerels), Sphyraenidae (barracuda).

Four species of Carangidae were recorded comprising 6.57% of commercially marketable fish. The schooling, *Decapterus punctatus* (the Round Scad) made up the 83% of the carangids recorded. This is an important baitfish on St. Croix which is sometimes eaten. Bar jacks were the only carangid recorded in port samples with >300 individuals sampled (McCarthy and Gedamke 2009). This species was present in all but one habitat (SARI) in this study but comprised only <0.05% of individuals recorded in transect and roving surveys.

The Holocentridae comprised 14.77% of the marketable fish recorded in transects. Squirrelfishes made up only 1.5% of species with >300 fish port sampled (McCarthy and Gedamke 2009). The longspine squirrelfish, *Holocentrus rufus*, was the most common holocentrid in this study, comprising 63.8% of squirrelfish recorded. It was also the most common squirrelfish in port samples (1.3%) (McCarthy and Gedamke 2009).

The Lutjanidae are considered generalized carnivores (Randall 1967) consuming fish, crabs, etc. and comprised only 1.46% of the marketable fish recorded in transects (Table 3.4). The most common snapper recorded was the mahogany snapper (*Lutjanus mahogoni*). Only 4 individuals (all adults) of the mutton snapper (*L. analis*) were recorded in two habitats in roving fish and transect surveys: ALIN and COLI (Table A3-1.2), though *L. analis* was observed in COLI and GOPL habitats during mutton snapper searches. No snappers were recorded in SANR, SARI or SPAL habitat.

A few nurse sharks (*Ginglymostoma cirratum*) were caught while fishing for mutton snapper and six individuals were recorded from two habitats, COLI and DEAL. This was the only species of shark recorded during this study during any of the activities. The paucity of other shark species is consistent with the findings of (Ward-Paige et al. 2010), who found that "contemporary sharks, other than nurse sharks, are largely absent on reefs in the greater-Caribbean," owing, primarily, to fishing pressure.

The Serranidae made up 6.34% of the commercially harvested species (Table 3.4). Four small to medium sized grouper species made up the marketable grouper. The largest of the 4 species, the rock hind, *Epinephelus adscensionis*, grows to 60 cm maximum total length and most commonly inhabits reefs at depths of 1 - 15 m (Clavijo et al., 1980), though it inhabits depths to 30 m (Humann, undated; Randall, 1967). It was recorded as common on St. Croix by Clavijo et al. (1980) in the 1970's and comprised 2.31% of the landings in the US Virgin Islands in the 1980's (Olsen, 1988). Only 4 individuals of this species in two habitats (COLI and SAIN) were recorded. However, depths sampled ranged from about 14m to 35m, outside the depth range where they are most commonly found.

The next largest species is the red hind, *E. guttatus* (45 cm max total length), which is a reef dwelling species that occurs in both shallow and deep water (Clavijo et al. 1980). A total of 33 individuals were recorded in six of the eight habitats surveyed. It comprised 8.71% of the landings in the US Virgin Islands in the 1980's (Olsen, 1988) and was common on St. Croix in the 1970's (Clavijo et al. 1980). This is a very desirable commercial species. The CFMC implemented a seasonal area closure on St. Croix to protect a spawning aggregation on Lang Bank in 1993 (CFMC 1993).

The coney, *Cephalopholis fulvus*, and graysby, *E. cruentatus*, both have a maximum size of 30 cm (Clavijo et al. 1980). Both were common on St. Croix in the 1970's (Clavijo et al. 1980), but only the coney is listed in the U.S. Virgin Islands' commercial landings >0.01% (Olsen, 1988) comprising 2.37% of the landings. It is reportedly more common on St. Croix than St. Thomas, comprising >6% of the landings on St. Croix vs <2% of landings on St. Thomas/St. John District between 1984 and 1989 (Beets et al. 1994). The differences in commercial landings between districts were thought to be a function of habitat and recruitment differences on the two shelves (Beets et al. 1994). When Beets et al. (1994) analyzed port sample data from 1984 - 1989, they found significant declines in mean length and the proportional representation of coneys in the total catch, providing evidence of a declining stock.

A more recent analysis of port samples from St. Croix found that the coney (locally known as the "butterfish" for its yellow hue) was the most common grouper in port samples and ranked sixth in total number of measured fish on St. Croix (McCarthy and Gedamke 2009). It also comprised 43.54% of the biomass (kg. of fish caught) recorded in SEAMAP catches in 1993/4 on St. Croix and 55.37% of biomass in 2002 (Whiteman 2005). It was also the only grouper with >300 records in port samples.

In this study, 80 graysby were recorded in six habitats and 749 coney in all eight habitats. The relatively high relative abundance of the Serranidae in samples was primarily a function of the ubiquitous presence and high abundance of the coney in the sampled habitats. The coney was also the most abundant grouper in transects at Bajo de Sico, Puerto Rico (Garcia-Sais 2004). Despite the high fishing pressure on coney, it clearly remains relatively abundant on St. Croix and in other parts of the Caribbean. Spear fishers on St. Croix tend to target only larger individuals of this species, which may protect spawning stock. Comparing density of coney in visual transects between this study and that of Chiappone et al. (2000), density of coney on hard bottom habitats in the MSSCA on St. Croix was similar to if not higher than sites surveyed by the latter. Density of coney (no. individuals $100m^{-2}$) ranged from 0.38 - 2.50 on St. Croix while density in the six sites surveyed by Chiappone et al. (2000) ranged from 0.1 in the heavily fished and highly managed Florida Keys to 1.3 in the lightly fished South Exumas, Bahamas.

Chiappone et al. (2000) indicated that coneys were not targeted at intensively fished sites. This contrasts with the intense fishing pressure on this species in the Virgin Islands. Further study of its fishery status, life history including reproduction, recruitment, and spawning behavior would provide important information as to why this species was so resilient on St. Croix in the face of high fishing pressure and would help in establishing annual catch limits for this species. How important is life history in comparison with release from predation pressure and habitat? One item to note is that no spawning aggregations have been reported for coney in the literature (Beets et al. 1994, Claro and Lindeman 2003). Fishers in the US Virgin Islands have not mentioned targeting spawning aggregations of this species. Both pair spawning (Colin et al. 1987 cited in Beets et al. 1994) and haremic spawning have been reported (Beets et al. 1994) for this species.

In general, grouper abundance decreased with the increasing maximum size of species; the largest of the 4 species, the rock hind, was only represented by four individuals. No large (>60 cm total length) grouper species were recorded in 135 dives in the MSSCA. Many of the larger grouper are primarily found in water deeper than surveyed in this study. However, Nassau (*E. striatus*) and goliath grouper (*E. itajara*) commonly inhabit the habitats and depths surveyed in this study (this includes roving fish censuses, transect surveys and mutton snapper searches within the MSSCA and to the west of the MSSCA) (Clavijo et al. 1980, Kojis pers. obs.). The goliath grouper was not reported in landings from the 1980's (Olsen, 1988). However, goliath grouper may have been harvested in low numbers because Olsen only reported on species that comprised at least 0.1% of total landings. In contrast to the goliath grouper, the Nassau grouper was a significant component of U.S. Virgin Islands landings in the 1980's comprising 2.25% of total landings (Olsen 1988). It was surprising that Nassau grouper were not observed in the MSSCA.

Two species of Sphyraenidae were recorded: the great barracuda (*Sphyraena barracuda*) and the southern sennet (S. *picudilla*). Great barracuda were found in seven of the nine habitat surveyed (Table A3.1), missing only in SAIN and SARI, and comprised only 0.25% of the marketable fish. A total of 40 great barracuda were recorded. At each site, usually one or two medium to large barracuda, an estimated 2- 2.5 m in length, hovered in the water column near the divers. The southern sennet was recorded only in COLI.

Herbivorous Fish

Two families of herbivores, Acanthuridae and Scaridae, made up a total of 62.48% of the marketable fish recorded in transects (Table 3.4). These two families make up a significant portion of the catch on St. Croix. The top three species in port samples on St. Croix were two parrotfish species (redtail and stoplight parrotfish) and the blue tang (McCarthy and Gedamke 2009). Other parrotfish measured >300 times were redband, princess, redfin, queen, and unidentified parrotfishes. Parrotfishes comprised 30.5% of fish port sampled >300 times on St.

Croix and acanthurids 16.6%., comprising a total of 47% of fish port sampled >300 times (McCarthy and Gedamke 2009).

Crucians have a preference for parrotfish or "bluefish". Not only do they enjoy eating parrotfish, especially red parrotfish (initial phase stoplight and redtail parrotfishes), but also they sell for less ($4/lb) than some of the other prized fish such as mutton snapper, which can sell for $6 - $8 per lb (pers. obs. - Kojis). Parrotfish are also largely caught as plate sized fish, the preferred eating size in the Virgin Islands. Mutton snapper and some other snappers are often caught at large sizes. Large fish are more expensive because of the poundage and don't meet the plate size requirement. While dolphinfish and other large pelagic fish are often cut into steaks and sold in portions, large snappers and groupers are usually sold whole making them expensive fish to buy. However, despite the cost mutton snapper is a prized food fish in the U.S. Caribbean.

Of the three large Caribbean parrotfish, midnight (*Scarus coelestinus*), rainbow (*S. guacamaia*) and blue (*S. coeruleus*) (maximum length 3 - 4 ft (Humann, undated)), only a two juvenile blue parrotfish was recorded. Olson (1988) reported species comprising $\geq$0.01 percent of landings in the U.S. Virgin Islands. While the midnight and rainbow parrotfish were not reported in landings by Olson (1988), the blue parrotfish comprised a significant portion of total landings (1.84%); more than any other parrotfish species with exception of the stoplight parrotfish (3.99% of landings). Rainbow parrotfish may be more common in near shore in shallow water than offshore waters. Fishers report that rainbow parrotfish were once fairly common in very shallow water close to shore. Because of their size (length >1m), they were sometimes harvested by shooting them with a rifle from shore (J. LaPlace, St. Thomas, pers. com and E. Schuster, St. Croix, pers. com.). There are still reports of small schools of rainbow parrotfish grazing in shallow water on the very eastern tip of St. Croix. Juvenile rainbow parrotfish have also been observed in Secret Harbor Bay, St. Thomas, and adults in St. Thomas just off the southern reef slope at Buck Island and in shallow water in Lindberg Bay (Kojis, obs.).

In conclusion, the MSSCA harbors a high diversity of fish species and a high abundance of commercially harvested coneys, surgeonfishes and parrotfishes. None of the larger grouper species and few of the large snapper and parrotfish species were observed.

LITERATURE CITED

Anon. 2009. Caribbean Fisheries Data Evaluation, SEDAR Procedures Workshop 3. NOAA, NMFS, SEFSC. San Juan, PR. pp. 195.

Beets, J., A. Friedlander and W. Tobias. 1994. Stock analysis of coney, *Epinephelus fulvus*, in St. Croix, U.S. Virgin Islands. Proc. Gulf and Caribbean Fisheries Institute. 43:403-416.

Caribbean Fishery Management Council (CFMC). 1993. Amendment 2 to the Fishery Management Plan for the Shallow-water Reef Fishery of Puerto Rico and the U.S. Virgin Islands. San Juan, Puerto Rico. CFMC. San Juan, PR. 574 pp.

Caribbean Fishery Management Council (CFMC). 1998. Essential Fish Habitat (EFH) Generic Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean, Including a Draft Environmental Assessment. Vol. 1. CFMC, San Juan, PR.

Caribbean Fishery Management Council (CFMC) and National Marine Fisheries Service (NMFS). 2005. Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act. CFMC, San Juan, PR. 624 pp. http://www.caribbeanfmc.com/SCANNED%20FMPS/06%20FINAL%20SFA%20-%20MAY%2003,2005/Caribbean_SFA_DSEIS/Text/SECTION%201-3.pdf. Accessed 14 Feb 2011.

Chiappone, M., R.Sluka, and K. Sullivan-Sealey. 2000. Groupers (Pisces: Serranidae) in fished and protected areas of the Florida Keys, Bahamas, and northern Caribbean. Mar Ecol Prog Ser. 198:261-272.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. Gulf and Caribbean Research. 14(2):91-106.

Clavijo, I.E., J.A. Yntema, J.C. Ogden. 1980. An annotated List of the Fishes of St. Croix, U.S. Virgin Islands. West Indies Laboratory, St. Croix, U.S. Virgin Islands. 49 pp.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, Epinephelus guttatus and E. striatus in the West Indies. Bull. Mar. Sci. 40(2):220-230.

Froese R. and D. Pauly. 2007. FishBase. Electronic source document available at www.fishbase.org.

Garcia-Sais, J.R., R. Castro, J. Sabater-Vlavel, M. Carlo, R Esteves. 2004. Characterization of benthic Habitats and Associated Reef Communities at Bajo de Sico Seamount, Mona Passage, Puerto Rico. CFMC, San Juan, PR. 98 pp.

McCarthy, K. and T. Gedamke. 2009. United States Virgin Islands Fisheries Description and Available Data: Preliminary Evaluation. NOAA, NMFS SEFSC, Sustainable Fisheries Division Contribution. SFD-2009-02. 13 pp.

Olsen, D.A. 1988. The impact of ciguatera fish poisoning within a changing Caribbean environment. Population and Environment: A Journal of Interdisciplinary Studies. 10(1):15-31.

Prada, M. 2003. Delineation of benthic habitats from side scan sonar mosaics from the Marine conservation District, St. Thomas, Lang Bank and Mutton Snapper Closed Area in St. Croix, U.S. Virgin Islands. Report to Caribbean Fishery Management Council, October 2003. pp 23.

Randall, J.E. 1967. Food Habits of the Reef Fishers of the West Indies. Hawaii Institute of Marine Biology, University of Hawaii and Bernice P. Bishop Museum. Honolulu, HI. 94 pp.

Ward-Paige, CA, C. Mora, H.K. Lotze, C. Pattengill-Semmens, L. McClenachan, E. Arias-Castro, R.A. Myers. 2010. Large-scale absence of reefs in the Greater-Caribbean: A footprint of human pressures. PLoS ONE 5(8): e11968. doi:10.1371/journal.pone.0011968.

Whiteman, E.A. 2005. St. Croix & St. Thomas/St. John Fisheries Independent Trap and Line Survey, 1992-2002 Summary Report: Data analysis and Conclusions. UPR Sea Grant College Program/NMFS Cooperative SEAMAP-C. UPR, Mayagüez, PR.

APPENDICIES - CHAPTER 3

Appendix 1: List of Presence / Absence of Fish Species by Habitat

Table A3-1.1. Presence / Absence List of species by habitat in MSSCA in rank order of abundance. All fish recorded using roving fish census and transect techniques are combined. This table includes individuals of small species of fish originally recorded in a few roving fish censuses, but omitted from roving fish analyses in all other tables, except this table and A3.1.2. COPA habitat was omitted because the habitat described by Prada (2003) was not identified in the MSSCA.

Family	Scientific name	Common Name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	X	X	X	X	X	X	X	X	5563	100.0%
Pomacentridae	*Eupomacentrus partitus*	Bicolordamselfish	X	X	X	X	X	X	X	X	2810	100.0%
Acanthuridae	*Acanthurus* s *chirurgus/bahianus*	Surgeon - Doctor or Ocean	X	X	X	X	X	X	X	X	2273	100.0%
Pomacentridae	*Chromis cyanea*	Blue chromis	X	X	X	X	X	X		X	1616	87.5%
Balistidae	*Melichthys niger*	Black durgon	X	X	X	X	X	X	X	X	1099	100.0%
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	X		X		X			X	1041	50.0%
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	X	X	X	X	X	X	X	X	854	100.0%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	X	X	X	X	X	X	X		854	87.5%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	X	X	X	X	X	X	X	X	751	100.0%
Serranidae	*Cephalopholis fulvus*	Coney	X	X	X	X	X	X	X	X	749	100.0%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	X	X	X	X	X	X	X	X	622	100.0%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	X	X	X	X	X	X	X	X	609	100.0%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	X	X	X	X	X	X	X	X	481	100.0%
Labridae	*Clepticus parrae*	Creole wrasse		X		X					461	25.0%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish		X	X	X	X	X			277	62.5%
Labridae	*Halichoeres bivittatus*	Slippery Dick	X	X	X	X	X	X	X	X	246	100.0%
Pomadasyidae	*Haemulon plumieri*	White grunt	X	X	X	X	X	X	X	X	214	100.0%

Family	**Scientific name**	**Common Name**	**ALIN**	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**	**Ubiquity**
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish			X	X	X	X	X		212	62.5%
Holocentridae	*Myripristis jacobus*	Blackbar		X	X	X		X	X	X	208	75.0%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	X	X	X	X	X	X	X	X	163	100.0%
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	X		X	X	X	X		X	154	75.0%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	X	X	X	X	X	X		X	150	87.5%
Balistidae	*Balistes vetula*	Queen triggerfish	X	X	X	X	X	X	X	X	140	100.0%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper		X	X	X	X				116	50.0%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	X	X	X	X	X	X		X	114	87.5%
Carangidae	*Caranx ruber*	Bar jack	X	X	X	X	X	X		X	102	87.5%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	X	X		X	X	X		X	101	75.0%
Holocentridae	*Holocentrus* sp.	Squirrelfish (*adscensionis* or *rufus*)	X	X		X	X	X			97	62.5%
Scaridae	*Sparisoma viride*	Stoplight parrotfish		X	X	X	X				95	50.0%
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	X	X				X		X	93	50.0%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	X	X	X	X	X	X	X	X	91	100.0%
Scaridae	*Scarus iserti*	Striped parrotfish		X	X	X		X			91	50.0%
Pomacentridae	*Chromis multilineata*	Brown chromis	X	X		X	X	X		X	89	75.0%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	X	X	X	X	X	X		X	81	87.5%
Serranidae	*Epinephelus cruentatus*	Graysby		X	X	X	X		X	X	80	75.0%
Carangidae	*Decapterus sp.*	Scad						X			71	12.5%
Scaridae	*Scarus vetula*	Queen parrotfish		X	X	X	X			X	67	62.5%
Labridae	*Bodianus rufus*	Spanish hogfish	X	X	X	X	X	X		X	61	87.5%
Holocentridae	*Holocentrus* sp.	unidentified	X	X			X	X	X		59	62.5%

Family	Scientific name	Common Name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Serranidae	*Serranus tigrinus*	Harlequin bass	X	X	X	X	X	X	X		58	87.5%
Labridae	*Halichoeres maculipinna*	Clown wrasse	X			X	X	X		X	56	62.5%
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	X	X	X	X	X	X	X	X	55	100.0%
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	X	X		X				X	53	50.0%
Serranidae	*Serranus baldwini*	Lantern bass	X		X		X	X		X	50	62.5%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt		X	X	X	X	X		X	42	75.0%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	X	X	X	X		X		X	42	75.0%
Pomadasyidae	*Haemulon sciurus*	Bluestriped grunt		X		X	X				40	37.5%
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	X	X			X	X		X	39	62.5%
Grammatidae	*Gramma loreto*	Fairy basslet		X		X					36	25.0%
Lutjanidae	*Rhomboplites aurorubens*	Vermillion snapper		X		X					36	25.0%
Serranidae	*Epinephelus guttatus*	Red hind	X		X	X	X	X	X		33	75.0%
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	X		X	X	X	X			31	62.5%
Serranidae	*Serranus tabacarius*	Tobaccofish			X	X	X	X			31	50.0%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	X	X		X	X	X			30	62.5%
Scaridae		Small unidentified parrotfish	X			X					30	25.0%
Carangidae	*Caranx crysos*	Blue runner		X			X	X			26	37.5%
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	X	X		X					26	37.5%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	X	X		X	X	X			23	62.5%
Holocentridae	*Neoniphon marianus*	Longjaw squirrelfish		X		X					22	25.0%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	X	X	X	X		X		X	21	75.0%
Gobidae	*Coryphopterus personatus/hyalinus*	Masked/Glass goby		X							19	12.5%

Family	Scientific name	Common Name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper		X		X	X				16	37.5%
Labridae	*Xyrichtys splendens*	Green razorfish			X					X	15	25.0%
Pomadasyidae	*Haemulon aurolineatum*	Tomtate		X		X		X			15	37.5%
Gobidae		unidentified	X		X					X	14	37.5%
Pomacentridae	*Microspathodon chrysurus*	Yellowtail damselfish		X							14	12.5%
Rhincodontidae	*Ptereleotris helenae*	Hovering dartfish			X			X			14	25.0%
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterfyfish		X				X			13	25.0%
Pomacentridae	*Chromis insolata*	Sunshinefish				X					13	12.5%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	X	X		X	X				13	50.0%
Ostraciidae	*Lactrophrys sp.*	Trunkfish unid.				X	X	X	X		12	50.0%
Pomacentridae	*Stegastes planifrons*	Three spot damselfish		X							12	12.5%
Scombridae	*Scomberomorus*	Spanish mackerel		X		X		X			12	37.5%
Labridae		unidentified	X	X		X					11	37.5%
Ostraciidae	*Lactrophrys trigonus*	Trunkfish						X		X	11	25.0%
Pomadasyidae	*Stegastes variabilis*	Cocoa damselfish		X							11	12.5%
Blenniidae		Blenny			X			X		X	10	37.5%
Serranidae	*Hypoplectrus puella*	Barred hamlet		X			X				10	25.0%
Serranidae	*Paranthias furcifer*	Creole-fish		X							10	12.5%
Chaetodontidae	*Chaetodon sedentarius*	Reef butterflyfish						X		X	9	25.0%
Labridae	*Halichoeres pictus*	Rainbow wrasse	X								9	12.5%
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish		X		X	X				9	37.5%
Monacanthidae		Filefish unidentified	X			X		X	X		9	50.0%
Sphyraenidae	*Serranus tortugarum*	Chalk bass						X			9	12.5%
Chaetodontidae	*Prognathodes aculeatus*	Longsnout		X			X				8	25.0%
Labridae	*Halichoeres radiatus*	Puddingwife	X	X				X			8	37.5%

Family	Scientific name	Common Name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory		X		X					8	25.0%
Pomadasyidae	*Haemulon*	Smallmouth grunt		X							8	12.5%
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard						X			7	12.5%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper				X	X				7	25.0%
Balistidae	*Canthidermis sufflamen*	Ocean triggerfish	X	X							6	25.0%
Chaenopsidae	*Chaenopsis limbaughi*	Yellowface / Bluethroat Pikeblenny			X			X			6	25.0%
Dasyatidae	*Dasyatis americana*	Southern stingray	X			X		X			6	37.5%
Monacanthidae	*Aluterus scriptus*	Scrawled filefish	X		X						6	25.0%
Muraenidae	*Gymnothorax moringa*	Spotted moray	X							X	6	25.0%
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish		X			X	X			6	37.5%
Serranidae	*Hypoplectrus unicolor*	Butter hamlet		X		X					6	25.0%
Serranidae	*Rypticus saponaceus*	Greater soapfish				X	X				6	25.0%
Muraenidae		unknown	X			X					5	25.0%
Ostraciidae	*Acanthstracion quadricornis*	Scrawled cowfish	X								5	12.5%
Pomadasyidae	*Haemulon macrostomum*	Spanish grunt		X						X	5	25.0%
Apogonidae	*Apogon sp.*	Black spot on tail					X	X			4	25.0%
Aulostomidae	*Aulostomus maculatus*	Trumpetfish		X							4	12.5%
Carangidae	*Caranx hippos*	Crevalle jack						X			4	12.5%
Gobidae	*Elacatinus genie*	Cleaning goby	X			X					4	25.0%
Gobidae	*Elactinus cf. prochilos*	Broadstripe goby			X		X				4	25.0%
Lutjanidae	*Lutjanus analis*	Mutton snapper	X	X							4	25.0%
Ostraciidae		Boxfish unidentified	X					X			4	25.0%
Rhincodontidae	*Ginglymostoma*	Nurse shark		X	X						4	25.0%
Serranidae	*Epinephelus*	Rock Hind		X			X				4	25.0%

Family	Scientific name	Common Name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Serranidae	*Hypoplectrus chlorurus*	Yellowtail hamlet		X							4	12.5%
Synodontidae	*Synodus intermedius*	Sand diver		X				X			4	25.0%
Pomadasyidae	*Haemulon sp.*					X					3	12.5%
Scorpaenidae	*Scorpaena plumieri*	Spotted scorpionfish					X				3	12.5%
Sphyraenidae	*Sphyraena borealis/picudilla*	Northern/Southern sennet		X							3	12.5%
Balistidae	*Xanthichthys ringens*	Saragassum triggerfish				X					2	12.5%
Bothidae	*Bothus* sp.	Flounder						X			2	12.5%
Cirrhitidae	*Amblycirrhitus pinos*	Redspotted hawkfish	X								2	12.5%
Diodontidae	*Diodon hystrix*	Porcupinefish	X								2	12.5%
Gobidae	*Elacatinus evelynae*	Sharknose goby			X						2	12.5%
Holocentridae	*Sargocentron*	Dusky squirrelfish		X							2	12.5%
Labridae	*Xyrichtys martinicensis*	Rosy razorfish						X			2	12.5%
Myliobatidae	*Aetobatus narinari*	Spotted eagle ray						X			2	12.5%
Ostraciidae	*Lactrophrys triqueter*	Smooth trunkfish		X							2	12.5%
Pomadasyidae	*Anisotremus virginicus*	Porkfish		X							2	12.5%
Pomadasyidae	*Haemulon striatum*	Striped grunt		X							2	12.5%
Priacanthidae	*Heteropriacanthus cruentatus*	Glasseye snapper								X	2	12.5%
Scaridae	*Cryptotomus roseus*	Bluelip parrotfish								X	2	12.5%
Scaridae	*Scarus coeruleus*	Blue parrotfish		X				X			2	12.5%
Sciaenidae	*Equetus punctatus*	Spotted drum	X								2	12.5%
Sciaenidae	*Pareques acuminatus*	Highhat		X							2	12.5%
Scombridae	*Scomberomorus regalis*	Cero		X							2	12.5%
Tetraodontidae	*Sphoeroides spengleri*	Bandtail puffer					X				2	12.5%
								Total # Individuals			**24,223**	

Table A3-1.2. Presence / Absence List of fish species by habitat in MSSCA, alphabetical order by family and then species. Total = total number of individuals recorded in all habitats. All fish recorded using roving fish census and transect techniques are combined. This table includes individuals of small species of fish originally recorded in a few roving fish censuses, but omitted from roving fish analyses in all tables except A3.1 and A3.2. COPA habitat was omitted because the habitat described by Prada (2003) was not identified in the MSSCA (see Chapter 2 for explanation).

Family	Scientific name	Common name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Acanthuridae	*Acanthurus coeruleus*	Blue tang	X	X	X	X	X	X	X	X	481	100.0%
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	X	X	X	X	X	X	X	X	2273	100.0%
Apogonidae	*Apogon sp.*						X	X			4	25.0%
Aulostomidae	*Aulostomus maculatus*	Trumpetfish		X							4	12.5%
Balistidae	*Balistes vetula*	Queen triggerfish	X	X	X	X	X	X	X	X	140	100.0%
Balistidae	*Canthidermis sufflamen*	Ocean triggerfish	X	X							6	25.0%
Balistidae	*Melichthys niger*	Black durgon	X	X	X	X	X	X	X	X	1099	100.0%
Balistidae	*Xanthichthys ringens*	Saragassum triggerfish				X					2	12.5%
Blenniidae		Blenny			X			X		X	10	37.5%
Bothidae	*Bothus*	Flounder						X			2	12.5%
Carangidae	*Caranx crysos*	Blue runner		X			X	X			26	37.5%
Carangidae	*Caranx ruber*	Bar jack	X	X	X	X	X	X		X	102	87.5%
Carangidae	*Caranx cf. hippos*	Crevalle jack						X			4	12.5%
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	X		X		X			X	1041	50.0%
Carangidae	*Decapterus sp.*	Scad						X			71	12.5%
Chaenopsidae	*Chaenopsis limbaughi*	Yellowface Pikeblenny/Bluethroat Pikeblenny			X			X			6	25.0%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	X	X	X	X	X	X		X	150	87.5%
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterfyfish		X				X			13	25.0%
Chaetodontidae	*Chaetodon sedentarius*	Reef butterflyfish						X		X	9	25.0%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	X	X		X	X	X		X	101	75.0%

Family	Scientific name	Common name	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total	Ubiquity
Chaetodontidae	*Prognathodes aculeatus*	Longsnout butterflyfish		X			X				8	25.0%
Cirrhitidae	*Amblycirrhitus pinos*	Redspotted hawkfish	X								2	12.5%
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard						X			7	12.5%
Dasyatidae	*Dasyatis americana*	Southern stingray	X			X		X			6	37.5%
Dasyatidae	*Dasyatis sabina*	Atlantic stingray									0	0.0%
Diodontidae	*Diodon hystrix*	Porcupinefish	X								2	12.5%
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	X		X	X	X	X		X	154	75.0%
Gobidae	*Coryphopterus personatus/hyalinus*	Masked/Glass Goby		X							19	12.5%
Gobidae	*Elacatinus cf. evelynae*	Sharknose goby			X						2	12.5%
Gobidae	*Elacatinus genie*	Cleaning goby	X			X					4	25.0%
Gobidae	*Elactinus cf prochilos*	Broadstripe goby			X		X				4	25.0%
Gobidae	sp.	unidentified	X		X					X	14	37.5%
Grammatidae	*Gramma loreto*	Fairy basslet		X		X					36	25.0%
Holocentridae	*Holocentrus*	Squirrelfish unidentified	X	X			X	X	X		59	62.5%
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	X	X			X	X		X	39	62.5%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	X	X	X	X	X	X	X	X	751	100.0%
Holocentridae	*Holocentrus* sp.	Squirrelfish (*adscensionis* or *rufus*)	X	X		X	X	X			97	62.5%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish		X	X	X		X	X	X	208	75.0%
Holocentridae	*Neoniphon marianus*	Longjaw squirrelfish		X		X					22	25.0%
Holocentridae	*Sargocentron vexillarium*	Dusky squirrelfish		X							2	12.5%
Labridae	*Bodianus rufus*	Spanish hogfish	X	X	X	X	X	X		X	61	87.5%
Labridae	*Clepticus parrae*	Creole wrasse		X		X					461	25.0%
Labridae	*Halichoeres bivittatus*	Slippery Dick	X	X	X	X	X	X	X	X	246	100.0%
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	X	X	X	X	X	X	X	X	854	100.0%
Labridae	*Halichoeres maculipinna*	Clown wrasse	X			X	X	X		X	56	62.5%
Labridae	*Halichoeres pictus*	Rainbow wrasse	X								9	12.5%

Family	**Scientific name**	**Common name**	**ALIN**	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**	**Ubiquity**
Labridae	*Halichoeres radiatus*	Puddingwife	X	X				X			8	37.5%
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	X	X	X	X	X	X	X	X	5563	100.0%
Labridae	*Xyrichtys martinicensis*	Rosy razorfish						X			2	12.5%
Labridae	*Xyrichtys splendens*	Green razorfish			X					X	15	25.0%
Labridae		unidentified	X	X		X					11	37.5%
Lutjanidae	*Lutjanus analis*	Mutton snapper	X	X							4	25.0%
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper		X		X	X				16	37.5%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper		X	X	X	X				116	50.0%
Lutjanidae	*Lutjanus synagris*	Lane snapper									0	0.0%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper				X	X				7	25.0%
Lutjanidae	*Rhomboplites aurorubens*	Vermillion snapper		X		X					36	25.0%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	X	X	X	X	X	X	X	X	163	100.0%
Monacanthidae	*Aluterus scriptus*	Scrawled filefish	X		X						6	25.0%
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish		X		X	X				9	37.5%
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	X	X		X					26	37.5%
Monacanthidae		Filefish unidentified	X			X		X	X		9	50.0%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish		X	X	X	X	X			277	62.5%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	X	X	X	X	X	X	X	X	91	100.0%
Muraenidae	*Gymnothorax moringa*	Spotted moray	X							X	6	25.0%
Muraenidae		unidentified	X			X					5	25.0%
Myliobatidae	*Aetobatus narinari*	Spotted eagle ray						X			2	12.5%
Ophichthidae	*Myrichthys ocellatus*	Goldspotted eel									0	0.0%
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish			X	X	X	X	X		212	62.5%
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish		X			X	X			6	37.5%
Ostraciidae	*Acanthstracion quadricornis*	Scrawled cowfish	X								5	12.5%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	X	X		X	X	X			23	62.5%

Family	**Scientific name**	**Common name**	**ALIN**	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**	**Ubiquity**
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	X	X	X	X		X		X	21	75.0%
Ostraciidae	*Lactrophrys* sp.	Trunkfish unidentifed				X	X	X	X		12	50.0%
Ostraciidae	*Lactrophrys trigonus*	Trunkfish						X		X	11	25.0%
Ostraciidae	*Lactrophrys triqueter*	Smooth trunkfish		X							2	12.5%
Ostraciidae		Boxfish unidentified	X					X			4	25.0%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	X	X		X	X	X			30	62.5%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	X	X	X	X	X	X		X	81	87.5%
Pomacentridae	*Chromis cyanea*	Blue chromis	X	X	X	X	X	X		X	1616	87.5%
Pomacentridae	*Chromis insolata*	Sunshinefish				X					13	12.5%
Pomacentridae	*Chromis multilineata*	Brown chromis	X	X		X	X	X		X	89	75.0%
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory		X		X					8	25.0%
Pomacentridae	*Eupomacentrus partitus*	Bicolordamselfish	X	X	X	X	X	X	X	X	2810	100.0%
Pomacentridae	*Microspathodon chrysurus*	Yellowtail damselfish		X							14	12.5%
Pomacentridae	*Stegastes planifrons*	Three spot damselfish		X							12	12.5%
Pomacentridae	*Stegastes sp.*										0	0.0%
Pomacentridae	*Stegastes variabilis*	Cocoa damselfish		X							11	12.5%
Pomadasyidae	*Anisotremus virginicus*	Porkfish		X							2	12.5%
Pomadasyidae	*Haemulon aurolineatum*	Tomtate		X		X		X			15	37.5%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt		X	X	X	X	X		X	42	75.0%
Pomadasyidae	*Haemulon chrysargyreum*	Smallmouth grunt		X							8	12.5%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	X	X	X	X	X	X	X	X	622	100.0%
Pomadasyidae	*Haemulon macrostomum*	Spanish grunt		X						X	5	25.0%
Pomadasyidae	*Haemulon plumieri*	White grunt	X	X	X	X	X	X	X	X	214	100.0%
Pomadasyidae	*Haemulon sciurus*	Bluestriped grunt		X		X	X				40	37.5%
Pomadasyidae	*Haemulon* sp.					X					3	12.5%

Family	**Scientific name**	**Common name**	**ALIN**	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**	**Ubiquity**
Pomadasyidae	*Haemulon striatum*	Striped grunt		X							2	12.5%
Priacanthidae	*Heteropriacanthus cruentatus*	Glasseye snapper								X	2	12.5%
Ptereleotridae	*Ptereleotris helenae*	Hovering dartfish			X			X			14	25.0%
Rhincodontidae	*Ginglymostoma cirratum*	Nurse shark		X	X						4	25.0%
Scaridae	*Cryptotomus roseus*	Bluelip parrotfish								X	2	12.5%
Scaridae	*Scarus coeruleus*	Blue parrotfish		X				X			2	12.5%
Scaridae	*Scarus iserti*	Striped parrotfish		X	X	X		X			91	50.0%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	X	X	X	X	X	X	X		854	87.5%
Scaridae	*Scarus vetula*	Queen parrotfish		X	X	X	X			X	67	62.5%
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	X		X	X	X	X			31	62.5%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	X	X	X	X	X	X	X	X	609	100.0%
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	X	X		X				X	53	50.0%
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	X	X				X		X	93	50.0%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	X	X	X	X	X	X		X	114	87.5%
Scaridae	*Sparisoma viride*	Stoplight parrotfish		X	X	X	X				95	50.0%
Scaridae		Small parrotfish	X			X					30	25.0%
Sciaenidae	*Equetus punctatus*	Spotted drum	X								2	12.5%
Sciaenidae	*Pareques acuminatus*	Highhat		X							2	12.5%
Scombridae	*Scomberomorus maculatus*	Spanish mackerel		X		X		X			12	37.5%
Scombridae	*Scomberomorus regalis*	Cero		X							2	12.5%
Scorpaenidae	*Scorpaena plumieri*	Spotted scorpionfish					X				3	12.5%
Serranidae	*Cephalopholis fulvus*	Coney	X	X	X	X	X	X	X	X	749	100.0%
Serranidae	*Epinephelus adscensionis*	Rock hind		X			X				4	25.0%
Serranidae	*Epinephelus cruentatus*	Graysby		X	X	X	X		X	X	80	75.0%
Serranidae	*Epinephelus guttatus*	Red hind	X		X	X	X	X	X		33	75.0%

Family	**Scientific name**	**Common name**	**ALIN**	**COLI**	**DEAL**	**GOPL**	**SAIN**	**SANR**	**SARI**	**SPAL**	**Total**	**Ubiquity**
Serranidae	*Hypoplectrus chlorurus*	Yellowtail hamlet		X							4	12.5%
Serranidae	*Hypoplectrus puella*	Barred hamlet		X			X				10	25.0%
Serranidae	*Hypoplectrus unicolor*	Butter hamlet		X		X					6	25.0%
Serranidae	*Paranthias furcifer*	Creole-fish		X							10	12.5%
Serranidae	*Rypticus saponaceus*	Greater soapfish				X	X				6	25.0%
Serranidae	*Serranus baldwini*	Lantern bass	X		X		X	X		X	50	62.5%
Serranidae	*Serranus tabacarius*	Tobaccofish			X	X	X	X			31	50.0%
Serranidae	*Serranus tigrinus*	Harlequin bass	X	X	X	X	X	X	X		58	87.5%
Serranidae	*Serranus tortugarum*	Chalk bass						X			9	12.5%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	X	X	X	X		X		X	42	75.0%
Sphyraenidae	*Sphyraena borealis/picudilla*	Northern/Southern sennet		X							3	12.5%
Synodontidae	*Synodus intermedius*	Sand diver		X				X			4	25.0%
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	X	X	X	X	X	X	X	X	55	100.0%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	X	X		X	X				13	50.0%
Tetraodontidae	*Sphoeroides spengleri*	Bandtail puffer					X				2	12.5%
								Total # individuals			**24,223**	

Appendix 2: Benthic Transect Fish Abundance by Habitat

Table A3-2.1. Benthic Transect Fish Counts: Fish species in rank order of abundance in ALIN (Algae Invertebrates) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	1266	52.6%	52.6%	79.13
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	549	22.8%	75.4%	34.31
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	127	5.3%	80.7%	7.94
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	100	4.2%	84.9%	6.25
Labridae	*Halichoeres bivittatus*	Slippery dick	55	2.3%	87.2%	3.44
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	46	1.9%	89.1%	2.88
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	46	1.9%	91.0%	2.88
Pomacentridae	*Chromis cyanea*	Blue chromis	46	1.9%	92.9%	2.88
Pomacentridae	*Chromis multilineata*	Brown chromis	24	1.0%	93.9%	1.50
Serranidae	*Cephalopholis fulvus*	Coney	20	0.8%	94.7%	1.25
Scaridae		Small unidentified parrotfish	17	0.7%	95.4%	1.06
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	16	0.7%	96.1%	1.00
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	12	0.5%	96.6%	0.75
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	10	0.4%	97.0%	0.63
Serranidae	*Serranus baldwini*	Lantern bass	10	0.4%	97.4%	0.63
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified	7	0.3%	97.7%	0.44
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	6	0.2%	98.0%	0.38
Labridae	*Halichoeres maculipinna*	Clown wrasse	6	0.2%	98.2%	0.38
Labridae	*Halichoeres pictus*	Rainbow wrasse	6	0.2%	98.5%	0.38
Scaridae	*Scarus taeniopterus*	Princess parrotfish	5	0.2%	98.7%	0.31
Serranidae	*Serranus tigrinus*	Harlequin bass	4	0.2%	98.8%	0.25
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	3	0.1%	99.0%	0.19
Gobidae		unidentified	3	0.1%	99.1%	0.19
Balistidae	*Melichthys niger*	Black durgon	2	0.1%	99.2%	0.13
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	2	0.1%	99.3%	0.13

Family	**Species**	**Common name***	**Total**	**Grand %**	**Cum %**	**# fish 100 m^{-2}**
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	2	0.1%	99.3%	0.13
Muraenidae	*Gymnothorax moringa*	Spotted moray	2	0.1%	99.4%	0.13
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	2	0.1%	99.5%	0.13
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	2	0.1%	99.6%	0.13
Carangidae	*Caranx ruber*	Bar jack	1	0.0%	99.6%	0.06
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	1	0.0%	99.7%	0.06
Cirrhitidae	*Amblycirrhitus pinos*	Redspotted hawkfish	1	0.0%	99.7%	0.06
Gobidae	*Elacatinus genie*	Cleaning goby	1	0.0%	99.8%	0.06
Labridae	*Bodianus rufus*	Spanish hogfish	1	0.0%	99.8%	0.06
Labridae		unidentified	1	0.0%	99.8%	0.06
Ostraciidae		unidentified	1	0.0%	99.9%	0.06
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	1	0.0%	99.9%	0.06
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	1	0.0%	100.0%	0.06
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	1	0.0%	100.0%	0.06
		Total	**2406**			**150.38**
		Total # sites surveyed	**4**			
		Shannon Diversity Index (H')	**2.41**			
		Total # species	**39**			

*Common names based on Humann (undated).

Table A3-2.2. Roving Diver Fish Counts: Fish species in rank order of abundance in ALIN (Algae Invertebrates) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	320	26.0%	26.0%
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	272	22.1%	48.0%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	145	11.8%	59.8%
Serranidae	*Cephalopholis fulvus*	Coney	138	11.2%	71.0%
Pomadasyidae	*Haemulon plumieri*	White grunt	135	10.9%	81.9%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	41	3.3%	85.2%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	36	2.9%	88.2%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	21	1.7%	89.9%
Balistidae	*Balistes vetula*	Queen triggerfish	20	1.6%	91.5%
Holocentridae	*Holocentrus* sp.	Squirrelfish (*adscensionis* or *rufus*)	20	1.6%	93.1%
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	20	1.6%	94.7%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	9	0.7%	95.5%
Balistidae	*Melichthys niger*	Black durgon	7	0.6%	96.0%
Chaetodontidae	Chaetodon striatus	Banded butterflyfish	7	0.6%	96.6%
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	7	0.6%	97.2%
Serranidae	*Epinephelus guttatus*	Red hind	6	0.5%	97.6%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	4	0.3%	98.0%
Monacanthidae	*Aluterus scriptus*	Scrawled filefish	3	0.2%	98.2%
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	3	0.2%	98.5%
Ostraciidae	*Acanthstracion quadricornis*	Scrawled cowfish	3	0.2%	98.7%
Balistidae	*Canthidermis sufflamen*	Ocean triggerfish	2	0.2%	98.9%
Muraenidae		unidentified	2	0.2%	99.0%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	1	0.1%	99.1%
Dasyatidae	*Dasyatis americana*	Southern stingray	1	0.1%	99.2%
Labridae	*Halichoeres radiatus*	Puddingwife	1	0.1%	99.3%
Lutjanidae	*Lutjanus analis*	Mutton snapper	1	0.1%	99.4%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Monacanthidae		Filefish unidentified	1	0.1%	99.4%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	1	0.1%	99.5%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	1	0.1%	99.6%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	1	0.1%	99.7%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	1	0.1%	99.8%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	1	0.1%	99.8%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	1	0.1%	99.9%
Sciaenidae	*Equetus punctatus*	Spotted drum	1	0.1%	100.0%
		Total # individuals	**1233**		
		Total # roving fish surveys	**7**		
		Shannon Diversity Index (H')	**3.20**		
		Total # of species	**34**		

*Common names based on Humann (undated).

Table A3-2.3. Benthic Transect Fish Counts: Fish species in rank order of abundance in COLI (Coral Limestone) habitat.

Family	Scientific name	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Pomacentridae	*Chromis cyanea*	Blue chromis	1152	32.57%	32.57%	57.60
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	876	24.77%	57.34%	43.80
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	414	11.70%	69.04%	20.70
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	226	6.39%	75.43%	11.30
Scaridae	*Scarus taeniopterus*	Princess parrotfish	224	6.33%	81.76%	11.20
Labridae	*Clepticus parrae*	Creole wrasse	100	2.83%	84.59%	5.00
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	88	2.49%	87.08%	4.40
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	62	1.75%	88.83%	3.10
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	38	1.07%	89.91%	1.90
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	38	1.07%	90.98%	1.90
Balistidae	*Melichthys niger*	Black durgon	36	1.02%	92.00%	1.80
Grammatidae	*Gramma loreto*	Fairy basslet	23	0.65%	92.65%	1.15
Pomacentridae	*Chromis multilineata*	Brown chromis	22	0.62%	93.27%	1.10
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	22	0.62%	93.89%	1.10
Pomadasyidae	*Haemulon flavolineatum*	French grunt	21	0.59%	94.49%	1.05
Scaridae	*Scarus iserti*	Striped parrotfish	20	0.57%	95.05%	1.00
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	18	0.51%	95.56%	0.90
Gobidae	*Coryphopterus personatus/hyalinus*	Masked/Glass goby	17	0.48%	96.04%	0.85
Serranidae	*Epinephelus cruentatus*	Graysby	13	0.37%	96.41%	0.65
Scaridae	*Sparisoma viride*	Stoplight parrotfish	11	0.31%	96.72%	0.55
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	8	0.23%	96.95%	0.40
Pomacentridae	*Microspathodon chrysurus*	Yellowtail damselfish	8	0.23%	97.17%	0.40
Acanthuridae	*Acanthurus coeruleus*	Blue tang	7	0.20%	97.37%	0.35
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	7	0.20%	97.57%	0.35
Serranidae	*Cephalopholis fulvus*	Coney	7	0.20%	97.77%	0.35
Pomacentridae	*Stegastes planifrons*	Three spot damselfish	7	0.20%	97.96%	0.35

Family	Scientific name	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Pomacentridae	*Stegastes variabilis*	Cocoa damselfish	7	0.20%	98.16%	0.35
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	5	0.14%	98.30%	0.25
Labridae	*Bodianus rufus*	Spanish hogfish	4	0.11%	98.42%	0.20
Chaetodontidae	Chaetodon striatus	Banded butterflyfish	4	0.11%	98.53%	0.20
Serranidae	*Hypoplectrus puella*	Barred hamlet	4	0.11%	98.64%	0.20
Holocentridae	*Neoniphon marianus*	Longjaw squirrelfish	4	0.11%	98.76%	0.20
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory	3	0.08%	98.84%	0.15
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	3	0.08%	98.93%	0.15
Chaetodontidae	*Prognathodes aculeatus*	Longsnout butterflyfish	3	0.08%	99.01%	0.15
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	3	0.08%	99.10%	0.15
Carangidae	*Caranx ruber*	Bar jack	2	0.06%	99.15%	0.10
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterfyfish	2	0.06%	99.21%	0.10
Serranidae	*Hypoplectrus chlorurus*	Yellowtail hamlet	2	0.06%	99.26%	0.10
Serranidae	*Hypoplectrus unicolor*	Butter hamlet	2	0.06%	99.32%	0.10
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	2	0.06%	99.38%	0.10
Scaridae	*Scarus vetula*	Queen parrotfish	2	0.06%	99.43%	0.10
Serranidae	*Serranus tigrinus*	Harlequin bass	2	0.06%	99.49%	0.10
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish	1	0.03%	99.52%	0.05
Aulostomidae	*Aulostomus maculatus*	Trumpetfish	1	0.03%	99.55%	0.05
Balistidae	*Balistes vetula*	Queen triggerfish	1	0.03%	99.58%	0.05
Tetraodontidae	*Diodon hystrix*	Porcupinefish	1	0.03%	99.60%	0.05
Pomadasyidae	*Haemulon aurolineatum*	Tomtate	1	0.03%	99.63%	0.05
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	1	0.03%	99.66%	0.05
Pomadasyidae	*Haemulon chrysargyreum*	Smallmouth grunt	1	0.03%	99.69%	0.05
Pomadasyidae	*Haemulon striatum*	Striped grunt	1	0.03%	99.72%	0.05
Holocentridae	*Holocentrus*	Squirrelfish unidentified	1	0.03%	99.75%	0.05
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	1	0.03%	99.77%	0.05
Ostraciidae	*Lactrophrys triqueter*	Smooth trunkfish	1	0.03%	99.80%	0.05
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	1	0.03%	99.83%	0.05

Family	**Scientific name**	**Common name***	**Total**	**Grand %**	**Cum %**	**# fish 100 m^{-2}**
Holocentridae	*Sargocentron vexillarium*	Dusky squirrelfish	1	0.03%	99.86%	0.05
Scaridae	*Scarus coeruleus*	Blue parrotfish	1	0.03%	99.89%	0.05
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	1	0.03%	99.92%	0.05
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	1	0.03%	99.94%	0.05
Synodontidae	*Synodus intermedius*	Sand diver	1	0.03%	99.97%	0.05
Labridae		unidentified	1	0.03%	100.00%	0.05
		Total	**3537**			**176.85**
		Total # sites surveyed	**5**			
		Shannon Diversity Index (H')	**3.16**			
		Total # species	**61**			

*Common names based on Humann (undated).

Table A3-2.4. Roving Diver Fish Counts: Fish species in rank order of abundance in COLI (Coral Limestone) habitat.

Family	Species	Common Name*	Roving Total	Grand %	Rov Cum %
Balistidae	*Melichthys niger*	Black durgon	246	16.52%	16.52%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	245	16.45%	32.98%
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	172	11.55%	44.53%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	123	8.26%	52.79%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	100	6.72%	59.50%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	75	5.04%	64.54%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	67	4.50%	69.04%
Serranidae	*Cephalopholis fulvus*	Coney	54	3.63%	72.67%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	46	3.09%	75.76%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	33	2.22%	77.97%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	29	1.95%	79.92%
Scaridae	*Scarus vetula*	Queen parrotfish	27	1.81%	81.73%
Serranidae	*Epinephelus cruentatus*	Graysby	27	1.81%	83.55%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	26	1.75%	85.29%
Pomadasyidae	*Haemulon sciurus*	Bluestriped grunt	26	1.75%	87.04%
Scaridae	*Scarus iserti*	Striped parrotfish	21	1.41%	88.45%
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified	15	1.01%	89.46%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	12	0.81%	90.26%
Carangidae	*Caranx ruber*	Bar jack	9	0.60%	90.87%
Serranidae	*Paranthias furcifer*	Creole-fish	9	0.60%	91.47%
Holocentridae	*Neoniphon marianus*	Longjaw squirrelfish	8	0.54%	92.01%
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	8	0.54%	92.55%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	8	0.54%	93.08%
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	7	0.47%	93.55%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	7	0.47%	94.02%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	7	0.47%	94.49%
Balistidae	*Balistes vetula*	Queen triggerfish	6	0.40%	94.90%

Family	Species	Common Name*	Roving Total	Grand %	Rov Cum %
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	6	0.40%	95.30%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	5	0.34%	95.63%
Labridae	*Bodianus rufus*	Spanish hogfish	5	0.34%	95.97%
Labridae	*Halichoeres bivittatus*	Slippery dick	5	0.34%	96.31%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	5	0.34%	96.64%
Pomadasyidae	*Haemulon chrysargyreum*	Smallmouth grunt	5	0.34%	96.98%
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterfyfish	4	0.27%	97.25%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	4	0.27%	97.52%
Pomadasyidae	*Haemulon aurolineatum*	Tomtate	4	0.27%	97.78%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	3	0.20%	97.99%
Scombridae	*Scomberomorus maculatus*	Spanish mackerel	3	0.20%	98.19%
Balistidae	*Canthidermis sufflamen*	Ocean triggerfish	2	0.13%	98.32%
Carangidae	*Caranx crysos*	Blue runner	2	0.13%	98.46%
Lutjanidae	*Lutjanus analis*	Mutton snapper	2	0.13%	98.59%
Lutjanidae	*Rhomboplites aurorubens*	Vermillion snapper	2	0.13%	98.72%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	2	0.13%	98.86%
Pomadasyidae	*Haemulon macrostomum*	Spanish grunt	2	0.13%	98.99%
Pomadasyidae	*Haemulon plumieri*	White grunt	2	0.13%	99.13%
Sphyraenidae	*Sphyraena borealis/picudilla*	Northern/Southern sennet	2	0.13%	99.26%
Aulostomidae	*Aulostomus maculatus*	Trumpetfish	1	0.07%	99.33%
Labridae	*Halichoeres radiatus*	Puddingwife	1	0.07%	99.40%
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish	1	0.07%	99.46%
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	1	0.07%	99.53%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	1	0.07%	99.60%
Pomadasyidae	*Anisotremus virginicus*	Porkfish	1	0.07%	99.66%
Rhincodontidae	*Ginglymostoma cirratum*	Nurse shark	1	0.07%	99.73%
Sciaenidae	*Pareques acuminatus*	Highhat	1	0.07%	99.80%
Scombridae	*Scomberomorus regalis*	Cero	1	0.07%	99.87%
Serranidae	*Epinephelus adscensionis*	Rock hind	1	0.07%	99.93%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	1	0.07%	100.00%

Family	Species	Common Name*	Roving Total	Grand %	Rov Cum %
		Total # individuals	**1489**		
		Total # roving fish surveys	**8**		
		Shannon Diversity Index (H')	**4.19**		
		Total # species	**57**		

*Common names based on Humann (undated).

Table A3-2.5. Benthic Transect Fish Counts: Fish species in rank order of abundance in DEAL (Dense Algae) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	133	27.82%	27.82%	16.63
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	73	15.27%	43.10%	9.13
Carangidae	*Caranx ruber*	Bar jack	51	10.67%	53.77%	6.38
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	50	10.46%	64.23%	6.25
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	45	9.41%	73.64%	5.63
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	26	5.44%	79.08%	3.25
Labridae	*Halichoeres bivittatus*	Slippery dick	20	4.18%	83.26%	2.50
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	14	2.93%	86.19%	1.75
Balistidae	*Melichthys niger*	Black durgon	12	2.51%	88.70%	1.50
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	7	1.46%	90.17%	0.88
Ptereleotridae	*Ptereleotris helenae*	Hovering dartfish	7	1.46%	91.63%	0.88
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	5	1.05%	92.68%	0.63
Gobidae		unidentified	4	0.84%	93.51%	0.50
Serranidae	*Serranus baldwini*	Lantern Bass	4	0.84%	94.35%	0.50
Labridae	*Xyrichtys splendens*	Green razorfish	3	0.63%	94.98%	0.38
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	3	0.63%	95.61%	0.38
Serranidae	*Cephalopholis fulvus*	Coney	3	0.63%	96.23%	0.38
Serranidae	*Serranus tigrinus*	Harlequin bass	3	0.63%	96.86%	0.38
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	2	0.42%	97.28%	0.25
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	2	0.42%	97.70%	0.25
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	2	0.42%	98.12%	0.25
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	2	0.42%	98.54%	0.25
Blenniidae		Blenny	1	0.21%	98.74%	0.13
Chaenopsidae	*Chaenopsis limbaughi*	Yellowface Pikeblenny/Bluethroat Pikeblenny	1	0.21%	98.95%	0.13
Gobidae	*Elactinus evelynae (cf.)*	Sharknose goby	1	0.21%	99.16%	0.13

Family	**Species**	**Common name***	**Total**	**Grand %**	**Cum %**	**# fish 100 m^{-2}**
Gobidae	*Elactinus prochilos (cf.)*	Broadstripe goby	1	0.21%	99.37%	0.13
Pomacentridae	*Chromis cyanea*	Blue chromis	1	0.21%	99.58%	0.13
Serranidae	*Serranus tabacarius*	Tobaccofish	1	0.21%	99.79%	0.13
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	1	0.21%	100.00%	0.13
		Totals	**478**			**59.75**
		Total # sites surveyed	**2**			
		Shannon Diversity Index (H')	**3.54**			
		Total # species	**29**			

*Common names based on Humann (undated).

Table A3-2.6. Roving Diver Fish Counts: Fish species in rank order of abundance in DEAL (Dense Algae) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Family	**Species**	**Common name**	ROV Total	ROV %	Rov Cum
Pomadasyidae	*Haemulon flavolineatum*	French grunt	217	20.43%	20.43%
Balistidae	*Melichthys niger*	Black Durgon	210	19.77%	40.21%
Acanthuridae	*Acanthurus* spp.	Surgeonfish - Doctor or Ocean	166	15.63%	55.84%
Serranidae	*Cephalopholis fulvus*	Coney	75	7.06%	62.90%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	68	6.40%	69.30%
Holocentridae	*Holocentrus rufus*	Longspine (Flag) squirrelfish	57	5.37%	74.67%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	41	3.86%	78.53%
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	40	3.77%	82.30%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	35	3.30%	85.59%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	31	2.92%	88.51%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	30	2.82%	91.34%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	17	1.60%	92.94%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	16	1.51%	94.44%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	12	1.13%	95.57%
Carangidae	*Caranx ruber*	Bar jack	9	0.85%	96.42%
Balistidae	*Balistes vetula*	Queen Triggerfish	6	0.56%	96.99%
Serranidae	*Epinephelus cruentatus*	Graysby	6	0.56%	97.55%
Pomadasyidae	*Haemulon plumieri*	White grunt	5	0.47%	98.02%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	5	0.47%	98.49%
Labridae	*Bodianus rufus*	Spanish hogfish	4	0.38%	98.87%
Scaridae	*Scarus vetula*	Queen parrotfish	3	0.28%	99.15%
Pomacanthidae	*Holacanthus tricolor*	Rock Beauty	2	0.19%	99.34%
Serranidae	*Epinephelus guttatus*	Red hind	2	0.19%	99.53%
Monacanthidae	*Aluterus scriptus*	Scrawled filefish	1	0.09%	99.62%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	1	0.09%	99.72%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	1	0.09%	99.81%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Rhincodontidae	*Ginglymostoma cirratum*	Nurse shark	1	0.09%	99.91%
Scaridae	*Scarus iserti*	Striped parrotfish	1	0.09%	100.00%
		Total # individuals	**1062**		
		Total # roving fish surveys	**3**		
		Shannon Diversity Index (H')	**3.54**		
		Total # species	**28**		

*Common names based on Humann (undated).

Table A3-2.7. Benthic Transect Fish Counts: Fish species in rank order of abundance in GOPL (Gorgonian Plain) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	1144	41.97%	41.97%	71.50
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	444	16.29%	58.25%	27.75
Pomacentridae	*Chromis cyanea*	Blue chromis	276	10.12%	68.38%	17.25
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	147	5.39%	73.77%	9.19
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	143	5.25%	79.02%	8.94
Scaridae	*Scarus taeniopterus*	Princess parrotfish	99	3.63%	82.65%	6.19
Labridae	*Clepticus parrae*	Creole wrasse	70	2.57%	85.22%	4.38
Balistidae	*Melichthys niger*	Black durgon	55	2.02%	87.23%	3.44
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	40	1.47%	88.70%	2.50
Serranidae	*Cephalopholis fulvus*	Coney	40	1.47%	90.17%	2.50
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	36	1.32%	91.49%	2.25
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	32	1.17%	92.66%	2.00
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	23	0.84%	93.51%	1.44
Pomadasyidae	*Haemulon flavolineatum*	French grunt	22	0.81%	94.31%	1.38
Labridae	*Halichoeres maculipinna*	Clown wrasse	18	0.66%	94.97%	1.13
Chaetodontidae	Chaetodon striatus	Banded butterflyfish	14	0.51%	95.49%	0.88
Labridae	*Halichoeres bivittatus*	Slippery dick	14	0.51%	96.00%	0.88
Pomacentridae	*Chromis insolata*	Sunshinefish	11	0.40%	96.40%	0.69
Pomacentridae	*Chromis multilineata*	Brown chromis	11	0.40%	96.81%	0.69
Serranidae	*Serranus tigrinus*	Harlequin bass	9	0.33%	97.14%	0.56
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	8	0.29%	97.43%	0.50
Scaridae		Small unidentified parrotfish	6	0.22%	97.65%	0.38
Balistidae	*Balistes vetula*	Queen triggerfish	5	0.18%	97.84%	0.31
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	5	0.18%	98.02%	0.31
Scaridae	*Sparisoma viride*	Stoplight parrotfish	5	0.18%	98.20%	0.31
Labridae		unidentified	4	0.15%	98.35%	0.25
Serranidae	*Epinephelus guttatus*	Red hind	4	0.15%	98.50%	0.25
Holocentridae	*Holocentrus sp.*	Squirrelfish (*adscensionis* or	3	0.11%	98.61%	0.19

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
		rufus)				
Holocentridae	*Neoniphon marianus*	Longjaw squirrelfish	3	0.11%	98.72%	0.19
Monacanthidae	*Cantherhines pullus*	Orangespotted filefish	3	0.11%	98.83%	0.19
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	3	0.11%	98.94%	0.19
Scaridae	*Scarus iserti*	Striped parrotfish	3	0.11%	99.05%	0.19
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	2	0.07%	99.12%	0.13
Labridae	*Bodianus rufus*	Spanish hogfish	2	0.07%	99.19%	0.13
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	2	0.07%	99.27%	0.13
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	2	0.07%	99.34%	0.13
Serranidae	*Epinephelus cruentatus*	Graysby	2	0.07%	99.41%	0.13
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	2	0.07%	99.49%	0.13
Balistidae	*Xanthichthys ringens*	Saragassum triggerfish	1	0.04%	99.52%	0.06
Dasyatidae	*Dasyatis americana*	Southern stingray	1	0.04%	99.56%	0.06
Gobidae	*Elacatinus genie*	Cleaning goby	1	0.04%	99.60%	0.06
Grammatidae	*Gramma loreto*	Fairy basslet	1	0.04%	99.63%	0.06
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	1	0.04%	99.67%	0.06
Muraenidae		unknown	1	0.04%	99.71%	0.06
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.04%	99.74%	0.06
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory	1	0.04%	99.78%	0.06
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	1	0.04%	99.82%	0.06
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	1	0.04%	99.85%	0.06
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	1	0.04%	99.89%	0.06
Serranidae	*Hypoplectrus unicolor*	Butter hamlet	1	0.04%	99.93%	0.06
Serranidae	*Serranus tabacarius*	Tobaccofish	1	0.04%	99.96%	0.06
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	1	0.04%	100.00%	0.06
		Total	**2726**			**170.38**
		Total # sites surveyed	**4**			
		Shannon Diversity Index (H')	**3.11**			
		Total # species	**52**			

*Common names based on Humann (undated).

Table A3-2.8. Roving Diver Fish Counts: Fish species in rank order of abundance in GOPL (Gorgonian Plain) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	326	25.04%	25.04%
Balistidae	*Melichthys niger*	Black durgon	258	19.82%	44.85%
Serranidae	*Cephalopholis fulvus*	Coney	102	7.83%	52.69%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	98	7.53%	60.22%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	71	5.45%	65.67%
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	66	5.07%	70.74%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	63	4.84%	75.58%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	60	4.61%	80.18%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	41	3.15%	83.33%
Lutjanidae	*Rhomboplites aurorubens*	Vermillion snapper	32	2.46%	85.79%
Balistidae	*Balistes vetula*	Queen triggerfish	24	1.84%	87.63%
Scaridae	*Scarus iserti*	Striped parrotfish	24	1.84%	89.48%
Holocentridae	*Holocentrus sp.*	Squirrelfish (*adscensionis* or *rufus*)	18	1.38%	90.86%
Labridae	*Bodianus rufus*	Spanish hogfish	10	0.77%	91.63%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	10	0.77%	92.40%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	9	0.69%	93.09%
Pomacanthidae	*Holacanthus tricolor*	Rock Beauty	9	0.69%	93.78%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	8	0.61%	94.39%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	7	0.54%	94.93%
Pomadasyidae	*Haemulon plumieri*	White grunt	7	0.54%	95.47%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	6	0.46%	95.93%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	6	0.46%	96.39%
Scaridae	*Scarus vetula*	Queen parrotfish	5	0.38%	96.77%
Pomadasyidae	*Haemulon sciurus*	Bluestriped grunt	4	0.31%	97.08%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	3	0.23%	97.31%
Pomadasyidae	*Haemulon aurolineatum*	Tomtate	3	0.23%	97.54%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	3	0.23%	97.77%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	3	0.23%	98.00%
Serranidae	*Epinephelus cruentatus*	Graysby	3	0.23%	98.23%
Serranidae	*Epinephelus guttatus*	Red hind	3	0.23%	98.46%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	3	0.23%	98.69%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	3	0.23%	98.92%
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	2	0.15%	99.08%
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish	2	0.15%	99.23%
Pomadasyidae	*Haemulon* sp.	unidentified	2	0.15%	99.39%
Carangidae	*Caranx ruber*	Bar jack	1	0.08%	99.46%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	1	0.08%	99.54%
Monacanthidae		Filefish unidentified	1	0.08%	99.62%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	1	0.08%	99.69%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	1	0.08%	99.77%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	1	0.08%	99.85%
Scombridae	*Scomberomorus maculatus*	Spanish mackerel	1	0.08%	99.92%
Serranidae	*Rypticus saponaceus*	Greater soapfish	1	0.08%	100.00%
		Total # individuals	**1302**		
		Total # roving fish surveys	**6**		
		Shannon diversity index	**3.41**		
		Total # species	**43**		

*Common names based on Humann (undated).

Table A3-2.9. Benthic Transect Fish Counts: Fish species in rank order of abundance in SAIN (Sand Invertebrate) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	1313	56.72%	56.72%	82.06
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	535	23.11%	79.83%	33.44
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	119	5.14%	84.97%	7.44
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	62	2.68%	87.65%	3.88
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	43	1.86%	89.50%	2.69
Labridae	*Halichoeres bivittatus*	Slippery dick	42	1.81%	91.32%	2.63
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	28	1.21%	92.53%	1.75
Pomacentridae	*Chromis cyanea*	Blue chromis	26	1.12%	93.65%	1.63
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	23	0.99%	94.64%	1.44
Carangidae	*Caranx crysos*	Blue runner	20	0.86%	95.51%	1.25
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	15	0.65%	96.16%	0.94
Serranidae	*Serranus tigrinus*	Harlequin bass	10	0.43%	96.59%	0.63
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	9	0.39%	97.37%	0.56
Serranidae	*Cephalopholis fulvus*	Coney	9	0.39%	96.98%	0.56
Scaridae	*Scarus taeniopterus*	Princess parrotfish	8	0.35%	97.71%	0.5
Serranidae	*Serranus baldwini*	Lantern bass	6	0.26%	98.23%	0.38
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	6	0.26%	97.97%	0.38
Acanthuridae	*Acanthurus coeruleus*	Blue tang	5	0.22%	98.44%	0.31
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	5	0.22%	98.66%	0.31
Labridae	*Halichoeres maculipinna*	Clown wrasse	4	0.17%	98.83%	0.25
Serranidae	*Serranus tabacarius*	Tobaccofish	3	0.13%	98.96%	0.19
Balistidae	*Balistes vetula*	Queen triggerfish	2	0.09%	99.05%	0.13
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	2	0.09%	99.22%	0.13
Scorpaenidae	*Scorpaena plumieri*	Spotted scorpionfish	2	0.09%	99.14%	0.13
Apogonidae	*Apogon* sp.	unidentified	1	0.04%	99.27%	0.06
Balistidae	*Melichthys niger*	Black durgon	1	0.04%	99.83%	0.06
Carangidae	*Caranx ruber*	Bar jack	1	0.04%	99.35%	0.06
Chaetodontidae	*Prognathodes aculeatus*	Longsnout butterflyfish	1	0.04%	99.87%	0.06

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Gobidae	*Elactinus prochilos (cf.)*	Broadstripe goby	1	0.04%	99.44%	0.06
Holocentridae	*Holocentrus*	Squirrelfish unidentified	1	0.04%	99.61%	0.06
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	1	0.04%	99.65%	0.06
Labridae	*Bodianus rufus*	Spanish hogfish	1	0.04%	99.31%	0.06
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	1	0.04%	99.78%	0.06
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	1	0.04%	99.91%	0.06
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	1	0.04%	99.74%	0.06
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	1	0.04%	99.52%	0.06
Pomacanthidae	*Holacanthus tricolor*	Rock Beauty	1	0.04%	99.57%	0.06
Pomacentridae	*Chromis multilineata*	Brown chromis	1	0.04%	99.40%	0.06
Serranidae	*Epinephelus adscensionis*	Rock hind	1	0.04%	99.48%	0.06
Serranidae	*Hypoplectrus puella*	Barred hamlet	1	0.04%	99.70%	0.06
Serranidae	*Rypticus saponaceus*	Greater soapfish	1	0.04%	99.96%	0.06
Tetraodontidae	*Sphoeroides spengleri*	Bandtail puffer	1	0.04%	100.00%	0.06
		Total	**2315**			**144.69**
		Total # sites surveyed	**4**			
		Shannon Diversity Index (H')	**2.20**			
		Total # species	**42**			

*Common names based on Humann (undated).

Table A3-2.10. Roving Diver Fish Counts: Fish species in rank order of abundance in SAIN (Sand Invertebrates) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	321	31.23%	31.23%
Balistidae	*Melichthys niger*	Black durgon	135	13.13%	44.36%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	100	9.73%	54.09%
Serranidae	*Cephalopholis fulvus*	Coney	89	8.66%	62.74%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	50	4.86%	67.61%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	48	4.67%	72.28%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	40	3.89%	76.17%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	28	2.72%	78.89%
Balistidae	*Balistes vetula*	Queen triggerfish	21	2.04%	80.93%
Holocentridae	*Holocentrus* sp.	Squirrelfish (*rufus* or *adscensionis*)	21	2.04%	82.98%
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	21	2.04%	85.02%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	21	2.04%	87.06%
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified	16	1.56%	88.62%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	16	1.56%	90.18%
Scaridae	*Scarus vetula*	Queen parrotfish	15	1.46%	91.63%
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	14	1.36%	93.00%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	12	1.17%	94.16%
Pomadasyidae	*Haemulon plumieri*	White grunt	9	0.88%	95.04%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	7	0.68%	95.72%
Labridae	*Bodianus rufus*	Spanish hogfish	6	0.58%	96.30%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	5	0.49%	96.79%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	4	0.39%	97.18%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	4	0.39%	97.57%
Chaetodontidae	Chaetodon striatus	Banded butterflyfish	3	0.29%	97.86%
Pomadasyidae	*Haemulon sciurus*	Bluestriped grunt	3	0.29%	98.15%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	3	0.29%	98.44%
Monacanthidae	*Cantherhines macrocerus*	Whitespotted filefish	2	0.19%	98.64%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Serranidae	*Epinephelus guttatus*	Red hind	2	0.19%	98.83%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	2	0.19%	99.03%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	2	0.19%	99.22%
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish	1	0.10%	99.32%
Tetraodontidae	*Diodon hystrix*	Porcupinefish	1	0.10%	99.42%
Serranidae	*Epinephelus cruentatus*	Graysby	1	0.10%	99.51%
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.10%	99.61%
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	1	0.10%	99.71%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	1	0.10%	99.81%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	1	0.10%	99.90%
Serranidae	*Rypticus saponaceus*	Greater soapfish	1	0.10%	100.00%
		Total # Individuals	**1028**		
		Total # surveys	**5**		
		Shannon Diversity Index (H')	**3.85**		
		Total # species	**44**		

*Common names based on Humann (undated).

Table A3-2.11. Benthic Transect Fish Counts: Fish species in rank order of abundance in SANR (Sand No Ripple) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	247	30.53%	30.53%	15.44
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	203	25.09%	55.62%	12.69
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	79	9.77%	65.39%	4.94
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	62	7.66%	73.05%	3.88
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	43	5.32%	78.37%	2.69
Labridae	*Halichoeres bivittatus*	Slippery Dick	37	4.57%	82.94%	2.31
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	17	2.10%	85.04%	1.06
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	17	2.10%	87.14%	1.06
Serranidae	*Serranus tabacarius*	Tobaccofish	12	1.48%	88.63%	0.75
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	11	1.36%	89.99%	0.69
Serranidae	*Cephalopholis fulvus*	Coney	11	1.36%	91.35%	0.69
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	6	0.74%	92.09%	0.38
Serranidae	*Serranus tortugarum*	Chalk Bass	6	0.74%	92.83%	0.38
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	5	0.62%	93.45%	0.31
Serranidae	*Serranus tigrinus*	Harlequin bass	5	0.62%	94.07%	0.31
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	4	0.49%	94.56%	0.25
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	4	0.49%	95.06%	0.25
Balistidae	*Balistes vetula*	Queen triggerfish	3	0.37%	95.43%	0.19
Carangidae	*Caranx* sp.	unidentified	3	0.37%	95.80%	0.19
Chaenopsidae	*Chaenopsis limbaughi*	Yellowface pikeblenny/Bluethroat pikeblenny	3	0.37%	96.17%	0.19
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	3	0.37%	96.54%	0.19
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	2	0.25%	96.79%	0.13
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterfyfish	2	0.25%	97.03%	0.13
Chaetodontidae	*Chaetodon sedentarius*	Reef butterflyfish	2	0.25%	97.28%	0.13
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	2	0.25%	97.53%	0.13

Family	**Species**	**Common name***	**Total**	**Grand %**	**Cum %**	**# fish 100 m^{-2}**
Labridae	*Halichoeres maculipinna*	Clown wrasse	2	0.25%	97.78%	0.13
Ptereleotridae	*Ptereleotris helenae*	Hovering dartfish	2	0.25%	98.02%	0.13
Serranidae	*Serranus baldwini*	Lantern bass	2	0.25%	98.27%	0.13
Apogonidae	*Apogon* sp.	unidentified	1	0.12%	98.39%	0.06
Balistidae	*Melichthys niger*	Black durgon	1	0.12%	98.52%	0.06
Blenniidae		Blenny	1	0.12%	98.64%	0.06
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard	1	0.12%	98.76%	0.06
Labridae	*Bodianus rufus*	Spanish hogfish	1	0.12%	98.89%	0.06
Labridae	*Xyrichtys martinicensis*	Rosy razorfish	1	0.12%	99.01%	0.06
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	1	0.12%	99.13%	0.06
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.12%	99.26%	0.06
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	1	0.12%	99.38%	0.06
Pomacentridae	*Chromis cyanea*	Blue chromis	1	0.12%	99.51%	0.06
Pomacentridae	*Chromis multilineata*	Brown chromis	1	0.12%	99.63%	0.06
Scaridae	*Scarus taeniopterus*	Princess parrotfish	1	0.12%	99.75%	0.06
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	1	0.12%	99.88%	0.06
Synodontidae	*Synodus intermedius*	Sand diver	1	0.12%	100.00%	0.06
		Total	**809**			**50.56**
		Total # sites surveyed	**4**			
		Shannon Diversity Index (H')	**3.26**			
		Total # species	**42**			

*Common names based on Humann (undated).

Table A3-2.12. Roving Diver Fish Counts: Fish species in rank order of abundance in SANR (Sand No Ripple) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	249	30.37%	30.37%
Serranidae	*Cephalopholis fulvus*	Coney	78	9.51%	39.88%
Carangidae	*Decapterus* sp.	Scad	70	8.54%	48.41%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	63	7.68%	56.10%
Mullidae	*Mulloidichthys martinicus*	Yellow goatfish	59	7.20%	63.29%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	43	5.24%	68.54%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	43	5.24%	73.78%
Pomadasyidae	*Haemulon plumieri*	White grunt	29	3.54%	77.32%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	21	2.56%	79.88%
Balistidae	*Melichthys niger*	Black durgon	20	2.44%	82.32%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	19	2.32%	84.63%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	17	2.07%	86.71%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	13	1.59%	88.29%
Holocentridae	*Holocentrus* sp.	Squirrelfish (*adscensionis* or *rufus*)	12	1.46%	89.76%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	12	1.46%	91.22%
Balistidae	*Balistes vetula*	Queen triggerfish	9	1.10%	92.32%
Carangidae	*Caranx ruber*	Bar jack	8	0.98%	93.29%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	8	0.98%	94.27%
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified	7	0.85%	95.12%
Ostraciidae	*Lactrophrys trigonus*	Trunkfish	5	0.61%	95.73%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	4	0.49%	96.22%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	4	0.49%	96.71%
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard	3	0.37%	97.07%
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	2	0.24%	97.32%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	2	0.24%	97.56%
Labridae	*Halichoeres radiatus*	Puddingwife	2	0.24%	97.80%
Scombridae	*Scomberomorus maculatus*	Spanish mackerel	2	0.24%	98.05%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Bothidae	*Bothus*	Flounder	1	0.12%	98.17%
Carangidae	*Caranx crysos*	Blue runner	1	0.12%	98.29%
Dasyatidae	*Dasyatis americana*	Southern stingray	1	0.12%	98.41%
Monacanthidae		filefish unidentified	1	0.12%	98.54%
Myliobatidae	*Aetobatus narinari*	Spotted eagle ray	1	0.12%	98.66%
Ostraciidae	*Acanthstracion polygonia*	Honeycomb cowfish	1	0.12%	98.78%
Ostraciidae	*Lactophrys triqueter*	Smooth trunkfish	1	0.12%	98.90%
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.12%	99.02%
Ostraciidae		boxfish unidentified	1	0.12%	99.15%
Pomacanthidae	*Holacanthus ciliaris*	Queen angelfish	1	0.12%	99.27%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	1	0.12%	99.39%
Pomadasyidae	*Haemulon aurolineatum*	Tomtate	1	0.12%	99.51%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	1	0.12%	99.63%
Scaridae	*Scarus coeruleus*	Blue parrotfish	1	0.12%	99.76%
Scaridae	*Scarus iserti*	Striped parrotfish	1	0.12%	99.88%
Serranidae	*Epinephelus guttatus*	Red hind	1	0.12%	100.00%
		Total # individuals	**820**		
		Total # roving fish surveys	**8**		
		Shannon Diversity Index (H')	**3.79**		
		Total # species	**43**		

*Common names based on Humann (undated).

Table A3-2.13. Benthic Transect Fish Counts: Fish species in rank order of abundance in SARI (Sand Ripple) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	90	53.57%	53.57%	22.50
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	24	14.29%	67.86%	6.00
Opistognathidae	*Opistognathus aurifrons*	Yellowhead jawfish	18	10.71%	78.57%	4.50
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	8	4.76%	83.33%	2.00
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	6	3.57%	86.90%	1.50
Scaridae	*Scarus taeniopterus*	Princess parrotfish	6	3.57%	90.48%	1.50
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	4	2.38%	92.86%	1.00
Labridae	*Halichoeres bivittatus*	Slippery dick	3	1.79%	94.64%	0.75
Serranidae	*Cephalopholis fulvus*	Coney	2	1.19%	95.83%	0.50
Acanthuridae	*Acanthurus coeruleus*	Blue tang	1	0.60%	96.43%	0.25
Balistidae	*Balistes vetula*	Queen triggerfish	1	0.60%	97.02%	0.25
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	1	0.60%	98.81%	0.25
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.60%	98.21%	0.25
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	1	0.60%	100.00%	0.25
Serranidae	*Serranus tigrinus*	Harlequin bass	1	0.60%	99.40%	0.25
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	1	0.60%	97.62%	0.25
		Total	**168**			**42.00**
		Total # of sites surveyed	**1**			
		Shannon Diversity Index	**2.40**			
		Total # species	**16**			

*Common names based on Humann (undated).

Table A3.14. Roving Diver Fish Counts: Fish species in rank order of abundance in SARI (Sand Ripple) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeonfish - Doctor or Ocean	55	27.50%	27.50%
Balistidae	*Melichthys niger*	Black durgon	51	25.50%	53.00%
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified	19	9.50%	62.50%
Serranidae	*Cephalopholis fulvus*	Coney	17	8.50%	71.00%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	15	7.50%	78.50%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	12	6.00%	84.50%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	9	4.50%	89.00%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	5	2.50%	91.50%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	4	2.00%	93.50%
Scaridae	*Scarus taeniopterus*	Princess parrotfish	4	2.00%	95.50%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	2	1.00%	96.50%
Monacanthidae		file fish unidentified	2	1.00%	97.50%
Balistidae	*Balistes vetula*	Queen triggerfish	1	0.50%	98.00%
Ostraciidae	*Lactrophrys* sp.	Trunkfish	1	0.50%	100.00%
Pomadasyidae	*Haemulon plumieri*	White grunt	1	0.50%	99.50%
Serranidae	*Epinephelus cruentatus*	Graysby	1	0.50%	98.50%
Serranidae	*Epinephelus guttatus*	Red hind	1	0.50%	99.00%
		Total # individuals	**200**		
		Total # roving fish surveys	**1**		
		Shannon Diversity Index (H')	**3.05**		
		Total # species	**17**		

*Common names based on Humann (undated).

Table A3-2.15. Benthic Transect Fish Counts: Fish species in rank order of abundance in SPAL (Sparse Algae) habitat.

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	329	33.64%	33.64%	41.13
Pomacentridae	*Eupomacentrus partitus*	Bicolor damselfish	278	28.43%	62.07%	34.75
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	88	9.00%	71.06%	11.00
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	63	6.44%	77.51%	7.88
Pomacentridae	*Chromis cyanea*	Blue chromis	37	3.78%	81.29%	4.63
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	32	3.27%	84.56%	4.00
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	32	3.27%	87.83%	4.00
Labridae	*Halichoeres bivittatus*	Slippery dick	25	2.56%	90.39%	3.13
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	14	1.43%	91.82%	1.75
Pomacentridae	*Chromis multilineata*	Brown chromis	10	1.02%	92.84%	1.25
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	10	1.02%	93.87%	1.25
Serranidae	*Serranus baldwini*	Lantern bass	9	0.92%	94.79%	1.13
Labridae	*Halichoeres maculipinna*	Clown wrasse	8	0.82%	95.60%	1.00
Labridae	*Xyrichtys splendens*	Green razorfish	7	0.72%	96.32%	0.88
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer	6	0.61%	96.93%	0.75
Chaetodontidae	*Chaetodon sedentarius*	Reef butterflyfish	4	0.41%	97.34%	0.50
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	4	0.41%	97.75%	0.50
Blenniidae		Blenny	3	0.31%	99.28%	0.38
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	3	0.31%	98.06%	0.38
Gobidae	*Coryphopterus glaucofraenum*	Bridled goby	3	0.31%	98.36%	0.38
Gobidae		unidentified	3	0.31%	98.98%	0.38
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	3	0.31%	98.67%	0.38
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	1	0.10%	99.39%	0.13
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	1	0.10%	99.49%	0.13
Muraenidae	*Gymnothorax moringa*	Spotted moray	1	0.10%	99.69%	0.13
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	1	0.10%	100.00%	0.13
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	1	0.10%	99.90%	0.13
Pomadasyidae	*Haemulon macrostomum*	Spanish grunt	1	0.10%	99.80%	0.13

Family	Species	Common name*	Total	Grand %	Cum %	# fish 100 m^{-2}
Scaridae	*Cryptotomus roseus*	Bluelip parrotfish	1	0.10%	99.59%	0.13
		Total	**978**			**122.25**
		Total # sites surveyed	**2**			
		Shannon Diversity Index	**2.95**			
		Total # species	**29**			

*Common names based on Humann (undated).

Table A3-2.16. Roving Diver Fish Counts: Fish species in rank order of abundance in SPAL (Sparse Algae) habitat.

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Carangidae	*Decapterus punctatus*	Round scad (Round robin)	550	54.40%	54.40%
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	131	12.96%	67.36%
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish	108	10.68%	78.04%
Acanthuridae	*Acanthurus coeruleus*	Blue tang	48	4.75%	82.79%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	47	4.65%	87.44%
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	33	3.26%	90.70%
Serranidae	*Cephalopholis fulvus*	Coney	20	1.98%	92.68%
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	9	0.89%	93.57%
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish	8	0.79%	95.15%
Pomadasyidae	*Haemulon plumieri*	White grunt	8	0.79%	94.36%
Balistidae	*Melichthys niger*	Black durgon	6	0.59%	96.34%
Pomadasyidae	*Haemulon carbonarium*	Caesar grunt	6	0.59%	95.75%
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	5	0.49%	96.83%
Sphyraenidae	*Sphyraena barracuda*	Great barracuda	5	0.49%	97.33%
Balistidae	*Balistes vetula*	Queen triggerfish	4	0.40%	97.73%
Ostraciidae	*Lactrophrys bicaudalis*	Spotted trunkfish	3	0.30%	98.02%
Ostraciidae	*Lactrophrys trigonus*	Trunkfish	3	0.30%	98.32%
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	3	0.30%	98.62%
Chaetodontidae	*Chaetodon striatus*	Banded butterflyfish	2	0.20%	99.01%
Holocentridae	*Holocentrus adscensionis*	Squirrelfish	2	0.20%	99.21%
Labridae	*Bodianus rufus*	Spanish hogfish	2	0.20%	98.81%
Scaridae	*Scarus vetula*	Queen parrotfish	2	0.20%	99.41%
Scaridae	*Sparisoma rubripinne*	Yellowtail or Redfin parrotfish	2	0.20%	99.60%
Carangidae	*Caranx ruber*	Bar jack	1	0.10%	99.70%
Pomacanthidae	*Holacanthus tricolor*	Rock beauty	1	0.10%	100.00%
Priacanthidae	*Heteropriacanthus cruentatus*	Glasseye snapper	1	0.10%	99.90%

Family	Species	Common name*	Roving Total	Grand %	Rov Cum %
Serranidae	*Epinephelus cruentatus*	Graysby	1	0.10%	99.80%
		Total # individuals	**1011**		
		Total # roving fish surveys	**4**		
		Shannon Diversity Index (H')	**2.46**		
		Total # species	**27**		

*Common names based on Humann (undated).

Appendix 3 - Queen conch (*Strombus gigas*) Distribution and Abundance in MSSCA Habitats

Introduction

Queen conch distribution and abundance were not the focus of this study. However, this is an important fishery species on St. Croix and the focus of one if the Caribbean Fisheries Management Council's fishery management plans (CFMC 1996). Thus, it was considered important to collect data on this species in the MSSCA while carrying out benthic transects and roving fish censuses.

Materials and Methods

Queen conch (*Strombus gigas*) were recorded in transects conducted during benthic fish transect data collection and during roving fish censuses. Transect data was collected primarily in June - August 2009 with some collected in May and June 2010. Therefore, surveys were done during the beginning and middle of the spawning season for queen conch and during the June 1st - October 30th closed season for queen conch and March 1st to June 30th closure of the MSSCA. Conch were classified as adult if they had a flared or thick lip.

Results

Transects

A total of 74 adult and juvenile live queen conch were observed in the benthic transect census. The highest density was in Dense Algae (DEAL) with 200 conch ha^{-2} followed by Algae with Invertebrates (ALIN) with 170 conch ha^{-2} (Table A3 - 3.1). Based on the density of queen conch and the total area of each habitat in the MSSCA, we estimated that ALIN has 59,728 queen conch and a total of about 69,786 queen conch are found in the MSSCA. The 4.7ha of COPA habitat were not included in the calculations because COPA habitat could not be identified and appeared to be a combination of COLI (Coral Limestone) and SAIN (Sand Invertebrates) habitat. (see Chapter 2).

Roving Fish Surveys

Queen conch were also counted during roving fish surveys. Table A3-3.2 provides further information on the habitats were queen conch were found in greatest abundance. Almost half the conch recorded in the roving surveys were found in Sand with No Ripples (SANR). ALIN and DEAL were the two other habitats where the majority of live conch were recorded. In contrast to the transect data, roving surveys indicate that conch density is higher in SANR than ALIN and conch are common in DEAL.

Though few queen conch were recorded in COLI habitat, they were observed to be fairly common at one site in the narrow sandy grooves that characterize this habitat. Also, there were a large number of live conch in the crook of the reef at Nicky's reef in 45.7m (150ft) depth (Fig.

1.10). Conch were likely migrating and piled up in the crook of this L-shaped reef. Conch tracks covered the bottom.

Table A3-3.1: Transects: Estimated adult and juvenile queen conch (*Strombus gigas*) in each habitat. Estimated number of adult and juvenile queen conch per hectare is based on identification of adults and juveniles during surveys and proportional distribution of conch identified only as live based on proportion of adults and juveniles recorded in the habitat. Zeros represent no observations of conch in transects in that habitat.

	ALIN	COLI	DEAL	GOPL	SAIN	SANR	SARI	SPAL	Total
Total # conch	28	1	16	2	0	27	0	0	74
Area surveyed (ha)	0.16	0.2	0.08	0.16	0.176	0.16	0.04	0.08	1.06
Estimated # of juv/adult conch		5[1]							
Est. # of adult conch per ha	100		185.71	0	0	158.5	0	0	
Est. # of juvenile conch per ha	75		14.29	12.5	0	11.25	0	0	
Est. # of conch in habitat	59,728	78	560	1,286	0	8,134	0	0	69,786
% of conch in each habitat	85.59%	0.11%	0.80%	1.84%	0.00%	11.66%	0.00%	0.00%	100%

[1] Queen conch were not identified as adult or juvenile in this habitat.

Table A3-3. 2: Number of queen conch (*Strombus gigas*) recorded during roving fish surveys.

	ALIN	COLI	DEAL	GOPL	SPAL	SAIN	SANR	SARI	Total
No. of conch	96	1	59	0	1	5	159	2	323
No. of roving fish surveys	7	8	3	6	4	5	8	1	42
Mean no. of conch per survey	13.7	0.1	19.7	0.0	0.3	1.0	19.9	2.0	7.7
Percentage of conch observed in each habitat	29.72	0.31	18.27	0.00	0.31	1.55	49.23	0.62	100.00

Discussion

The Magnuson-Stevens Fisheries Conservation Act defines Essential Fish Habitat (EFH) as those habitats necessary for the species of concern to grow to maturity, spawn, breed, or feed. Stoner and Ray-Clup (2000) studied the critical density for queen conch to successfully reproduce. They concluded that the density at which mating and spawning never occurred was <56 conch ha^{-1} and <48 conch ha^{-1}, respectively (Stoner and Ray-Clup, 2000). Reproductive activity reached an asymptote at 200 conch ha-1. Adult queen conch density in 3 of the 8 habitats surveyed ranged from 100 - 186 ha^{-1}, well above the minimum density for mating and spawning, but less than the density for maximum reproductive activity. These habitats comprised 392.3 ha or 57% of the total area of the MSSCA.

Tobias (2005) reported that 98% of queen conch in back reef embayments on St. Croix were recorded in sand, algal plain and seagrass habitats, or a combination of these habitats. These habitats comprised 96.3% of the habitat surveyed. The majority of the conch recorded were juveniles (87%). In contrast, 80% of the conch recorded in this study were adults in ALIN, DEAL and SANR transects. Only SANR was truly a sand habitat. The other two habitats were hard bottom habitats with a thin overlay of sand with algae. There were scattered small, depressions with pockets of deeper sand.

Conch have the ability to move up to 9 km in six months and the natural migration of conch is from inshore waters to spawn in the summer months to deeper offshore waters in the winter months (Appeldorn 1997). Thus, the conch at 45 m at Nicky's reef in June 2010 may have been blocked from migrating into shallower water. Conch found in deepwater on St. Croix may, in some instances, be blocked from migrating into shallower waters by slope edge reefs. It is unknown if conch can obtain enough energy to reproduce at 45m depth. If they can, reefs that block conch migrations, may increase mating activities by increasing local density.

Literature Cited

Appeldorn, R.S. 1997. Status of the queen conch fishery in the Caribbean Sea. pp. 40-49. In: J.M. Posada and G. Garcia-Moliner (eds.). Proc. of the International Queen Conch Conference, San Juan, PR, July 29-31, 1996. CFMC, San Juan, PR. 155 pp.

Caribbean Fisheries Management Council. 1996. Fishery management plan, regulatory impact review, and final environmental impact statement for the queen conch resources of Puerto Rico and the United States Virgin Islands. San Juan, PR. 41 pp.

Stoner, A.W. and M. Ray-Clup. 2000. Evidence for Allee effects in an over-harvested marine gastropod: density-dependent mating and egg production. Mar. Ecol. Prog. Ser. 202:297-302.

Tobias, W. 2005. Assessment of Conch Densities in Backreef Embayments on the northeast and southeast coast of St. Croix, U.S. Virgin Islands. Report to the SEAMAP-C. 34 pp.

Appendix 4 - Abstract 63rd Gulf and Caribbean Fisheries Institute Meeting

Distribution and Abundance of Fish Populations in Various Habitats in the Mutton Snapper (*Lutjanus analis*) Conservation Area on the South Shelf St. Croix, U.S. Virgin Islands

Distribution et abondance des populations de poisons dans les divers habitats de la Snapper Mouton (*Lutjanus analis*) Zone de conservation de la Croix du Sud du plateau Saint-Laurent, les îles Vierges américaines

Distribución y abundancia de las poblaciones de peces en diferentes hábitats en el pargo criollo (*Lutjanus analis*) Área de Conservación en el Sur Plataforma St. Croix, Islas Vírgenes de EE.UU

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ABSTRACT

In 1993, the Caribbean Fishery Management Council and US Virgin Islands Government established the Mutton Snapper Seasonal Closed Area (MSSCA) south of St. Croix from March 1 – June 30th to protect a spawning aggregation of mutton snapper (*Lutjanus analis*). Bottom tended fishing gear was subsequently banned year round in the closed area to protect coral reef habitat. The habitat within the closed area was mapped. Using benthic transects and roving diver survey techniques a total of 143 fish species and 19,843 individuals were counted within the MSSCA. Eighty–seven species and 8,477 individuals in the roving surveys and 107 species and 13,552 individuals in the benthic transect surveys. *Eupomacentrus partitus*, *Thalassoma bifasciatum*, *Scarus taeniopterus* were among the most abundant fishes in all benthic habitats. Acanthuridae, Scaridae and Holocentridae were the most abundant preferred edible fish (PEF) families totaling 77.3% of the PEF. Family Lutjanidae was not common and comprised 1.46% of PEF. Ten individuals of *Lutjanus analis* were observed in 2009 and 2010. Only one lionfish (*Pterois volitans*) was observed on the outer reef slope in July 2010 despite over 250 diver hours from April 2009 to July 2010.

KEY WORDS: coral reef, fisheries management, *Lutjanus analis*, Virgin Islands

CHAPTER 4

Pilot Study of Back Reef Embayments and Bays on the East End of St. Croix as post settlement habitat for juvenile grouper and snapper

INTRODUCTION

The aim of this study was to assess the importance of the bays in the East End Marine Park (Fig. 4.1) in providing habitat for juvenile, mutton snapper, *Lutjanus analis*, the focus of this report, and the juvenile stages of other snappers (Lutjanidae) and commercially important groupers (Serranidae).

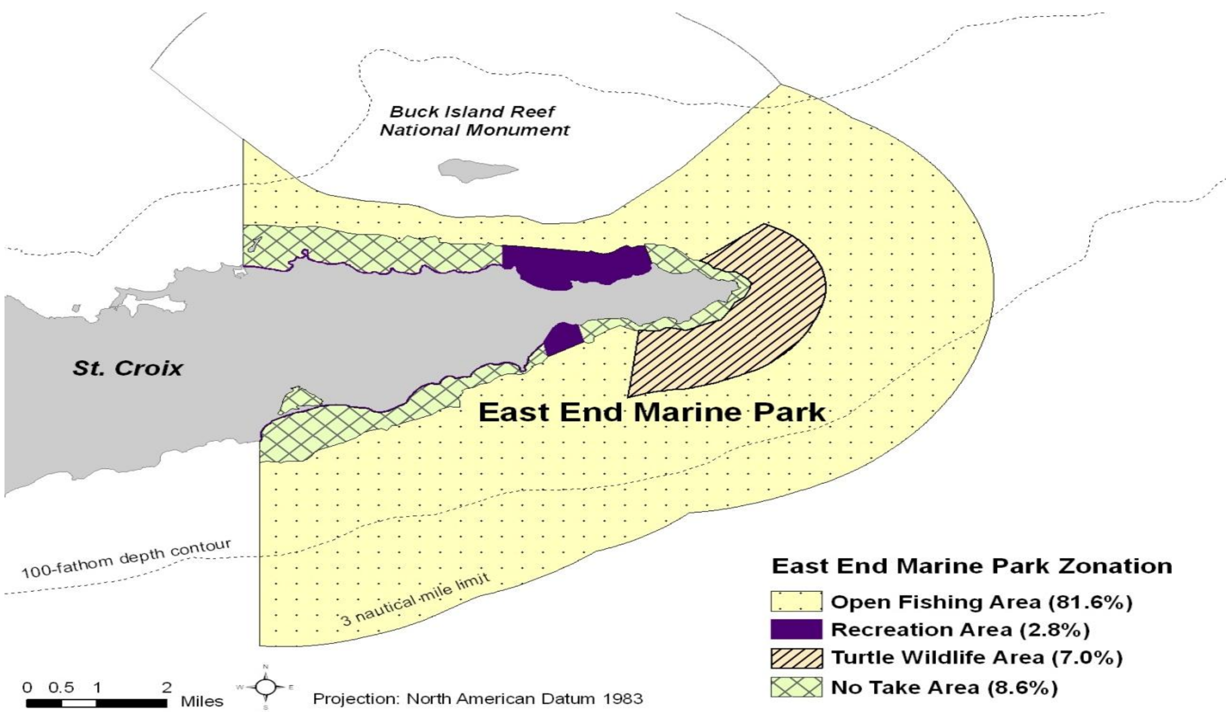

Figure 4.1. Map of the St. Croix East End Marine Park showing the management zones within the park (http://www.stxeastendmarinepark.org/maps.htm).

Ontogenetic habitat shifts, from shallow inshore habitats to offshore reefs have been reported for a number of tropical fish species. Juvenile snappers have been documented to recruit to shallow coastal habitats in Cuba (Claro and Lindeman 2003) and in specific habitats such seagrass in Florida (Bortone and Williams 1986, Anon. 2008), and seagrass meadows, algal plain, coral rubble, patch reefs and back reefs in back reef embayments in St. Croix (Mateo and Tobias 2001, 2004; Adams and Ebersole 2002). Mateo and Tobias (2001, 2004) and Adams and Ebersole (2002) also documented the presence of juveniles of commercially harvested groupers (Serranidae) in the eastern embayments of St. Croix. The bays studied by Mateo and Tobias (2001, 2004) and Adams and Ebersole (2002) were incorporated into the St. Croix East End Marine Park (Quinn 2010) in 2003 to in part protect fish nursery habitat.

The focal management area for the park, when it was established, was the bays. The management areas were selected based on public workshops that included representatives of commercial and recreational fishers, scuba dive organizations, government agencies, and non-profit organizations. The bays were acknowledged as important nursery areas for commercially harvested fish and queen conch. It was also acknowledged that they had been overfished because of their relatively limited area and easy access. Most of the shallow water bays have been zoned no-take areas, except for several areas which permit recreational line fishing: a strip along the shoreline throughout the park; Teague and Cotton Garden Bay, which includes Cramer Park, a public park, on the north shore; and part of Turner Hole on the south shore (Fig. 4.1). We chose to study two bays in the East End Marine Park which are subject to the parks no take provisions and will afford substantial protection once the regulations come into force.

Two types of bays are found within the park: 1) back reef embayments which consist of a shallow lagoon protected by an emergent reef, usually with shallow channels through which tidal and wind driven currents flow and 2) open bays with similar habitats but no emergent reef protecting them from heavy seas. In 2009, four bays were surveyed in the park. Two, Robin Bay, a back reef embayment and Chenay Bay, an open bay (Fig. 4.2) were selected for more intensive study. Robin Bay was previously studied by Mateo and Tobias (2004). In their monthly, one year study of six east end bays, they recorded juveniles of six species of Lutjanidae and five species of commercially important Serranidae, but only the yellowtail snapper was recorded in reasonably high density. Also, only two mutton snapper juveniles were recorded, both in a single bay, Turner Hole. They primarily sampled seagrass meadows (80% of samples), but reported the highest densities of juvenile fish in structured habitats, e.g. coral rubble and patch reefs. Less than 4% of their samples were taken in these structured habitats. Also, they did not survey the reefs behind the reef crest (back reefs). This habitat type was sampled by Adams and Ebersole (2002) in back reef embayments in St. Croix, but they did not sample Robin Bay. Based the results of these authors and our own observations, the back reef of Robin Bay, was sampled along with seagrass and sand habitats in Robin Bay.

Chenay Bay, an open bay, had not previously been sampled. It was chosen because it contained habitats found in the embayments, *e.g*. shallow seagrass meadows, sand, and coral rubble, and also contained deeper water seagrass and pavement habitats. Being an open bay, there were potentially fewer impediments to larval recruitment, *i.e*. no emergent reef potentially blocking recruits from entering the bay. It did not contain back reef habitat because there were no emergent reefs fronting the bay.

In 2010, the inshore beachrock habitat on the western shoreline of St. Croix south of Frederiksted was searched for juvenile snapper and grouper. The west end of St. Croix is down current of almost the entire St. Croix shelf and was considered a potential "sink" for snapper and grouper larval settlement.

MATERIALS AND METHODS

Four bays were surveyed to determine the range of shallow water habitat types in each bay, check for the presence of early and later stage juvenile snapper and grouper, and to select bays and habitats to more intensively survey. Robin Bay and Rod Bay on the south shore and Chenay Bay (Fig. 4.2) on the north shore were surveyed using snorkels and underwater scooters and Cotton Garden Bay (Fig. 4.2) was surveyed with snorkels only. Two bays, Chenay Bay on the north shore and Robin Bay on the south shore (Fig. 4.1), were selected for further study. In these bays, representative sites were selected based on the snorkel surveys and NOAA NOS habitat maps (Kendall et al 2001) (Fig. 4.3). Surveys were conducted during summer (July 2009), one of the two seasons (summer and fall) with the highest fish density (Mateo and Tobias 2004; Adams and Ebersole, 2002) and highest species diversity (H') and eveness (J') (Mateo and Tobias, 2004).

Figure 4.2. Google Earth image of the East End of St. Croix showing location of Rod Bay and Robin Bay on the south shore, Chenay Bay (west) and Cotton Garden Bay (east) on the north shore.

Selected representative habitat types in Chenay Bay and Robin Bay were more intensively surveyed. The location of each surveyed site was marked using a Garmin GPSmap 76Cx. Coordinates for the two deeper water sites in Chenay Bay (CBP1 and CBSG2) were obtained by recording the coordinates as divers entered the water. Shallow water sites sampled using snorkeling were marked by towing the Garmin GPS in tracking mode attached to a float and determining the GPS location of the site from the track (remainder of sites).

At each of the intensively surveyed sites (six in Chenay Bay and three in Robin Bay), five 10m transect lines were deployed with the exception of CBSG3 where six transect lines were deployed and six fish surveys, but only five benthic surveys, were conducted. Ten quadrats (0.25 m^2) were photographed using an Olympus SW1030 digital camera along five 10m transect lines in each habitat. The habitat in each quadrat was analyzed by estimating the percent cover of the major habitat components and averaging the results for the ten quadrats from each transect and averaging the mean for each transect at each site. Fish species and phase were recorded two meters either side of the transect line. Fifteen minute roving fish censuses were also conducted at each of the above sites. In Chenay Bay, a seventh site, CBBR7 - intertidal beach rock, was surveyed during a snorkel swim.

Two other sites, the eastern end of Cotton Garden Bay and the shallow inshore coastal beach rock habitat south of Frederiksted, were searched for snapper and grouper juveniles using snorkel for and, for the Frederiksted habitat, scuba.

Chenay Bay

Chenay Bay, located on the north coast of St. Croix, is a relatively large bay with extensive seagrass, sand, and colonized pavement habitat. Seven sites, representative of seven different habitats were surveyed. Table 4.1 provides the location, depth and description of each site. Figure 4.3 shows the NOAA NOS habitat map of Chenay Bay. Five of the six habitats mapped by NOAA were surveyed. The only habitat not surveyed was the deeper water patchy seagrass 70-90% habitat. CBP1 and CBSG2 were deeper water sites (7.6 - 9 m depth) accessed by boat and surveyed using scuba (Fig. 4.3). The other sites were shallow water sites accessed from shore and surveyed by snorkeling (Fig. 4.4 & 4.5).

Table 4.1. Summary of sites surveyed in Chenay Bay, north shore, St. Croix, U.S. Virgin Islands.

Site Code	Date of Survey	Latitude (N)*	Longitude (S)*	Depth (m)	NOAA NOS Habitat Category	Description of Site
CBP1	14 July 2009	17.7792	-64.66176	7.6	Reef/Colonized Pavement	Deeper water: Pavement with turf and macroalgae, sponges, and some shallow cracks and crevasses
CBSG2	15 July 2009	17.77343	-64.66062	9.0	Seagrass Patchy - 30-50%	Deeper water: Seagrass on sand with many sea pussys (*Meoma ventricosa*)
CBSG3	16 July 2009	17.76027	-64.66076	1.9	Continuous seagrass	Shallow water: >75% seagrass (primarily *Thalassia testudinum* (turtle grass) with some *Syringodium filiforme* (manatee grass).
CBSG4	24 July 2009	17.76046	-64.66175	2.0	Patchy Seagrass - 10-30%	Shallow water: Primarily sand with some coral rubble. Seagrass <1%
CBSG5	24 July 2009	17.76102	-64.66183	2.0	Patchy Seagrass - 10-30%	Shallow water: 10-30% seagrass on sand
CBP6	25 July 2009	17.76287	-64.66138	2.0	Reef/Colonized Pavement	Shallow water: Pavement with consolidated coral rubble (primarily dead *Porites* branches and slabs of dead *Acropora palmata*). Rubble rises about 1m above surrounding pavement and sand.
CBBR7	28 July 2009	17.909708	-64.66048	Inter-tidal	Reef/Colonized Bedrock	Intertidal: Beach rock with undercut ledge. Sand and seagrass seaward of beach rock.

* The coordinate system used is WGS84. Coordinates mark the approximate center of the area covered in transect surveys.

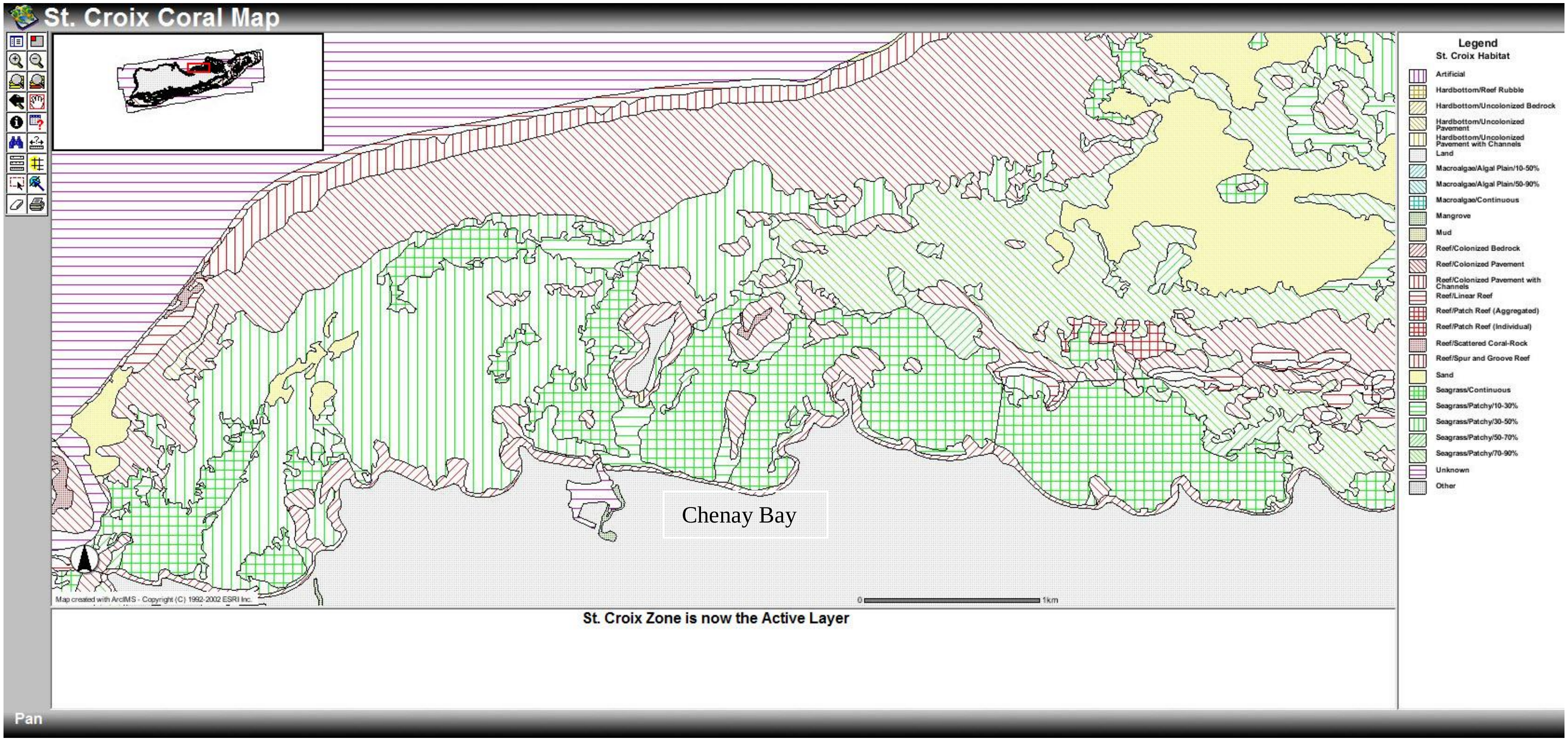

Figure 4.3. NOAA NOS habitat map encompassing Chenay Bay showing habitat breakdown.

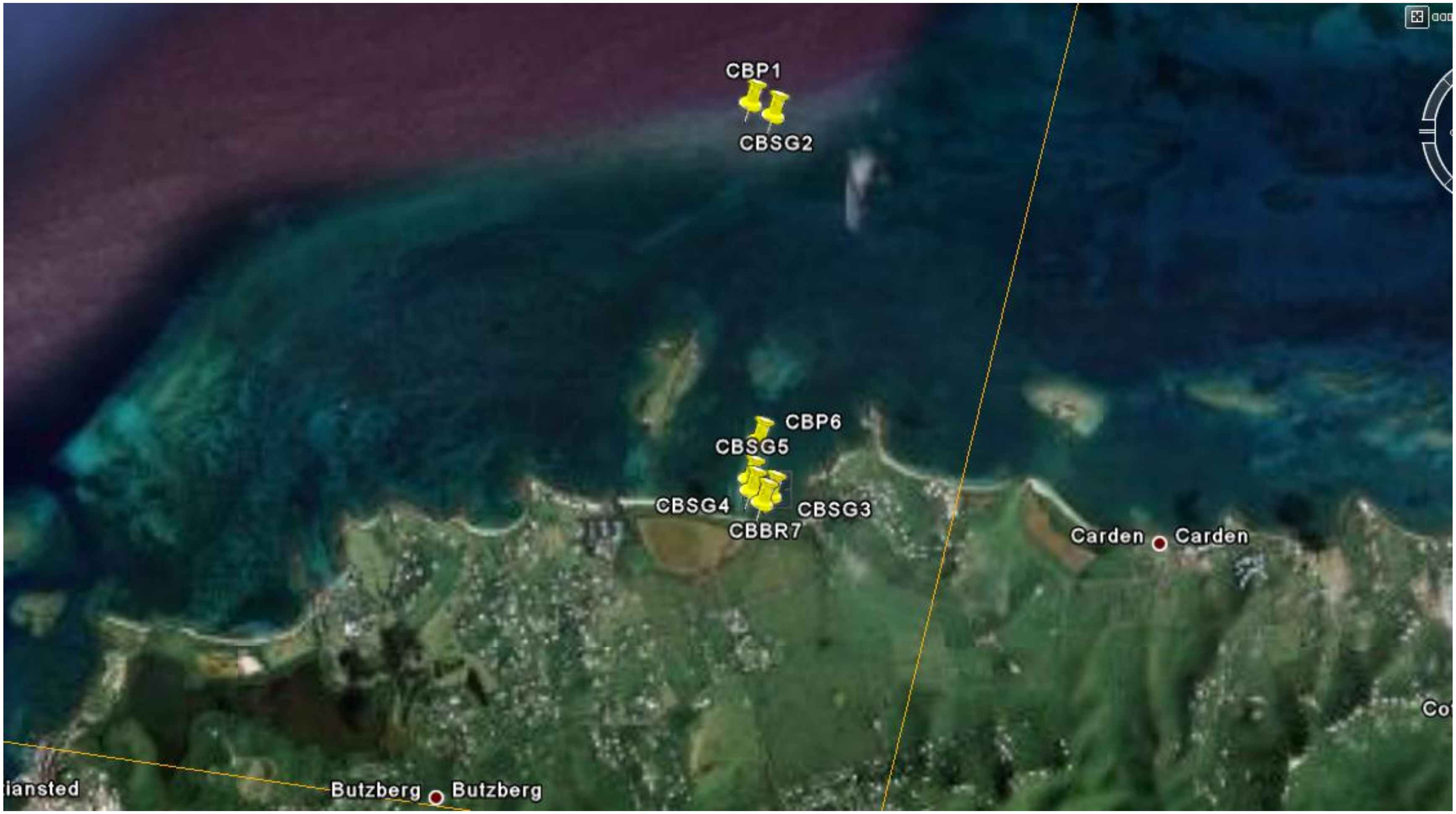

Figure 4.4. Google Earth map showing approximate locations of sample sites.

Figure 4.5. Google Earth map showing location of survey sites in inner Chenay Bay.

Robin Bay and Rod Bay

On the south shore, initially, snorkel surveys were conducted in Rod Bay and Robin Bay (Fig. 4.2), using underwater scooters, to get an overview of the habitat in the bays and the distribution and abundance of post settlement and juvenile snapper and grouper juveniles. Photographs were taken of the habitats, especially habitats with juvenile snapper. Three sites representative of the main habitat types in Robin Bay were more intensively surveyed using the transect/quadrat method described above. Table 4.2 lists the site coordinates, depth and briefly describes the habitat. Figure. 4.6 is the NOAA NOS habitat map for Rod and Robin Bays. Three of the six habitats mapped by NOAA NOS were intensively surveyed. Five of the six were surveyed by scooter transect. The only habitat not surveyed was the Reef/Spur and Groove which was too exposed to wave action to survey. The three sites intensively surveyed are shown on a Google Earth image (Fig. 4.7) and a Google Maps image (Fig. 4.8). The latter has much better resolution than the former.

Table 4.2. Summary of sites surveyed in Robin Bay, south shore, St. Croix, U.S. Virgin Islands on July 13, 2009.

Site Code	Latitude (N)*	Longitude (S)*	Depth (m)	NOAA NOS Habitat Category	Description of Site
RB1	17.72472	-64.63176	2	Seagrass/Continuous	Continuous seagrass: >75% seagrass - primarily *Thalassia testudinum* (turtle grass) with some *Syringodium filiforme* (manatee grass).
RB2 south end of survey site	17.72454	-64.63182	2	Seagrass Patchy 10-30%	Sand patch (<10% seagrass) - primarily *S. filiforme*.
RB2 north end of survey site	17.7246	-64.63182	2	Seagrass Patchy 10 -30%	Sand patch (<10% seagrass) primarily *S. filiforme.*
RB3- 1 Transects 1-3	17.72339	-64.63167	2	Reef/Linear Reef	Back reef habitat: coral reef located behind the reef crest - primarily dead coral reefs surrounded by pavement, coral rubble, seagrass (primarily *T. testudinum*) and/or sand.
RB3- 2 Transects 4&5	17.72316	-64.63165	2	Reef/Linear Reef	Back reef habitat as above.

* The coordinate system used is WGS84. Coordinates mark the approximate center of the area covered in transect surveys.

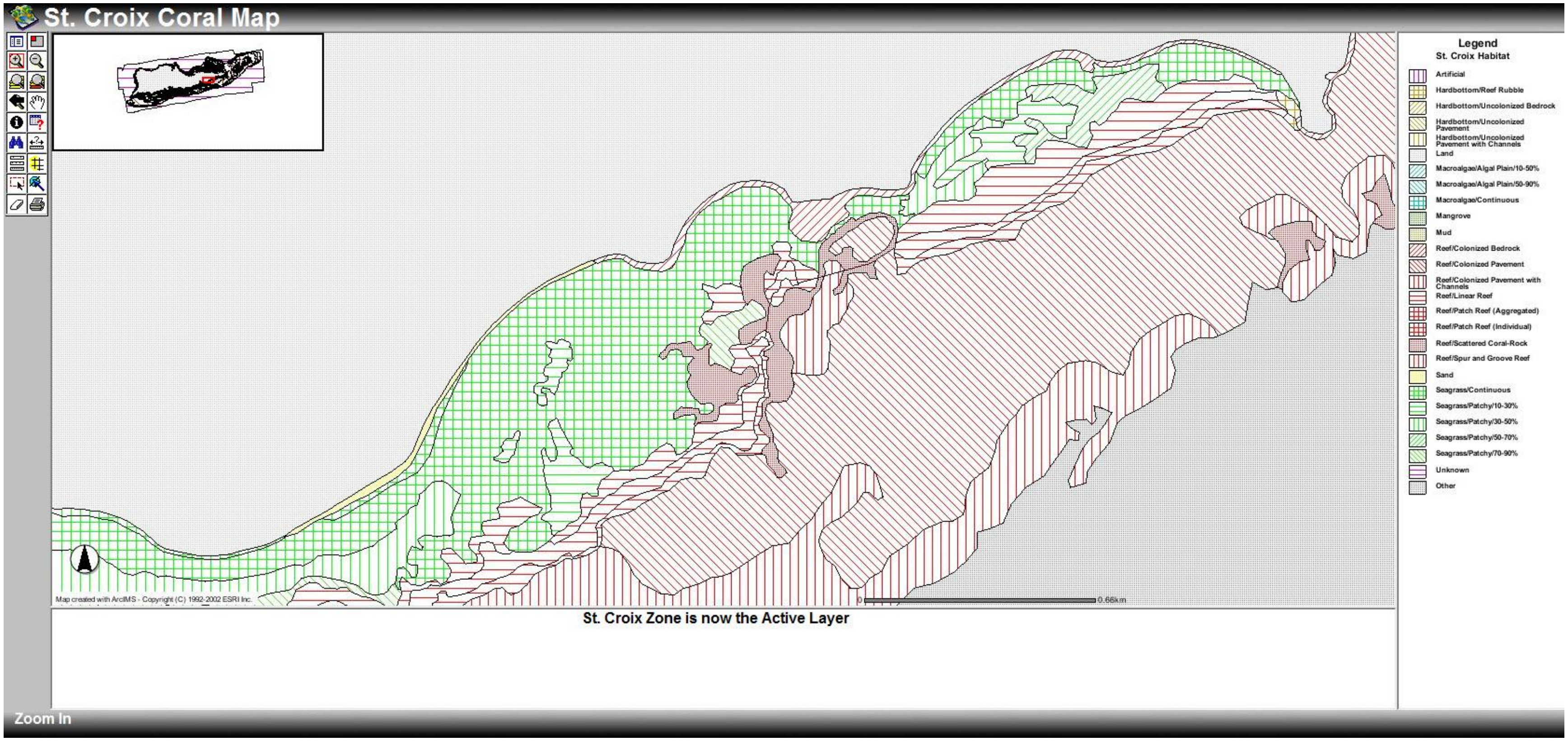

Figure 4.6. NOAA NOS habitat map of Robin and Rod Bays, south coast St. Croix.

Figure 4.7. Robin Bay, St. Croix with the location of the three sites surveyed marked.

Figure 4.8. Robin Bay, St. Croix with using the new Google Maps image with the three sites surveyed marked by the approximate coordinates. This Google Maps image has better habitat resolution.

RESULTS

Chenay Bay

A variety of habitat was searched for newly settled and juvenile grouper and snapper. Two habitats characteristic of the deeper water habitats in the outer part of Chenay Bay as shown on NOAA NOS habitat maps (Fig. 4.3) were more intensively sampled. Six habitats in the inner part of the bay which characterized habitats mapped by NOAA NOS and were observed during scooter surveys were also more intensively sampled.

Habitat

Table 4.3 provides a summary of the cover of various habitat components in the different types of habitats. Coral cover was highest at CBP1 (Fig. 4.9), though coral only comprised 0.6% of the total coral cover. Eleven scleractinian corals and one *Millepora* (*M. alcicornis*) were recorded. *Siderastrea siderea* (number of colonies: 22), *Diploria strigosa* (19), *Porites astreoides* (15), and *Montastrea cavernosa* (14) had the highest number of colonies recorded. A variety of algal genera were recorded, primarily the phaeophytes: *Dictyota*, *Turbinaria*, *Padina* and *Saragassum*; the rhodophyte *Amphiroa*, Chlorophyte algae: *Penicillus*, *Neomeris*, and *Avrainvillea*; and Cyanobacteria. The gorgonians *Briarium asbestinum* and *Gorgonia ventalina* were present but rare. The deeper water seagrass habitat CBSG2 (Fig. 4.10) was a sand and seagrass/algal habitat. *Thalassia testudinum* and *Syringodium filiforme* were present in all five transects. Cyanobacteria and Chlorophyta (e.g. *Halimeda* and c.f. *Avrainvillea)* were the predominant algal taxa.

Table 4.3. Mean percent cover of various biotic and abiotic habitat components at six sites in Chenay Bay, St. Croix, U.S. Virgin Islands.

Site	Sand Covered Pavement	Sand	Rubble*	Algae	Seagrass	Sponge	Coral	Other
CBP1	41.1	0	11.9	38.0	6.4	2.0	0.6	11.9
CBSG2	0	60.0	2.7	14.9	21.6	0.3	0.1	0.4
CBSG3	0	17.0	0.9	12.5	69.5	0.1	0.0	0
CBSG4	0	77.00	21.42	1.28	0.20	0	0	0
CBSG5	0	57.2	0.9	6.1	35.7	0	0	0
CBP6	0	12.3	72.1	15.0	0	0	0.2	0.3

*Rubble is defined as "low relief, calcareous structure composed primarily of conch shells or dead/dying coral fragments that are not attached to the substrate" (Adams and Ebersole 2002).

The sites in the inner bay ranged from the intertidal beachrock habitat to continuous seagrass with >75% seagrass cover. The sandy beach in Chenay Bay is underlain by beachrock. In certain locations the beachrock is exposed to a depth of about 0.5m and highly eroded with pits and crevasses. These features and an undercut ledge create habitat for a variety of fish,

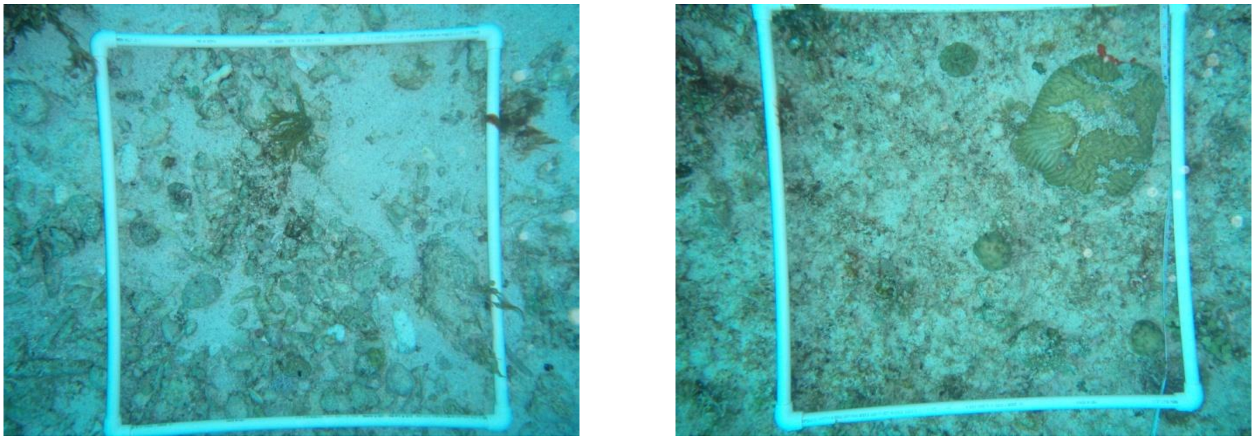

Figure 4.9. Representative photos showing the type of habitat found in CBP1 in the outer part of Chenay Bay, St. Croix, USVI. Square is $0.25m^2$.

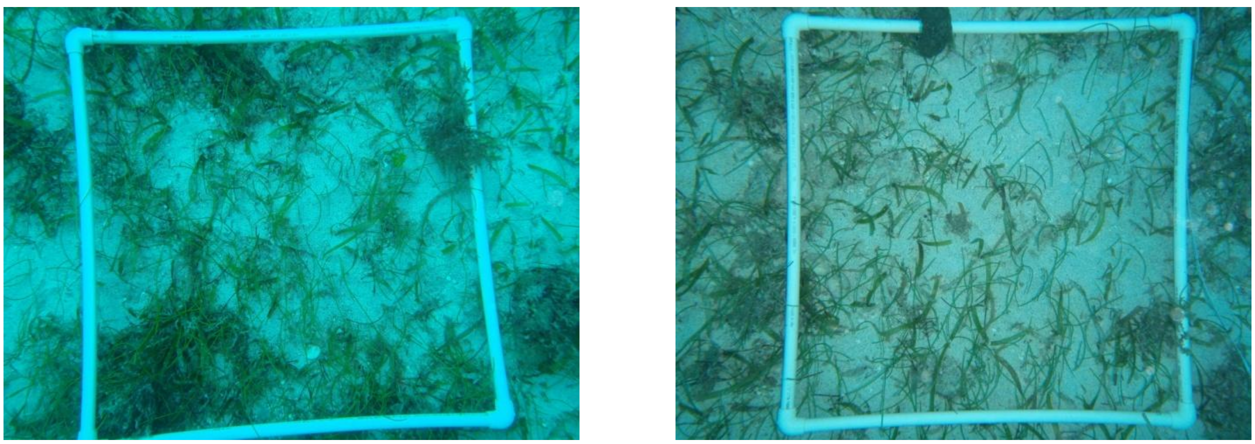

Figure 4.10. Representative photos of habitat found in CBSG2 in the outer part of Chenay Bay. Square is $0.25m^2$.

especially juvenile snapper. Snapper and grouper counts were carried out along the length of the exposed beachrock habitat - approximately 75m. Visibility was too poor to obtain photos of this habitat.

The sites in the inner bay ranged from the intertidal beachrock habitat to continuous seagrass with >75% seagrass cover. The sandy beach in Chenay Bay is underlain by beachrock. In certain locations the beachrock is exposed to a depth of about 0.5m and highly eroded with pits and crevasses. These features and an undercut ledge create habitat for a variety of fish, especially juvenile snapper. Snapper and grouper counts were carried out along the length of the exposed beachrock habitat - approximately 75m (15 minute census). Visibility was too poor to obtain photos of this habitat.

The three sand/seagrass habitats surveyed, represented the variety of sand habitats in the inner portion of the bay. The highest seagrass density, primarily *T. testudinum*, recorded was 70% in CBSG3 (Fig. 4.11). Algae, primarily Chlorophyta (*Penicillus*, *Halimeda*, and *Caulerpa*

Figure 4.11. Inner Chenay Bay, St. Croix, USVI - CBSG3, continuous seagrass habitat with >75% cover of seagrass.

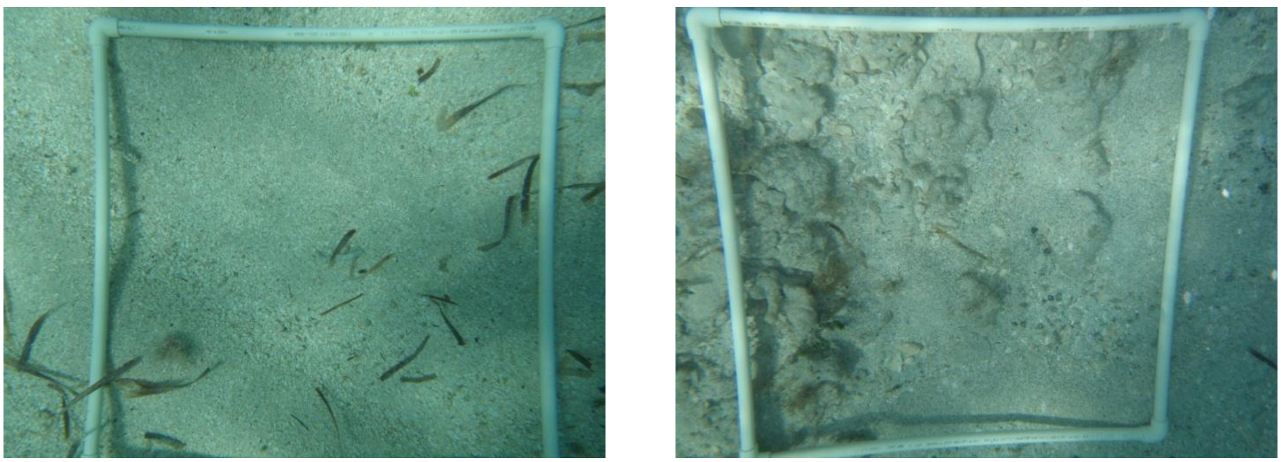

Figure 4.12. Sand and sand/coral rubble habitat characteristic of CBSG4 in inner Chenay Bay, St. Croix, USVI. Square is $0.25m^2$.

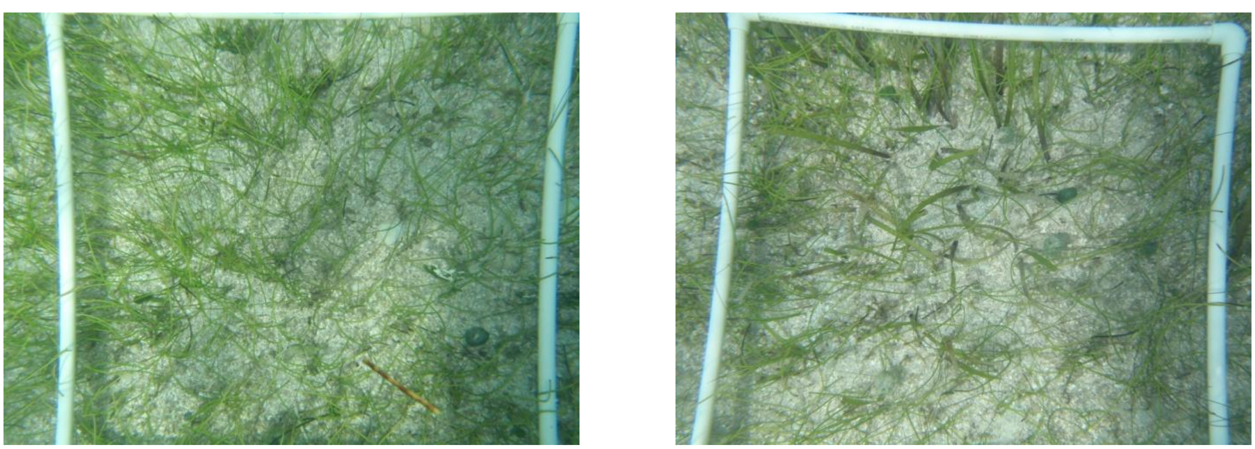

Figure 4.13. Inner Chenay Bay, St. Croix USVI - Photos representative of CBSG5 showing patchy seagrass habitat with seagrass comprising 30-50% cover. Square is $0.25m^2$.

prolifera) comprised 13% of the biota. The only coral recorded was one colony of *P. furcata*. CBSG4 was primarily a sand habitat with coral rubble (Fig. 4.12). Seagrass, primarily *T. testudinum*, comprised <1% of the habitat. CBSG5 was primarily sand (57%) and seagrass (36%) habitat with 6% algae (Fig. 4.13). Both *T. testudinum* and *S. filiforme* were present. The algal component was primarily *Halimeda* and *Penicillus* with some Cyanobacteria. The only consolidated coral rubble habitat surveyed was CBP6 (Fig. 4.14). This site represented the large hard bottom/coral rubble habitat that extended north/south in the center of the inner bay. Consolidated coral rubble comprised 72% of the habitat. The rubble was primarily comprised of dead Porites branches and slabs of *A. palmata* cemented to limestone. Algae, primarily Phaeophyta , *Dictyota*, *Turbinaria*, *Saragassum* and *Padina* with some Rhodophyta and Chlorophyta, covered 15% of the bottom and sand 12%. Sea urchins, including *Diadema antillarum*, were common.

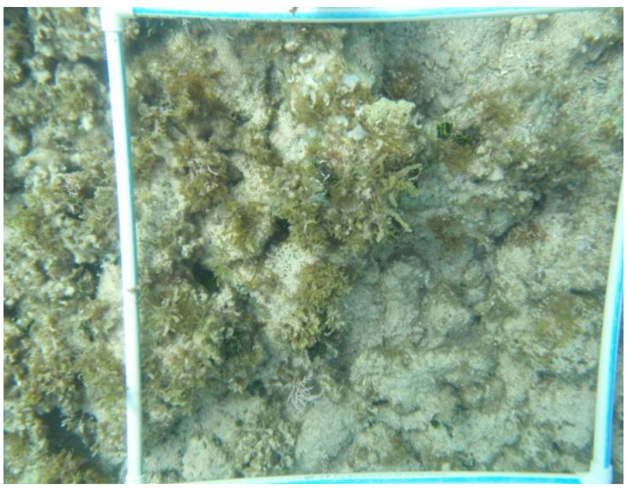
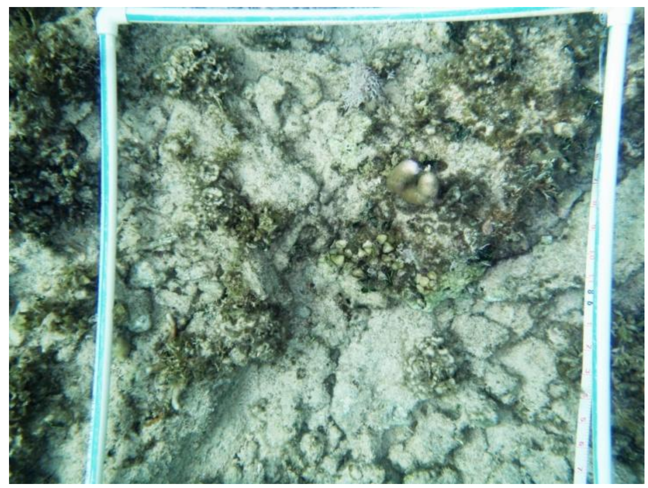

Figure 4.14. Photos of consolidated coral rubble habitat characteristic of CBP6 in inner Chenay Bay, St. Croix, USVI. Square is $0.25m^2$.

Fish Surveys

Twenty-eight species of fish were recorded in roving fish census and 10m transect surveys at two sites in outer Chenay Bay (Table 4.4). At the these two sites, the largest number of species and individuals were in the pavement habitat (CBP1). Only two commercially harvested serranid species were recorded in the outer part of the bay, both at the CBP1 site: 15 juvenile / subadult coneys (*Cephalopholis fulvus*) and four red hind (*Epinephelus guttatus*) (Table 4.4). Other serranids reported were the lantern bass (*Serranus baldwini*) and the harlequin bass (*S. trigrinus*). No snappers, adult or juvenile, were recorded. Five parrotfish species, three of which are commercially harvested (redband, redtail and yellowtail) were recorded. Most of the parrotfish were juvenile and initial stages (Table 4.4).

In contrast to outer Chenay Bay, no commercially harvested groupers, juvenile or adult, were recorded, but snappers were (Tables 4.5 and 4.6). All snappers recorded were juveniles or subadults. They were present in four of the five habitats surveyed. The only habitat they were not recorded was CBSG4 which was predominately a sand habitat with some buried coral rubble and a very minor seagrass component. Juvenile snapper look for structure and while present in CBSG3, >75% seagrass, they were mostly in locations with dead conch shells, coral rubble, and blowouts. The one time juvenile snapper were seen away from these habitats, they were swimming rapidly through the seagrass in a small group.

Size varied among the snapper species in the roving fish surveys with lane snapper ranging in size from 1cm (semi-transparent) - 5cm, yellowtail 1.5 - 9 cm, mahogany 7 - 9cm, and gray and schoolmaster 14 cm. The highest numbers (22 individuals) and species diversity (5 species) of snappers were recorded along the beachrock (CBBR7) (Table 4.5). The area surveyed included a seagrass ledge (blow out) immediately adjacent to a section of the beachrock where a small school of mahogany snapper were seen. The continuous seagrass habitat (CBSG3) had the second highest number of individual snappers (18) and species diversity (3) (Table 4.5). Yellow tail snapper were most common in CBSG3 (>75% seagrass habitat) where they comprised 67% of the snapper recorded in this habitat. They were also present but much less common in the beachrock habitat.

Mostly small labrids, pomacentrids and scarids were recorded in transect surveys in inner Chenay Bay. The only commercially harvested parrotfish recorded was the striped parrotfish (*Scarus iserti*) (Table 4.6). All *S. iserti* were juvenile or small initial stages. Almost equal numbers of juvenile and adult *Acanthurus chirurgus/bahianus* were recorded.

Table 4.4. Fish species, including maturity stages, recorded at the two outer Chenay Bay sites.

Family	Scientific name	Common name	Stage	CBP1 Roving Fish Survey	CBP1 Transects	CBSG2 Roving Fish Survey	CBSG2 Transects	Total
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	adult	9	6	27	0	42
			juvenile	40	0	0	6	46
Balistidae	*Balistes vetula*	Queen triggerfish	juvenile	1	0	0	0	1
Carangidae	*Trachinotus falcatus*	Permit		1	0	0	0	1
Dactylopteridae	*Dactylopterus volitans*	Flying gurnard	juvenile	0	0	1	0	1
Holocentridae	*Holocentrus sp.*	Squirrelfish adscensionis or rufus	adult	15	0	0	0	15
Holocentridae			juvenile	6	0	0	0	6
Labridae	*Halichoeres bivittatus*	Slippery dick	terminal	0	0	0	1	1
			initial	0	0	0	4	4
			intermediate	0	0	0	6	6
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	juvenile	0	1	0	0	1
Labridae	*Halichoeres maculipinna*	Clown wrasse	intermediate	0	2	0	0	2
			juvenile	0	1	0	0	1
Labridae	*Halichoeres poeyi*	Blackear wrasse	intermediate	0	0	0	1	1
Labridae	*Halichoeres radiatus*	Puddingwife	juvenile	0	0	1	0	1
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	terminal	0	3	0	0	3
			juvenile/initial	0	68	0	0	68
Labridae	*Xyrichtys martinicensis*	Rosy razorfish	male	0	0	0	1	1
			juvenile	0	0	0	2	2
			unreported	0	0	0	1	1
Malacanthidae	*Malacanthus plumieri*	Sand tilefish	adult	1	0	0	0	1
			juvenile	2	0	0	0	2
Monocanthidae		file fish unidentified		0	0	2	0	2
Monacanthidae	*Monacanthus ciliatus*	Fringed filefish		0	0	0	1	1
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	juvenile	2	0	0	1	3
Ostraciidae	*Lactrophrys sp.*	Trunkfish		5	0	1	0	6
Pomacentridae	*Eupomacentrus partitus*	Bicolordamselfish		0	11	0	0	11
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	juvenile	0	16	0	6	22
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	initial/juvenile	0	1	11	0	12
			intermediate	0	0	0	2	2
			juvenile	0	2	0	1	3
Scaridae	*Sparisoma chrysopterum*	Redtail parrotfish	terminal	5	0	0	0	5
			initial	7	0	0	0	7
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	terminal	0	0	0	1	1

Family	Scientific name	Common name	Stage	CBP1 Roving Fish Survey	CBP1 Transects	CBSG2 Roving Fish Survey	CBSG2 Transects	Total
			juvenile	0	4	0	0	4
Tetraodontidae	*Sparisoma rubripinne*	Yellowtail parrotfish	initial/juvenile	0	0	8	0	8
			juvenile	10	0	0	0	10
Serranidae	*Cephalopholis fulvus*	Coney	juvenile	15	0	0	0	15
Serranidae	*Epinephelus guttatus*	Red hind	juvenile	4	0	0	0	4
Serranidae	*Serranus baldwini*	Lantern Bass		0	3	0	1	4
Serranidae	*Serranus tigrinus*	Harlequin Bass	adult	0	2	0	0	2
Tetraodontidae	*Sphoeroides spengleri*	Bandtail puffer		0	0	0	1	1
		Total number fish		**123**	**120**	**51**	**36**	**330**
		Total number of species		**12**	**10**	**7**	**9**	**28**

Table 4.5. Snapper and commercially important grouper species and life stages recorded at the five sites surveyed during 15 minute roving fish surveys in the inner part of Chenay Bay, St. Croix, USVI.

Family	Scientific name	Common name	Stage	CBSG3	CBSG4	CBSG5	CBP6	CBBR7	Total
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	juvenile	3		4		2	9
Lutjanidae	*Lutjanus griseus*	Gray snapper	juvenile					1	1
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	juvenile					13	13
Lutjanidae	*Lutjanus synagris*	Lane snapper	juvenile	3		4		4	11
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	juvenile	12				2	14
Serranidae									0
		Total number fish		**18**	**0**	**9**	**0**	**22**	**48**
		Total number of Lutjanidae species		**3**	**0**	**2**	**0**	**5**	**5**

Table 4.6. Fish species and life stages recorded in transect surveys at four sites in inner Chenay Bay, St. Croix, USVI.

Family	Scientific name	Common name	Stage	CBSG3	CBSG4	CBSG5	CBSG6	Total
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	adult	0	0	0	8	8
			juvenile	0	3	0	6	9
Bothidae	*Bothus* sp.	Flounder		0	1	0	0	1
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	juvenile	2	0	0	0	2
Labridae	*Halichoeres bivittatus*	Slippery dick	terminal	0	0	0	1	1
			intermediate - terminal/initial	0	1	0	13	14
			intermediate - initial/juvenile	1	4	1	0	6
			juvenile	6	4	0	2	12
			unreported	0	0	0	2	2
Labridae	*Halichoeres garnoti*	Yellowhead wrasse	intermediate	1	0	0	0	1
			juvenile	3	0	0	0	3
Labridae	*Halichoeres maculipinna*	Clown wrasse	terminal	0	0	0	1	1
			juvenile	0	0	0	2	2
Labridae	*Halichoeres poeyi*	Blackear wrasse	intermediate	1	1	0	1	3
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	intermediate	0	0	0	5	5
			juvenile/initial	0	0	0	8	8
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	juvenile	2	0	0	0	2
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	juvenile	0	2	0	0	2
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory	adult	0	0	0	5	5
			juvenile	7	0	0	7	14
Pomacentridae	*Eupomacentrus partitus*	Bicolordamselfish		0	0	0	3	3
Scaridae		Small unidentified parrotfish		5	2	0	0	7
Scaridae	*Scarus iserti*	Striped parrotfish	juvenile/initial	0	0	3	0	3
Scaridae	*Sparisoma atomarium*	Greenblotch parrotfish	unreported	1	0	0	0	1
			initial - juvenile	0	4	0	0	4
			juvenile	2	2	2	1	7
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	initial	4	0	0	0	4
			juvenile	1	0	0	0	1
			unreported	0	0	0	1	1
Serranidae	*Serranus tabacarius*	Tobaccofish	adult	0	0	0	1	1
Serranidae	*Serranus tigrinus*	Harlequin Bass	adult	0	0	0	2	2
Synodontidae	*Synodus intermedius*	Sand diver		0	0	0	1	1

Family	Scientific name	Common name	Stage	CBSG3	CBSG4	CBSG5	CBSG6	Total
Tetraodontidae	*Canthigaster rostrata*	Sharpnose puffer		0	0	1	0	1
		Total number fish		44	24	7	70	145
		Total number of Lutjanidae species		**9**	**7**	**3**	**12**	**20**

Robin Bay

Habitat

Robin Bay is a large bay located in the drier east end of the island. The bay is protected by an emergent reef that extends from Grass point (the eastern end of Rod Bay) to the western end of Great Pond Bay (Fig. 4.2). It harbors a variety of habitats including dense seagrass (primarily in the inner two-thirds of the bay), sand, consolidated coral rubble, patch reefs, and coral reef (back reef). The latter three habitats are predominately located in the outer third of the bay behind the reef crest. The back reef and patch reefs are largely dead today, but it is still clear from the skeletons of the corals and the remaining living tissue, that three genera (branching *Porites*, *Montastrea annularis*, and *Acropora palmata*) were the predominant reef builders in the back reef. Today, most of these large, formerly monotypic reefs are covered in algae (calcareous, turf and macro algae). Coral cover is low (Table 4.7) and, except for *M. annularis*, predominately of species, other than those that originally constructed the reefs.

Table 4.7. Mean percent cover of various habitat components at three sites in Robin Bay, St. Croix, U.S. Virgin Islands. Sites were sampled on July 13, 2009.

Site	Sand	Rubble	Algae	Seagrass	Sponge	Coral	Dead Coral Reef	Other
RB1 $\bar{x}$ (SD)	15.5 (±7.4)	0.0	1.6 (±0.5)	82.8 (+7.7)	0.0	0.0	0.0	0.1[1] (±0.2)
RB2 $\bar{x}$ (SD)	97.4 (±3.3)	0.0	0.7 (+0.6)	2.0 (+3.2)	0.0	0.0	0.0	0.0
RB3 $\bar{x}$ (SD)	3.3 (±4.0)	1.1 (±0.8)	25.0 (±7.4)	6.3 (±5.5)	0.2 (±0.4)	2.0 (±1.5)	62.0 (±9.7)	0.1[2] (±0.2)

[1] "Other" in dense seagrass was one *Echinometra ventricosa* (West Indian sea egg).
[2] "Other" in back reef habitat was *Briarium asbestinum* (corky sea fingers).

RB1 was almost exclusively as seagrass habitat (Table 4.7) dominated by *Thalassia testudinum* (turtle grass) with *Syringodium filiforme* (Fig. 4.15). No coral rubble was recorded at this site. However, seagrass extends into the back reef crest habitat (RB3) and coral rubble becomes increasingly common closer to the reef. One *Echinometra ventricosa* was recorded in the quadrats. This species was common in seagrass in the middle of the bay. Algae was only a minor component of the seagrass community. The primary algal species recorded was *Penicillus capitatus/ lamourouxii* (species indistinguishable in photographs). RB2 was almost exclusively sand (Table 4.7) with a few strands of *S. filiforme* (Fig. 4.15). Two queen (*Strombus gigas*) and eight milk (*S. costatus*) conch (Fig. 4.15) were recorded in the sand patch during a timed 15 minute swim. An egg mass (12cm in length) and a milk conch laying eggs was observed.

Figure 4.15. Left: Dense seagrass habitat (similar to RB1) near back reef crest community (RB3) dominated by *Thalassia testudinum*. As shown in this photo, coral rubble is present in seagrass beds immediately behind the back reef crest. Right: Milk conch (*Strombus costatus*) n the sand patch surveyed (RB2).

RB3, the back reef habitat, was the most diverse of the three habitats (Table 4.7). It harbored a wide range of largely dead reefs, each predominately composed of a single species. The reefs consisted of the skeletons of *Acropora palmata* (Fig. 4.16), *A. cervicornis rubble* (Fig. 4.17), *Porites furcata* (Fig. 4.18), *Montastrea annularis* and *M. faveolata* (Fig. 4.19). These previously, predominately single species reefs, are now being colonized by a variety of coral species. The reef building species that formed these reefs are not substantially recovering and coral cover is low (2%) (Table 4.8). No acroporids and only two colonies of *M. faveolata* were present in quadrats. The most common species of coral recorded in quadrats was *Montastrea annularis* (16 colonies) and *Agaricia agaricites* (14) (Table 4.8). Most colonies of *M. annularis* were small or exhibited partial mortality, resulting in up to 15 remnants of what was clearly once a much larger colony (Fig. 4.20). No coral disease was observed.

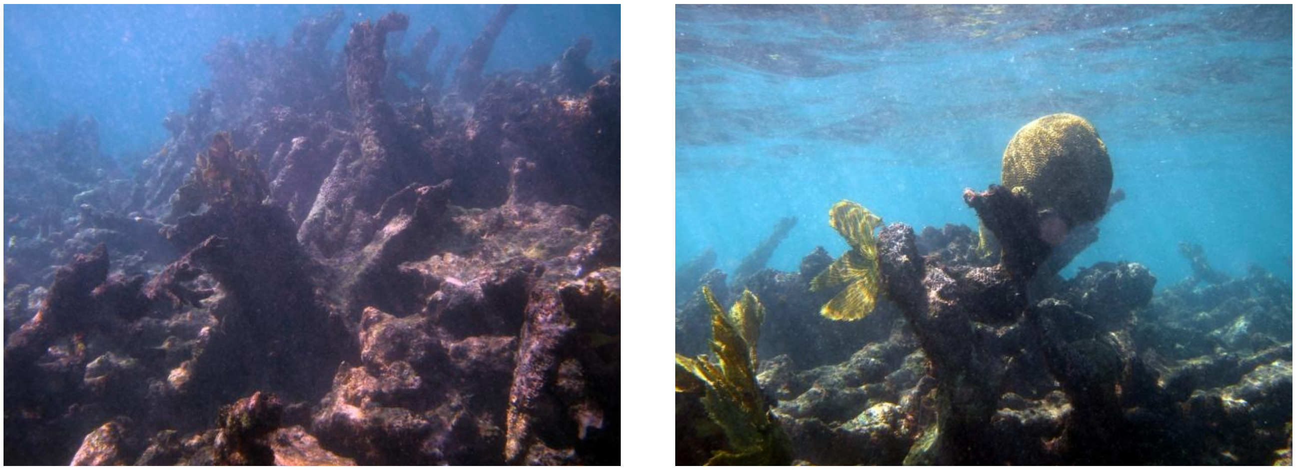

Figure 4.16. Back reef crest habitat in Robin Bay, St. Croix (RB3): Dead, in situ *Acropora palmata* reef. These *A. palmata* reefs in Robin Bay are slowly eroding and breaking up. The dead branches provide settlement sites for other coral species such as the *Diploria strigosa* and gorgonian sea fans. Live colonies of *A. palmata* were extremely rare.

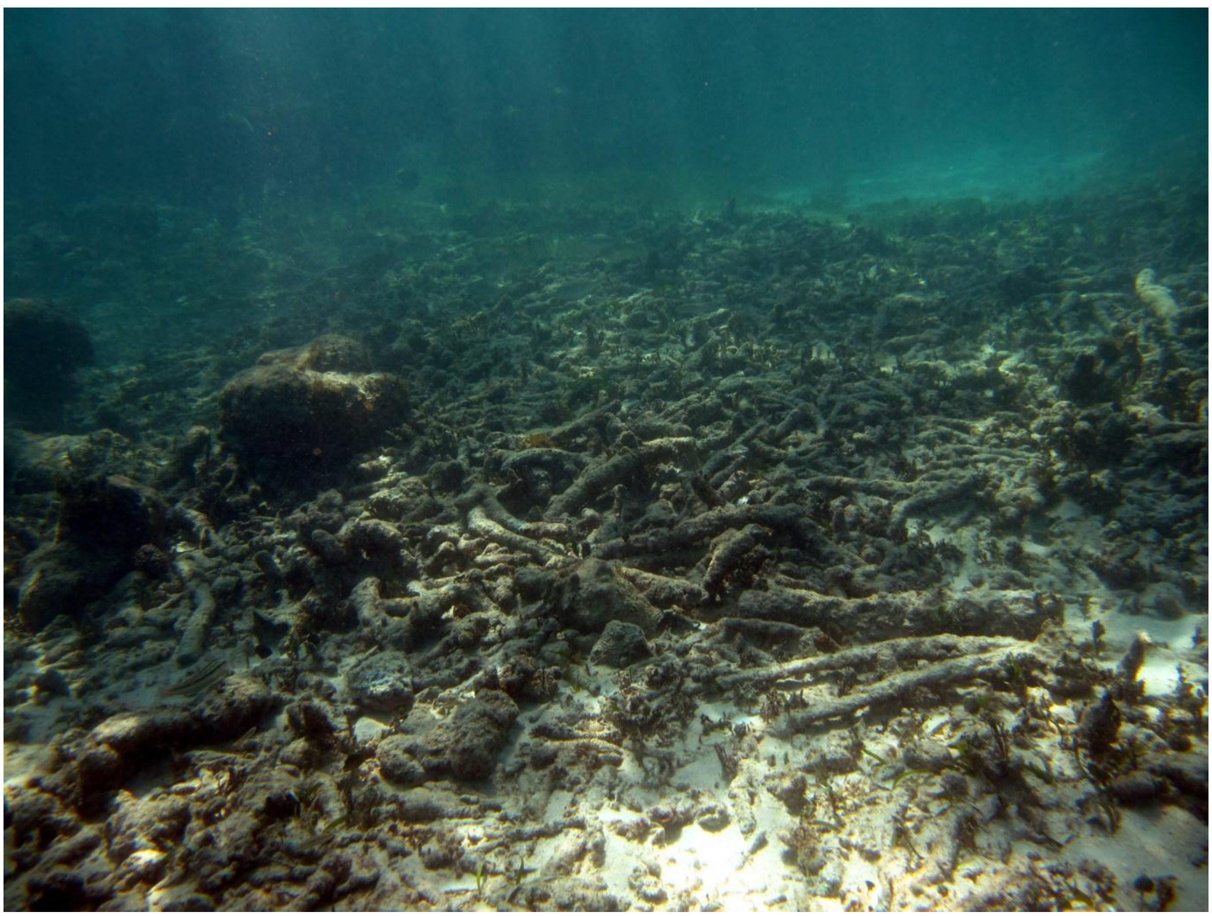

Figure 4.17. Rubble habitat near back reef in Robin Bay, St. Croix (RB3): Former *Acropora cervicornis* reef, now a branching coral rubble field on pavement and sand.

Figure 4.18. Back reef crest habitat in Robin Bay, St. Croix (RB3) (above): Large *Porites furcata* reef (right) with very little living tissue remaining on branches. Smaller isolated *P. furcata* patch reef (left) located in seagrass bed shoreward of back reef with about half of the colony alive.

Figure 4.19. Back reef crest habitat in Robin Bay, St. Croix (RB3) (right): *Montastrea annularis* (upper right photo) and *M. faveolata* patch reefs (lower right photo) frequently showed partial colony mortality. *M. annularis* was the species most frequently recorded in quadrats. Scooter used in transects (bottom photo).

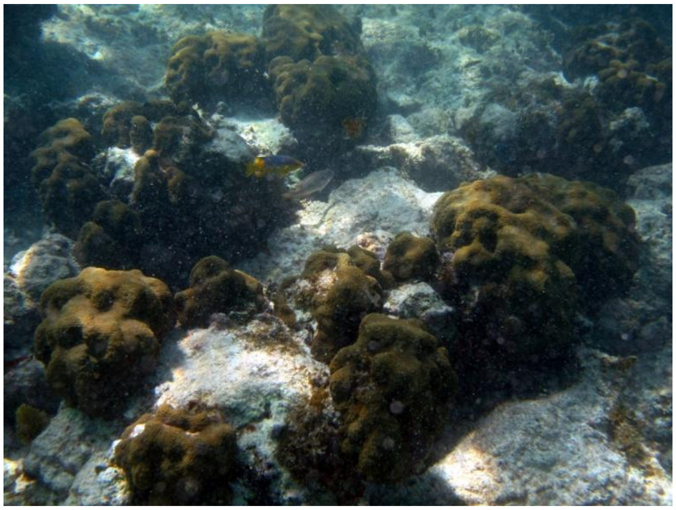

Table 4.8. Back reef crest habitat in Robin Bay, St. Croix (RB3): Coral species and number of colonies recorded in quadrats in RB3.

Coral Species		Number of colonies*
Hydrozoa		
	Millepora alcicornis	1
Scleractinia		
	Agarica agaricites	12 (14)
	A. tenuifolia	1
	Diploria strigosa	1
	Montastrea annularis	16(64)
	Porites astreoides	2
	P. porites	5
	S. siderea	2

*Numbers in parentheses count remnants (partial mortality) as separate colonies.

Figure 4.20. Back reef crest habitat in Robin Bay, St. Croix (RB3): partial mortality of *Montastrea annularis* colony.

Fish Surveys

A total of 31 fish species and 273 individuals were recorded in the Robin Bay surveys (Table 4.9). Most of species, especially the larger species, were represented by juveniles (Table 4.10). The number and species of fish were very low in the dense seagrass and sand habitats in Robin Bay (RB1 and RB2) (Table 4.9). No snappers or groupers, adult or juvenile, were recorded in these two habitats. Fish abundance and numbers of species were much higher in the back reef areas (RB3) (Table 4.9). The families with the highest density in RB3 transects were the Labridae (wrasses) and Pomadasyidae (grunts). Juveniles of four species of Lutjanidae (snappers) were recorded along with one adult serranid, *Cephalopholis fulvus* (coney). The predominant life stage for most species of larger fish size of adults $\geq$20cm) were juveniles or sub adults (1.5-15cm in length). Sub adults of the schoolmaster snapper (*Lutjanus apodus*) in were the largest snappers recorded with a maximum length of about 15 cm, but all had bars on their back, which is characteristic of juveniles (Humann and Deloach 2002).

During scooter and snorkel surveys conducted in Rod Bay on the July 3 - 4, 2009 and in Robin Bay on July 6, 2009 only one mutton snapper juvenile (15 cm) was observed. Juvenile lane, yellowtail, and mahogany snapper were common, invariably associated with the dead coral reefs of the outer bay in Robin Bay and Rod Bay or the small largely dead *Porites* patch reefs in inner Rod Bay (Fig. 4.21 and 4.22). No juvenile or adult grouper were observed.

The bluehead wrasse (*Thalassoma bifasciatum*) was common in the back reef habitats. The juvenile/initial phase is different in the back reef embayments than in the Mutton Snapper Seasonal Closed Area (MSSCA). It is almost exclusively yellow backed without a prominent black stripe in the MSSCA and white or yellow backed with prominent black mid-body stripe and white belly in Robin Bay, a back reef embayment. The white phase is totally absent in the MSSCA.

Figure 4.21. Rod Bay, St. Croix: Juvenile lane snapper (*Lutjanus synagris*), possibly a juvenile schoolmaster snapper (*L. apodus*), blue tang (*Acanthurus coeruleus*), and grunts (*Haemulon* spp.) in a dead *Porites* patch reef.

Figure 4.22. Rod Bay, St. Croix: Juvenile mahogany (*Lutjanus mahogoni*) and schoolmaster snapper (*L. apodus*), school of blue tang (*Acanthurus coeruleus*), and several squirrelfish (*Holocentrus* sp.) on largely dead reef in outer part of the bay

Table 4.9. Robin Bay: Summary of species and life stages of fish observed at three sites in Robin Bay, St. Croix, USVI. Transect surveys were conducted on July 13, 2009 and the roving fish surveys on August 8, 2009.

Family	Scientific name	Common name	Stage	RB1 Roving Fish Census	RB1 Tran-sects	RB2 Roving Fish Census	RB2 Tran-sects	RB3 Roving Fish Census	RB3 Tran-sects	Total
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	adult	0	0	0	0	0	4	4
			juvenile	0	0	0	0	4	4	8
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	adult	0	0	0	0	0	1	1
Carangidae	*Caranx ruber*	Bar jack		0	0	0	0	0	2	2
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	juvenile	0	0	0	0	0	3	3
Holocentridae	*Holocentrus* sp.	Squirrelfish unidentified		0	0	0	0	0	1	1
Holocentridae	*Holocentrus adscensionis*	Squirrelfish		0	0	0	0	0	1	1
Holocentridae	*Holocentrus rufus*	Longspine squirrelfish		0	0	0	0	0	10	10
Holocentridae	*Myripristis jacobus*	Blackbar soldierfish		0	0	0	0	0	3	3
Labridae	*Bodianus rufus*	Spanish hogfish	juvenile	0	0	0	0	0	1	1
Labridae	*Halichoeres bivittatus*	Slippery dick	terminal	0	0	0	0	0	1	1
			Intermediate - terminal/initial	0	1	0	1	0	0	2
			Intermediate - initial/juvenile	0	0	0	0	0	7	7
			juvenile	0	0	0	0	0	9	9
Labridae	*Halichoeres maculipinna*	Clown wrasse	intermediate	0	0	0	0	0	2	2
			juvenile	0	0	0	0	0	2	2
Labridae	*Halichoeres poeyi*	Blackear wrasse	unreported	0	0	0	0	0	1	1
Labridae	*Halichoeres radiatus*	Puddingwife	juvenile	0	0	0	0	0	3	3

Family	Scientific name	Common name	Stage	RB1 Roving Fish Census	RB1 Tran-sects	RB2 Roving Fish Census	RB2 Tran-sects	RB3 Roving Fish Census	RB3 Tran-sects	Total
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	terminal	0	0	0	0	0	1	1
			intermediate	0	0	0	0	0	13	13
			juvenile/initial	0	0	0	0	0	10	10
Labridae	*Xyrichtys martinicensis*	Rosy razorfish	unreported	0	0	3	1	2	0	6
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	juvenile	0	0	0	0	1	0	1
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	juvenile	0	0	0	0	3	0	3
Lutjanidae	*Lutjanus synagris*	Lane snapper	juvenile	0	0	0	0	3	0	3
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	juvenile	0	0	0	0	0	4	4
Mullidae	*Pseudupeneus maculatus*	Spotted goatfish	unreported	0	0	0	0	0	10	10
Pomacentridae	*Chromis multilineata*	Brown chromis	adult	0	0	0	0	0	1	1
Pomacentridae	*Eupomacentrus leucostictus*	Beaugregory	adult	0	0	0	0	0	4	4
			juvenile	0	0	0	0	0	3	3
			unreported	0	0	0	0	0	6	6
Pomacentridae	*Microspathodon chrysurus*	Yellowtail damselfish	adult	0	0	0	0	0	3	3
Pomacentridae	*Stegastes*	Damselfish		0	0	0	0	1	0	1
Pomacentridae	*Stegastes fuscus*	Dusky damselfish	unreported	0	0	0	0	3	1	4
Pomadasyidae	*Haemulon flavolineatum*	French grunt	4-6"	0	0	0	0	0	50	50
			stage unidentified	0	0	0	0	0	19	19
Pomadasyidae	*Haemulon melanurum*	Cottonwick	juvenile	0	0	0	0	0	1	1
Pomadasyidae	*Haemulon plumieri*	White grunt	juvenile	0	0	0	0	0	13	13
			unreported	0	0	0	0	0	5	5

Family	Scientific name	Common name	Stage	RB1 Roving Fish Census	RB1 Tran-sects	RB2 Roving Fish Census	RB2 Tran-sects	RB3 Roving Fish Census	RB3 Tran-sects	Total
Pomadasyidae	*Haemulon* sp.		juvenile	0	0	0	0	0	9	9
Scaridae	*Scarus iserti*	Striped parrotfish	juvenile/initial	0	0	0	0	0	19	19
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	juvenile	0	0	0	0	0	6	6
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	juvenile	0	1	0	0	0	3	4
			unreported	0	0	0	0	3	0	3
Scaridae	*Sparisoma viride*	Stoplight parrotfish	juvenile	0	0	0	0		5	5
Serranidae	*Cephalopholis fulvus*	Coney	adult	0	0	0	0	2	0	2
		Total number fish		**0**	**2**	**3**	**2**	**21**	**245**	**273**
		Total number of species (excluding fish only identified to genus)		**0**	**2**	**1**	**2**	**9**	**27**	**31**

Table 4.10. Robin Bay, St. Croix, USVI: Percentage of each developmental stage recorded based on morphology (especially Labridae and Scaridae) and/or size.

Family	Scientific name	Common name	Stage	Total	Percent juvenile (highlighted turquoise) or intermediate (juvenile/initial) (highlighted yellow) stage
Acanthuridae	*Acanthurus chirurgus/bahianus*	Surgeon - Doctor or Ocean	adult	4	33%
			juvenile	8	67%
Acanthuridae	*Acanthurus coeruleus*	Blue Tang	adult	1	0%
Chaetodontidae	*Chaetodon capistratus*	Foureye butterflyfish	juvenile	3	100%
Labridae	*Bodianus rufus*	Spanish hogfish	juvenile	1	100%
Labridae	*Halichoeres bivittatus*	Slippery dick	terminal	1	5%
			Intermediate - terminal/initial	2	11%
			Intermediate - initial/juvenile	7	37%
			juvenile	9	47%
Labridae	*Halichoeres maculipinna*	Clown wrasse	intermediate	2	50%
			juvenile	2	50%
Labridae	*Halichoeres poeyi*	Blackear wrasse	unreported	1	
Labridae	*Halichoeres radiatus*	Puddingwife	juvenile	3	100%
Labridae	*Thalassoma bifasciatum*	Bluehead wrasse	terminal	1	4%
			intermediate	13	54%
			juvenile/initial	10	42%
Lutjanidae	*Lutjanus apodus*	Schoolmaster snapper	juvenile	1	100%
Lutjanidae	*Lutjanus mahogoni*	Mahogany snapper	juvenile	3	100%
Lutjanidae	*Lutjanus synagris*	Lane snapper	juvenile	3	100%
Lutjanidae	*Ocyurus chrysurus*	Yellowtail snapper	juvenile	4	100%
Pomadasyidae	*Haemulon flavolineatum*	French grunt	4-6"	50	72%
			stage unidentified	19	28%
Pomadasyidae	*Haemulon melanurum*	Cottonwick	juvenile	1	100%
Pomadasyidae	*Haemulon plumieri*	White grunt	juvenile	13	72%
			unreported	5	28%
Pomadasyidae	*Haemulon* sp.		Juvenile	9	100%
Scaridae	*Scarus iserti*	Striped parrotfish	juvenile/initial	19	100%

Family	Scientific name	Common name	Stage	Total	Percent juvenile (highlighted turquoise) or intermediate (juvenile/initial) (highlighted yellow) stage
Scaridae	*Sparisoma aurofrenatum*	Redband parrotfish	juvenile	6	100%
Scaridae	*Sparisoma radians*	Bucktooth parrotfish	juvenile	4	57%
			unreported	3	43%
Scaridae	*Sparisoma viride*	Stoplight parrotfish	juvenile	5	100%
Serranidae	*Cephalopholis fulvus*	Coney	adult	2	100%

Other Sites Surveyed

Cotton Garden Bay, Cramer Park

Eight juvenile lane/mahogany snapper, two schoolmaster snapper with juvenile markings (6-8"), and possibly one mutton snapper (reddish fins, black spot, vertical patterns on dorsal, were observed associated with coral rubble during a snorkel along the eastern shore of Cotton Garden Bay. No grouper were seen. The habitats surveyed included dense seagrass, coral rubble in seagrass and sand, and intertidal bedrock. Juvenile snapper within or adjacent to dense seagrass were exclusively associated with coral rubble (Fig. 4.23).

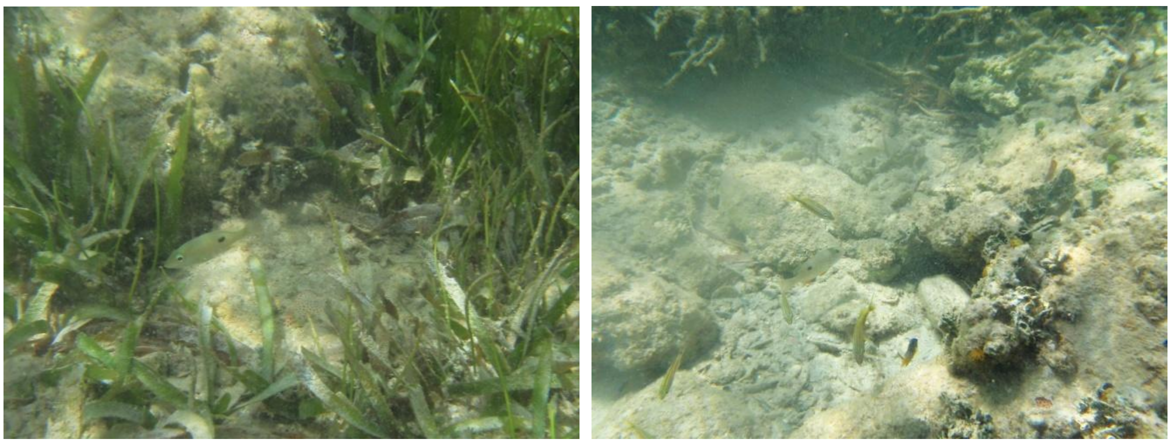

Figure 4.23. Cotton Garden Bay: Juvenile snapper within or adjacent to dense seagrass are invariably associated with coral rubble.

Western shoreline of St. Croix

The highest abundance of juvenile snapper were found on a day time snorkel on July 5, 2010 and a subsequent dive survey conducted on the morning of July 6, 2010 off the western shoreline of St. Croix in front of and south of the hotel, Sand Castle on the Beach. Large schools of a variety of species of Pomadaysidae (grunts) and schools of up to 30 snapper were common among the eroded beach rock along the shoreline in depths of $\leq$3m (Fig 4.24). The snapper schools were often mixed with larger schools of juvenile grunts.

The beachrock in this location is highly eroded with undercuts and caves. It is covered with turf and macroalgae, sponges and a few scleractinian corals. The lack of coral cover is likely a function of the high surf that periodically assaults this coastline and the shifting sand that likely intermittently buries the beachrock, especially rock close to the bottom. Few large fish were observed. Most of the larger fish were grazers such as surgeonfish or an occasional large parrotfish, e.g. initial phase yellowtail parrotfish. Intermediate and initial phase slippery dicks, juvenile and initial phase bluehead wrasse, and night sergeants were common.

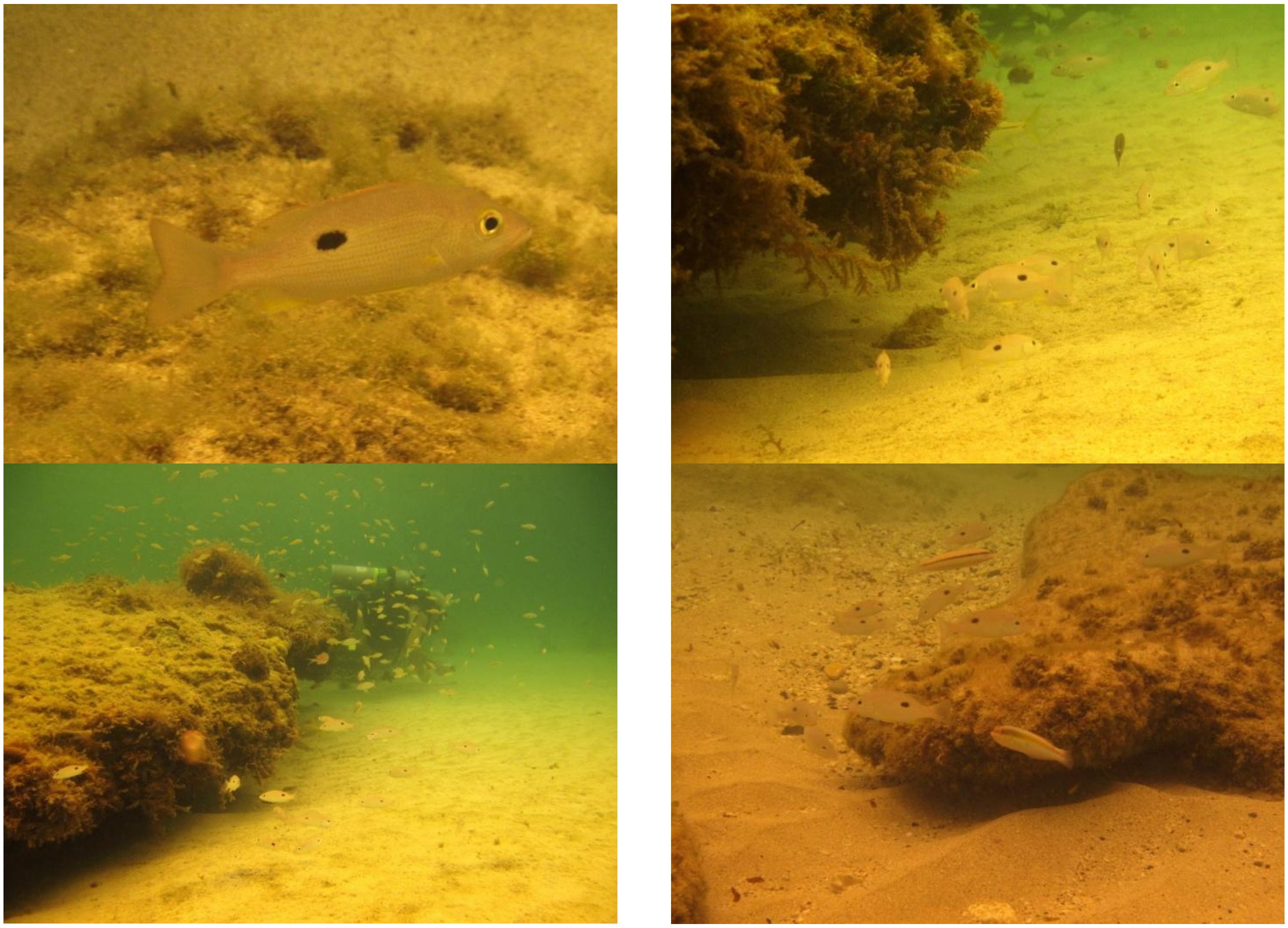

Figure 4.24. Western shoreline of St. Croix. Clockwise from top left: Juvenile lane snapper (*Lutjanus synagris*), small snapper school adjacent to beachrock, small snapper school with two intermediate phase slippery dicks (one juvenile/initial phase and one initial/terminal phase), a school of juvenile snapper and grunts.

D ISCUSSION

Nagelkerken (2002) listed 17 Caribbean reef fish species that had relatively high juvenile density in nursery habitats (mangrove and seagrass). However, when he compared fish density on islands with nursery habitat and those without nursery habitat only some of these nursery species were highly dependent on nursery habitats. Others may be dependent on nursery habitat, but results were inconclusive, and others clearly were not dependent (Nagelkerken 2002). Five snappers (Lutjanidae) were among the 17 nursery species. Two lutjanids, the schoolmaster snapper (*Lutjanus apodus*) and the yellowtail snapper (*Ocyurus chrysurus*), were considered to have a high dependence on nursery habitat with the schoolmaster having the highest density in mangroves and the yellowtail snapper in seagrass. The mutton snapper (*L. analis*) and the gray snapper (*L. griseus*) were considered to have a possible dependence on nursery habitat, with juveniles of *L. analis* having about equal but low density in mangrove and seagrass, while *L. griseus* had the highest density in mangroves. The mahogany snapper (*L. mahogoni*) had no dependence on nursery habitats, but was found in the highest densities mangroves. In Pacific mangroves Quinn and Kojis (1985) found few juveniles of coral reef fish inhabiting a mangrove lined estuary adjacent to coral reefs.

No lutjanids, juvenile or adult, were recorded in the two habitats sampled in outer Chenay Bay or in two of the three habitats sampled (seagrass and sand) in Robin Bay. Three lutjanid species were recorded in continuous seagrass (CBSG3) in inner Chenay Bay, *L. apodus*, *L. synagris*, and *O. chrysurus*, in roving fish censuses. *O. chrysurus* was the most abundant snapper in roving fish censuses and the only lutjanid recorded in transects in the four inner bay sites. Over 85% of *O. chrysurus* were recorded in roving fish surveys in continuous seagrass habitat (CBSG3) (Table 4.5) and it was the only habitat in which they were recorded in transects (Table 4.6). However, in Robin Bay, *O. chrysurus* and the four other snapper species recorded in Robin Bay were only recorded in the back reef habitat. The continuous seagrass habitat sampled in Chenay Bay differed from the seagrass habitat sampled in Robin Bay in that rubble was intermixed among the seagrass. *L. apodus* and *L. synagris* were also recorded in 10-30% seagrass habitat (CBSG5) in roving fish surveys, but not in transects. Roving fish surveys covered a larger area than transects, and included coral rubble which was adjacent to and interspersed among the seagrass, especially along the edge of this habitat. Juveniles of all five snapper species were recorded in the highly structured beachrock habitat.

Snappers, including *O. chrysurus*, were almost invariably associated with some structure in this study. *O. chrysurus* may initially recruit to seagrass or dense algae (personal obs. Kojis), but migrate to structured habitat. *O. chrysurus* and other snappers may prefer structured habitat associated with seagrass. While the structured habitat provides shelter and the seagrass may provide a food resource.

No grouper (Serranidae) was listed among the 17 nursery species by Nagelkerken (2002). The only commercially important grouper recorded in this study were small coneys and red hind recorded as juveniles from outer Chenay Bay (Table 4.6). No commercially important grouper of any size was recorded in inner Chenay Bay or Robin Bay. In fact, the only juvenile coney (as depicted and described in Humann and Deloach (2002)) recorded in this entire study was in hard bottom algae/invertebrate habitat (ALIN) in the Mutton Snapper Seasonally Closed Area.

Mateo and Tobias (2001, 2004) had similar results to our study in their study of six bays on the east end of St. Croix. They recorded a total of six snapper species (*Lutjanus analis, L. apodus, L. griseus*, *L. mahogoni*, *L. synagris*, and *O. chrysurus*). None comprised >3% of individuals recorded in a bay and most comprised <0.2%. Only two mutton snapper juveniles were recorded, both in a single bay, Turner Hole. The Serranidae were even less abundant; only four species of commercially important Serranidae were recorded, *Alphestes afer*, *Epinephelus fulvus*, *E. guttatus and E. striatus*. None comprised more than 0.3% of individuals in any bay.

Although they sampled five habitats in each bay, they sampled habitats proportionally and seagrass made up 60 - 94% of sampled habitat in the three northeastern bays (Mateo and Tobias 2001) and 66 - 85% of sampled habitat in the three southeastern bays (Mateo and Tobias 2004). Less than 4.5 % of their samples were taken in rubble and patch reef habitat in the northeastern bays and 3% in the three southeastern bays. They did not sample the back reef habitat sampled in this study and in Adams and Ebersole's (2002) study. Consistent with this study and Adams and Ebersole (2002), they reported the highest fish density and species density in structured habitats (coral rubble and patch reefs in their study).

In Robin Bay, they recorded juveniles of two species of Lutjanidae (*L. mahogoni* and *O. chrysurus)* and one species of commercially important Serranidae (*Cephalopholis fulvus*). *L. mahogoni* comprised 2% of the total fish recorded, *O. chrysurus* comprised only 0.4% and *C. fulvus* comprised 0.1%. The relative fish density of the two lutjanids by size class was reported. Juvenile *O. chrysurus* 3-5 cm in length had the highest densities in algal plain and rubble. Larger individuals 5-10 cm and >10 cm were more abundant in patch reef habitat. *L. mahogoni* juveniles 3-5 cm were present in all habitats, but much more abundant in patch reef and rubble habitats. At sizes >5 cm they were uncommon and found only in patch reef habitat.

Commercially important lutjanids and serranids made up a minor component of the juvenile fish recorded in six habitats in the embayments surveyed in SE St. Croix by Adams and Ebersole (2002). Five commercially important grouper were recorded only in the large size class (>5 cm) and at percent relative abundance levels ranging from 0 - 0.51% with abundance <0.1% in most of the six habitats surveyed. Five commercially important lutjanids were recorded in all three size classes. Relative abundance was higher ranging from 0 - 11.1% with most less than 0.5%. The species with the highest relative abundance were *Ocyurus chrysurus* and *Lutjanus mahogoni*. They were present in all sampled habitats. *L. analis* was present in four of the six habitats (patch-reef, seagrass, algal plain, and sand) with by far the highest relative abundance in sand (3.85%) compared to the other three habitats (0.06 - 0.32%). All *L. analis* recorded were large (>5 cm). According to Adams and Ebersole (2002), this size class includes adults. *L. analis* often roams over sand and seagrass as large juveniles (subadults) and adults.

The shallow water habitats of bays on the east end of St. Croix did not appear to contain preferred habitat of commercially important grouper (Serranidae) recruits or juveniles. It also appeared that they are not a major nursery habitat for lutjanids, except possibly the yellowtail snapper (*O. chrysurus)* and the mahogany snapper (*L. mahogoni*), which had the highest occurrence in all four studies (Adams and Ebersole 2002; Mateo and Tobias 2001, 2004 and this study). *L. analis* was uncommon in these studies despite the fact that two of the studies (Mateo and Tobias 2001, 2004) carried out most of their fish surveys in seagrass habitat, the presumably preferred habitat for *L. analis* recruits and juveniles (Anon. 2008).

The beachrock on the west end of St. Croix was the only site where actual schools of *L. synagris* and *L. mahogoni* were recorded. This habitat appears to be important nursery habitat for these *Lutjanus* spp. It may be important for others if sampled year round. Nursery habitat for grouper and *L. analis* was not established. Fishermen (G. Martinez, pers com) reported that larger juvenile *L. analis* are commonly seen in the seagrass meadows along the southwest shore of St. Croix. Seagrass is dense in this site, but visibility poor owing to the long shore current moving sediment from east to west. This site was briefly searched but no juvenile *L. analis* were sighted, large or small.

It is possible that the paucity of juveniles of *L. analis* and commercially important serranid species may be a function of the number of recruits available. Although *L. analis* is now seasonally protected during its peak spawning months and harvest and possession of *E. striatus* is prohibited, these management measures have only recently been implemented in both territorial and federal waters. The *L. analis* seasonal closure appears to be working well with no signs of sale of *L. analis* during the closure period. *E. striatus* unfortunately is uncommon and when caught is usually hauled from water depths >20 m, resulting in a high release mortality. This likely is slowing its recovery. A spawning aggregation of *E. guttatus* has been seasonally closed for fishing since 1995, but it is located on Lang Bank in a relatively remote location where enforcement is difficult and mature adults are likely harvested as they migrate to the spawning site. The sizes of red hind in this spawning aggregation have been declining and are considerably smaller than the red hind aggregation in the St. Thomas, Marine Conservation District (Nemeth 2005), which was seasonally closed in 1990 and closed year-round in 1999.

LITERATURE CITED

Adams, A.J. and J.P. Ebersole. 2002. Use of back-reef and lagoon habitats by coral reef fishes. Mar. Ecol. Prog. Ser. 228:213-226.

Anon. 2008, SEDAR 15A: Stock Assessment Report 3 (SAR 3), South Atlantic and Gulf of Mexico Mutton Snapper. SAFMC, North Charleston, SC. 410 pp.

Bortone, S.A. and J.L. Williams. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida): Gray, lane, mutton and yellowtail snappers. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.52). US. Army Corps of Engineers, TR EL-82-4. 25pp.

Claro, R. and K.C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. Gulf and Carib. Res. 14(2): 91-106.

Humman, P. and N. Deloach. 2002. Reef Fish Identification: Florida, Caribbean, Bahamas. New World Publications Inc., Jacksonville, FL. 489 pp.

Kendall, M.S., M.E. Monaco, K.R. Buja, J.D. Christensen, C.R. Kruer, M. Finkbeiner, and R.A. Warner. 2001. (On-line). Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands. Accessed online 17 Nov 2010. URL: http://biogeo.nos.noaa.gov/projects/mapping/caribbean/startup.htm.

Mateo, I. and W.J. Tobias. 2001. Distribution of shallow water coral reef fishes on the Northeast coast of St. Croix, USVI. Caribbean Journal of Science. 37(3-4): 210-226.

Mateo, I. and W.J. Tobias. 2004. Survey of nearshore fish communities on tropical backreef lagoons on the southeastern coast of St. Croix. Caribbean Journal of Science. 40(30):327-342.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. Mar. Ecol. Prog. Ser. 286:81-97. Accessed online on 30 Nov 2010. URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1435719/pdf/nihms2972.pdf

Nagelkerken, I., C.M. Roberts, G. van der Velde, M. Dorenbosch, M.C. van Riel, E. Cocheret de la Moriniere, and P.H. Nienhuis. 2002. How important are mangroves and seagrass beds for coral-reef fish? The nursery hypothesis tested on an island scale. Mar. Ecol. Prog. Ser. 244:299-305.

Quinn, N.J. 2010. St Croix East End Marine Park: The U.S. Virgin Islands' First Territorial Marine Park. Proc. 11th International Coral Reef Symp. 1139-1143.

Quinn, N.J. and B.L. Kojis. 1985. Does the presence of coral reefs in proximity to a tropical estuary affect the estuarine fish assemblage? Proc 5th Int, Coral Reef Cong., Tahiti 5:445-450.

RECOMMENDATIONS

Future *Lutjanus analis* (mutton snapper) Research

Furture research should concentrate on locating mutton snapper spawning aggregations on the southwest corner of St. Croix. A reef near the red buoy (Nicky's Reef) was the only location where a spawning aggregation of mutton snapper was found and it is an area with the geomorphological characteristics of other mutton snapper spawning sites. This site, or adjacent sites, may be the spawning focal reef(s) for a number of fish species. The site is deeper and more exposed than the site in the Mutton Snapper Seasonal Closed Area (MSSCA) where ripe fish were caught in 2009.

The actual location of spawning site should be determined. This could be done by initially by divers conducting searches on Nicky's reef during the peak spawning months of May and June. A more comprehensive research program would include mapping the southwest corner of the St. Croix shelf and then focusing searches on sites with the topography that is characteristic of other spawning sites in the Caribbean. Spawning aggregations may shift location and mapping would provide alternate sites to search during the spawning season. Location of the spawning site could also be done by acoustic tagging of fish. The later technique could also provide information on the movement of mutton snapper during and before/after the spawning season. This could provide information on the migratory pathways to the spawning site and the movement of snapper during the spawning season.

The size of *L. analis* at the onset of reproduction was only broadly determined owing to the small sample size of fish under 440 mm. This small sample size of smaller fish was because we did not catch small fish in April - June when we fished during the spawning season and we were unable to purchase large numbers of small fish in March before the seasonal closure came into effect in April. Spearfishers usually don't target small *L. analis*, they are too skittish. Trap fishers catch some small *L. analis*, but not in large numbers. To obtain a more accurate determination of size at the onset of reproduction for each sex, sample size of small fish must increase. It would be best to sample small fish throughout the spawning season (April - June) and pay fishers to make an effort to target small *L. analis* by paying them either to fish exclusively for small mutton snapper or to pay a considerable bonus for small *L. analis* to make it worth their while to target them and make the effort to provide them to the researcher.

Management Recommendations

Considering the association of fish communities with habitat and the apparent decline of scleractinian (hard coral) populations in the MSSCA, management practices that work to preserve coral habitat, such as the ban of bottom tended gear in the federal portion of the MSSCA, should be expanded to the territorial portion of at least the southern half of the MSSCA where spur and groove coral reefs and hillocky reefal habitat dominates. The CFMC should make a formal request to the U.S. Virgin Islands' Government to promulgate compatible regulations in at least the southern portion of the MSSCA.

The seasonal prohibition of fishing of *Lutjanus analis* (mutton snapper) should continue, since the actual location of the aggregation appears to be outside the closed area. It also appears that reproductive fish migrating to the aggregation site within the MSSCA are vulnerable to fishing at least several km from the spawning aggregation site. Fishers stated that they could readily catch mutton snapper outside the Mutton Snapper Seasonal Closed Area by chumming during the spawning season. Fishers mentioned that there were other locations where they thought mutton snapper aggregated to spawn on both the southern and northeastern St. Croix shelf. The seasonal closure protects aggregations of mutton snapper that have not been documented by managers or scientists.

The high CPUE and the size distribution of *L. analis* at fishing sites within the MSSCA indicated that the mutton snapper aggregation a) still exists and b) appears to be reasonably healthy. If, in the future, a quota system is established and St. Croix fishers show a high compliance rate, a quota for mutton snapper during the spawning season, but outside spawning aggregation areas, should be considered. The quota should also be contingent on an adequate enforcement presence.

Underwater temperature recorders should be deployed in the MSSCA to record seasonal and annual variation in the subsurface water temperature to understand the relationship between climate change and the spawning period of reef fish.

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Lutjanus analis were caught during April, May and June within the MSSCA during the closed season under letters of acknowledgement dated April 7, 2009 and April 16, 2010 from the US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office and Permit No. STT-014-09 and STT-013-10 from the Government of the Virgin Islands of the United States, Department of Planning and Natural Resources, Division of Fish and Wildlife.

After the fish were processed, they were donated to the Herbert Grigg Home for the Aged and the Lighthouse Mission on St. Croix.

Of course, we could not have accomplished this work without the competent boat handling, fishing, diving, and marine safety skills of G. Martinez and S. Martinez – Corcino and we appreciate the assistance of Gerson Martinez, Jr. G. Martinez was crucial to the success of this project. He freely provided his considerable knowledge of fish, fish habitats, and fishing garnered from his experience as a trap, line and spearfisher. He has dived all over the St. Croix shelf and has extensive knowledge of the habitats where fish and lobsters are found. He is always learning and gathering information on the behavior, abundance and distribution of fish.

We would also like to thank Maximilliano Valasquez for sharing his knowledge of the best fishing spot for mutton snapper in the MSSCA and for pulling in the most mutton snapper. Thanks also to fishers Carlos Farchette and Eddie Schuster, who didn't give up fishing for mutton snapper when seas were high and productivity low in April, 2009.

We would like to especially thank Liam Carr for his assistance with fishing, diving searches for mutton snapper, and otolith removal and his diligence in working with others to process otoliths at Texas A&M. Thanks also to Cindy Grace, who assisted on several dives in 2010.

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Jeremy Blondeau of the University of the Virgin Islands, CMES very kindly provided habitat maps and topographic images based on side scan and multi-beam images of the overall MSSCA from the side scan sonar and multi-beam work done by Side Geophysics GPR International, Inc and Dr. Martha Prada's habitat maps. Blondeau promptly provided coordinates of sample sites upon request for the various habitat types.