2645-06-08-Final

Assessment of Population and Community Structure of Sessile Macro Invertebrates following a Benthic Mortality Event in the Eastern Gulf of Mexico

This report was prepared by The Florida Fish and Wildlife Commission under award number NA06NMF4410082 from The Gulf of Mexico Fishery Management Council, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of The Gulf of Mexico Fishery Management Council or the U.S. Department of Commerce.

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28 August 2008

Abstract

A benthic habitat monitoring project was conducted from April 2007 to March 2008 to determine the status and trends of important ecological constituents following a major red tide event in 2005 off Pinellas and Sarasota Counties, Florida. Photographic transects, line-intercept transects, and survey quadrats were used to document the percent benthic coverage of coral, macroalgae and other sessile invertebrates, and enumerate the total number of sessile and motile invertebrates. Although there is limited baseline data available to compare benthic community structure prior to the 2005 mortality event, the benthic habitat surveys conducted for this study indicate a recovery from this event may still be ongoing. The sparse collection of baseline information and the inability to initiate the project immediately after the 2005 bloom preclude this study from making definitive comments on the recovery of benthic habitats in the eastern Gulf of Mexico. However, resuts of this study will provide the information required to assess the damage and subsequent recovery of benthic communities in the eastern Gulf of Mexico related to future red tide events.

Introduction correction F2645

Red tides, or algal blooms, are natural phenomena in the eastern Gulf of Mexico. They can occur almost annually, typically in late summer/early autumn, but do not always have detrimental consequences for marine organisms. The first documented cases of toxic red tides in the eastern Gulf of Mexico occurred in the 1800's (Walker, 1884), long before the development of coastal areas in west Florida. While more than 40 species of potentially toxic microalgae live in Gulf of Mexico waters, the most common is the dinoflagellate *Karenia brevis*.

Karenia brevis is found year-round in the Gulf of Mexico at background concentrations of 1,000 cells per liter of seawater or less. When blooms occur, concentrations of *K. brevis* can exceed millions of cells per liter and can cause toxic effects at 5,000 cells per liter. This species of dinoflagellate contains a compound known as brevetoxin which can directly have adverse effects on marine organisms and result in massive fish kills. This toxin is also the cause of NSP (Neurotoxic Shellfish Poisoning) in humans when contaminated shellfish are consumed. When *K. brevis* blooms persist and concentrations of brevetoxin increase, other organisms can be affected including manatees, sea turtles, sea birds and humans. During persistent red-tides increased turbidity and hypoxic/anoxic conditions (oxygen depletion), due to the decomposition of dead fish, can also lead to large scale mortality of other marine organisms.

Mortalities of benthic hardbottom communities that are attributable to *K. brevis* blooms are not common. However, large scale benthic mortalities have been reported. The most comprehensive report (Smith 1975) documented extensive fish and invertebrate (including coral and sponges) mortalities in 1971 off of Sarasota County, Florida. This large-scale *K. brevis* bloom, approximately 600 square miles, affected marine pelagic and benthic biota down to 33 meters depth and up to 30 miles offshore. An estimated 80-90% of fishes perished during the event and at some locations complete mortalities of benthic communities were reported. Recovery of the benthic habitats affected by the 1971 red-tide proceeded immediately after concentrations of *K. brevis* dropped to non-toxic levels. Within one year, fishes and benthic algae had returned to their pre red-tide state. However, up to three years later several important macro-invertebrate benthic species had not returned to the area including the Florida spiny lobster. In this case, recovery may have been enhanced by the passing of a hurricane through the eastern Gulf of Mexico.

Between the catastrophic bloom event of 1971 and that of 2005, only one major red-tide event occurred. In 1995, a *K. brevis* bloom resulting in large-scale fish kills over an area of 5,000 square kilometers was reported. Reports on the degradation of benthic habitats resulting from this red-tide are not available. In 2005, a *K. brevis* bloom persisted off the west coast of Florida for 13 months and covered an area greater than 5,600 square kilometers. Extended commercial shellfish closures, as well as manatee, dolphin, sea turtle, and fish mortalities occurred. Large scale mortality of benthic communities also resulted from this event. During the 13 months of this bloom, cell concentrations of *K. brevis* in the area of this study frequently exceeded 100,000 cellsL^{-1}. In at least 8 of these months, *K brevis* concentrations were recorded at >1 million cellsL^{-1} in portions of the study area. The result of this persistent and concentrated *K. brevis* bloom was a mass mortality of benthic hardbottom communities due to hypoxia/anoxia.

In response to reports from stakeholders, the Florida Fish & Wildlife Research Institute (FWRI) and Mote Marine Laboratory (Mote) conducted surveys in an area from Tarpon Springs southward to Sarasota and seaward for 30 miles. The results of these surveys indicated that some reef communities had a complete loss of both sessile and motile residents while some reefs in the area appeared to be unaffected.

Benthic Habitats of West Central Florida

Benthic habitats along the west Florida shelf are described as hardbottom habitats and are generally low relief carbonate structures (commonly called reef ledges) that rise less than a meter to several meters off the sandy bottom. These discontinuous ledges are generally oriented north/south. Relief is usually greatest on the seaward side, sloping to a sand or silt bottom shoreward.

Although there are few ecological assessments/studies of these ledges, they support a diverse community of marine organisms. They are typically dominated by calcareous macroalgae (i.e. *Halimeda sp., Udotea sp.*) and fleshy macroalgae (i.e. *Sargassum sp., Dictyota sp.*). Sessile organisms of these communities typically include sponges, tunicates, bryozoans, octocorals and stony corals. Other invertebrates such as decapod crustaceans, gastropod and bivalve mollusks, echinoderms and polychaete worms are also common. These include several important commercial species such as Florida spiny lobster (*Panulirus argus*) and stone crab (*Menippe mercenaria*).

Objective

This monitoring effort was designed to document the recovery of hardbottom habitats off west central Florida from mass mortalities caused by *K. brevis* blooms. While several published qualitative descriptions of these benthic habitats exist, no quantitative studies of the habitats under ideal, healthy conditions are available for comparison. Because baseline data is not available, post-mortality communities cannot be statistically compared to pre-mortality communities. While this limits the ability to study recovery, trajectories of various community components (i.e. key species, total algal cover, coral cover, etc…) can still be observed and quantified.

Methods

Site Selection

Sixteen sites were selected for monitoring (Figure 1, Table 1). Nine sites are located off of Sarasota County and were surveyed by the Mote Marine Laboratory (MML) and seven sites are located off of Pinellas County and were surveyed by the Fish and Wildlife Research Institute (FWRI). The study sites were grouped into six regions (Figure 1) and were selected to survey benthic communities located at increasing distances from shore and at increasing depths. It was the original design of the study to select one non-impacted site from each region to use as a control. However, after preliminary observations were made, non-impacted/control sites were indistinguishable. A a result, all sites surveyed represent benthic communities that experienced considerable impacts from the *K. brevis* bloom.

Sampling was to be conducted quarterly; however, procurement of funding delayed the projects inception. Survey sites were first visited between April and June 2007, which was nearly 1.5 years after the mortality events occurred. During this time, recovery had already started.

Although monitoring commenced in April 2007, several sites were not surveyed within the allotted time periods. No surveys were conducted by MML off Sarasota County during the first quarter (April to June 2007). All sites were surveyed during the second quarter (July to September 2007). In the third quarter, all sites off Sarasota County were surveyed. Only one site was surveyed off of Pinellas County as a result of mechanical breakdown of the FWRI research vessel. In the fourth quarter (January to March 2008), no sites were surveyed by MML off of Sarasota County due to inclement weather conditions. All survey sites off of Pinellas County were sampled during this quarter. Originally, only one full year (four quarters) of surveys were to be conducted. However, an additional quarter was added (April to March 2008) to survey sites to make up for missed surveys (Table 1).

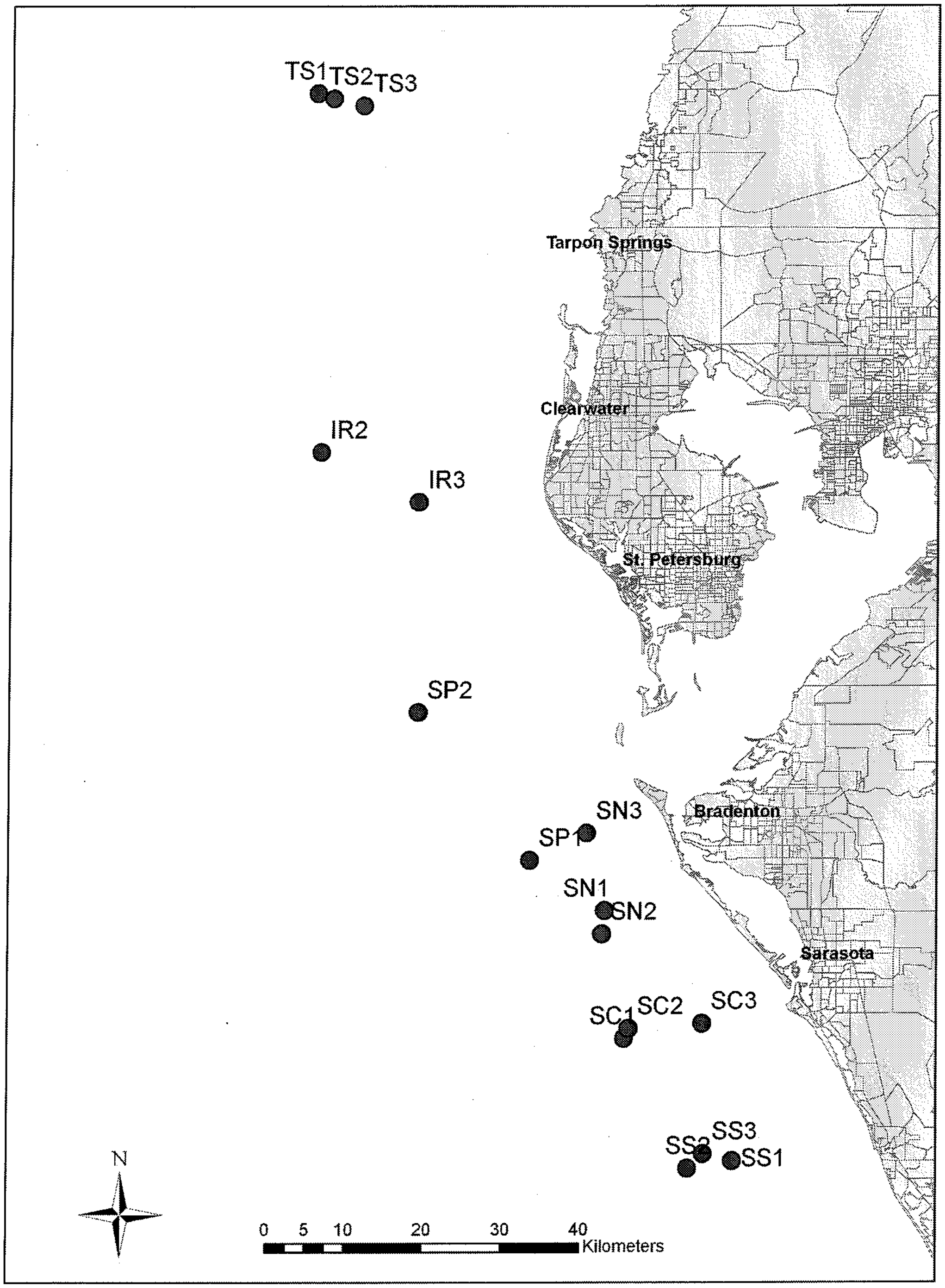


Figure 1: Map of survey locations off of Sarasota and Pinellas Counties.

Table 1: A list of survey site locations, depths and sampling dates.

Site Locations					Survey Dates				
Region	Site	Latitude	Longitude	Depth(ft.)	Q1; Apr-Jun07	Q2; Jul-Sep07	Q3; Oct-Nov07	Q4; Jan-Mar08	Q5; Apr-Jun08
Tarpon Springs	TS1	28.3275	-83.1134	50	5/3/2007	9/14/2007		1/16/2008	5/6/2008
Tarpon Springs	TS2	28.3209	-83.0947	48	5/4/2007	9/13/2007		3/27/2008	5/6/2008
Tarpon Springs	TS3	28.3130	-83.0602	42	6/14/2007	9/14/2007		3/27/2008	5/13/2008
Indian Rocks	IR2	27.9155	-83.1071	60	4/3/2007	10/3/2007	11/29/2007		5/8/2008
Indian Rocks	IR3	27.8577	-82.9942	40	4/12/2007	10/10/2007		3/28/2008	5/8/2008
South Pinellas	SP1	27.4461	-82.8652	45	5/1/2007	10/11/2007		3/13/2008	5/9/2008
South Pinellas	SP2	27.6161	-82.9941	45	4/24/2007	10/11/2007		4/1/2008	5/9/2008
Sarasota North	SN1	27.3882	-82.7794	44		7/26/2007	12/7/2007		5/31/2008
Sarasota North	SN2	27.3613	-82.7822	40		8/6/2007	12/12/2007		5/31/2008
Sarasota North	SN3	27.4770	-82.7998	40		8/7/2007	12/8/2007		5/30/2008
Sarasota Central	SC1	27.2410	-82.7565	40		7/13/2007	12/3/2007		4/23/2008
Sarasota Central	SC2	27.2523	-82.7513	44		7/16/2007	12/5/2007		5/13/2008
Sarasota Central	SC3	27.2583	-82.6669	47		7/17/2007	12/6/2007		5/29/2008
Sarasota South	SS1	27.1002	-82.6322	50			12/10/2007		6/9/2008
Sarasota South	SS2	27.0915	-82.6828	53		8/16/2007	12/11/2007		6/3/2008
Sarasota South	SS3	27.1083	-82.6653	60		8/14/2007	12/11/2007		6/9/2008

Survey Station Setup

Repeated sampling at marked survey stations (Figure 2) was conducted. The stations were marked by two rebar stakes 50 meters apart, arranged to facilitate benthic habitat sampling along the edge of a reef ledge using several methods. A navigation line was laid between the marker stakes. Six transects were extended perpendicular to the navigation line at the 0, 10, 20, 30, 40, and 50 meter marks. These transects were for the photographic transect and line-intercept survey methods. Ten random quadrats were placed along the navigation line to assess motile invertebrates.

These permanent survey stations were sampled during the first three quarters of monitoring. The ledges were relocated using GPS; however, the rebar station markers were disclodged during the winter of 2008 and could not be relocated at some sites. At those sites, survey stations were set up along the ledges where the original sampling occurred.

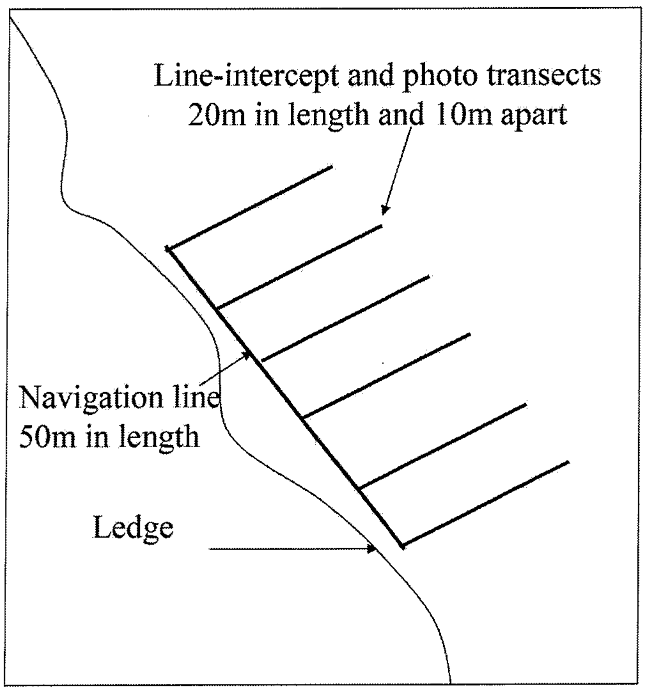


Figure 2: Survey station layout for benthic habitat surveys

Photographic Transects

An Olympus E-330 DSLR camera with an Ikelite underwater housing was used to photograph the substrate and benthos along each of the six transect lines. Images were taken from approximately 50 cm above the substrate using a wide-angle lens resulting in each image being approximately 50cm by 50cm. Two abutting images were taken for each meter of each transect, which resulted in a total of approximately 40 pictures per transects and 240 pictures per survey at a site. High quality camera settings were used and provided images that allow for the identification of corals and other sessile marine biota to the species level and marine algae often to the genera level. Once a survey was completed, images were stored on secure web-servers at FWRI.

Images were analyzed using Coral Point Count with Excel Extensions (CPCe), which is a custom software package written by Kevin Kohler at the National Coral Reef Institute. This software randomly places 10 points over each of the benthic images. The points from every photo are identified and added together for each survey to determine the benthic substrate coverage. For these surveys, benthic cover was identified as stony coral (to species level), octocoral, sponge, zoanthid, other sessile invertebrate, cyanobacteria, macroalgae, and bare substrate. Although the image quality was often adequate to identify octocorals, sponges, and macroalgae to finer taxonomic levels, that was avoided in order to remain consistent between survey sites and times. These taxonomic groups typically cannot be identified beyond genera or family levels solely from images.

Line Intercept Transects

Line intercept surveys were conducted on the same six transect lines as the photographic (digital) transects were sampled. The number of each sessile invertebrate species that crossed the transect line was quantified for each meter (0-1m, 1-2m....19-20m) and summed for each transect. Invertebrate counts collected by this method were fairly reliable. However, macroalgae counts were probably underestimated as macroalgae often grows in patches and individuals cannot be easily distinguished.

For line intercept surveys, organisms were identified to the lowest possible taxon. In most cases, this was to species for stony corals, genus for algae and octocorals, and phylum for other organisms. However, several common sponges were regularly identified to the genus and species level.

Motile Invertebrate Survey

For the motile invertebrate survey, a one square meter quadrat was placed at the 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45 meter marks on the navigation line. All motile invertebrates visible within each quadrat were counted. Sampling did not include burrowing or cryptic species that could be found under ledges or in holes. All motile invertebrate species were identified to the lowest possible taxon, which was typically the species level. Motile invertebrate surveys were only conducted at Pinellas County sites and were not conducted in the winter of 2008, quarter 4 (January to March 2008).

Water Quality Measurements

Water quality was measured using an YSI incorporated multiparameter water quality sonde (YSI), which measures temperature, salinity, pH, and dissolved oxygen concentrations at depth in situ. At some Pinellas County sites, several water quality measurements were not recorded each quarter because complications with this instrument frequently occurred. For Sarasota County sites, water quality data is only available for two quarters, October to December 2007 and April to June 2008.

Water and Sediment Samples

Three water samples (surface, mid-depth, and bottom), and a sediment sample were collected during each survey. Water samples were collected at depth using a niskin bottle. Sediment samples were collected by a diver during the benthic habitat surveys. A portion of each water sample was immediately preserved in Lugols for phytoplankton community analysis.

Phytoplankton Community Composition

All Lugol's preserved water samples were examined with Olympus CK-30, Olympus IX-71, or Zeiss Axiovert 450 inverted microscopes by settling 3 ml of sample for a minimum of 30 minutes in a Lab-Tek coverglass chamber (Nalge Nunc #155380). The entire chamber was examined and cells were identified to the lowest taxon possible and enumerated at 10x and 20x magnification. Identification of *Karenia brevis* was based on cell morphology and nuclear shape and placement based on Steidinger et al. (2008).

In addition to determining phytoplankton community composition, counts of *K. brevis* dinocysts, the short- or long-term resting stage, located in the sediment during each survey were also made. All sediment samples were processed for the recovery of dinocysts based on a modification of Bolch (1997) and Garrett et al (in prep). Recovered dinocysts were enumerated at 10x using an Olympus CK-30 inverted microscope.

Seawater and Sediment Brevetoxin Concentrations

Brevetoxin was extracted from seawater by passing 0.5 L through an Empore Si-C18 disc that had been preconditioned with 20 mL of methanol and then 20 mL of DI water. Brevetoxin was eluted from the discs into clean glass test tubes using 2 10-mL washes of methanol. The combined eluent was evaporated to dryness and re-dissolved in 2 mL of methanol. Extracts were stored at -20°C until analyzed.

Sediments were transferred to aluminum dishes and dried in an oven at 50°C overnight prior to brevetoxin extraction. A 2-g sub-sample was then extracted using 80% aqueous methanol (5 ml g^{-1}), heated in a hot water bath at 60°C for 20 minutes, and centrifuged at 3,000 x g for 10 minutes. The supernatant was retained, and the pellet was extracted a second time in the same manner. The supernatants were pooled and partitioned once with 100% hexane (1:1, v:v), and the methanol fraction was retained. Extracts were stored at -20°C until analyzed.

Extracts were screened for brevetoxins using a competitive ELISA performed according to Naar et al. (2002). In this assay, samples and controls compete with plate-bound brevetoxin for goat anti-brevetoxin antibodies. The antibodies bound to the plate are then visualized using an HRP-conjugated secondary antibody (rabbit anti-goat antibodies), and the HRP substrate TMB. Absorbance of the wells is read at 450 nm. The color intensity is inversely proportional to the concentration of brevetoxins in the sample. This assay recognizes all congeners and metabolites of brevetoxin that have a PbTx-2-type backbone. The lower limit of detection for the ELISA as performed here was 0.003 µg/L for seawater and 5 ng/g for sediments.

Results

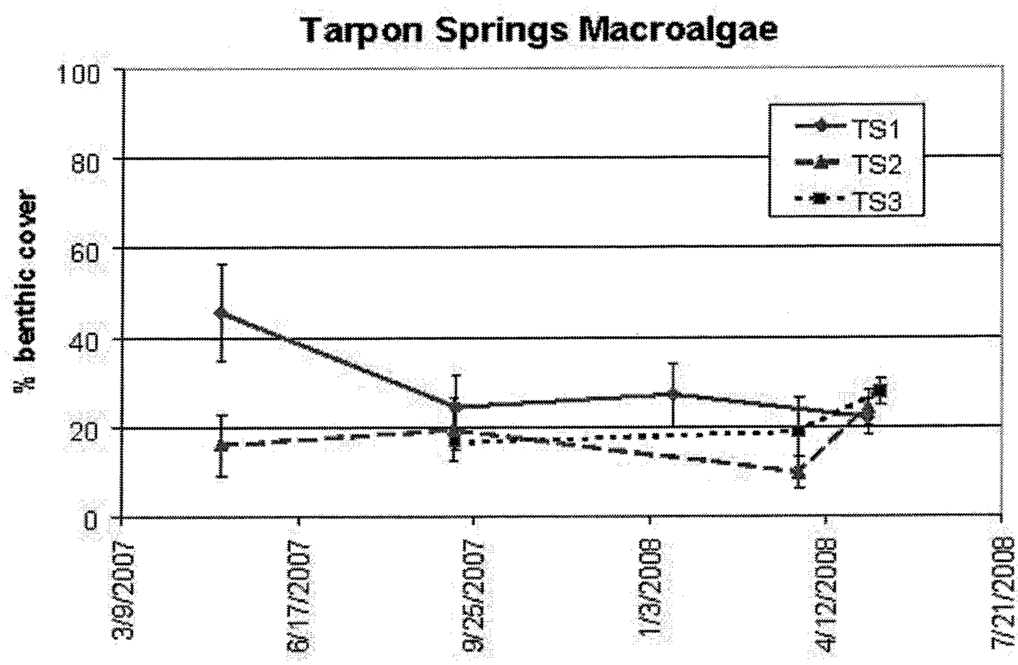
Photographic Transects

The most abundant benthic group at all sites throughout the monitoring period was macroalgae, followed by stony corals, sponges, and octocorals. Other sessile invertebrates identified included ascidians, bryozoans, hydrozoans, and zoanthids. The most abundant of these were ascidians, which provided greater than 1% cover during several sampling periods at TS1, TS2, TS3, and IR2. Several of these less abundant taxa (e.g. bryozoans and hydrozoans) may have been underestimated because they are difficult to identify in photographs and often resemble or are associated with tufts of algae. No apparent seasonal trends were observed; however, several notable changes occurred throughout the course of monitoring.

Macroalgae cover ranged from 1.7% to 88.2%, but was typically between 25% and 35%. In general, macroalgae cover was highest in the first quarter of sampling (April – June 2007), then decreased considerably by the second quarter of sampling (July – September 2007) (Figure 3). Although not present at all locations, this trend was also observed for cyanobacteria, especially at the Tarpon Spings sites (Figure 4). Benthic coverage of cyanobacteria was never greater than 2.0% except in the first quarter of sampling where it was 6.7% and 9.2% at TS1 and TS2, respectively. Photographic transects were not conducted at site TS3 in the first quarter.

Stony coral cover ranged from 0% to 5.3%. Stony corals were most abundant at f Sarasota County (Figure 5) sites. At sites off Pinellas County, stony coral cover never exceeded 2%, but stony corals were present at nearly every location during every sampling period. Sponge cover ranged from 0% to 9.7%, but rarely exceeded 5%, except at one location, IR2, where sponges were the dominant sessile marine invertebrate with cover greater than 5% during every sampling period (Figure 6). The higher sponge coverage at IR2 may be attributed to the greater depth at this location. Although a slight increase in sponge and coral cover may be apparent at some locations, sponge and coral cover has remained fairly consistent throughout monitoring. The observed increase was most likely due to the drastic decrease in algae cover, which would make more encrusting or cryptic sponge and coral species more visible in still images.

Octocoral cover ranged from 0% to 7.5%, but was generally below 1% except at several central and southern Sarasota sites (SC2, SC3, and SS2) (Figure 7). At these locations, octocoral cover has remained fairly consistent through time. Octocorals were not observed at sites off of Indian Rocks, South Pinellas, or Sarasota North. In the first quarter of monitoring, octocorals were not found at any Tarpon Springs sites; however, during more recent sampling periods octocorals have been observed at all 3 (TS1, TS2, and TS3). The octocoral species found at Tarpon Springs sites are not the same as those found at central and southern Sarasota sites.



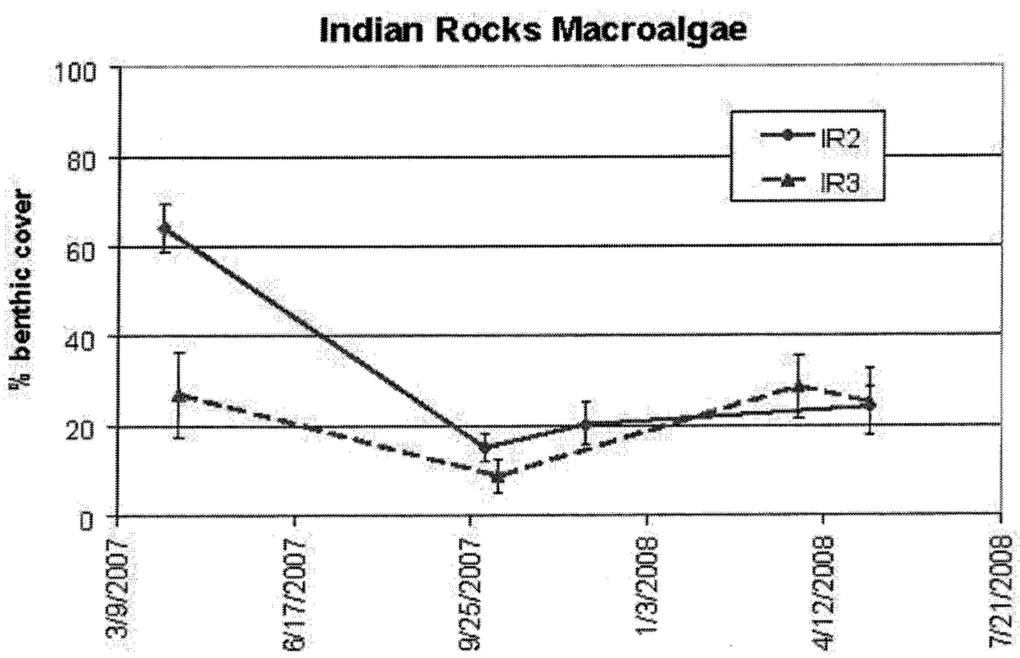
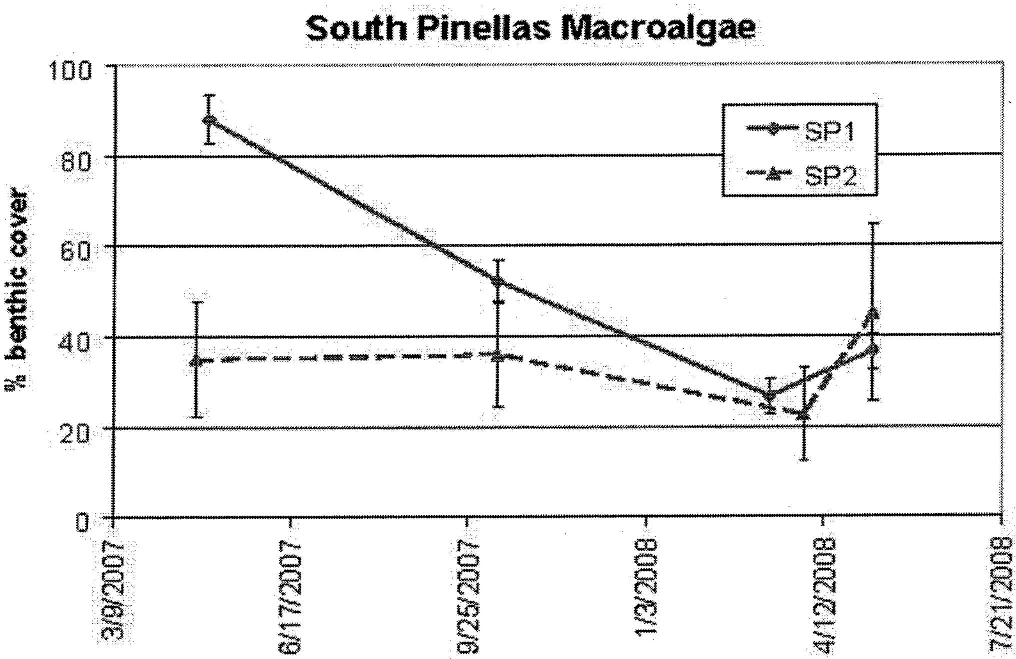
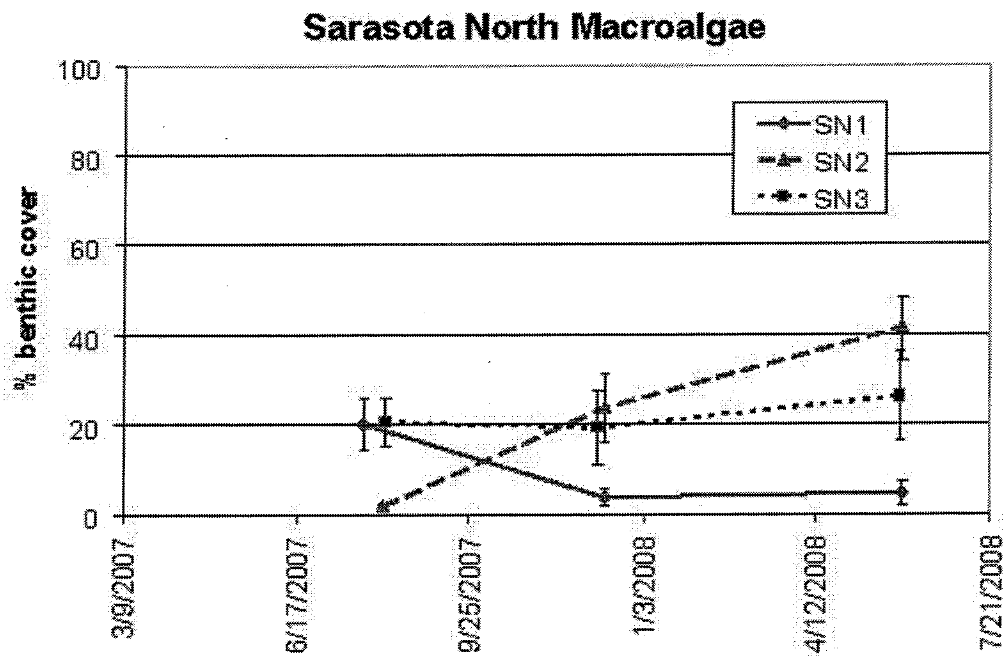


Figure 3: Percent benthic coverage of macroalgae during each sampling event for each survey site. Error bars are standard deviation (n=6).





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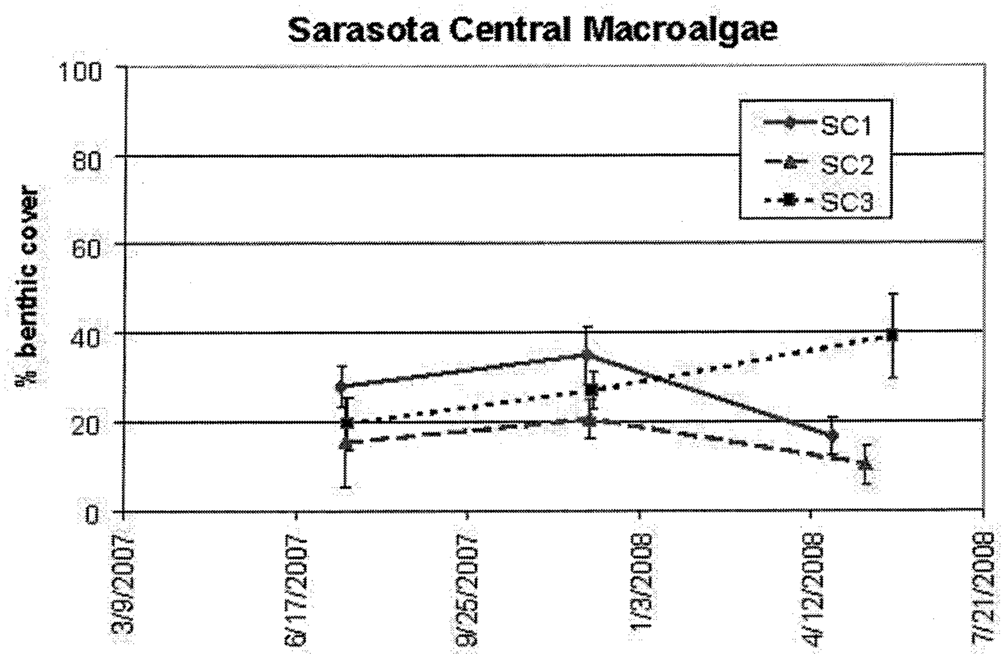

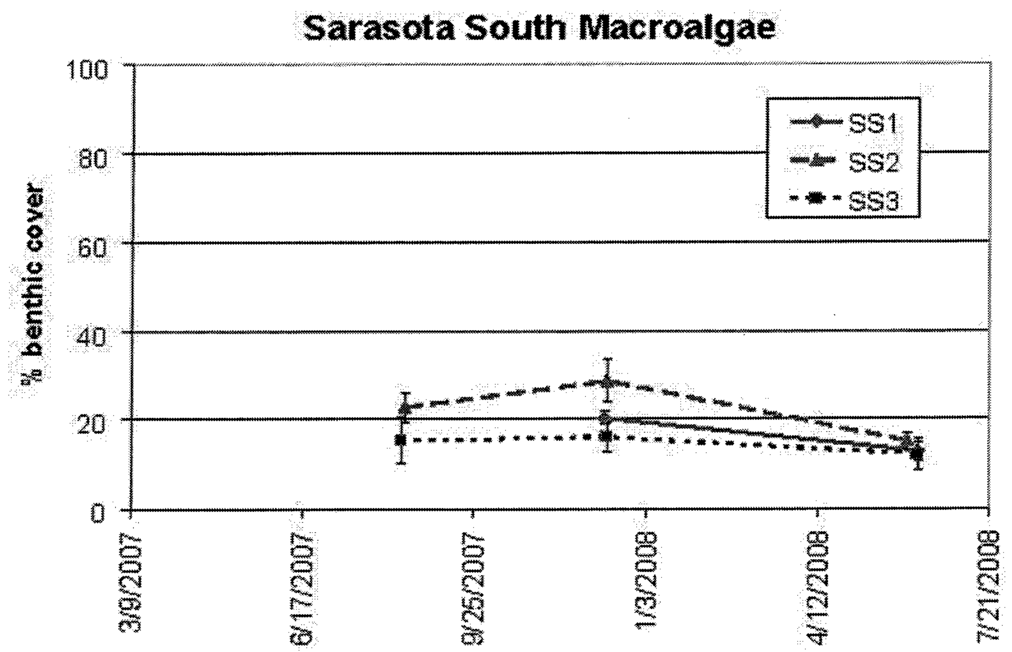

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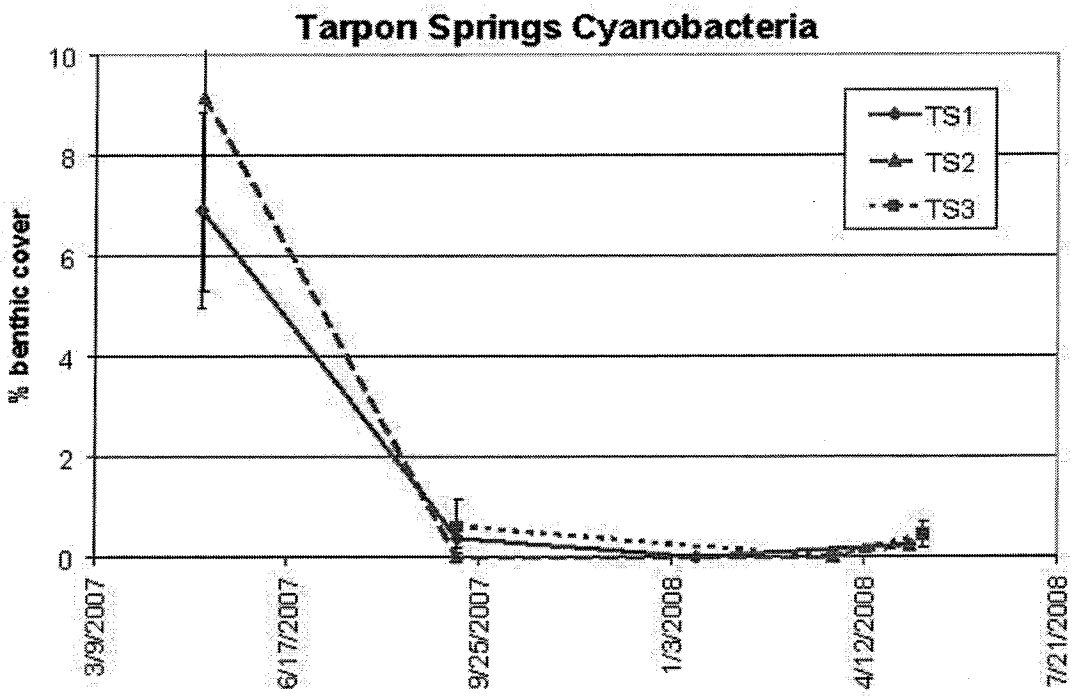


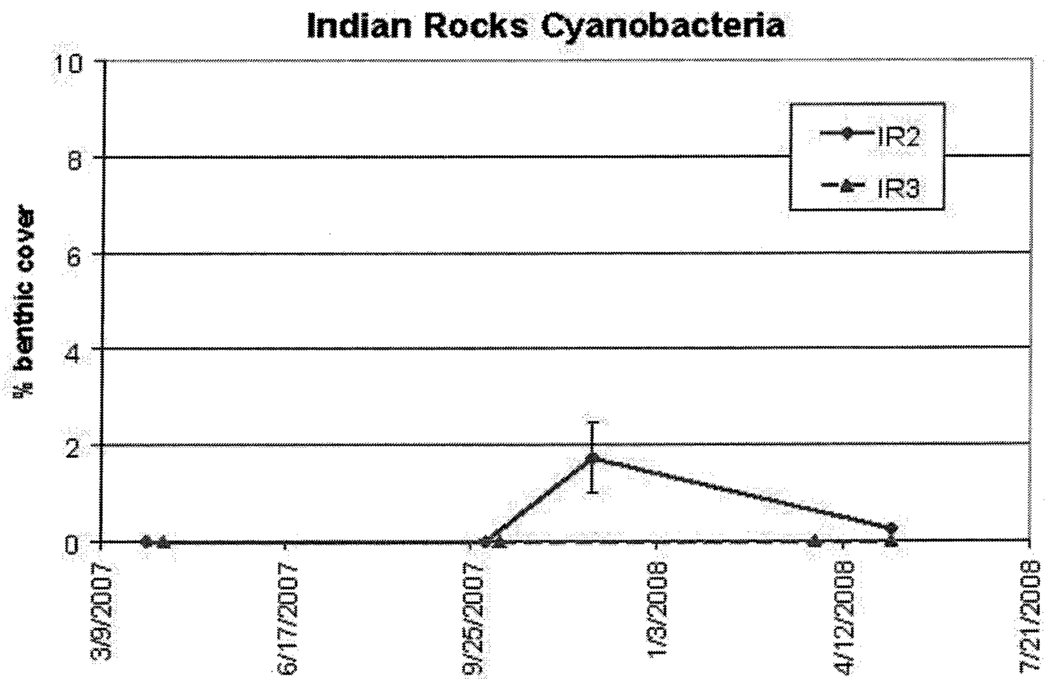
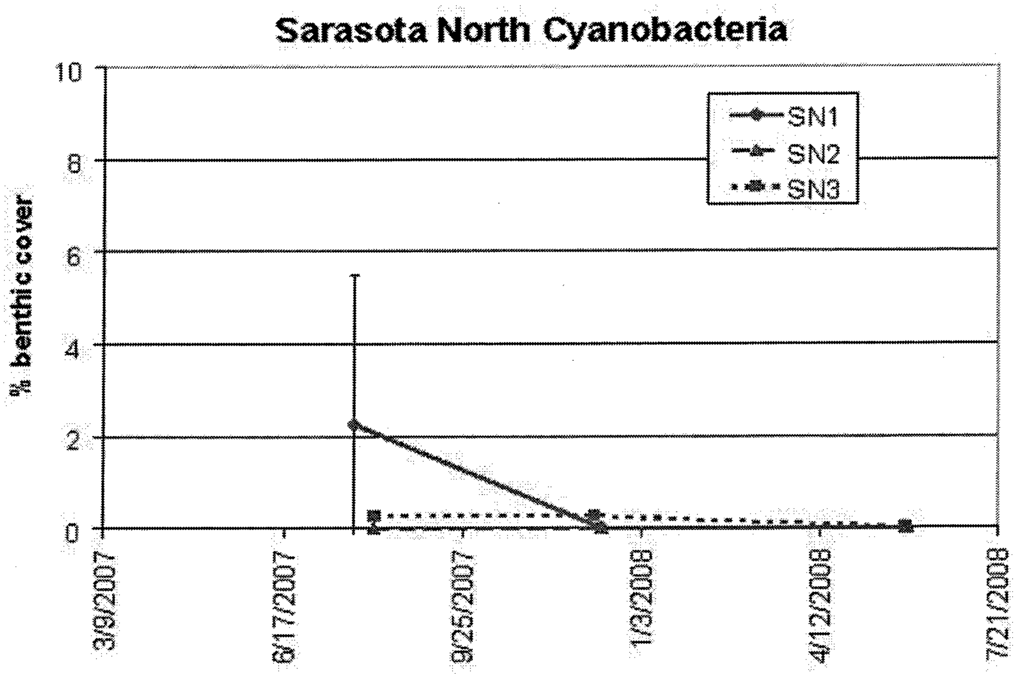
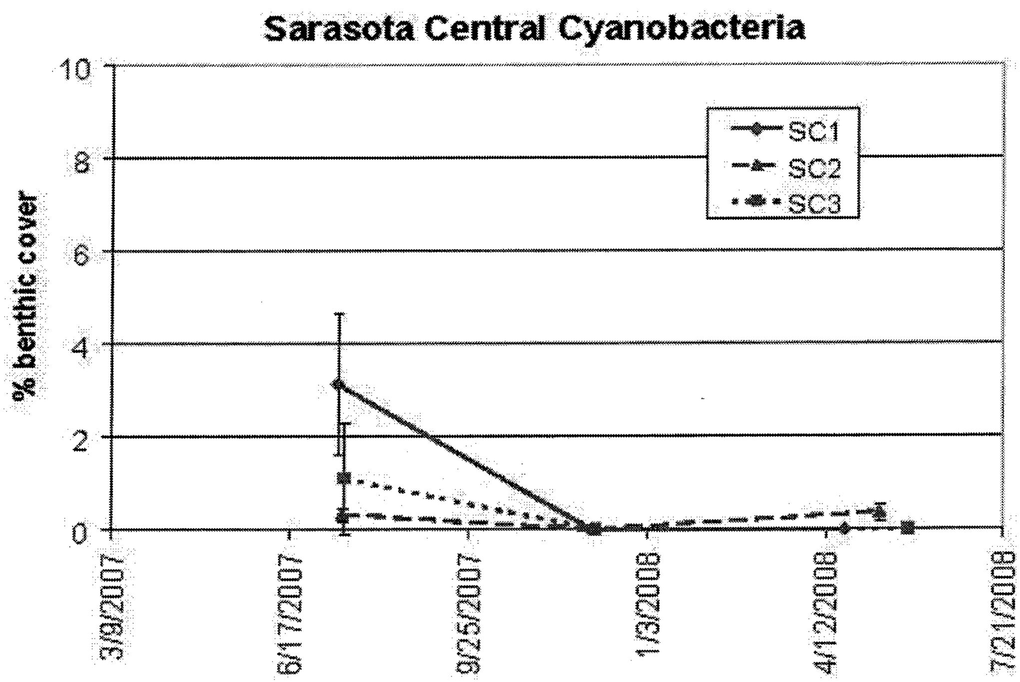


Figure 4: Percent benthic coverage of cyanobacteria during each sampling event for each survey site. Sarasota South and South Pinellas sites are not included because cyanobacteria coverage was negligible. Error bars are standard deviation (n=6).





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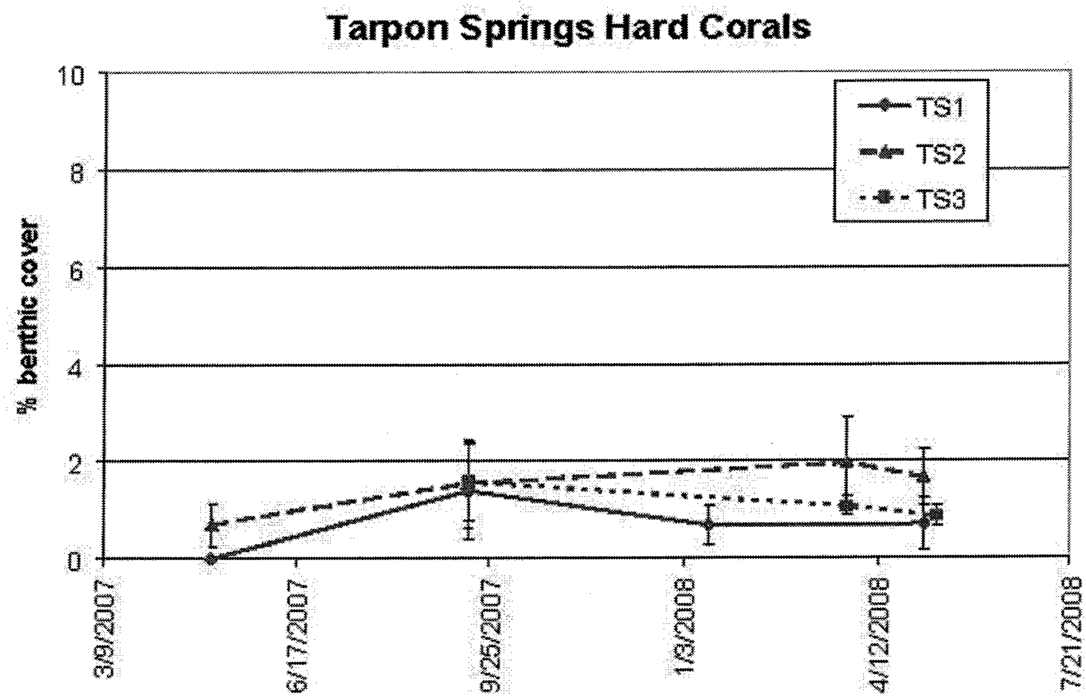


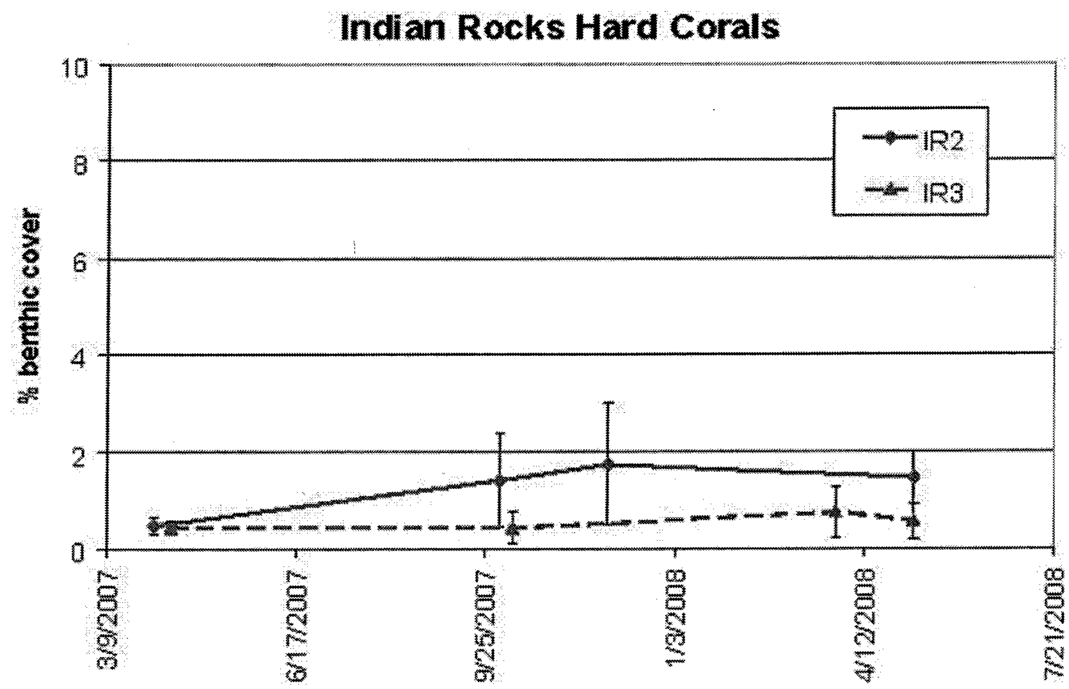
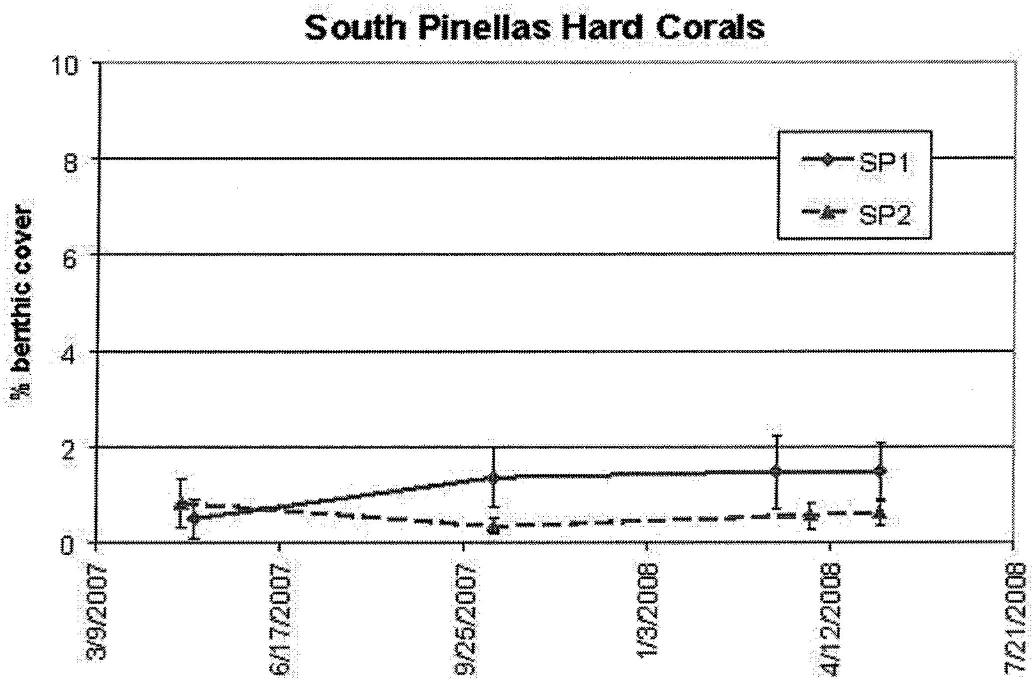
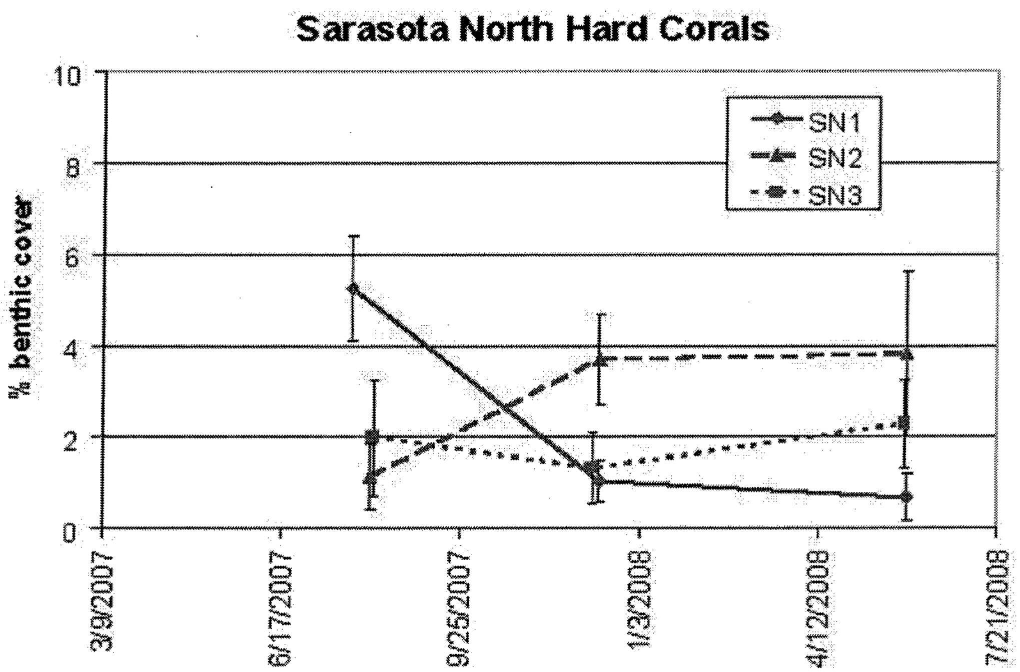


Figure 5: Percent benthic coverage of stony corals during each sampling event for each survey site. Error bars are standard deviation (n=6).





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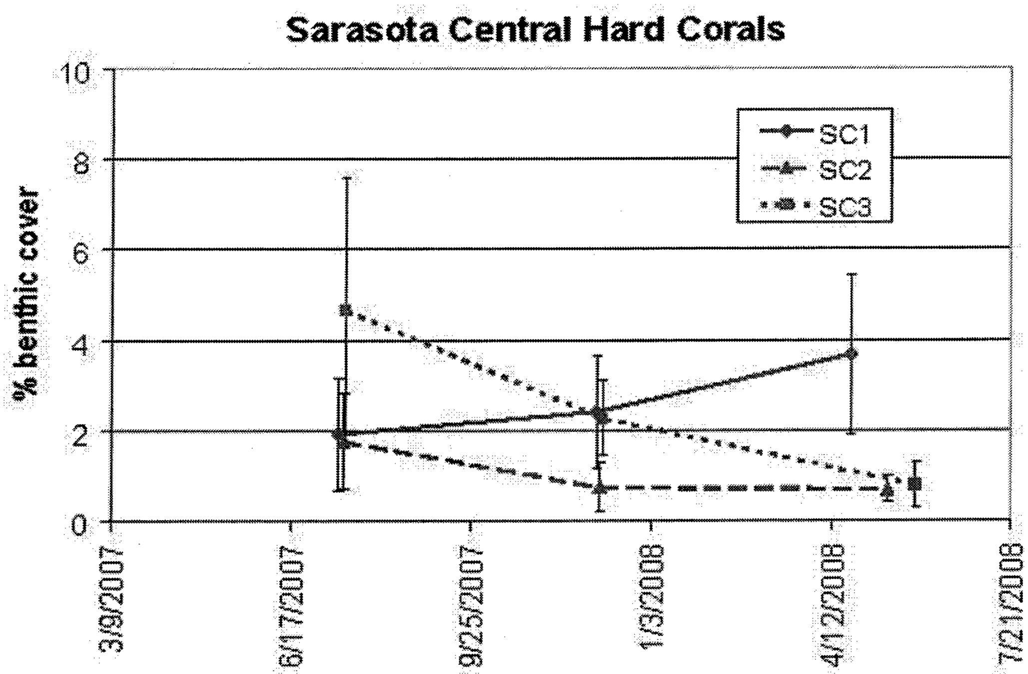

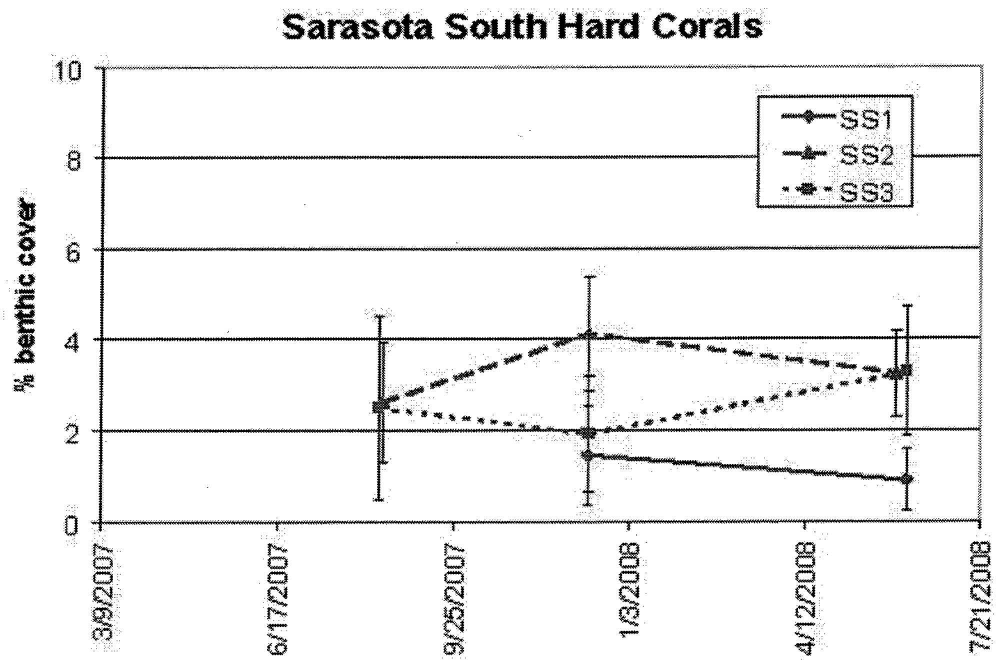

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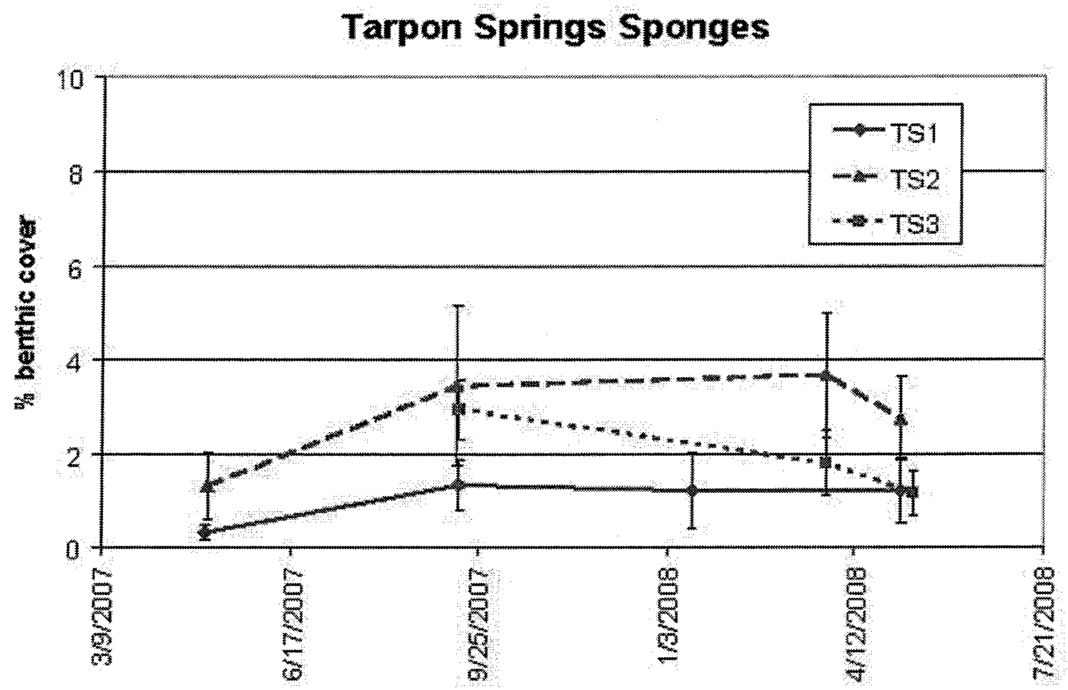


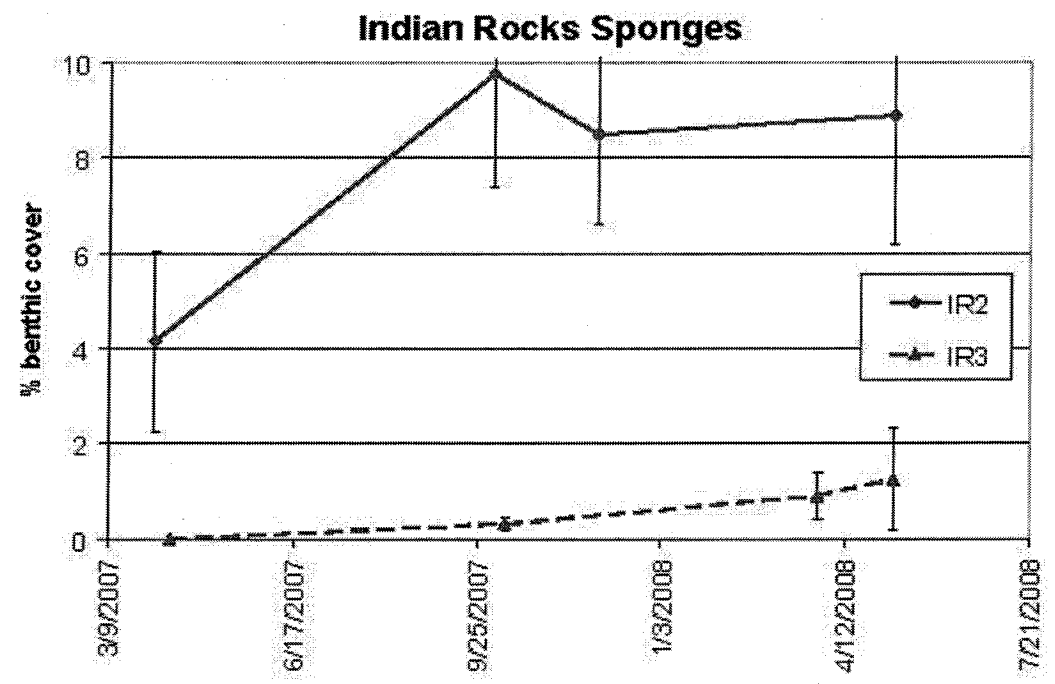
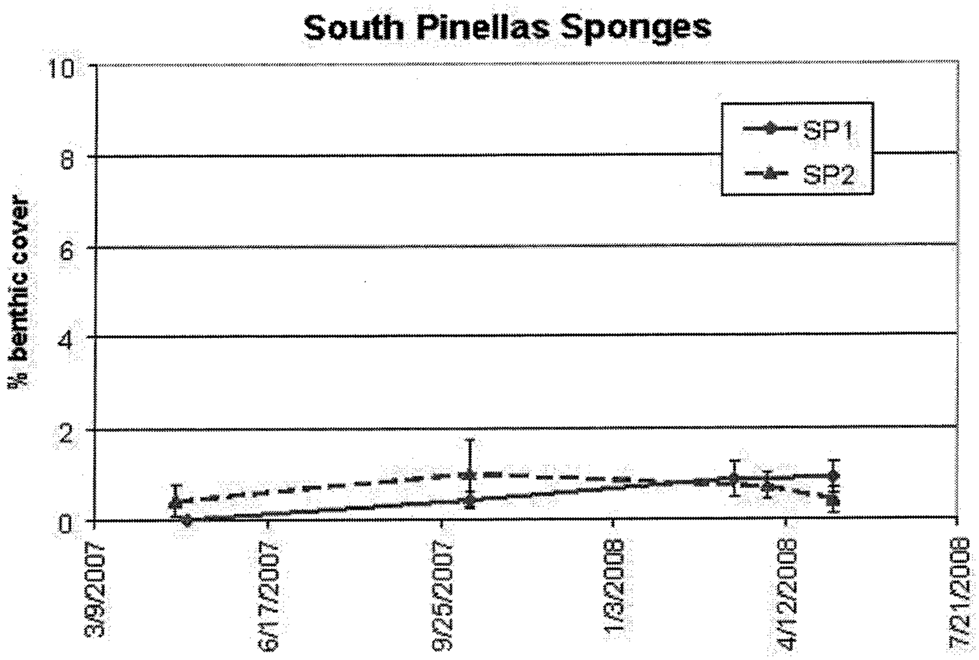
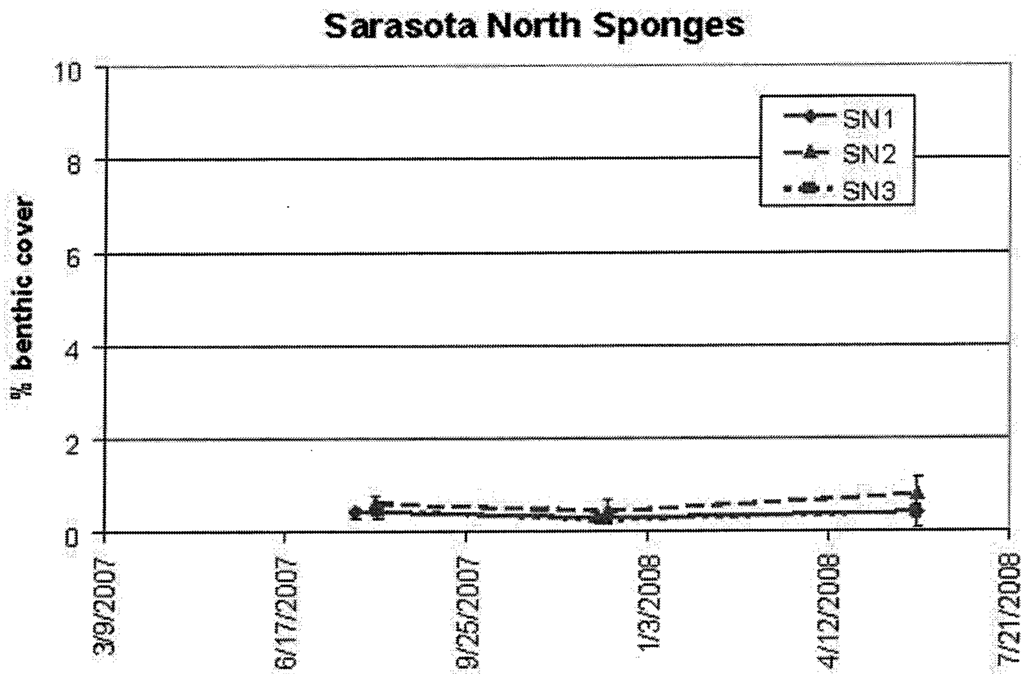


Figure 6: Percent benthic coverage of sponges during each sampling event for each survey site. Error bars are standard deviation (n=6).





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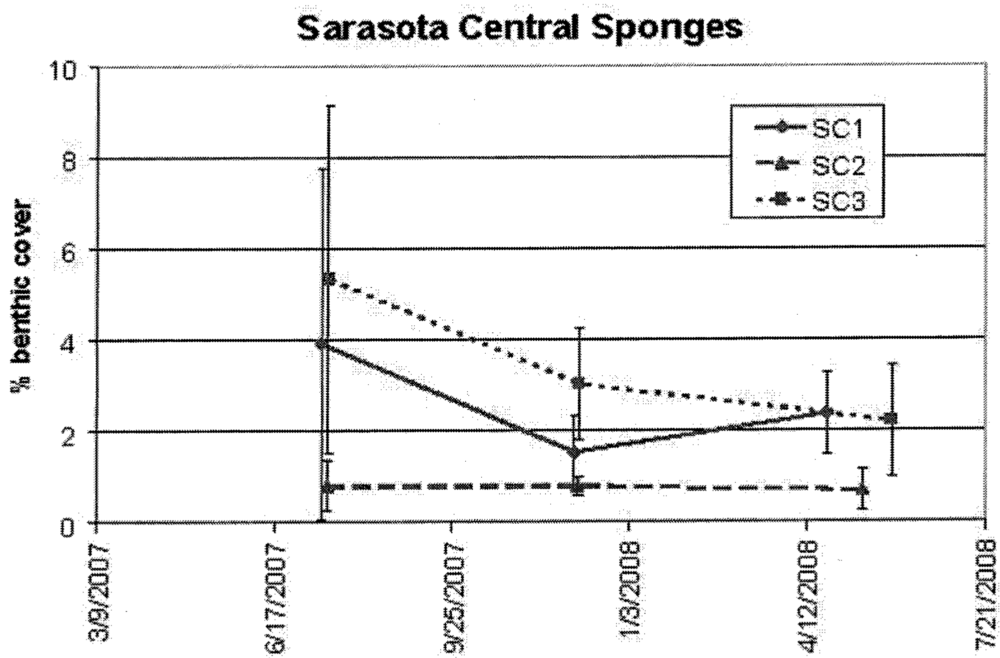

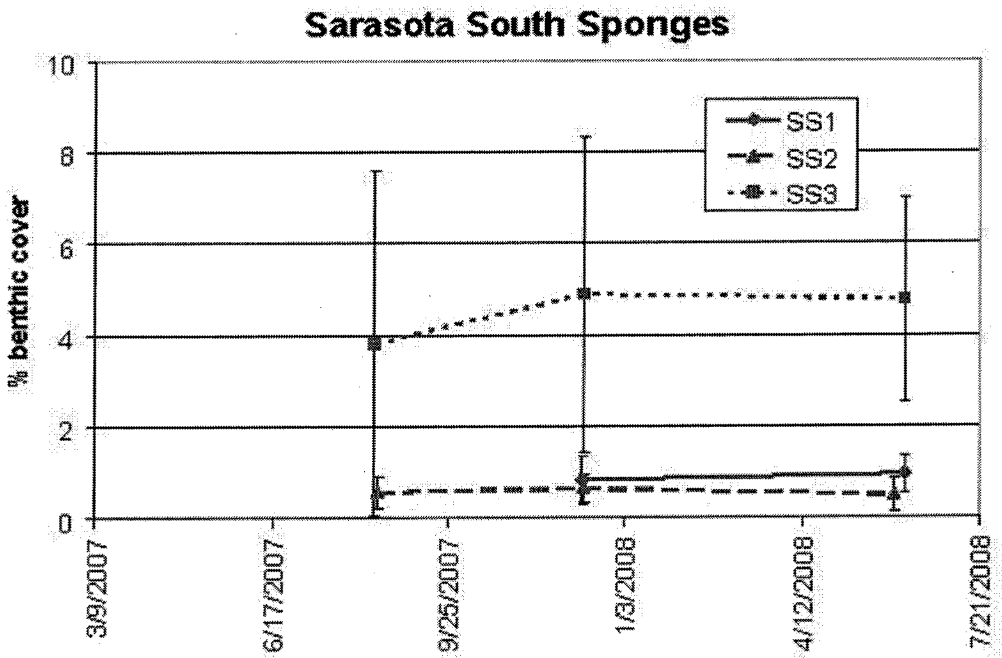

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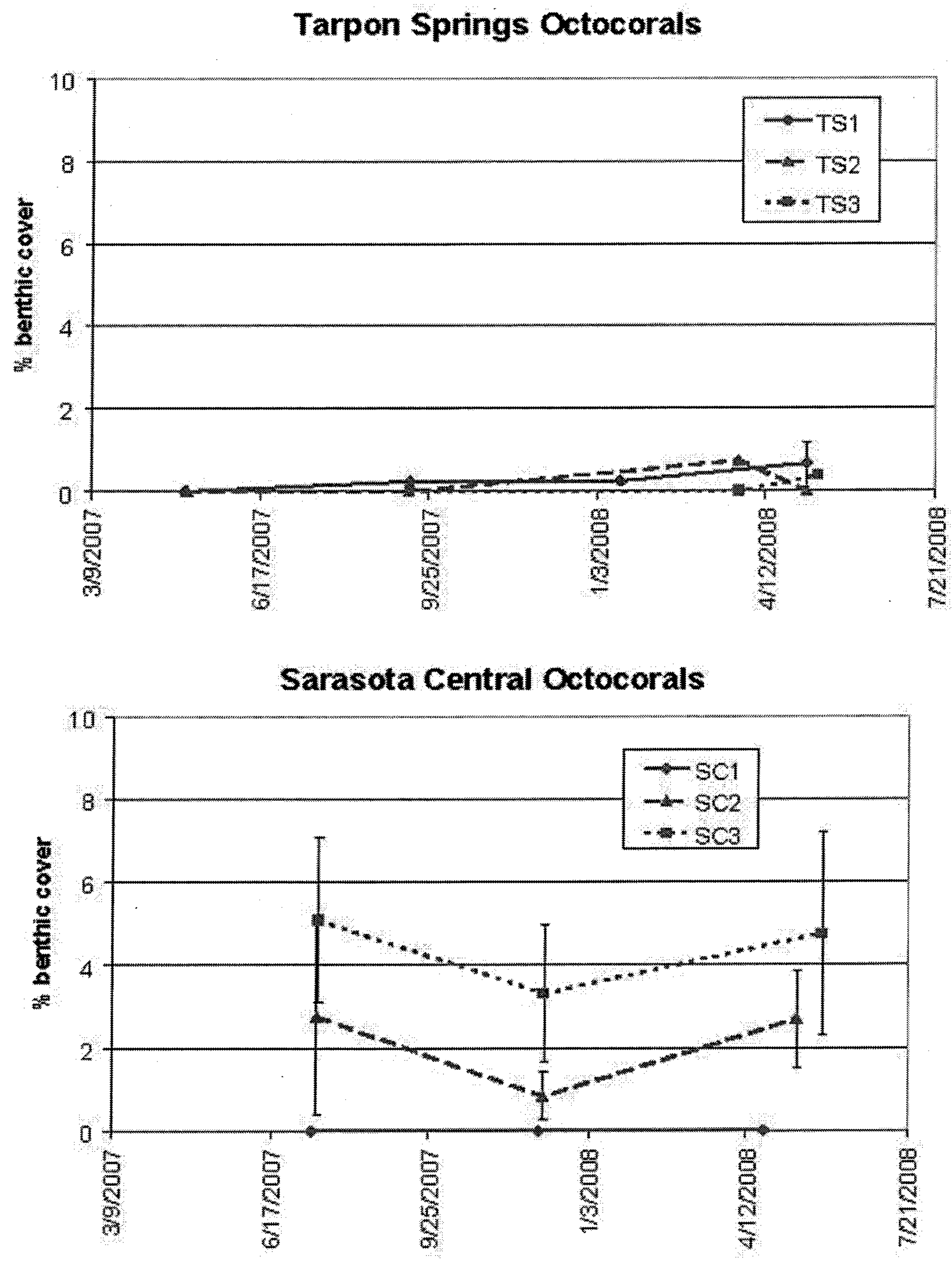

Figure 7: Percent benthic coverage of octocorals during each sampling event for each survey site. Indian Rocks, South Pinellas and Sarasota North sites are not included because octocorals were not present at these locations. Error bars are standard deviation (n=6).

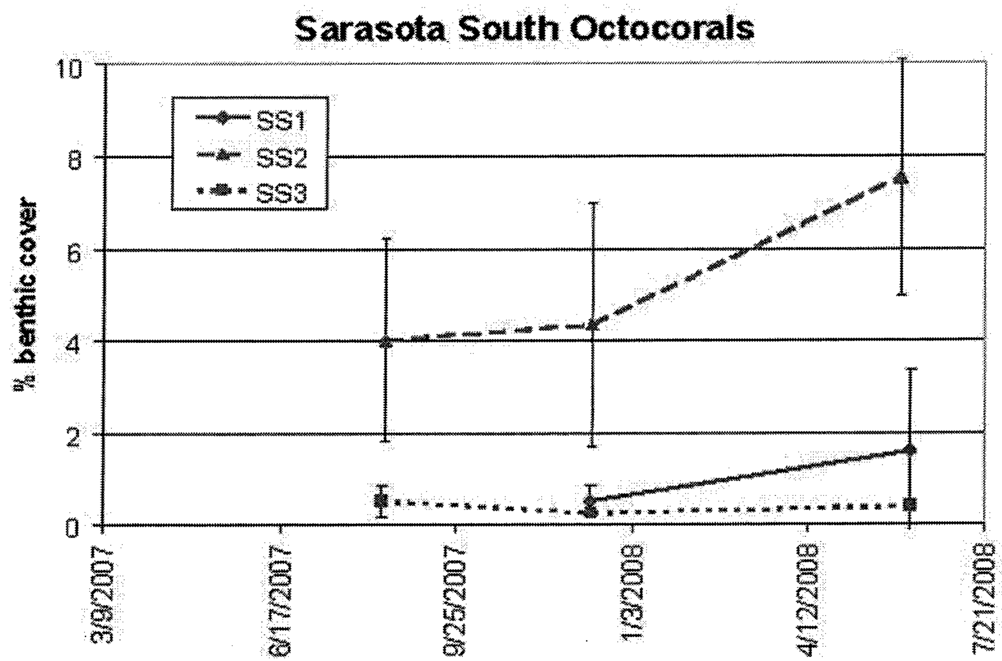

Figure 7 con't.

Line Intercept Transects

A total of 27 genera of macroalgae were identified during this study. This should be considered a low estimate as there were a number of algae specimens grouped as "unknown macroalgae". The most common genera of algae were *Sargassum sp., Dictyota sp., Caulerpa sp.* (particularly *C. sertularioides*), *Halimeda sp.*, and *Udotea sp.* At sites located off of Sarasota County, no seasonal trends were observed. However, off of Pinellas County, the abundance of various unidentified filamentous algae is apparent in the spring months. In the first quarter of sampling, an orange-colored filamentous alga was the dominant algae at nearly all Pinellas County sites. The dominance of this alga is associated with the highest macroalgae cover observed during monitoring. This alga was not abundant at any other time during monitoring, although different filamentous algae were dominant in the fifth quarter of sampling (April to June 2008).

For invertebrates, there were 5 genera of octocorals, 13 species of stony corals representing 10 different genera, and at least 9 genera of sponges. However, many sponges were grouped as "unknown sponge" because they could not be identified in the field. A number of different ascidians were also noted, but no attempt was made to identify species. At nearly all sites, the most numerically abundant sessile invertebrates were stony coral species. The most common species of stony coral observed were *Siderastrea siderea, Solenastrea hyades, Stephanocoenia michellini,* and *Cladocora arbuscula*. At SC2, SC3, and SS2 an octocoral (*Plexaurella sp.*) was the most dominant sessile invertebrate during the final quarter of sampling (April to June 2008), but not during previous surveys. At IR2, a sponge (*Aplysina sp.*) was the most dominant sessile invertebrate during all sampling periods.

There were no consistent changes in species diversity (Shannon-Wiener Diversity) of sessile marine invertebrate observed throughout monitoring. Species diversity ranged from 0.96 to 2.46, but was typically between 1.0 and 2.0, except at TS1, TS2, TS3 and SC3 which consistently had the highest diversity of all survey sites in the study (range: 2.00 to 2.46).

Table 2 lists the most numerically abundant macroalgae and sessile invertebrates, the Shannon Weiner species diversity indices of sessile invertebrates and the percent benthic cover of stony corals, macroalgae, and bare substrate (determined from photographic transects) for each site and sampling period. A complete list of coral species and octocoral, sponge, and macroalgae genera can be found in Appendix A.

Table 2: A list of the most abundant and second most abundant macroalgae and sessile invertebrate for each survey site and sampling period. Also listed is the Shannon-Wiener species diversity index for sessile invertebrates and the percent benthic cover of stony corals, macroalgae, and bare substrate as determined by photographic transects. *algae functional group: FIL – filamentous, F – fleshy, B – cyanobacteria, C – calcareouos. **Invertebrate taxonomic group: P – Porifera, H – Hard Coral, A – Ascidian, O - Octocoral

Sampling Event			Most Abundant Macroalgae	*	2nd Most Abundant Macroalgae	*	Most Abundant Invertebrate	**	2nd Most Abundant Invertebrate	**	Species Diversity	% stony coral cover	% Macroalgae cover	% bare substrate
Tarpon Springs														
TS1	apr-jun	5/3/2007	Filamentous Algae	FIL	Schizothrix sp.	B	Cinachyra sp.	P	S. hyades	H	2.00	0.00	45.48	44.39
	jul-sep	9/14/2007	Udotea sp.	C	C. sertularioides	F	Siderastrea sp.	H	Porifera	P	2.14	1.39	24.32	70.29
	jan-mar	1/16/2008	Rhodophyta	F	Sargassum sp.	F	Tunicate	A	S. hyades	H	2.36	0.69	27.02	67.40
	apr-jun	5/6/2008	C. sertularioides	F	Udotea sp.	C	Siderastrea sp.	H	Cinachyra sp.	P	2.36	0.71	21.96	72.46
TS2	apr-jun	5/4/2007	Schizothrix sp.	B	Filamentous Algae	FIL	Porifera	P	Siderastrea sp.	H	2.32	0.70	16.04	71.64
	jul-sep	9/13/2007	Halimeda sp.	C	Rhodophyta	F	Porifera	P	S. michellini	H	2.06	1.54	19.26	71.89
	jan-mar	3/27/2008	Halimeda sp.	C	Sargassum sp.	F	Siderastrea sp.	H	Spongiae sp.	P	2.46	1.96	9.50	81.67
	apr-jun	5/6/2008	Halimeda sp.	C	Rhodophyta	F	Siderastrea sp.	H	Spongiae sp.	P	2.32	1.67	24.17	66.42
TS3	apr-jun	6/14/2007	Filamentous Algae	FIL	Halimeda sp.	C	Siderastrea sp.	H	Porifera	P	2.39			
	jul-sep	9/14/2007	Udotea sp.	C	Halimeda sp.	C	Siderastrea sp.	H	Porifera	P	2.26	1.58	16.44	74.99
	jan-mar	3/27/2008	Sargassum sp.	F	Halimeda sp.	C	Siderastrea sp.	H	Tunicate	A	2.37	1.08	18.67	75.79
	apr-jun	5/13/2008	Filamentous Algae	FIL	Udotea sp.	C	Siderastrea sp.	H	Cinachyra sp.	P	2.35	1.62	20.30	66.78
Indian Rocks														
IR2	apr-jun	4/3/2007	Filamentous Algae	FIL	Dictyota sp.	F	Aplysina sp.	P	S. michellini	H	1.85	0.49	64.09	27.57
	jul-sep	10/3/2007	Halimeda sp.	C	C. sertularioides	F	Aplysina sp.	P	Siderastrea sp.	H	1.65	1.42	15.11	71.39
	oct-dec	11/29/2007	Halimeda sp.	C	Filamentous Algae	FIL	Aplysina sp.	P	Spongiae sp.	P	2.01	1.75	20.31	63.39
	apr-jun	5/8/2008	Halimeda sp.	C	C. sertularioides	F	Aplysina sp.	P	Spongiae sp.	P	2.04	1.46	24.25	61.13
IR3	apr-jun	4/12/2007	Filamentous Algae	FIL	C. sertularioides	F	Siderastrea sp.	H	Cinachyra sp.	P	1.73	0.44	26.96	71.70
	jul-sep	10/10/2007	C. sertularioides	F	Gracilaria sp.	F	Siderastrea sp.	H	S. hyades	H	1.43	0.44	8.80	88.41
	jan-mar	3/28/2008	Rhodophyta	F	C. sertularioides	F	Siderastrea sp.	H	Aplysina sp.	P	2.01	0.75	28.54	68.54
	apr-jun	5/8/2008	Rhodophyta	F	C. sertularioides	F	Siderastrea sp.	H	S. hyades	H	1.80	0.56	25.21	71.75
South Pinellas														
SP1	apr-jun	5/1/2007	Filamentous Algae	FIL	Codium sp.	C	Siderastrea sp.	H	S. hyades	H	1.78	0.48	88.19	9.17
	jul-sep	10/11/2007	Dictyota sp.	F	Gracilaria sp.	F	S. michellini	H	Siderastrea sp.	H	1.42	1.34	52.32	43.74
	jan-mar	3/13/2008	Rhodophyta	F	Rhodophyta	F	Siderastrea sp.	H	Cinachyra sp.	P	1.43	1.46	26.76	68.32
	apr-jun	5/9/2008	Dictyota sp.	F	Botryocladia sp.	F	Siderastrea sp.	H	Cinachyra sp.	P	1.32	1.46	36.67	57.79
SP2	apr-jun	4/24/2007	Sargassum sp.	F	Filamentous Algae	FIL	C. arbuscula	H	Aplysina sp.	P	1.43	0.81	35.06	62.47
	jul-sep	10/11/2007	Dictyota sp.	F	Sargassum sp.	F	C. arbuscula	H	Aplysina sp.	P	1.27	0.33	36.08	60.04
	jan-mar	4/1/2008	Sargassum sp.	F	Halimeda sp.	C	C. arbuscula	H	Aplysina sp.	P	1.07	0.55	22.72	74.27
	apr-jun	5/9/2008	Sargassum sp.	F	Filamentous Algae	FIL	C. arbuscula	H	Aplysina sp.	P	1.44	0.60	45.13	52.13

Table 2 con't.

Sampling Event			Most Abundant Macroalgae	*	2nd Most Abundant Macroalgae	*	Most Abundant Invertebrate	**	2nd Most Abundant Invertebrate	**	Species Diversity	% stony coral cover	% Macroalgae cover	% bare substrate
Sarasota North														
SN1	jul-sep	7/26/2007	Udotea sp.	C	Dictyota sp.	F	S. hyades	H	S. michellini	H	1.77	5.25	19.96	72.75
	oct-dec	12/7/2007	C. prolifera	F	Udotea sp.	C	S. michellini	H	S. hyades	H	1.66	5.25	19.96	94.97
	apr-jun	5/31/2008	Dictyota sp.	F	Udotea sp.	C	S. hyades	H	S. michellini	H	1.34	0.69	4.63	93.04
SN2	jul-sep	8/6/2007	Udotea sp.	C	Dictyota sp.	F	S. hyades	H	S. michellini	H	1.72	1.15	1.67	96.79
	oct-dec	12/12/2007	Sargassum sp.	F	C. sertularioides	F	S. hyades	H	S. michellini	H	2.04	3.71	23.79	70.33
	apr-jun	5/31/2008	Dictyota sp.	F	Sargassum sp.	F	S. michellini	H	S. hyades	H	1.40	3.83	41.42	52.04
SN3	jul-sep	8/7/2007	C. sertularioides	F	Gracilaria sp.	F	S. hyades	H	S. michellini	H	1.83	2.00	20.51	75.14
	oct-dec	12/8/2007	C. sertularioides	F	C. prolifera	F	S. hyades	H	O. robusta	H	1.68	1.33	19.25	78.54
	apr-jun	5/30/2008	Dictyota sp.	F	C. sertularioides	F	S. michellini	H	S. hyades	H	1.67	2.29	26.25	69.58
Sarasota Central														
SC1	jul-sep	7/13/2007	C. racemosa	F	Dictyota sp.	F	S. michellini	H	S. hyades	H	1.78	1.92	28.08	62.58
	oct-dec	12/3/2007	Sargassum sp.	F	C. sertularioides	F	S. michellini	H	C. arbuscula	H	1.50	2.42	34.92	60.13
	apr-jun	4/23/2008	Sargassum sp.	F	Dictyota sp.	F	C. arbuscula	H	S. michellini	H	1.84	3.67	16.58	76.38
SC2	jul-sep	7/16/2007	Dictyota sp.	F	Udotea sp.	C	S. hyades	H	S. michellini	H	2.01	1.75	15.29	80.67
	oct-dec	12/5/2007	Dictyota sp.	F	Udotea sp.	C	S. michellini	H	S. hyades	H	1.82	0.75	20.58	76.29
	apr-jun	5/13/2008	Udotea sp.	C	Dictyota sp.	F	Plexaurella sp.	O	S. hyades	H	0.96	0.70	10.38	84.88
SC3	jul-sep	7/17/2007	Dictyota sp.	F	Udotea sp.	C	S. michellini	H	Plexaurella sp.	O	2.10	4.67	19.58	62.58
	oct-dec	12/6/2007	Dictyota sp.	F	Halimeda sp.	C	S. michellini	H	C. arbuscula	H	2.05	2.27	27.12	62.75
	apr-jun	5/29/2008	Dictyota sp.	F	Halimeda sp.	C	Plexaurella sp.	O	Muricea sp.	O	2.02	0.79	39.08	51.42
Sarasota South														
SS1	oct-dec	12/10/2007	C. prolifera	F	C. sertularioides	F	S. hyades	H	S. michellini	H	1.72	1.45	20.46	76.63
	apr-jun	6/9/2008	C. sertularioides	F	Udotea sp.	C	S. hyades	H	Muricea sp.	O	1.68	0.90	12.83	81.46
SS2	jul-sep	8/16/2007	Udotea sp.	C	Dictyota sp.	F	S. michellini	H	S. hyades	H	1.97	2.63	22.88	68.83
	oct-dec	12/11/2007	Udotea sp.	C	C. sertularioides	F	S. hyades	H	Siderastrea sp.	H	1.95	4.13	28.88	59.75
	apr-jun	6/3/2008	C. sertularioides	F	Udotea sp.	C	Plexaurella sp.	O	S. hyades	H	1.85	3.25	15.21	71.58
SS3	jul-sep	8/14/2007	Halimeda sp.	C	Udotea sp.	C	Siderastrea sp.	H	S. michellini	H	1.77	2.50	15.50	75.25
	oct-dec	12/11/2007	Dictyota sp.	F	Udotea sp.	C	C. arbuscula	H	Solenastrea sp.	H	1.89	1.92	16.04	77.46
	apr-jun	6/9/2008	Halimeda sp.	C	Udotea sp.	C	C. arbuscula	H	Solenastrea sp.	H	1.72	2.21	15.77	76.72

Motile Invertebrate Survey

A total of 38 motile invertebrate species were identified during this study. The most common were hermit crabs (*Pagurus sp.)*, arrow crabs (*Stenorhynchus seticornis)*, clinging reef crabs (*Mithraculus forceps)*, gorilla crabs (*Pilumnus sayi)*, the rock boring urchin (*Echinometra lucunter)*, and the Florida cerith snail (*Cerithium floridanum)*. A complete list of motile invertebrate species can be found in Appendix A. The total number of species found during any one sampling period ranged from 1 to 13 and varied at all sites (Table 3). The highest motile invertebrate densities were found at sites SP1 and SP2, while the lowest densities were found at IR3. Seasonal trends were not identified; however, 5 of 7 sites increased in motile invertebrate densities from the first to the last quarter of sampling.

Shannon-Weiner species diversity indices ranged from 0 to 3.44. The highest diversity was observed at TS3 in the final quarter of sampling. Throughout the study highest motile invertebrate species diversity indices were calculated for SP1, SP2, TS2, and TS3, while the lowest were for IR2 and IR3. Motile invertebrate species diversity increased at four of seven sites from the first to the last quarter of sampling.

Site	Sampling Quarter	Date	H'	R	total invertebrates per m^2	Dominant Species common name	Dominant Species scientific name
Tarpon Springs							
TS1	Apr-Jun	5/3/2007	2.74	10	0.3	Rock Boring Urchin	*Echinometra lucunter*
	Jul-Sep	9/14/2007	0.78	4	1.2	Hermit Crab	*Pagurus sp.*
	Apr-Jun	5/6/2008	1.79	7	1.1	Hermit Crab	*Pagurus sp.*
TS2	Apr-Jun	5/4/2007	1.59	6	0.5	Clinging Reef Crab	*Mithraculus forceps*
	Jul-Sep	9/13/2007	2.87	11	1.2	Clinging Reef Crab	*Mithraculus forceps*
TS3	Apr-Jun	6/14/2007	1.27	7	0.3	Yellowline Arrow Crab	*Stenorhynchus seticornis*
	Jul-Sep	9/14/2007	2.12	9	0.5	Gorilla Crab	*Pilumnus sayi*
	Apr-Jun	5/13/2008	3.44	13	1.6	Rock Boring Urchin	*Echinometra lucunter*
Indian Rocks							
IR2	Apr-Jun	4/3/2007	0.69	3	0.4	Gorilla Crab	*Pilumnus sayi*
	Jul-Sep	10/3/2007	0.00	1	0.6	Florida Cerith Snail	*Cerithium floridanum*
	Oct-Dec	11/29/2007	1.47	9	3.1	Florida Cerith Snail	*Cerithium floridanum*
	Apr-Jun	5/8/2008	0.25	4	4.6	Florida Cerith Snail	*Cerithium floridanum*
IR3	Apr-Jun	4/12/2007	0.64	3	0.8	Tube Worm	ORDER: Sabellida
	Jul-Sep	10/10/2007	0.35	2	0.2	Gorilla Crab	*Pilumnus sayi*
	Apr-Jun	5/8/2008	0.37	2	0.3	Chione Clam	*Chione elevata*
South Pinellas							
SP1	Jul-Sep	10/11/2007	1.11	7	2.6	Spaghetti Worm	*Eupolymnia crassicornis*
	Apr-Jun	5/9/2008	1.93	10	1.3	Yellowline Arrow Crab	*Stenorhynchus seticornis*
SP2	Jul-Sep	10/11/2007	2.43	9	1.6	Rock Boring Urchin	*Echinometra lucunter*
	Apr-Jun	5/9/2008	2.76	13	2	Rock Boring Urchin	*Echinometra lucunter*

Table 3: A list of the Shannon-Wiener species diversity (H'), species richness (R), total number of motile invertebrates per square meter and the most abundant motile invertebrate species for each survey site and sampling period when surveys were conducted.

Water Quality Measurements

Seasonal trends in water quality data were difficult to determine because of the limited number of samples. However, where water quality measurements were completed, data indicate a well-mixed water column. Throughout the year, temperatures ranged from 19°C to 26°C and salinities ranged from 36 to 39 $^{o}/_{oo}$. A thermo-cline greater than 2°C was only observed once (April to June 2007) at IR2, which is the deepest and furthest offshore site. For Pinellas County sites, dissolved oxygen concentrations are only available from 1 sampling period, April to June 2007, when they ranged from 6.4 to 9.9 mg/L. For Sarasota County sites, dissolved oxygen concentrations ranged from 5.7 to 8.7 mg/L. For both regions, dissolved oxygen concentrations we observed were typical of marine environments.

Phytoplankton Community Composition

During this project, 157 Lugols preserved water samples were analyzed for the abundance of *Karenia brevis*. Of these 157 samples, 9.55% were positive for the presence of *K. brevis*. Of the samples containing *K. brevis*, only one (BMSS1, surface, 12/10/07) had a concentration higher than background level (1000 cellsL^{-1} or less). *Karenia brevis* cell concentrations in this sample were 5,600 cellsL^{-1}, which is a concentration at which respiratory irritation may be noted, but mortality events are unlikely. No conclusions about the geographic distribution of *K. brevis* in the survey area were made because so few samples contained *K brevis*. Of the 15 samples testing positive for the presence of *K. brevis*, 6 (2 groups of 3) samples were from the same station on the same date, just at varying depths.

There were 102 different phytoplankton species identified in the study area. A total of 121 samples were analyzed for complete phytoplankton species composition and abundance. The majority were dinoflagellate (49.02%) and diatom (38.24%) species, but species of flagellates (10.78%) and blue-green algae (2.96%) were also noted. Of the 102 species identified, 25.49% of them are known or potential Harmful Algal Bloom (HAB) species. Throughout the study diatoms were the most abundant in 62.80% of the samples. The most prominent genera were *Pseudo-nitzschia* spp. and *Rhizosolenia* spp.

The most prominent dinoflagellate genus was *Gyrodinium* spp. A complete list of phytoplankton species can be found in Appendix A.

No seasonal trends within the phytoplankton community were noted. Comparisons of the phytoplankton community between surface, mid, and bottom samples indicate that the sampling area is well mixed. In 83.33% of the samples, the same organism dominated all three sampling depths.

Spatially, dinoflagellates were more abundant more frequently at Tarpon Springs sites as opposed to that at sites further south. In the offshore waters of the survey area, the dominant dinoflagellate was *Gyrodinium*, a heterotrophic genus which, like *K. brevis*, is well adapted to oligotrophic conditions.

Analysis of sediments for dinocysts from the survey area showed that dinocysts were present in all sediments sampled. The number of dinocysts ranged from 14 dinocysts/60mL sample volume to 762 dinocysts/60mL sample volume. The most dominant dinocyst in the samples was identified as a "round brown", a term used to identify a group of protoperidinioid dinocysts (Marret and Zonneveld, 2003). Spatially, the highest average number of dinocysts was found in the Sarasota North transects. Temporally, the highest average number of dinocysts was found in the months of May and December. However, a correlation between the number and type dinocysts recovered from sediments and phytoplankton data from the water samples could not be determined.

<u>Brevetoxin Concentrations</u>

Tarpon Springs

Samples from the sites off of Tarpon Springs (TS1, TS2, and TS3) that were analyzed for PbTx were collected between May 2007 and May 2008. *Karenia brevis* was either not observed or present only at background levels. Brevetoxins in seawater and sediments were either not detectable (<LD) or present at very low background levels. The highest concentrations measured were 0.03 µg/L in seawater and 8.95 ng/g in sediments.

Indian Rocks

A *K. brevis* bloom was present in SW Florida in the fall of 2006. However, samples collected from IR2 in October of 2006 contained only very low concentrations of *K. brevis* (4,600 cells/L). No sediments were analyzed for this collection, but PbTx concentrations in seawater at this site were low (0.07-0.17 µg/L). For the remainder of the project, *K. brevis* was absent from samples collected from sites IR2 and IR3 (between April 2007 and May 2008) except for a single sample that contained 1,300 *K. brevis* cells/L. Brevetoxins were either not detectable or present at background levels in seawater except for samples collected at IR2 in October and November 2007, when we measured 0.25 and 0.37µg/L respectively. Brevetoxins in sediments were either not detectable (<LD) or, in one case, present at very low background levels (10.06 ng/g).

South Pinellas

Samples collected from South Pinellas sites (SP1 and SP2) during the *K. brevis* bloom in October 2006 contained concentrations of *K. brevis* ranging from 49,300 to 270,300 cells/L. Brevetoxin concentrations in these water samples ranged from 1.68 to 8.69 µg/L and were typical concentrations that would be found in a moderate *K. brevis* bloom. No sediments were analyzed from this bloom period. For the rest of the project period, *K. brevis* was absent from samples collected from sites SP1 and SP2 (between April 2007 and May 2008) except for a single sample that contained 1,300 *K. brevis* cells/L. Brevetoxins in seawater and sediments were either not detectable (<LD) or present at very low background levels. The highest concentrations measured were 0.04 µg/L in seawater and 5.74 ng/g in sediments.

Sarasota North

Samples from off of Longboat Key (SN1, SN2, and SN3) that were analyzed for PbTx were collected in August 2007, December 2007, and May 2008. *Karenia brevis* was not observed in any water samples. Brevetoxins in seawater were either not detectable (<LD) or present at very low background levels (max. 0.10 µg/L). Sediments were consistently positive but low, ranging from 11.33 to 55.23 ng/g.

Sarasota Central

Samples from off of New Pass (SC1, SC2, and SC3) that were analyzed for PbTx were collected in July 2007, December 2007, and May 2008. *Karenia brevis* was either not observed or present only at background levels except for one sample in December 2007 that contained 1,300 cells/L. Brevetoxins in seawater were consistently detectable, but were mainly present at background levels. At SC1 and SC2, brevetoxin concentrations in December 2007 were slightly higher than background (0.25-0.35 μg/L) as well as at SC3 in May 2007 (0.41 μg/L). Sediments were also consistently positive at these sites but were again low, ranging in concentration from 10.13 to 88.53 ng/g. The maximum sediment concentration was seen at site SC3 in December 2007 and co-occurred with the maximum *K. brevis* and PbTx concentration in seawater at that site.

Sarasota South

Samples from off of Venice (SS1, SS2, and SS3) that were analyzed for PbTx were collected in September 2007, December 2007, and June 2008. *Karenia brevis* was either not observed or present only at background levels except for one sample in December 2007 that contained 5,600 cells/L. Brevetoxins in seawater were consistently detectable, but were mainly present at background levels except for a single sample (SS2, September 2007) that was 0.27μg/L. Sediments were consistently positive for brevetoxins but with low concentrations, ranging from 12.58 to 37.65 ng/g.

Discussion

Benthic Habitat Recovery

Prior to 2005, only one large scale benthic mortality event caused by a *K. brevis* red tide, has been documented for Gulf of Mexico waters off of Pinellas and Sarasota Counties (Simon and Dauer 1972, Smith 1975, Tiffany and Heyl 1978). Smith (1975) reported heavy mortalities, and in some locations complete destruction, of various invertebrate species, including echinoderms, mollusks, crustaceans, corals and sponges at a number of sites located off of Sarasota, Florida. Secondary effects such as oxygen depletion, hydrogen-sulfide poisoning, and bacterial and fungal infections were reported as the primary cause of mortality of benthic communities.

Following the red tide event in 1971, Smith (1975) monitored a number of sites to examine the re-colonization of the affected area by fishes, invertebrates and algae and reported that many ecological components were considered fully recovered after just one year. The recovery of fish communities reported by Smith was complete in about one year but fish recovery will not be discussed in detail here as the focus of this project was invertebrate recovery. Cyanobacteria (blue-green algae) were the first organisms to re-colonize the substrate. They did so almost immediately after the red tide receded (October 1971) and quickly formed dense mats covering the substrate. By the end of winter 1972, the cyanobacteria were being replaced by filamentous red algae and brown algae, notably *Giffordia sp.*, which is a filamentous brown algae that grows in dense tufts. In early summer of 1972, a hurricane passed through the eastern Gulf of Mexico that scoured attached algae from the benthic communities. Over several months following that hurricane, a number of algal species that were common before the red tide event colonized the substrate and became abundant once again. These species included *Caulerpa sp.*, *Halimeda sp.*, *Udotea sp.*, *Sargassum sp.* and *Gracilaria sp.* Algal communities returned to their pre-red tide state in about one year; however, invertebrate species recovered much slower. Up to three years following the red tide, several invertebrate species had not returned to the area, including the Florida spiny lobster and several species of octocorals, mollusks and echinoderms.

Preliminary surveys indicated that the 2005 red tide event that occurred off of Pinellas and Sarasota Counties resulted in large-scale fish kills and complete devastation of benthic habitats at a number of locations. Lawrence et al. (2006) examined the mass mortality of sand dollars off of Sarasota County following the 2005 red tide event and found that complete mortality had occurred at several locations. Although *K. brevis* seawater concentrations are not available for the summer 1971, the 2005 red tide was likely similar if not denser (higher *K. brevis* cell concentrations) and longer-lived than the 1971 red tide.

The habitat assessments conducted by Smith (1975) provide a detailed description of the ecological succession that occurred following the 1971 red tide. A number of the ecological components examined in this monitoring effort reflect the ecological succession described by Smith in spite of the 15 months of recovery that occurred prior to the first sampling quarter. In the first quarter (April to June 2007), macroalgae generally made up more of the benthic substrate than it did in any other sampling period. Unfortunately, MML was not able to sample sites off of Sarasota County during the first quarter. The macroalgae communities observed off of Pinellas County were made up of mostly filamentous algae in spring 2007. Although filamentous algae were abundant at some locations in spring 2008, the types of filamentous algae were different from those observed in 2007.

The percent benthic cover of cyanobacteria observed during the first two quarters of sampling is more informative. At Tarpon Springs sites and at several Sarasota County sites, cyanobacteria made up considerable proportions of the substrate coverage during the first two quarters but were virtually absent during later sampling periods. Although other algae groups, *Caulerpa sp*., *Halimeda sp*., *Udotea sp.*, *Sargassum sp*. and *Gracilaria sp*., reported as abundant under 'normal' conditions were present during all sampling periods, the shift from a filamentous/cyanobacteria algae community to one with more fleshy and calcareous algae types is similar to the final stages of succession of algae communities described by Smith (1975).

The trends observed in octocoral abundance at SC2, SC3, and SS2 are also comparable to the succession described by Smith (1975). The percent benthic cover of octocorals at these sites increased throughout the monitoring effort. Furthermore, in the final quarter of sampling (April to June 2008), an octocoral (*Plexaurella sp.*) became the most dominant sessile invertebrate at each of these sites. By the final quarter of sampling, it also appeared as if octocorals (particularly *Pterogorgia sp.)* were becoming more abundant at Tarpon Springs sites where they were not even observed in the spring of 2007. The increases in octocoral coverage and abundance observed at these sites in the final quarter of sampling (approximately 2.5 years after the red tide mortality event), matches the timescale for recovery of invertebrate species observed by Smith (1975). Lack of octocorals at Indian Rocks, South Pinellas and Sarasota North sites may be related to their proximity to Tampa Bay and associated salinity gradients.

Succession of motile invertebrates appears to coincide with the ecological succession described by Smith (1975) as well, although motile invertebrate monitoring was not conducted at as many sites or as frequently. Although trends are not consistent at all sites, the majority of sampling surveys indicated that motile invertebrate diversity and abundance have increased slightly over the past year, which is again consistent with the timescale for the recovery of invertebrate species observed by Smith (1975).

The general trends discussed above indicate that recovery is likely near completion for algal communities, but is continuing for various invertebrates. The timescales for recovery may seem somewhat longer than those reported by Smith (1975); however, the 2005 red tide appears to have been a more severe bloom than that in 1971. Additionally, no major storms passed through the eastern Gulf of Mexico to potentially n remove the considerable amounts of decaying organic material. Despite these general trends and observed similarities to the ecological succession described by Smith (1975), observations on the recovery of these benthic resources are not definitive. All similarities observed are based on general trends (which are not true for all sites) and have not been tested for statistical significance. Furthermore, while ecological succession patterns may appear to be similar to those that occurred following a previous large scale benthic mortality event, lack of recent baseline data on these benthic habitats precludes making definitive statements regarding recovery of these benthic habitats.

Some evidence indicates the 2005 benthic mortality event may not have been as severe as originally suspected or several groups of animals are hardier than expected. Stony coral and sponge benthic cover was fairly consistent throughout the study. A slight increase in cover may have been documented at some sites, but this is more likely a result of decreasing macroalgae cover which improved visibility of coral and sponge colonies in digital still images. In particular, stony coral abundance remained fairly consistent during the monitoring period. This may indicate one or more factors at play: 1) they were not affected, 2) they are not recovering, 3) they are recovering more slowly or 4) they had recovered prior to the start of monitoring in spring 2007. The most likely scenario is that stony coral recovery is progressing slower than could be detected during the time span of this monitoring project. However, because of frequent disturbance such as red tides, high turbidity, hurricanes and cold winter temperatures it is a reasonable possibility that coral communities at these sites may exist in a dynamic natural state.

It is certain that complete mortalities did not occur at some localities as initially reported as obvious survivors were observed during monitoring. The size of several stony coral colonies at a number of sites indicate they were alive before the red tide event. Also, several large Florida spiny lobsters were observed at both South Pinellas sites in September and October of 2007 although they were not recorded in the motile invertebrate survey because they are cryptic and usually reside under ledges during the day,

Phytoplankton Community Dynamics and Brevetoxin Concentrations

No temporal trends in phytoplankton communities were observed. The only notable spatial trend is that Dinoflagellates were generally most abundant off of Tarpon Springs. Areas north of Tampa and Sarasota Bays are more oligotrophic and less impacted by estuarine outputs and coastal run off. In nutrient-limited conditions, dinoflagellates can out-compete diatoms (the other major phytoplankton group in the eastern Gulf of Mexico) for nutrients (Strom and Strom 1996). These water quality conditions are probably also responsible for the higher number and diversity of invertebrates recorded at Tarpon Springs than at other locations. Plankton dinocysts were present in every sediment sample collected; however, no correlations between dinocysts and plankton community structure are evident.

During the monitoring project, a minor red-tide event occurred in October of 2007. This event was not observed in phytoplankton counts and did not appear to cause any perturbations to benthic communities. One water sample had higher than background levels of *K. brevis*. This water sample was from site SS2 in December of 2007 and may have resulted from a minor unreported bloom or high concentrations of *K. brevis* remaining from minor red tide events earlier in the fall of 2007. Overall, brevetoxins were only present at background levels in both seawater and sediments for the vast majority of samples analyzed for this project. While brevetoxins can be present at very high levels during blooms and can accumulate in sediments, the persistence of brevetoxin at high levels in seawater and sediments after blooms is short-lived. The highest brevetoxin concentrations were found in water samples collected in October 2006 from IR2, before benthic monitoring commenced. Associated *K. brevis* counts indicate that a moderate red tide event was occurring during this time, which is consistent with the concentrations of brevetoxins measured. The consistent detection of brevetoxins at low levels in sediment samples from sites off of Sarasota County reflects the higher frequency of blooms in those areas and a more consistent presence of *K. brevis* at background levels.

During one sampling event at IR2 in October to December of 2007, higher than background levels of brevetoxin were detected. Although not reflected in the cell concentrations from these discrete samples, a bloom was present in SW Florida in October of 2007 and the brevetoxin measured was likely the lingering signature of higher cell densities at that site in the recent past.

Conclusions

Definitive comments on the recovery of benthic communities off of Pinellas and Sarasota Counties, Florida cannot be made because of a lack of recent baseline data and the 1.5 year gap between the end of the red tide mortality event and the initiation of benthic monitoring. However, trends in benthic substrate coverage and abundance and diversity of a number of important algae and invertebrate groups (although not consistent among all sites), generally reflect the patterns of benthic habitat recovery described by Smith (1975). That work still represents the only other documented benthic mortality event for the mid-eastern Gulf of Mexico. Recovery appears to be nearly complete for algal communities, but may still be in progress for many invertebrate species.

This ecological assessment of the benthic resources off of Pinellas and Sarasota Counties is important as a baseline for future reference although definite conclusions about recovery from the benthic mortality event cannot be drawn. Further, more quantitative studies should be conducted in the mid-eastern Gulf of Mexico to provide a more robust baseline for comparison following future mass mortality events.

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Appendix A

<u>Species lists</u>

Species lists presented for macroalgae, corals, and sponges. Macroalgae is presented by major division. For macroalgae and sponges, many species (including several common species), were listed as unknown because of the difficulty in field identification. The genera and species listed are those that were recorded. "Rare" indicates that the species was only found during a few surveys, whereas "common" indicates that the organism was consistently present.

Chlorophyta	
Acetabularia sp.	rare
Caulerpa mexicana	rare
C. prolifera	common
C. racemosa	common
C. sertularioides	common
Codium sp.	common
Halimeda discoides	common
H. goreaui	common
Penicillus sp.	common
Rhipocephalus phoenix	common
Udotea sp.	common
Ulva sp.	rare
Valonia sp.	rare
Ventricaria sp.	rare

Cyanophyta	
Schizothrix sp.	common

Phaeophyta	
Dictyota sp.	common
Padina sp.	rare
Sargassum sp.	common
Stypopodium sp.	rare

Rhodophyta	
Botryocladia sp.	common
Chondria sp.	common
Gracilaria sp.	common
Halymenia sp.	common
Jania sp.	common

Stony Corals	
Cladocora arbuscula	common
Colpophyllia natans	rare
Isophyllia sinuosa	rare
Manicina areolata	rare
Occulina diffusa	rare
Occulina robusta	common
Phyllangia americana	common
Porites sp.	rare
Siderastrea radians	common
Siderastrea siderea	common
Solenastrea bournoni	common
Solenastrea hyades	common
Stephanocoenia michellini	common

Sponges	
Agelas sp.	rare
Aplysina sp.	common
Chondrilla sp.	rare
Cinachyra sp.	common
Cliona delitrix	rare
Microciona prolifera	rare
Spheciospongiae vesparium	rare
Spongiae sp.	common
Tedania ignis	rare

Species list presented for octocorals. For octocorals several individuals were listed as unknown because of the difficulty in field identification. The majority of octocorals counted were in one of the 4 common genera below. The table also lists sites where these genera of octocorals occurred. "Rare" indicates that the species was only found during a few surveys, whereas "common" indicates that the organism was consistently present.

Octocorals		**Sites Located**
Eunicia sp.	rare	TS1
Leptogorgia sp.	common	TS1, SC2, SC3, SS1, SS2
Muricea sp.	common	TS1, SC2, SC3, SS1, SS2, SS3
Plexaurella sp.	common	TS1, SN2, SN3, SC2, SC3, SS1, SS2, SS3
Pterogorgia sp.	common	TS1, TS3

List of motile invertebrate species identified to the lowest taxonomic level.

Common Name	Species Name	Common Name	Species Name
Apple murex	*Phyllonotus pomum*	Rock Boring Urchin	*Echinometra lucunter*
Atlantic Wing Oyster	*Pteria colymbus*	Scallop	*Argopectin irradians*
Blue-eyed Hermit Crab	*Paguristes sericeus*	Sea Cucumber	*Istichopus badinotus*
Cerith snail	*Cerithium atratum*	Seastar (black/orange)	*Echinaster sentus*
Clam	*Chione elevata*	Spaghetti worm	*Eupolymnia crassicornis*
Clinging Reef Crab	*Mithraculus forceps*	Star Snail	*Lithopoma americanum*
Cone Snail	*Conus sp.*	Stone crab	*Menippe mercenaria*
Feather Duster Worm	*Bispira sp.*	Thorny Oyster	*Spondylus americanus*
Fighting Conch	*Strombus alatus*	Variegated Urchin	*Lytechinus variegatus*
Florida Cerith Snail	*Cerithium floridanum*	Yellowline Arrow Crab	*Stenorhynchus seticornis*
Gorilla Crab	*Pilumnus sayi*		
Hermit Crab	*Pagurus sp.*	Large Hermit Crab	FAMILY: Diogenidae
Horse Conch	*Pleuroploca gigantea*	Right Clawed Hermit Crab	FAMILY: Diogenidae
Mantis Shrimp	*Squilla empusa*	Snail	FAMILY: Buccinidae
Medusa worm	*Loimia medusa*		
Murex Snail	*Chicoreus brevifrons*	Anemone	ORDER: Actinaria
Pale Anemone	*Aiptasia sp.*	Tube Dwelling Anemone	ORDER: Ceriantharia
Pen Shell	*Atrina rigida*	Tube Worm	ORDER: Sabellida
Porcelin Crab	*Porcellana sp.*		

List of all phytoplankton species identified in water samples collected over the duration of the study. Species are also marked as a known or suspected harmful algal bloom (HAB) species.

Name	Known HAB Species	Potential HAB Species
Blue-Green Algae		
Johannebaptista pellicuda		
Trichodesmium erythraeum	x	
Diatom		
Asteromphalus hookeri		
Bacteriastrum sp.		
Chaetoceros affinis		
Chaetoceros criophilus		
Chaetoceros pendulus		
Chaetoceros spp.		x
Climacodium frauenfeldianum		
Corethron hystrix		
Coscinodiscus sp.		
Dactyliosolen fragilissimus		
Ditylum brightwellii		
Eucampia sp.		
Eucampia zodiacus		
Guinardia flaccida		
Guinardia striata		
Hemiaulus hauckii		
Hemiaulus sinensis		
Hemiaulus sp.		
Leptocylindrus danicus		
Leptocylindrus minimus	x	
Leptocylindrus sp.		
Nitzschia closterium		
Nitzschia longissima		
Nitzschia sp.		
Paralia sulcata		
Pleurosigma sp.		
Proboscia alata		
Pseudo-nitzschia spp.		x
Rhizosolenia calcar-avis		
Rhizosolenia imbricata		
Rhizosolenia robusta		
Rhizosolenia setigera		
Rhizosolenia spp.		x

Rhizosolenia stolterfothii		
Skeletonema costatum		
Thalassionema bacillare		
Thalassionema nitzschioides		
Thalassiosira delictula		
Thalassiothrix mediterranea		
Dinoflagellate		
Akashiwo sanguinea	x	
Alexandrium sp.		x
Amphidinium operculatum	x	
Ceratium furca		
Ceratium fusus		
Ceratium hircus		
Ceratium lineatum		
Ceratium trichoceros		
Cochlodinium polykrikoides	x	
Dinophysis caudata	x	
Diplopsaloid sp.		
Erythropsidinium sp.		
Goniodoma sphaericum		
Gonyaulax polygramma	x	
Gonyaulax sp.		x
Gymnodinium aureolum	x	
Gymnodinium sp.		x
Gymnodinoid sp.		
Gyrodinium falcatum		
Gyrodinium instriatum		
Gyrodinium spirale	x	
Gyrodinium spp.		x
Heterocapsa niei		
Heterocapsa sp.		
Karenia brevis	x	
Karenia cf longicanalis		
Karenia cf umbella		
Karenia mikimotoi	x	
Karenia papilionacea	x	
Karenia selliformis	x	
Karenia sp.		x
Karlodinium micrum	x	
Katodinium glaucum		
Katodinium rotundatum		
Katodinium sp.		
Phalacroma rotundatum		
Polykrikos schwartzii		
Prorocentrum compressum		

Prorocentrum gracile		
Prorocentrum mexicanum		
Prorocentrum minimum	x	
Prorocentrum scutellum		
Prorocentrum sp.		x
Protoperidinium divergens		
Protoperidinium leonis		
Protoperidinium spp.		
Scrippsiella sp.		
Takayama helix		x
Takayama sp.		x
Warnowia sp.		
Flagellate		
Calyptrosphaera sp		
Cryptomonas sp.		
Dictyocha fibula		
Ebria tripartita		
Euglena sp.		
Eutreptia lanowii		
Hermesinium adriaticum		
Pontosphaera sp.		
Pyramimonas sp.		
Rhabdosphaera hispida		
Syracosphaera sp.		

GULF OF MEXICO FISHERY MANAGEMENT COUNCIL

2006-CORAL COOPERATIVE AGREEMENT NO. NA06NMF4410082
as of
August-08
(Dollars in Thousands)

FINAL

ACCOUNT	OBLIGATIONS INCURRED	CY 2006-Coral	BALANCE REMAINING $	%
			Normal:	0.00%
Personnel Compensation:				
Council Members	0.0	0.0	0.0	0.0%
Staff - Permanents	21.4	21.4	0.0	0.0%
Temporaries	0.0		0.0	0.0%
Premium Pay	0.0	0.0	0.0	0.0%
	21.4	21.4	0.0	0.0%
	21.4	21.4	0.0	0.0%
Benefits - Council's Share:				
FICA/Medicare	1.6	1.6	0.0	0.0%
Health Insurance	2.8	2.8	0.0	0.0%
Life Insurance/Disability	0.1	0.1	0.0	0.0%
Retirement	2.2	2.2	0.0	0.0%
	6.7	6.7	0.0	0.0%
Travel:				
Council Members	0.0	0.0	0.0	
Staff	0.0	0.0	0.0	0.0%
Advisory Panels	0.0	0.0	0.0	0.0%
S&S Committees	0.0	0.0	0.0	0.0%
Other	0.0	0.0	0.0	0.0%
	0.0	0.0	0.0	0.0%
Rents:				
Office Space	0.0	0.0	0.0	0.0%
Office Equipment	0.0	0.0	0.0	0.0%
Meeting Rooms	0.0	0.0	0.0	0.0%
	0.0	0.0	0.0	0.0%
Other Expenses:				
Communications-Phone	0.0	0.0	0.0	0.0%
Communications-Other	0.0	0.0	0.0	0.0%
Transportation & Shipping	0.0	0.0	0.0	0.0%
Printing	0.2	0.0	-0.2	0.0%
Contractual Services	143.6	143.6	0.0	0.0%
Supplies	0.6	0.8	0.2	0.0%
Capital Equipment	0.0	0.0	0.0	0.0%
Non-Capital Equipment	0.0	0.0	0.0	0.0%
	144.4	144.4	0.0	0.0%
TOTAL ADMINISTRATIVE GRANT	172.5	172.5	0.0	0.0%