CLAM BAY NATURAL RESOURCE PROTECTION AREA (NRPA)
BENTHIC HABITAT ASSESSMENT

FINAL REPORT FOR THE CONTRACT AGREEMENT
Between
PELICAN BAY PROPERTY OWNERS ASSOCIATION (PBPOA), PELICAN BAY FOUNDATION, INC. (PBF), and the MANGROVE ACTION GROUP (MAG)
And the
CONSERVANCY OF SOUTHWEST FLORIDA (CSWF)

Prepared by:
Kathy Worley and Jeffrey R. Schmid

Environmental Science Division, Conservancy of Southwest Florida,
1450 Merrihue Drive, Naples, FL 34102
E-mail: kathyw@conservancy.org & jeffs@conservancy.org
Tel: 239-403-4223

May 2011

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

Mangrove and seagrass habitats provide different resources for a diverse community of benthic organisms that live in mangrove mud, seagrass, and/or bottom substrates. These communities are a vital component of the estuarine food web, providing key linkages between primary producers and higher trophic levels. Some are important economically, while others improve water quality by filtering the water or mediating nutrient remineralization within the sediment.

Clam Bay Natural Resource Protection Area (NRPA) is located on the shoreline of southwest Florida and consists of approximately 2,428,200 m^2 (243 ha) of bay and mangrove preserve. The objectives of the current study were to perform comprehensive mapping of benthic habitat distributions in Clam Bay; analyze benthic habitat compositions relative to the geographic location; and to perform a visual survey of any benthic species utilizing mangrove prop roots. Systematic benthic sampling was used to characterize sediments and biological assemblages and their distribution within the Clam Bay system.

Substrate is one of the most important abiotic factors influencing the spatial and temporal distribution of estuarine benthic communities. In the summer of 2010, 872 benthic sample sites within Clam Bay were investigated. Mud was the dominant substrate in the northern and southern portions of Clam Bay. This is consistent with other estuarine areas as mangroves tend to facilitate the deposition of fine sediments leading to high rates of accumulation of organic muddy material in the back bays of an estuary. A geographic gradient of sediment types existed within Clam Bay. Areas farther from Clam Pass consisted primarily of mud substrates; while those areas closer to Clam Pass were primarily composed of sand and shell substrate; and muddy sand and sandy mud dominated the Upper Tributary and Inner Clam Bay.

Flora components of an estuary that are important to macro-benthic organisms include seagrasses such as shoal grass, *Halodule beaudettei* (also known as *Halodule wrightii*), paddle grass, *Halophila decipiens*, and turtle grass (*Thalassia testudinum*), green macroalgae (Chlorophyta, such as *Caulerpa* spp.), and red macroalgae (Rhodophyta sps.). Green macroalgae, mainly filamentous species, were distributed throughout the Bays and red macroalgae were only found in Lower Clam Bay. Seagrass species were found primarily on muddy sand and sand substrates only in Lower Clam Bay. Shoal grass was the most prevalent species found during this survey. Previous seagrass studies suggest that the spatial distribution seagrasses in Clam Bay has persisted over the last 30 years, albeit seagrass species and extent of coverage have changed throughout the years. Seagrass coverage in all likelihood declined in Clam Bay between 1990 and 1996. Causes for this decline are speculative and could include physical environmental changes such as increased turbidity, salinity extremes and/or biological factors such as eutrophication during 1995-1996, when the Pass was closed for an extended period of time. Alternatively, the decline could be the result of a gradual increase in muddy, fine-grained sediments that do not favor seagrass establishment. Shoal grass has been the most prevalent, both spatially and temporally, and this species tolerance to environmental variability may explain its persistence in Lower Clam Bay.

Polychaetes create habitat and food for many organisms such as mulluscs, fish and even sea turtles. These worms are usually filter or deposit feeders that keep the substrate aerated and free of waste accumulation. Tubiculous polychaetes were primarily associated with muddy and sandy substrates and were the most abundant biological assemblage in Clam Bay. Polychaetes dominated Inner and Lower Clam Bays, but had substantially lower occurrence in Upper Clam Bay, the Lower Tributary, and, to a lesser extent, the Upper Tributary.

The distribution of oyster reefs has decreased within the Clam Bay system, more than likely a result of dredging or clearing activities. Bivalves, primarily shells of stout razor clam (*Tagelus plebeius),* and American oyster (*Crassostrea virginica),* were more commonly collected than gastropods such as Grass ceriths (*Bittiolu varium*). These gastropods seemed to have a preference for sandy substrate, which could explain there presence primarily in the upper reaches of Lower Clam Bay. Echinoderms including heart urchins (*Moira atropos*) and brittlestars (*Ophiophragmus filograneus* were primarily found in Lower Clam Bay in muddy substrates.

A total of 151 prop root sites were perused detailing biological assemblages including mussels (*Mytildae),* barnacles, American oysters, mangrove periwinkle (*Littoraria angulifera*), green filamentous algae, red algae, mangrove crabs, and Florida crown conch (*Melongena corona*). A visual survey of the prop roots throughout the system, revealed an abundance of algae and epiphytic vegetation on the submerged surface area of mature prop roots.

Estuaries are threatened by anthropogenic disturbance and pollution. So far, Clam Bay has proved to be somewhat resilient over the years, although indications of stress such as seagrass decline and mangrove die-backs are evident. The question that arises is whether or not impacts of anthropogenic disturbance (possibly in combination with natural stressors) could impact the estuary to the point where the original community structure is unable to rebound. To this end, estuarine management becomes increasingly important and must balance multiple ecological and anthropogenic objectives. Unfortunately, this usually results in tradeoffs, since management policies tend to benefit one aspect of the biological community, while adversely affecting another. Therefore, it is important to understand to the best of our ability what impacts our management has on all the different estuarine communities and whether or not benefits of initiating management strategies outweigh the detriments.

INTRODUCTION

Mangrove forests and seagrass beds are components of estuarine systems, situated in intertidal areas that are often in direct contact with the ocean (USFWS, 1999). These two communities are major sources of primary production in South Florida's coastal ecosystems, providing valuable nutrient input to both intertidal, inshore and offshore estuarine and marine ecosystems (Boer, 2000). When seagrass and mangrove communities are situated adjacent to each other, they compliment each other and provide richer resources for aquatic organisms (Koch and Madden, 2001). Protection of remaining mangrove forests and seagrass beds and restoration of areas where they have been destroyed are vital to the environmental and economic future of Florida. Both communities support local food chains, provide nurseries for commercial and recreational fisheries, provide habitat and shelter for a variety of organisms, and provide an indicator of overall estuarine health (Johannsson and Greening, 2000).

Estuaries are ranked as one of the most biologically productive ecosystems in the world. Yet, since estuaries are naturally stressed habitats where extreme and variable physiochemical conditions (such as fluctuating temperatures, changing salinity regimes, and variable sediment dynamics) are the norm, relatively few organisms have successfully colonized estuaries in comparison to other habitats (Heilmayer, et al., 2008; Marsden and Maclaren, 2010). Estuaries consist of different macro and micro habitats that occur in intertidal areas, narrow tributaries, bays, mudflats, mangroves, seagrass and organic detritus. Generally, estuaries are comprised of soft sediments, which are complex habitats that have variable physical components, such as different sized mineral grains, biological components, including microbes, fauna and flora, and varying chemical properties. Sediments vary in time and space and benthic species distributions often are governed by this environment. Their distribution may change in accordance with their changing habitat and other factors such as food availability and inundation patterns (Chapman and Tolhurst, 2007). Benthic species are expected to be tolerant of these environmental extremes (Marsden and Maclaren, 2010). Mangrove forests contain different habitats, with diverse macrobenthic fauna living on or in the sediment. This habitat differs structurally in the varying configurations of prop roots, pneumatophores, algae and leaf litter, all of which can affect the diversity of benthic inhabitants (Chapman and Tolhurst, 2007).

Benthic invertebrates are a vital component of the estuarine food web, providing key linkages between primary producers and higher trophic levels. Some are important economically; others improve water quality by filtering the water or mediating nutrient remineralization within the sediment. Some benthic invertebrates promote nutrient recycling or aerate the sediment, thereby modifying the actual structure of the sediment, which in turn influences geochemical processes within their habitat. Benthic species are even important in distributing food resources (Nordhaus, et al., 2009).

Mangrove and seagrass habitats are important substrates for a diverse community of benthic organisms. These two habitats provide different resources that can be exploited by different groups of benthic fauna (Alfaro, 2006). Benthic communities consist of a plethora of faunal and floral organisms that live in mangrove mud, seagrass, and/or bottom sediments or depend on the mangroves to complete some aspect of their lifecycle. Faunal taxa encompass a variety of phyla including sessile (non-motile) invertebrates such as Mollusca (bivalves such as oysters and clams), Porifera (sponges), Chordata (tunicates) along with non-sessile (motile) organisms that are associated with the benthic community including members of the phyla Arthropoda such as crabs, lobsters, prawns, etc. (Ellison, 2008). Flora components of an estuary that are important to the macro-benthic organisms include seagrasses such as shoal grass, *Halodule beaudettei* (also known as *Halodule wrightii*), paddle grass, *Halophila decipiens,* and turtle grass (*Thalassia testudinum*), green macroalgae (Chlorophyta, such as *Caulerpa* spp.), red macroalgae (Rhodophyta sps.), and mangrove prop roots and detritus.

Seagrasses are recognized as a keystone species in the estuarine environment and are useful bioindicators given their response to changes in water quality (Livingston, et al., 1998; Fourqurean, et al., 2003; Dawes, et al., 2004; and Lirman, et al., 2008). Variation in the distribution of seagrass has been correlated with a number of factors, including salinity (Phillips, 1960; Durako, 1995; Doering and Chamberlain, 2000; Irlandi, et al., 2002; Hackney and Durako, 2004), temperature (Durako, 1995; Hackney and Durako, 2004), light intensity (Phillips, 1960; Phillips and Lewis, 1983; Lee and Dunton, 1997; Carlson, et al., 2003), nutrient availability (Powell, et al., 1989; Lee and Dunton, 2000), reproduction (Durako and Moffler, 1985), and epiphyte load (Tomasko and Lapointe, 1991).

Mangroves provide one of the key building blocks for a healthy estuary and serve as hosts for macroalgal assemblages that reside on aerial roots, stems, and trunks (Melville and Pulkownik, 2006). Mangrove roots stabilize the substrate and provide structure on which many species reside such as epiphytes (including tunicates, sponges, algae, and bivalves). The mangrove litter breaks down into detritus, forming the basis of detrital-based food webs that include plankton, epiphytic algae and microphytobenthos. Factors that influence benthic distribution residing or utilizing mangrove roots include physical factors such as current intensity, tidal extremes, shade, salinity and temperature, sediment characteristics, food and nutrient availability, age of the roots, and biological factors such as competition and predation (Chen, et al., 2007).

Habitat mapping via remote sensing has been identified as the basis for management and protection of resources in various estuaries and submerged aquatic vegetation (SAV), mudflats, live bottom, and oyster bars have been identified for protection and restoration in many estuarine management plans. However, the resolution of aerial photography often does not allow for differentiation among species of seagrasses (Robbins, 1997; Greenawalt-Boswell, et al., 2006) and thus other methods of habitat mapping are preferable in areas with low visibility. Species-specific distributions of benthic vegetation are commonly used as indicators of estuarine conditions in coastal waters of Florida (Tabb, et al., 1962; Iverson and Bittaker, 1986; Zieman, et al., 1989; Montague and Ley, 1993; Livingston, et al., 1998; Fourqurean, et al., 2003; Hale, et al., 2004; Greenawalt-Boswell, et al., 2006; Lirman, et al., 2008) and this information is needed to adequately manage and protect aquatic habitat in the Clam Bay estuary. However some methods of habitat mapping do not provide sufficient information on the associated benthic communities or the aquatic fauna that they may support. The unvegetated bottom substrate that supports colonies of sessile invertebrates such as tube worms, tunicates, and sponges (i.e., live bottom) has been identified as essential foraging habitat for mulluscs, fish and even sea turtles, however, there are no current datasets on their distribution or use of habitat within Clam Bay, both of which are obligatory for improving the existing management strategies for this estuary. Only a few reports are available that mention the benthic community within Clam Bay, most of which are focused on seagrasses. These reports include:

1. Humm, H.J. and Rehm, A.E. 1972. Ecological Appraisal an Ecological Study of the Clam Pass Complex. Study for the Collier Company at Clam Pass Properties. Tri-County Engineering, Inc. TCE Project No. 1516.
2. Devlin, D. J., Gore, R.H., and Proffitt, C.E. 1987. Natural Resources of Collier County. Preliminary Analysis of Seagrass and Benthic Infauna in Johnson and Clam Bays, Collier County Natural Resources Dept. CM 169. Technical Report No. 87-2.
3. Grabe, S. 1975. Field studies Parkshore and Clam Bay systems Naples Florida November 1975 Region IV U.S. EPA Surveillance and Analysis Division Athens, GA.

4. Ogilby, R.R. 1972. Investigation of the Bottom Sediments in the Clam Bay System. Prepared for the Collier Company at Clam Pass Properties. Tri-County Engineers Inc. pp.22.
5. Collier County Environmental Services Division, Natural Resources Department. 1991. Collier County Seagrass Protection Plan. Technical Report No. 91-01.
5. Turrell & Associates, Inc. 1995. Clam Pass Inlet Management Plan, Interim Report NO. 1. pp 4:1 - 7:1.
6. Turrell, Hall & Associates, Inc (THA) 1999-2009 Clam Bay Restoration and Management. Biological Monitoring Annual Reports
7. PBS&J. 2008. Clam Bay Seagrass Assessment. Prepared for: Collier County Coastal Zone Management Department. PBS&J. Tampa, Florida. pp 7.
8. PBS&J, 2009. Clam Bay System Data Collection & Analysis. Prepared for: Collier County Coastal Zone Management Department. PBS&J. Tampa, Florida. pp 75.

The objectives of the current study were (1) to perform comprehensive mapping of macro benthic habitat distributions in Clam Bay, (2) to analyze macro benthic habitat compositions relative to the geographic attributes of the Clam Bay estuarine system (inclusive of Lower Clam Bay, Clam Pass, Inner Clam Bay, Upper Clam Bay, connecting tributaries and mangrove fringe), (3) to perform a visual survey of any benthic species utilizing mangrove prop roots. This study is limited to benthic macrofauna and does not include any meio or micro fauna that exist in the benthos.

STUDY AREA: Historical Review

Clam Bay Natural Resource Protection Area (NRPA) is located on the shoreline of southwest Florida and consists of approximately 2,428,200 m^2 (243 ha) of bay and mangrove preserve (Figure 1). It is one of the few estuarine systems remaining in the Cocohatchee-Gordon River Drainage System, federally designated as an undeveloped coastal barrier system (Burch, 1990). Historically, Clam Bay was tidally connected to the Gulf of Mexico via Wiggins Pass to the north, Doctor's Pass to the south and centrally located Clam Pass. The northern and southern ends of Clam Bay became isolated in the 1950's when roads were constructed. Today, the area consists of three bays, two of which are for all intensive purposes dead-end bays that connect to the Gulf at Clam Pass. The Clam Bay estuary is bound by the Gulf of Mexico to the west; Vanderbilt Beach Road to the north; Pelican Bay PUD to the east; and Seagate Drive to the south. The surrounding area includes the Vanderbilt Beach Coastal Unit and the developments of Vanderbilt Beach, Park Shore, Moorings, Seagate, Naples Cay and Pelican Bay (Benedict, 1984). The Clam Bay system extends to the Seagate development in the south, approximately 3/4 mile north of Seagate Drive, and Pelican Bay to the north and east. The Ritz-Carlton resort to Vanderbilt Beach road marks the northern boundary of the Clam Bay system. In these developed areas, the natural drainage systems have been altered extensively by the construction of roads, residences, and commercial developments (Burch, 1990). The land use changes and effects on the quantity and quality of freshwater in the watershed have had subsequent impacts to the estuarine habitats within Clam Bay. Today, a series of inter-connected extremely shallow lagoons are all that remain of a coastal mangrove system that once extended from Lee County to Doctors Pass. The basin-like bays include Lower, Inner and Upper Clam Bays. These bays are relatively viable, although evidence of slow deterioration in the mangroves around Inner Clam Bay has been documented for over forty years (Worley, 1995; Benedict, 1984). Clam Pass opens into Lower Clam Bay to the south and Inner and Upper Clam Bays to the north. These irregularly shaped shallow bays are connected by narrow creeks and surrounded by approximately 500 acres of estuarine plant communities (Burch, 1990). Lower Clam Bay is connected to Inner Clam Bay to the north through a meandering tributary, hereafter referred to as the Lower Tributary. Inner Clam Bay is also connected by a tributary (hereafter referred to as the Upper Tributary) to Upper Clam Bay to the north. The bays are separated from the Gulf of Mexico to the west by a narrow band of mangrove swamp, dune ridge and beach varying from 100 to 200 feet in width. This area represents the only remaining vegetative barrier resources between Clam Bay and DelNor Wiggins State Park.

CLAM PASS

Clam Pass is an unimproved inlet connected to the Gulf of Mexico and to a number of small lagoons and creeks that are aligned approximately parallel to the shoreline. Clam Pass connects the Gulf of Mexico to the Clam Bay system. At the entrance to Clam Pass, depths vary from one to six feet with shoal areas which are less than 1 foot inland of the inlet. The location of the channel historically varied seasonally; turning south during the winter and north during the summer, occasionally closing entirely. The mouth has poor navigability and historically had widths of 30 to 50 feet (Burch, 1990). From 1969 to 1995 pass dimensions ranged in width from 50 to 140 feet with depths of two and a half to four feet. In November of 1994, width variations of 31 to 62 feet were measured in three cross sections with maximum depths of two to three and a half feet (Turrell and Associates Inc., 1995). Recent dredging in the past decade has established width variations from 30 to 80 ft and depths from -4 to -5.5 ft (Humiston and Moore, Engineers, 2007). Clam Pass serves a critical function by flushing a large portion of the back bay area which, in turn, maintains estuarine productivity by providing a source of saline water to the estuary. The inlet is bound on both sides by undeveloped beaches, Clam Pass Park to the south and Pelican Bay Beach (part of the Pelican Bay PUD) to the north. The Clam Pass system includes two miles of beach and dune ridge north to Vanderbilt Beach Road and 0.6 miles south to Seagate Drive (Burch, 1990).

LOWER CLAM BAY

Lower Clam Bay, sometimes referred to as Outer Clam Bay, is an estimated 72-acre lagoon connected to the Gulf by a small channel leading north, then west to Clam Pass. The channel is has a natural tendency to be constricted in places; thus at times restricting flow to the southern parts of the bay. Depths vary from less than one to four feet with an average depth of three feet. The north end of the bay and channel is sometimes exposed at low tide. This bay is strongly influenced by mixed tides (diurnal and semi-diurnal) and is usually turbid due to the suspension of fine sands in tidal currents. Salinities range from 15 to 35 parts per thousand. This bay has been reported to have the highest algal diversity of the back bay system, consisting mainly of epiphytic species found on the prop roots of red mangroves in the intertidal zone (Humm and Rehm, 1972). Sea beds, mainly shoal grass (*Halodule beaudettei* also known as *Halodule wrightii*) (Devlin, et al, 1987), were historically present along with eighty-four species of flora and fauna (Coral Ridge Collier Properties, 1979). Included are tunicates, horn and dove shells, pink shrimp, xanthid and portunid crabs, lizardfish, mullet, perch, file and pinfish, mojarra, goby and juvenile gray snapper (FDER, 1984).

Lower Clam Bay and its surrounding mangrove forest appear at a glance to be in a nearly natural state, although 14 acres were altered by illegal fill activity by a previous property owner in 1972 in the northern portion of the bay. A 2,900 foot long and 10 foot wide boardwalk and beach overlook facility were constructed through the mangroves over a narrow section of Lower Clam Bay in 1986. Stressors to this bay include the restriction of overland flow of fresh water by the Pelican Bay and Naples Cay developments and runoff from drainage canals within the Seagate subdivision (Devlin, et al., 1987).

INNER CLAM BAY

Inner Clam Bay is an estimated 32 acres in size and is connected to Lower Clam Bay by a narrow winding tributary with varying depths. This bay is approximately 6,600 feet long and between one and five deep. Historically, oyster bars in the channel restricted tidal flow to the upper reaches of this bay except during high tide. Today only remnants of these bars remain as these features were blasted apart to increase flow into and out of upper reaches of the bay system (1999 Clam Bay Restoration Plan). Depths in Inner Clam Bay range from two to five feet (estimated average of 3 ft). Historically, the substrate was referred to as muddy with no seagrass beds and the algal diversity was reported to be the highest in February and the lowest in September (Humm and Rehm, 1972). The eastern shoreline of Inner Clam Bay is a mixed mangrove forest dominated by white and red mangroves, while mature black mangroves dominate toward the western shoreline. This area grades into a dense black-rush marsh, eastward to sweet-bay hammocks and adjacent upland development. Northwest of this bay an intermittent pond forms during the rainy season and dries out during the winter. This area exhibits typical mixed-tide characteristics. In 1990, Burch reported that during periods of heavy precipitation, excess runoff water overrides tidal activity and the wetlands exhibit tidal fluctuations with spring tides.

UPPER CLAM BAY

Upper Clam Bay, the smallest of the three bays, is connected to Inner Clam Bay by the Upper Tributary**.** Average depth in the Upper Tributary ranges from approximately one to four feet and approximately two to four feet in Upper Clam Bay. Several small ponds are intermittently connected to this channel. Previous reports indicated that no oyster bars or seagrass beds existed and that fewer aquatic species were found in this bay (Ogilby, 1972). Upper Clam Bay is adjacent to a mature, but degenerating black mangrove forest to the west and north. West of the bay is a system of intermittent ponds fringed by red mangroves. In 1982 these ponds were connected by a series of man-made ditches in attempt to increase tidal flow. Subsequent studies indicated that fish populations increased in diversity, however tidal influence only extended to an area 150 feet from the pond margins (Worley and Gore, 1995). Further north, a fill area of 100 acres is located in an area of historic black mangrove wetlands. This fill area includes the Ritz-Carlton Hotel and Pelican Bay development. To the east of this bay is a mixed mangrove forest of red and white mangroves with a few interspersed black mangroves. In 1991, within six months of completion of the Strand Road in Bay Colony, 5.67 hectares of black mangroves died in the northwest corner of the mangrove forest adjacent to the road. In 1992 the die-off continued to expand and by 1995 (coincident with an unusually high rainfall season that summer), a massive die-off of black mangroves began adjacent to the original dieback, and soon extended southward along the western shore of Upper Clam Bay.

Residential development is present east of the mangrove forest and the northern terminus of Upper Clam Bay is almost completely surrounded by roads, walls and houses. This resulted in soil compaction during building that subsequently reduced natural interstitial water flow – a situation of altered natural hydrology. This situation was accompanied by a change in tidal flow and/or increased rainfall and runoff into the mangroves that resulted in an altered hydroperiod. Constant waterlogging resulted in extended periods of inundation, compromising gaseous storage and exchange in the root systems. Black mangrove pneumatophores were submerged for a prolonged period of time, causing stressed mangroves to figuratively ‘drown’ and this resulted in mass mortality. The die-off triggered belowground decay of the extensive root system of the deceased black mangroves, which intuitively lead to soil level subsidence and increased flooding during the wet season (Worley, 2006).

In 1999, the Pelican Bay residents and local government initiated a ten-year restoration project. Tidal flow was improved by dredging the main arteries and by channelization within the mangrove die-off area. In 2002, an extensive system of drainage ditches were installed throughout Clam Bay in attempt to prevent extended surface water retention periods during the wet season and lower standing surface water levels. This effort included clearing existing mosquito ditches and extending this channel network into the die-off areas. This had a visible effect on the local hydrology within the die-off by draining off floodwaters during the wet season. Restoration in the northern and upper mid sections of the Clam Bay die-off have shown evidence of revegetation (Worley 2006).

Landward of the mangroves, elevations rise sharply, supporting vegetative species such as leather fern (*Acrostichum aureum*), rubbervine (*Cryptostegia grandiflora*) and Brazilian pepper (*Schinus terebinthifolius*). This transition zone extends to the east and abuts an elevated man-made berm that separates Pelican Bay residential community from the estuary. To the south is a series of small ponds and fringing red mangrove trees. Standing water, which drains through seepage, evaporation and runoff, is often present. Significant tidal flushing is not apparent except during exceptionally high spring tides. For the remainder of the time, Upper Clam Bay exhibits mixed tide characteristics except during periods of high precipitation when excess runoff overrides tidal characteristics (Burch, 1990).

MATERIALS AND METHODS

Benthic Habitat Characterization

Aerial photographs (1999 Digital Ortho Quarter Quads) were used to delineate the shoreline boundary of Clam Bay and subsequently establish the benthic sampling grid. A study area polygon was created by digitizing the shoreline using ArcView (version 3.2, Environmental Systems Research Institute, Redlands, CA) geographic information system (GIS) software (Figure 1). The precision obtained by digitizing the shoreline from aerial images was greater than that available from other digital mapping files of the area. The Universal Transverse Mercator (UTM, zone 17N, WGS 84) coordinate system was used for the sampling grid. Using the methodology of Schmid (2000) and Schmid, et al. (2003), east-west transects were systematically placed over the study area polygon every 25 m and sampling sites were located at 25 m intervals along each transect. Sampling sites were uploaded to a handheld global positioning system with differential correction (DGPS; GPSMAP 76, Garmin Ltd., Olathe, KS) and sites were navigated in the field using the system's graphic display. Due to the sinuous and narrow nature of the Lower and Upper tributaries, sampling sites were established mid-tributary at 25 m intervals along the length of each tributary when the aforementioned grid pattern was not possible.

Sediment (Lambe and Whitman, 1969) and biotic characteristics (Continental Shelf Associates, Inc. and Martel Laboratories Inc., 1985; Wolfe, 1990) were used to characterize habitats within the study area. Taxonomic nomenclature was retrieved from the Integrated Taxonomic Information System on-line database (ITIS; http://www.itis.usda.gov); however, there was disagreement among researchers concerning the nomenclature/synonymy of seagrasses listed below (Michael Durako via Nathan Gavin, University of North Carolina Wilmington, *pers. comm.*).

Benthic substrates were classified as:

a) shell- mollusc shell fragments retained by a No. 4 sieve (4.76 mm).

b) sand- shell and rock particles passing through a No. 4 sieve and retained on a No. 200 sieve (0.074 mm).

c) mud- silt and clay particles passing through a No. 200 sieve.

Biological assemblages were classified as:

a) seagrasses- *Halodule beaudettei* (syn. *Halodule wrightii* - shoal grass), and *Halophila decipiens* (paddle grass)

b) green macroalgae- *Caulerpa sertularoides*, *Acetabularia crenulata*, and unidentified filamentous green algae.

c) red macroalgae- *Acanthophora spicifera* and unidentified red algae species.

d) echinoderms- *Moira atropos* (heart urchin) and *Ophiophragmus filograneus* (brittlestar).

e) mulluscs Bivalves such as living clusters and shell of *Crassostrea virginica* (oysters), *Anomalocardia amberiana* (pointed venus clam), and *Tagelus plebeius* (stout razor clam). Gastropods such as living and shell specimens of *Melongena corona* (Florida crown conch, *Strombus alatus* (Florida fighting conch) and *Bittiolum varium* (grass cerith)

f) worm tubes- sedentary marine polychaetes such as sand or shell-encrusted tubes, trumpet worm tubes, and unidentified worm and mud tubes.

Benthic samples were collected within 10 m of the sample site coordinates (GPS variance). A grab sampler was deployed at each sample site to collect a benthic sample for substrate characterization and floral/faunal classification. A wet-sieving method (adopted from ASTM, 1993) was used to sort benthic substrates in the field. Approximately 125 ml of wet sediment was rinsed through No. 4 and No. 200 sieves with seawater pumped through a 360 gph submersible bilge pump. Percent composition of shell, sand, and mud was estimated from visual inspection of the portions remaining in the sieves. A handheld depth sounder (Depthmate SM-5, Speedtech Instruments, Great Falls, VA) was used to record water depth (0.1 ft increments) at each sample site.

Seagrasses were given a qualitative abundance in the following order: observed (but not collected), isolated (few blades and/or shoots), sparse (low abundance), present (intermediate abundance), and dense (high abundance). Green filamentous algae were not identifiable to lower taxonomic levels in the field; however, examination suggests the assemblage was composed of *Chaetomorpha*, *Ulva* and/or *Rhizoclonium* species. Red algae were also difficult to identify in the field and the assemblage includes multiple species in genera such as *Gracilaria*, *Laurencia*, and *Hypnea*. Presence of oyster reef was determined by the occurrence of living oysters in the benthic sample or visual observation of reefs near the sampling site. Incidental sightings of benthic invertebrates were noted and the locations were recorded to the nearest sampling site.

Habitat data were entered into an Excel spreadsheet and the resulting habitat database was used to produce raster maps of the study area using the ArcView Spatial Analyst extension. Metadata for the GIS files were generated according to the Federal Geographic Data Committee (FGDC) *Content Standard for Digital Geospatial Metadata (CSDGM)* using ArcCatalog in the ArcGIS software package (version 9.3, Environmental Systems Research Institute, Redlands, CA). Primary substrate at each sample site was determined from the highest percentage of mud, sand, or shell, and secondary substrate as high proportion (30-40%) of sand in sites designated as mud (sandy mud) and high proportion of mud in sites designated as sand (muddy sand). The habitat maps consisted of 25X25 m grids of the benthic substrate with floral (seagrasses and algae) and faunal layers (oyster reefs, polychaete worm tubes, and other species). Biological assemblage layers were overlaid on the base maps to calculate percent composition of each component relative to substrate type. For purposes of discussion graphical depictions the study area was subdivided into 5 areas (Upper Clam Bay, the Upper Tributary between Inner and Upper Clam Bay; Inner Clam Bay, the Lower Tributary between Inner and Lower Clam Bay; and Lower Clam Bay including Clam Pass).

Mangrove Fringe Assessment

Mangrove prop roots were visually assessed at alternating sampling locations directly adjacent to the mangrove fringe along the perimeter of the bays and tributaries for presence of benthic organisms. Data were entered into an Excel spreadsheet and the resulting database was used to evaluate assemblage percentages.

RESULTS

Benthic Habitat Characterization

The digitized shoreline of Clam Bay produced a study area with four polygons (each bay and a small embayment on the Upper Tributary) and 2 linear features for the tributaries (Figure 1). A total of 929 sample sites were located in the study area; however, 57 sites were not sampled as they overlapped with shoreline features and were located within the mangrove fringe. Of the remaining total, 153 sites were sampled in Upper Clam Bay, 38 sites in the Upper Tributary, 216 sites in Inner Clam Bay, 42 sites in the Lower Tributary, and 423 sites in Lower Clam Bay and Clam Pass area (Figure 2).

Benthic Substrates

In Upper Clam Bay, 72.5% (*n* = 111) sampling sites were classified as mud, 25.5% (*n* = 39) as sand, and 2% (*n* = 3) as shell (Table 1; Fig. 3). Although mud was the dominant benthic substrate, 25.5% (*n* =39) of the mud sites had relatively high proportions of sand and 24.2% (*n* = 37) of the sand sites had relatively high proportions of mud (Table 1; Figs. 3 and 4). The Upper Tributary had a similar composition of primary benthic substrates; however, sandy mud (31.6%; *n* = 12) followed by muddy sand (28.9%; *n* = 11) were dominant when considering secondary substrates.

For Inner Clam Bay, 66.7% (*n* = 144) of the sample sites were classified as mud, 32.9% (*n* = 71) as sand, and 0.5% (*n* = 1) as shell (Table 1; Fig. 3). Although mud was the dominant primary substrate, 48.1% (*n* =104) of the mud sites had relatively high proportions of sand and 32.4% (*n* = 70) of the sand samples had a relatively high proportions of mud, making these the dominant secondary substrates (Table 1; Fig. 4). Sand was the dominant benthic substrate in the Lower Tributary (47.6%), although the percentage of sites classified as shell (40.5%; *n* = 17) was substantially higher than the other portions of the Clam Bay complex (Table 1).

In Lower Clam Bay, 66.2% (*n* = 280) of the samples were classified as mud, 32.6% (*n* = 138) as sand, and 1.2% (*n* = 5) as shell (Table 1; Fig. 3). Mud was the dominant benthic substrate, particularly in the southern portion of Lower Clam Bay, and 13.7% (*n* = 58) of the mud sites had relatively high proportions of sand and 11.6% (*n* = 49) of the sand sites had relatively high proportions of mud (Table 1; Fig. 4).

High organic content, consisting largely of detritus and mangrove leaf litter, was found in the substrates of the Inner and Upper Bays, the Upper Tributary, and peripheral to the mangrove fringe of Lower Clam Bay (Fig. 5).

Seagrasses

Seagrass species were only found in Lower Clam Bay at 6.6% (*n* = 28) of the sampling sites in this portion of the system (Tables 2 and 3). Shoal grass (*Halodule beaudettei* syn. *Halodule wrightii*) was the principal component (96.4%; *n* = 27) of the seagrass assemblage. Shoal grass samples were given a qualitative abundance: isolated (few blades and/or shoots) at 7.4% of the sites**;** sparse (low abundance) at 3.7% of the sites**;** present (intermediate abundance) at 44.4% of the sites**;** dense (high abundance) at 37.0% of the sites; and observed but not sampled at 7.4% of the sites. Shoal grass was patchily distributed in the northern and southern areas of Lower Clam Bay (Fig. 6) and was primarily collected on muddy sand and sand substrate (Table 4). Paddle grass (*Halophila decipiens*) was collected at 1 site in the west-central portion of the bay (Fig. 6) on sandy mud substrate (Table 4). Seagrass coverage was estimated at 4.3 acres; however, this estimate should be viewed cautiously given the patchy distribution and variable abundance within the 25 X 25 m sampling grids.

Macroalgae

Green macroalgae were only collected from the bay portions of the Clam Bay complex and primarily from the Inner and Lower Bays (Table 2; Fig. 7). Unidentified filamentous forms comprised 92.7% of the green algae assemblage and occurred at 59.7% of the Inner Clam Bay sampling sites and 20.1% of the Lower Clam Bay sites (Table 3). Other green algae components include *Acetabularia crenulata*, which only occurred in Inner Clam Bay (5.1% of sampling sites), and *Caulerpa sertularoides*, which only occurred along the west-central edge of Lower Clam Bay (1.2% of sampling sites). Green algae were collected on sandy mud and muddy sand substrates in Inner Clam Bay and primarily mud, muddy sand, and sand substrates in Lower Clam Bay (Table 5). Red macroalgae were only found in Lower Clam Bay (Table 2; Fig. 8) and the assemblage was composed of unidentified species (2.8% of the Lower Clam Bay sites; Table 3) and *Acanthophora spicifera* (1.4% of the sites). Unidentified species of red algae were primarily collected on mud substrate and *Acanthophora spicifera* collected on sandy mud and sand substrate (Table 5).

Polychaetes

Tube-building, or tubiculous, polychaete worms were the dominant biological assemblage in the Clam Bay complex and were collected at 43.2% (*n* = 377) of the benthic sampling sites, primarily in the Inner and Lower Bays (Table 2; Figs. 9 and 10). Unidentified worm tubes were the principal component (83.8%, *n* = 316 sites) of the polychaete assemblage and were encountered more often in Inner Clam Bay and Lower Clam Bay (Table 3). Unidentified worm tubes were collected on muddy sand and sandy mud in the upper portions of the complex and sand and mud in the lower portions (Table 6). The other polychaete components were primarily collected in Lower Clam Bay (Table 2) at substantially fewer sampling sites (Table 3). Mud tubes were prevalent in the southern portion of Lower Clam Bay (Fig. 9) and were primarily collected in mud substrate (Table 6). Trumpet worm (*Pectinaria gouldi*) tubes were typically found in peripheral areas of the Bays (Fig. 10) and were collected on all substrates, but were more frequent in Lower Clam Bay (Table 6). Shell-encrusted tubes were distributed in the northern portion of Lower Clam Bay and to a lesser extent in the southern portion of the Lower Tributary. These tubes were primarily collected on sand, shell and sandy mud substrate.

Molluscs

Shells of stout razor clams, *Tagelus plebeius*, were the dominant component (47.7%; *n* = 104) of the mollusc assemblage, followed by shells of American oysters, *Crassostrea virginica* (38.1%; *n* = 83). Stout razor clam shells were typically found in Upper Clam Bay (Table 2; Fig. 11) at 53.6% of the sample sites (Table 3). These shells were collected on mud, sandy mud, muddy sand and sand substrates (Table 7). Oyster shell was found throughout the Clam Bay complex (Table 2; Fig. 11), but comprised a relatively high proportion of the sample sites in the Lower Tributary (64.3%; Table 3). With the exception of the aforementioned tributary, oyster shells were primarily collected on mud and sandy mud substrates (Table 7). A living oyster cluster was found in the northeastern portion of Upper Clam Bay and another in the central portion of the Lower Tributary, but the majority of living clusters were found in peripheral areas of Lower Clam Bay (Fig. 11). Living clusters were primarily collected with shell substrate, but were also collected with mud and muddy sand substrate in Lower Clam Bay (Table 7). Shells and living specimens of pointed venus clams *(Anomalocardia auberiana)* were primarily found in the central portion of Inner Clam Bay and the northern portion of Lower Clam Bay (Table 2; Fig. 11). Pointed venus clams were primarily collected on sandy mud substrate for the former bay and sand substrate for the latter (Table 7). Grass ceriths (*Bittiolu varium*) were only found in Lower Clam Bay at 6.1% (*n* = 26) of the sampling sites (Tables 2 and 3). These gastropods were primarily located in the northern and, to a lesser degree, west-central positions of this Bay (Fig.

12) and were primarily collected on sandy substrate (Table 8). Shells of Florida crown conch (*Melongena corona*) shells were only found in Inner Clam Bay (Table 2). A living specimen was also found in Inner Clam Bay, but the majority of living Florida crown conch were found in Lower Clam Bay. Shells were distributed on the periphery of Inner Clam Bay (Fig. 12) and collected on sandy mud and mud substrate (Table 8). Live conchs were distributed in the northern sections of the Inner and Lower Bays and collected on sandy mud substrate for the former and primarily sand substrate for the latter.

Echinoderms

Heart urchins (*Moira atropos*) were only found in Lower Clam Bay at 2.4% (n = 10) of the sampling sites (Tables 2 and 3). These urchins were collected in the central region of Lower Clam Bay (Fig. 13) in mud and sandy mud substrate (Table 9). Brittlestars (*Ophiophragmus filograneus*) were predominately found in Lower Clam Bay, comprising 1.9% (n = 8) of the sampling sites (Tables 2 and 3). Brittlestars were primarily collected on mud substrate (Table 9).

Benthic Biota Associated with Red Mangrove Prop Roots

Benthic macro flora and fauna were characterized on red mangrove prop roots at random sites along perimeter of the Bays and along the edge of the tributaries. A total of 151 prop root sites were perused, of this in Upper Clam Bay and the Upper Tributary a total of 50 sites were sampled (n = 32 and n = 18 respectively), 49 sites in Inner Clam Bay and the Lower Tributary (n = 28 and n = 21 respectively) and 52 sites in Lower Clam Bay including the Clam Pass Area. Biological assemblages included mussels, barnacles, American oysters (*Crassostrea virginica*), mangrove periwinkle (*Littoraria angulifera*), green filamentous algae, red algae, mangrove crabs, and Florida crown conch (*Melongena corona*).

Unidentified mussel species were primarily found in Upper Clam Bay (91.4%) and to a lesser extent in the Upper Tributary (8.6%) (Table 10; Fig. 14). Unidentified barnacle shell was found in Upper and Inner Clam Bays, with Inner Clam Bay having the higher rate of occurrence. Live barnacle specimens were found throughout the Bays and Tributaries, with higher percentages found on prop roots in the Lower and Upper Bays (37.1% and 21% respectively) (Table 10; and Fig. 17). Oyster shell was distributed on prop roots throughout Clam Bay, with the exception of Upper Clam Bay, slightly higher in Inner Clam Bay (42.8%) than in the Lower Bay (28.6%) and the Lower and Upper Tributaries (14.3% each). Overall there was a higher rate of occurrence of living oysters on prop roots at the sites visited than oyster shells. Sixty and a half percent of living oysters were found on prop roots in Lower Clam Bay, 32.6% in the Lower Tributary, 4.7% in Inner Clam Bay and 2.2% in Lower Clam Bay (Table 10; Fig.14). Mangrove periwinkles were found on prop roots in Lower and Inner Clam Bays and the Lower Tributary. The highest percentage of periwinkles was found in the Lower Tributary (61.5%) and to a lesser extent in Lower Clam Bay (23.1%) and Inner Clam Bay (15.4%) respectively (Table 10; Fig. 15). Green filamentous algae were on prop roots through out the Clam Bay system, whereas, red algae were only found in Lower Clam Bay (n = 2). In Upper Clam Bay, 21.9% (n = 7) of the prop root sites contained green macroalgae within this Bay, 17.9% at the sites in Inner Clam Bay (n = 5), 14.3% in the Lower Tributary (n = 3), 9.6% in Lower Clam Bay (n = 5), and 5.6% (n = 1) in the Upper tributary (Table 10: Fig. 16). Mangrove crabs were found on prop roots in all of the sampling areas with the exception of the Upper Tributary. The highest percentage of mangrove crabs was found in Lower Clam Bay (37.5%) and to a lesser extent in Inner Clam Bay and the Lower Tributary (25.0% each), followed by Upper Clam Bay (12.5%) (Table 10). Two Florida Crown Conch were also found on prop roots in the Lower Tributary (Table 10). A visual survey of the prop roots throughout the system, revealed an abundance of algae and epiphytic vegetation on the submerged surface area of mature prop roots. Young or newly formed prop roots were largely devoid of these species.

Incidental Species Collected and Observed during Sampling

The following species listed below were collected or observed during benthic sampling or when the red mangrove prop roots were inventoried. These occurrences were isolated or extremely minimal. In Upper Clam Bay, mussels and barnacles; in the Upper Tributary, clam shell; in Inner Clam Bay, Atlantic bay scallop, mussels and duckweed; in the Lower Tributary, blue crab; and in Lower Clam Bay, sponge, portunid crab, blue-green algae, unidentified clam, glass eel, penaid shrimp, quahog and tunicate (Table 11 and Appendix 1).

DISCUSSION

Historic Benthic Comparison

Historically several studies investigated benthic species that occurred in the Clam Bay system, but no studies were found prior to the 1970's or predevelopment of the Pelican Bay PUD. In 1975, a field study of the Parkshore, Seagate and Lower Clam Bay was performed by Steven Grabe as part of an EPA surveillance study. This benthic community study documented species that occurred using a qualitative methodology that employed various collection devices and visual observations. Typical of canal systems, the sediment in the Parkshore and Seagate areas was found to be highly organic. Crustaceans and mulluscs were the major constituents in shallow areas and seawalls; and polychaetes were the most abundant in deeper areas (southern Lower Clam Bay). Finer sediments were assumed to be responsible for lower invertebrate diversity in areas of deep water. A minimal number of other invertebrate species were found in Lower Clam Bay near the Seagate canals including mulluscs such as ceriths (*Cerithidae*) and cockles; polychaetes; amphipods; a mudcrab (*Eurypanopeus depressus)*; and a marine decopod (Grabe, 1975).

The current CSWF study also found that polychaetes were the dominant species in Lower Clam Bay in the mud areas that Grabe referred to in his 1975 study. There were similarities between benthic macrofaunal documented in the current study and Grabe's study including the sampling of ceriths, cockles, polychaetes and mud crabs. Differences in faunal components between the Grebe study and this study could be due to differences in collection methods that targeted different benthic faunal species. Grebe used sediment cores which penetrated the substrate to a deeper level targeting mesofauna, which were not the focus of this study. Additionally, Grebe only investigated the muddy substrates in and near Seagate, whereas this study was focused on the entire Clam Bay system.

In 1987, Devlin, Gore and Proffitt performed a preliminary analysis of seagrass and benthic organisms in Johnson Bay, which they classified as "unstressed" and Clam Bay, which they classified as "stressed". Both bays contained monospecific shoal grass seagrass beds and the fauna residing in these beds exhibited high intrastation variability. Johnson Bay was dominated by tube worms and crustaceans, while Clam Bay was dominated by non-tubiculous fauna including mulluscs, oligochaetes, nematodes, and a cirratulid polychaete. They concluded that while many species were found in both Johnson and Clam Bay, the schism in dominant species was most likely due to causative factors that favored the colonization of one species over another. It was speculated that the differences in species composition between the two Bays could be due to differences in water volume or physical factors such as waves, currents or sedimentation that could affect larval recruitment; some natural biological activity like predation or competition; or an unnatural factor created as a result of anthropogenic development. The authors concluded that although Johnson and Clam Bays had similar sandflats and seagrasses, Johnson Bay, which lacked anthropogenic disturbance, contained more species and individuals than Clam Bay; and that the infaunal community that resided on the seagrasses in Clam Bay was not typical of other Florida estuaries. Polychaetes, including worm tubes, mud tubes and mulluscs, are the dominant assemblage in Clam Bay today. These species may be dominant in estuaries regardless of disturbance, since they also are the dominant assemblage in Estero Bay, which has extensive seagrass beds (Schmid, 2009).

In 1990, Collier County Natural Resources Department conducted helicopter surveys that were subsequently ground-truthed via transects. An estimated 60 acres or the majority of Lower Clam Bay was vegetated with seagrasses (Collier County Natural Resources Department, 1991). The dominant species was turtle grass in contrast to shoal grass, which was reported as the dominant seagrass feature by Devlin et al. in 1987. This shift in dominant seagrass species could indicate that the flushing rates increased allowing turtle grass to dominate, since this species prefers clearer water and higher salinity than shoal grass (Coastal Zone Management Plan, 1991).

From 1999 to 2008, Turrell, Hall and Associates, (THA) performed transect seagrass surveys in Lower Clam Bay. During this timeframe shoal grass dominated with sporadic occurrences of paddle and turtle grasses. Shoal grass was largely found in transects 6-9 (Figure 18), which were located on the north eastern side of Lower Clam Bay. Paddle grass was found in transects 1 and 2 located in southern Lower Clam Bay and turtle grass was found for the most part in transect 4, south of the bridge (Figure 18). THA reported that seagrasses had declined more than 80% in the period between 1994 and 1996. In 1999, prior to the 1999-2000 dredging of Clam Pass, parts of Lower Clam Bay and the associated tributaries (Cuts 1 – 4 in the Clam Bay Restoration Plan of 1999), seagrass appeared to have greater spatial extent than in years following dredging activities. Although there are signs that seagrass recovery could have occurred starting in 2006 and throughout the remainder of the years when THA conducted their assessments (THA, reports 1999 -2009). The current CSWF study also found shoal grass was the dominant seagrass in Lower Clam Bay in the summer of 2010.

In May of 2007, Post, Buckley, Schuh & Jernigan, Inc. (PBS&J) conducted a seagrass assessment that included historical review of past studies in addition to their own assessment. PBS&J surveyed 30 random sites within a suite of 100 potential sites in Lower Clam Bay and they found seagrass in 13 of the samples (rate of occurrence was reported as 43% of the samples). They found a “sprig” of turtle grass, in the southwestern portion of Clam Pass and paddle grass was found in Lower Clam Bay, which had an average Braun Blanquet score of 1.8 or bottom coverage of between 5 – 25%. PBS&J concluded that seagrass was not an uncommon feature in Clam Bay however, they questioned the validity of earlier reports that suggested that Lower Clam Bay had seagrass coverage of 60 acres (PBS&J, 2008). In the current CSWF study, seagrasses were found in 28 of the 423 samples in Lower Clam Bay (6.6%) the mean abundance was intermediate or in Braun Blanquet terminology between a mean of 25-50% coverage. PBS&J used a random survey method, whereas the current study used a systematic grid approach. The systematic sampling provided a comprehensive investigation of the entire bay, whereas random sampling may miss patchily or sparsely distributed benthic features.

In August of 2009, PBS&J conducted a stratified random survey using PVC sediment cores at 25 stations scattered throughout the Clam Bay system. According to their methodology, observations were made of the general biological community at each station in regard to the presence of mulluscs, seagrass and macroalgae (PBS&J, 2009). PBS&J reported that seagrass (paddle grass) was only rarely encountered (1 station) in Lower Clam Bay during the 2009 survey, a much lesser extent than PBS&J found in May of 2007 (albeit different methodologies). Macroalgae were found in Inner and Lower Clam Bay at 5 of their 25 stations throughout the system (20% of the sites). No mention of mulluscs was reported in their results (PBS&J, 2009).

The aforementioned studies suggest that the spatial distribution seagrasses in Clam Bay has remained relatively consistent over the last 30 years (Figures 19 and 20). Estimating acreage is difficult given that isolated and sparsely vegetated areas can yield underestimates or overestimates of coverage (as seagrass might not be sampled, but exist within a quadrant or conversely be sampled within a quadrant, but be the only existing sprig within that quadrant). Keeping in mind the limitations stated above, the current study yielded a conservative estimate of 4-5 acres of seagrass in Lower Clam Bay in 2010, while THA estimated a coverage of 5.13 acres in 2000 (THA, 2000). Seagrass coverage in all likelihood declined in Clam Bay between 1990 and 1995. Causes for this decline are speculative and could include physical environmental changes such as increased turbidity, salinity extremes and or biological factors such as eutrophication during 1995-1996, when the Pass was closed for an extended period of time, or a gradual decline as a result of possible increased mud and fine sediments in the Lower Clam Bay area. The major cause of seagrass decline worldwide is eutrophication (or nutrient enrichment), where seagrasses are replaced by faster growing species of macroalgae or phytoplankton (Burkholder, et al., 2007). Alternatively, siltation could have resulted in a gradual increase in muddy, fine-grained sediments that do not favor seagrass establishment. Mangrove estuaries are in a constant state of change as open water areas can silt in and over time be colonized by mangroves. Regardless of the probable cause(s), seagrass species and extent of coverage have changed throughout the years. Shoal grass has been the most prevalent, both spatially and temporally, and this species tolerance to environmental variability may explain its persistence in Lower Clam Bay.

Benthic Substrate Composition

Substrate is one of the most important abiotic factors influencing estuarine benthic communities (Drew and Schomer, 1984) and the distribution of substrate types is the result of physical sorting of particles and the prevailing hydrographic conditions (Yokel, 1979). Mud was the dominant substrate in the northern and southern portions of Clam Bay, similar to results found in the northern and middle portions of Naples Bay (Schmid, et al., 2006). Dredging likely resulted in the complete removal of benthic communities where the dredging occurred. In Clam Bay dredging was for the most part limited to the Clam Pass, Lower Clam Bay, (primarily for flushing purposes), and historically in the Seagate canals, whereas in Naples Bay dredging occurred at a much greater scale to create waterfront property and a navigational channel. The resulting change in bathymetry and substrate types makes recolonization by benthic communities difficult, if not impossible, particularly if dredging is an ongoing activity. Muddy sand and sandy mud (i.e., fine-grain sediment) dominated the Upper Tributary and Inner Clam Bay, similar to the northern portion of Estero Bay, as well as the extreme southern portion and the basin along the east-central shoreline. Unlike Estero Bay, Clam Bay does not experience riverine discharge, but rather primarily freshwater runoff and interstitial flow. Additionally, Clam Bay has reduced tidal flow and greater depths in the tributaries and Seagate canals that contribute to the deposition and retention of finer particles within the system. The lower region of the Clam Bay complex was comprised of coarser sandy substrates, similar to the lower regions of Naples Bay and most of Estero Bay. A gradient of sediment types was documented in Clam Bay, whereby areas farther from Clam Pass were dominated by mud substrate and those areas closer to Clam Pass were primarily comprised of sand and shell substrate. Areas situated near passes experience greater tidal flushing and wind/wave action that contribute to the resuspension of finer particles and retention of courser particles such as sand or shell. Mangroves tend to facilitate the deposition of fine sediments leading to high rates of accumulation of organic muddy material in the back bays of an estuary. As far back as the 1970's, (post Pelican Bay and Seagate development), the substrates of Inner and Upper Clam Bays were reported to consist of primarily muddy sediments, with the greatest amount of organic debris in Upper Clam Bay (Ogilby, 1972; Worley, 1995).

Benthic Habitat Characterization and Composition

As a regulator of salinity, freshwater inflow is probably the most important function in an estuary (Stickney, 1984). While many estuaries are plagued by reductions in freshwater inflow, Clam Bay receives a seasonal pattern of freshwater inflow, (particularly in the northern part of the estuary), albeit at different volumes and timing than nature intended due to anthropogenic changes to the natural hydrology. Given species-specific salinity tolerances, the species distribution of seagrasses in Lower Clam Bay was consistent with the freshwater inflow, rainfall variations and resulting salinity patterns. Shoal grass, the most broadly euryhaline (tolerant of a wide range of salinity) seagrass species, was the dominant species found primarily scattered along sandy shoals along the edges of Lower Clam Bay. Shoal grass dominance indicates that the Clam Pass and Lower Clam Bay are only marginally suited for seagrass development (Turrell and Associates Inc., 1995). Shoal grass is tolerant of changing environmental conditions and colonizes disturbed areas. It is often found in locations where other types of seagrasses cannot survive, such as areas of varying salinity and temperature or tidal exposure (Worley, 1995).

Paddle grass has been identified as being more stenohaline (tolerant of a narrow range of salinity) (Zieman, 1982); although some have suggested *Halophila* species may in fact be euryhaline (Phillips and Meñez, 1988; Zieman and Zieman, 1989). Paddle grass was found only at one site in the central southern part of Lower Clam Bay during this study, but was the dominant seagrass documented by PBS&J in Lower Clam Bay in 2007. Paddle grass may be more salinity tolerant than has been suggested or the drought conditions that prevailed in 2006/2007 allowed this more "ruderal" species (Hammerstrom, et al., 2006) to expand its distribution. Turtle grass has an intermediate tolerance to salinity variation (>20 ppt) and although it was not found during the current study, it has been previously documented in Lower Clam Bay (Collier County Natural Resources Department, 1991).

Hydrologic alterations in the watershed are likely to have affected the distribution of seagrass habitat in Clam Bay, but the conditions are not as extreme as some other estuaries in southwest Florida. Naples Bay receives excessive pulses of freshwater from inland canal and urban stormwater systems and only a few sparse beds of shoal grass were found in the extreme lower portions on the bay (Schmid, et al., 2006). The Seagate canal system likely conveys higher stormwater input during the wet season, but there is also exchange of Gulf waters through Clam Pass. This latter feature has no doubt allowed the seagrass communities to persist despite alterations within the watershed. Salinity is the commonly used proxy for freshwater inflow (Tolley, et al., 2005; Greenawalt-Boswell, et al., 2006) and variability in salinity appears to be the dominant factor affecting species composition in submerged aquatic vegetation communities (Montague and Ley, 1993; Fourqurean, et al., 2003).

In addition to salinity patterns, other water quality parameters such as nutrient loading and light attenuation from suspended solids and color content can affect seagrass distribution (Burkholder et al., 2007). Water quality assessments have been conducted within the Clam Bay watershed and despite differences in methodology, data sets, and basin boundaries, there was agreement that water quality is typically below the median value for Florida estuaries. This means that the overall pollutant load is typically less in Clam Bay than in other Florida estuaries. The southern and northern termini of the estuary and Seagate canals tend to have slightly higher nutrient concentrations, (although overall not at impairment levels), and water clarity within the system is governed by turbidity (Worley, 2005; PBS&J, 2008). Turbidity is likely the primary contributor to light attenuation in Clam Bay. High nutrient content can be a problem for seagrasses since excessive nutrient concentrations can result in epiphytic algae and phytoplankton blooms, which in turn decreases sunlight necessary for growth. This could possibly be a concern in areas inland of Clam Pass where tidal flushing is decreased, if nutrient levels rise in the future (Turrell and Associates Inc., 1995). Additionally, the system receives tannin-rich waters emanating from the surrounding mangrove forests. A combination of the aforementioned water quality factors is probably responsible for the distribution of seagrasses in the bay.

As with seagrasses, interactions between spatially variable factors such as local water circulation patterns, nutrient availability, habitat diversity and physical factors such as salinity and light can influence the abundance of macroalgae. Red algae and filamentous green algae usually occur in low salinity waters typical of high freshwater discharges to estuaries (Carter, et al., 1973; Biber and Irlandi, 2006) and these algae respond to anthropogenic nutrient enrichment with enhanced growth and increased biomass (Valiela, et al., 1997; McGlathery, 2001; Österling and Pihl, 2001; Lapointe and Bedford, 2007). One of the basic tenets of floral estuarine communities is that nutrient loading can result in species replacement by shifting the vegetation from slower growing seagrasses to a more rapid developing macroalgae (Collado-Vides, 2007).

Red macroalgae exists as an attached or drifting form and are common in shallow-water estuaries in South Florida and Gulf of Mexico. Red algae were found primarily in the southern region of Lower Clam Bay at relatively low abundances. Due to the passive movement of drift algae, spatial distribution is often dependant on tidal and wind driven currents as well as local hydrologic conditions. The transport of red algae serves as an important dispersal and transport mechanism for the associated flora and fauna and can have implications on their distribution (Biber, 2007). Clusters of the red algae *Acanthophora spicifera* were collected primarily in a small area in the east-central side of Lower Clam Bay. Green algae, *Caulerpa sertilaroides* was also relatively abundant in this region. The benthic habitat compositions in Inner Clam Bay were dominated by green filamentous algae. The central and northern reaches of Lower Clam Bay also contained this algae, but to a lesser extent than in Inner Clam Bay. Green and red algal species are a common and important component of estuaries as their structural biomass can house and provide food for a variety of species. The threat to an estuary comes when excessive growth or blooms of macroalgae displace other floral species, destroying the natural balance and diversity within an estuary and is usually a sign of eutrophication (Cummins, et al., 2004).

Benthic Macro Fauna

The distribution of sessile organisms (such as bivalves, sponges, barnacles, etc.) is dependant upon differential larval dissemination and settlement by currents, wind, shoreline, availability; types of substrate, light, sedimentation; and other factors such as salinity, life history, competition, fecundity and mortality rates (Marques-Silva, et al., 2006). Tubiculous polychaetes were primarily associated with muddy and sandy substrates and were the most abundant biological assemblage in Clam Bay. Polychaetes dominated Inner and Lower Clam Bays, but had substantially lower occurrence in Upper Clam Bay, the Lower Tributary, and, to a lesser extent, the Upper Tributary. In 1987 Devlin, Gore and Proffitt also reported that Upper Clam Bay had relatively low numbers of polychaetes and benthic organisms. They speculated that this was due to the lack of available sand grain for building tubes in Upper Clam Bay and these worms were avoiding areas that consisted of muddy fine-grained sediments where oxygen was depleted or where food was not readily available. However in the current study, polychaetes were numerous in Lower Clam Bay, which was mud dominant. The low occurrence of polychaetes and bottom organisms in Upper Clam Bay is probably due to some other factor influencing benthic distributions in this Bay than sediment composition, such as low oxygen and seasonally low salinity. Lower polychaete abundance in the Lower Tributary is likely caused by strong water currents that tend to exist in narrow tributaries as food can remain suspended within the water column and not as assessable to bottom dwelling organisms (Busch and Loveland, 1975). Channel environments often support low benthic productivity (Murrel, et al., 2009).

Bivalves, primarily shells of stout razor clam and American oyster, were more commonly collected than gastropods in the Clam Bay system. Stout razor clams burrow into the substrate which may explain the lack of living specimens in surficial grab samples. Stout Razor Clam shell was found primarily in Upper Clam Bay, whereas oysters were more scattered throughout the system. Oysters serve a crucial role in estuaries by removing contaminants by filtering water, creating substrate for many invertebrates and providing food for other benthic organisms (Volety, 2008). Remnant oyster bars and living specimens were still present in the Clam Bay system, but to a lesser extent than the more robust distributions found in Estero or Rookery Bays. Overtime, the distribution of oyster reefs have decreased in Clam Bay (Hartwell, 1995), more than likely a result of dredging or clearing activities and the smaller special extent of Clam Bay. Coarse substrates (sand, shell, and gravel) are suitable for reef development and these areas may be conducive to oyster restoration efforts, provided the other factors affecting their distribution are identified and ameliorated. Grass ceriths had the highest abundance of gastropods collected in the Clam Bay system, all of which were found in Lower Clam Bay. These gastropods seemed to have a preference for sandy substrate, which could explain there presence primarily in the upper reaches of Lower Clam Bay.

Benthic Macro Flora and Fauna that reside on Mangrove Prop Roots

Mangrove prop roots and pneumatophores, the substrate, and the associated flora and fauna that utilize the roots are the primary components fringing the waterways in a mangrove estuary. These features extend into the narrow seaward areas providing a hard substrate that host a variety of species (Nagelkerken, et al., 2008). Bivalves, algae and periphyton tend to dominate the subtidal and intertidal areas, while crabs and gastropods tend to dominate above water. The associated fauna provide a variety of useful functions to mangrove forests including retaining, burying and ingesting leaf litter. The flora such as macroalgal mats promote decomposition and prevent nutrient loss (Kristensen, 2008). Barnacles, oysters, mussels, and periwinkles comprised the highest observations of benthic macrofauna assemblages on prop roots in Clam Bay respectively. Oysters were found on prop roots throughout the Clam Bay system, though most prevalent in Lower Clam Bay and the mid and upper stretches of the Lower Tributary. Lack of oysters in some areas of the mangrove fringe could be due to lower salinities and/or higher water temperatures in the summer rainy season; or increased water velocity that can lead to undercutting and bank erosion in narrow tributaries such as the Lower Tributary just north of the Pass (Heilmayer, et al., 2008). Alternatively recruitment rates could be impacted by some natural or anthropogenic disturbance in the watershed.

Mussels and barnacles were found in close association on the same prop roots primarily in the upper reaches of Clam Bay. When present on the same prop root, mussels were often found in clumps and tended to reside lower in the water when complex assemblages of bivalves or barnacles were present. This suggests that competitive exclusion may be occurring since barnacles have a tendency to be outcompeted for substrate by mussels and have adapted to reside higher in the water column (Cannicci, et al., 2008; Nagelkerken, et al., 2008).

Mulluscs occupy a variety of levels within the ecosystem food web as predators, herbivores, detritivores and filter feeders. Although mulluscs can reach a high level of diversity within a mangrove forest (Cannicci, et al., 2008), very few, have an obligate association with mangrove systems (Reid, et al., 2010). Periwinkles are true mangrove associates that depend on mangroves for food, substrate, shade and protection from predators. Periwinkles can be found on trunks, roots, branches and leaves of mangroves, but cannot exist on soft substrates (Reid, et al., 2010). Periwinkles were found south of the Upper Tributary and are an important component of this estuary.

Visual observations of the prop roots within Clam Bay showed some signs of isopod activity as some roots appeared to be perforated and severed at the ends. Rehm and Humm (1973) called these isopods “speroma destructors”, as these isopods appeared to be damaging mangrove roots. Later it was discovered that these burrowers were actually filter feeders (Brussca and Iverson, 1985), although recently it was found that these isopods can also digest wood (Benson, et al., 1995). It has been speculated that these isopods have a role in managing tidal channels by preventing the roots from growing into the channel and blocking flow (personnel communications Robin Lewis).

In mangrove systems, land crabs act as ecological engineers and play many roles in mangrove community dynamics (Lindquist, et al., 2009; Cannicci, et al., 2008). They influence the physical environment by creating burrows that aerate reduced soils (Lindquist, et al., 2009), while at the same time affecting groundwater flow by facilitating exchange of overlying water and the soil (Cannicci, et al., 2008). This habit of bioturbation decreases the amounts of ammonium and sulphide in the soil, which benefits mangroves by increasing their productivity (Cannicci, et al., 2008). Land crabs accelerate decomposition of organic material through grazing on leaf litter and are considered the primary agent responsible for high leaf litter turnover rates, thereby facilitating the conversion of organic nitrogen to ammonia, which provides energy to other organisms (Cannicci, et al., 2008). Additionally, crabs can act as ecological filters, impacting community structure by influencing the density, species composition and distribution of tree recruitment, since crabs will differentially consume, damage or bury propagules and seedlings – an example of predator guild pressure on community development. Alternatively, as crabs store leaf litter in burrows and regularly move the soil around through their excavation activities, they may increase local carbon and nutrient resources that may in turn facilitate seedling recruitment (Lindquist, et al., 2009). Land crabs were observed at eight sites during the prop root survey in Clam Bay. The seemingly low occurrence may be due to their cryptic behavior and activity patterns. These crabs tend to be less active during periods of high temperatures and direct sunlight. They remain out of sight in their burrows during daytime in order to conserve water and are more active during the cooler night periods (Lindquist, et al., 2009). Crabs are very important to the structure and function of mangroves and are potentially the most important macrofaunal component of these forests (Mchenga, et al., 2007; Cannicci, et al., 2008).

CONCLUDING REMARKS

Estuaries are a result of a unique set of circumstances formed by wind, wave action and the input of freshwater runoff, rivers and streams. Estuaries on the southwest coast of Florida are low energy sites that are protected from the open ocean by barrier islands and are dependant upon the mixing action of freshwater runoff and the Gulf waters. Anthropogenic changes to the landscape surrounding Clam Bay and within the system has altered the timing, volume and hydroperiod of both freshwater and saltwater input and outputs, which has adversely affected the habitats and species that reside within the estuary.

Despite changes in distribution and species composition, seagrass communities have persisted in Lower Clam Bay during 30 years of monitoring. The absence of seagrasses and the lower occurrence of macroalgal and faunal communities in the upper regions of Clam Bay may be due to water quality issues that may or may not be related to anthropogenic changes in the landscape. The absence of seagrass in Inner and Upper Clam Bay may be the result of some limiting factor or a combination of factors such as salinity, turbidity, nutrient enrichment, light attenuation, substrate or siltation. Acreage estimates overtime, though a useful tool, have difficulties in that seagrasses respond to a changing environment. What is important is its long-term resilience, as throughout the years seagrasses have been documented in the same general areas regardless of methodology or who has performed the study.

Lower species diversity and abundance are typical for the terminus of mangrove systems that are more influenced by fresh water and tend to accumulate higher organic fine grained substrate. Alternatively, the distance from the Gulf of Mexico could hamper passive dispersal mechanisms of some benthic species that spawn in ocean waters. Over the years, Upper Clam Bay has exhibited lower salinity than the other Bays or tributaries, possibly a result of higher stormwater discharges during the wet season and lack of flushing (Hatcher, 1995; Hartwell, 1995; Worley, 1995). However, any explanations are speculative without comparative baseline data prior to development in the Clam Bay watershed.

Estuaries are under threat worldwide as a result of increasing anthropogenic pressure, habitat loss and climate change (Marsden and Maclaren, 2010). Currently, mangroves, seagrasses and coral reef communities are experiencing a high degree of degradation as a result of the combination of human and natural disturbance that have led to mangrove and seagrass die-offs, sponge mortality, cyanobacterial blooms and a decline in fisheries in Florida Bay and the Keys (Collado-Vides, et al., 2007). In the last three decades, eutrophication and resultant hypoxia, algae blooms and macroalgae mats have increased globally, possibly adversely affecting the distribution and abundance of macrofauna (Marsden and Maclaren, 2010). The question that arises is at what point and when will the impacts of anthropogenic disturbance in combination with natural stressors impact estuaries to the point where they become less resilient to these pressures and can not compensate or return to their original community structure. Estuarine management becomes increasingly important and must balance multiple ecological and anthropogenic objectives. Unfortunately, this usually results in tradeoffs, since management policies tend to benefit one aspect of the biological community, while adversely affecting another (Armitage, et al., 2006). Therefore, it is important to understand to the best of our ability what impacts our management has on all the different estuarine communities and whether or not benefits of initiating management strategies outweigh the detriments.

ACKNOWLEDGEMENTS

We are indebted to staff of Pelican Bay Foundation for access to the gate at Clam Pass Park and to Brett Kohan and the residents of Naples Cay for allowing us to dock our boat at their facilities. We also thank the Pelican Bay Homeowners Association, the Mangrove Action Group and the Pelican Bay Foundation for providing the funds to accomplish this study.

LITERATURE CITED

Alfaro, A.C. 2006. Benthic macro-invertebrate community composition within a mangrove seagrass estuary in northern New Zealand. Estuarine, Coastal and Shelf Science 66: 97-110.

Armitage, A.R., Frankovich, T.A. and Fourqurean, J.W. 2006. Variable responses within epiphytic and benthic microalgal communities to nutrient enrichment. In Interaction of Hydrology and Nutrients in Controlling Ecosystem Function in Oligotrophic Coastal Environments of South Florida Trexler, J.C., Gaiser, E.E., and Childers, D.L. (eds), Hydrobiologia 569:423–435. Springer 2006.

ASTM, 1993. Standard test method for the amount of materials in soils finer than the no. 200 (75 μm) sieve. *In*: Annual Book of ASTM Standards, Section 4, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA, pp. 191-193.

Benedict, M.A. 1984. Department of Natural Resources Collier County Part 4 Natural Resources Management Plan. Tech. Report NO. 84-4. pp. 6-9, 69-80.

Benedict, M.A. 1984. Department of Natural Resources Collier County Part 1 Natural Resources Management Plan. Tech. Report NO. 84-1. pp. 36.

Benson, L.K., Rice, S.A. and Johnson, B.R. 1999. Evidence of cellulose digestion in the wood boring isopod *Sphaeroma terebrans*. Florida Scientist. 62(2): 128-144.

Biber, P.D. and E.A. Irlandi. 2006. Temporal and spatial dynamics of macroalgal communities along an anthropogenic salinity gradient in Biscayne Bay (Florida, USA). Aquatic Botany 85:65-77.

Biber, P.D. 2007. Short Communication Hydrodynamic transport of drifting macroalgae through a tidal cut. Estuarine, Coastal and Shelf Science 74: 565-569.

Boer, W.F. 2000. Biomass Dynamics of Seagrasses and the Role of Mangrove and Seagrass Vegetation as Different Nutrient Sources for an Intertidal Ecosystem. Aquatic Botany. 66(3):225-239.

Burch, J.N. 1990. Coastal Barrier Management Plan, Collier County Department if Natural Resources. pp. 32-36, 46-61.

Burkholder, J.M., Tomasko, D.A., Touchette, B.W. 2007. Seagrasses and eutrophication. Journal of Experimental Marine Biology and Ecology 350: 46–72.

Bursch, D.A. and Loveland, R.E. 1975. Tube-Worm-Sediment Relationships in Populations of Pectinaria gouldii (Polychaeta: Pectinariidae) from Barnegat Bay, New Jersey, USA. Marine Biology 33: 255-264.

LITERATURE CITED

Brussca, R. C., and E. W. Iverson. 1985. A guide to the marine isopod crustacea of Pacific Costa Rica. Rev. Biol. Trop., 33 (Suppl. 1):1-77.

Cannicci, S., Burrows, D., Fratini, S., Smith III, T.J., Offenberg, J. and Dahdouh-Guebas, F. 2008. Review Faunal impact on vegetation structure and ecosystem function in mangrove forests: A review. Aquatic Botany 89: 186–200.

Carlson, P.R., Yarbro, L.A., Madley, K., Arnold, H., Merello, M., Vanderbloemen, L., McRae, G., and Durako, M.J., 2003, Effect of El Niño on demographic, morphological, and chemical parameters in turtle-grass (*Thalassia testudinum*): an unexpected test of indicators: Environmental Monitoring Assessment, v. 81, p. 398–408.

Carter, M.R., L.A. Burns, T.R. Cavinder, K.R. Dugger, P.L. Fore, D.B. Hicks, H.L. Revells, and T.W. Schmidt. 1973. Ecosystems Analysis of the Big Cypress Swamp and Estuaries. U.S. Environmental Protection Agency Region IV, Atlanta, Georgia. EPA 904/9-74-002.

Chapman, M.G. and Tolhurst , T.J. 2007. Relationships between benthic macrofauna and biogeochemical properties of sediments at different spatial scales and among different habitats in mangrove forests. Journal of Experimental Marine Biology and Ecology 343: 96–109.

Chen, J., Ye, Y and Lu, Chang-Yi. 2007. Changes of macro-benthic faunal community with stand age of rehabilitated *Kandelia candel* mangrove in Jiulongjiang Estuary, China. ecological engineering 3 1: 215–224.

Coastal Zone Management Plan for Collier County Florida. 1991**.** Collier County Natural Resources Department. pp 279-294.

Collado-Vides, L.. Caccia, V.G., Boyer, J.N., and Fourqurean, J.W. 2007. Tropical seagrass-associated macroalgae distributions and trends relative to water quality. Estuarine, Coastal and Shelf Science 73: 680-694.

Collier County Environmental Services Division, Natural Resources Department. 1991. Collier County Seagrass Protection Plan. Technical Report No. 91-01.

Collier County Seagrass Inventory. 1994. Collier County, Naples, Florida

Continental Shelf Associates, Inc. and Martel Laboratories Inc. 1985. Florida Big Bend Seagrass Habitat Study Narrative Report. A final report by Continental Shelf Associates, Inc. submitted to the Minerals Management Service, Metairie, LA. Contract No. 14-12-001-30188.

LITERATURE CITED

Cummins, S.P., Roberts, D.E. and Zimmerman, K.D. 2004. Effects of the green macroalga Enteromorpha intestinalis on macrobenthic and seagrass assemblages in a shallow coastal esturary. Marine Ecology Progress Series. 266 (77-87).

Dawes, C. J., R. C. Phillips, and G. Morrison. 2004. Seagrass Communities of the Gulf Coast of Florida: Status and Ecology. Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute and the Tampa Bay Estuary Program. 74 p. http://research.myfwc.com/features/view_article.asp?id=23508.

Devlin, D. J., Gore, R.H., and Proffitt, C.E. 1987. Natural Resources of Collier County. Preliminary Analysis of Seagrass and Benthic Infauna in Johnson and Clam Bays, Collier County Natural Resources Dept. CM 169. Technical Report No. 87-2.

Doering, P.H. and R.H. Chamberlain. 2000. Experimental studies on the salinity tolerance of turtle grass, *Thalassia testudinum*. *In*: S.A. Bortone (Ed.), Seagrasses: Monitoring, Ecology, Physiology, and Management, CRC Press, Boca Raton, FL. pp. 81-98.

Drew, R.D. and N.S. Schomer. 1984. An ecological characterization of the Caloosahatchee/Big Cypress watershed. U.S. Fish and Wildlife Service, FWS/OBS-82/58.2. pp. 225.

Durako, M.J. 1988. The seagrass bed: a community under assault. Florida Naturalist Fall 1988 pp. 6-8.

Durako, M.J., and Moffler, M.D., 1985. Observations on the reproductive ecology of *Thalassia testudinum* (Hydrocharitaceae). II. Leaf width as a secondary sex character. Aquat. Bot. 21, 265–275.

Durako, M.J., 1995. Indicators of seagrass ecological condition: an assessment based on spatial and temporal changes associated with the mass mortality of the tropical seagrass *Thalassia testudinum*. In: Dyer, K.R., Orth, R.J. (Eds.), Changes in Fluxes in Estuaries: Implications for Science to Management. Olsen & Olsen, Fredensborg, Denmark, pp. 261–266.

Ellison, A.M. 2008. Managing mangroves with benthic biodiversity in mind: Moving beyond roving banditry. Journal of Sea Research 59: 2–15.

Florida Department of Environmental Regulation. 1984. Department of Natural Resources, Collier County. Part 1. Natural Resources Management Plan. Rech. Rpt NO 84-1; 84-4.

Fourqurean, J.W., J.N. Boyer, M.J. Durako, L.N. Hefty, and B.J. Peterson. 2003. Forecasting responses of seagrass distributions to changing water quality using monitoring data. Ecological Applications 13:474–489.

Grabe, S. 1975. Field studies Parkshore and Clam Bay systems Naples Florida November 1975 Region IV U.S. EPA Surveillance and Analysis Division Athens, GA

LITERATURE CITED

Greenawalt-Boswell, J.M., J.A. Hale, K.S. Fuhr, and J.A. Ott. 2006. Seagrass species composition and distribution trends in relation to salinity fluctuations in Charlotte Harbor, Florida. Florida Scientist 69:24-35.

Hackney, J.W. and M.J. Durako. 2004. Size-frequency patterns in morphometric characteristics of the seagrass *Thalassia testudinum* reflect environmental variability. Ecological Indicators 4:55-71.

Hale, J.A., T.K. Frazer, D.A. Tomasko, and M.O. Hall. 2004. Changes in the distribution of seagrass species along Florida's central Gulf Coast–Iverson and Bittaker revisited. Estuaries 27:36–43.

Hammerstrom, K.K., W.J. Kenworthy, M.S. Fonseca, and P.E. Whitfield. 2006. Seed bank, biomass and productivity of *Halophila decipiens*, a deep water seagrass on the west Florida continental shelf. Aquatic Botany 84: 110 - 120.

Hartwell, R.W.. 1995.Clam Bay NRPA Mangrove Survey and Salinity Testing. Natural Resources Department Memorandum, Collier County, Florida. pp 4.

Hatcher, M. 1995. Summary of Findings and Proposed Solutions to Clam Bay Mangrove Expert Review Panel. Natural Resources Department Memorandum, Collier County, Florida. pp 5.

Heilmayer, O., Digialleonardo, J., Qian, L., and Roesijadi, G. 2008. Stress tolerance of a subtropical Crassostrea virginica population to the combined effects of temperature and salinity. Estuarine, Coastal and Shelf Science 79: 179–185.

Humiston and Moore Engineers. 2007. Clam Pass Restoration and Management Plan Bathymetric Monitoring Report No. 8. HM File No. 9-068/13-078. Humiston and Moore Engineers, Naples Fl. pp. 21.

Humm, H.J. and Rehm, A.E. 1972. Ecological Appraisal an Ecological Study of the Clam Pass Complex. Study for the Collier Company at Clam Pass Properties. Tri-County Engineering, Inc. TCE Project No. 1516.

Irlandi, E., Orlando, B., Maciá. S., Biber, P., Jones, T., Kaufman, L., Lirman, D., and Patterson, T. 2002. The influence of freshwater runoff on biomass, morphometrics, and production of *Thalassia testudinum*. Aquatic Botany 72:67-78.

Iverson, R.L. and H.F. Bittaker. 1986. Seagrass distribution and abundance in eastern Gulf of Mexico waters. Estuarine, Coastal, and Shelf Science 22:577-602.

Johansson, J.O.R. and H.S.Greening. 2000. Seagrass Restoration in Tampa Bay: A Resource-Based Approach to Estuarine Management. In: *Seagrasses Monitoring, Ecology, Physiology, and Management.* (S.A. Bortone (ed.) CRC Press LLC. 2000. pp. 279-293.

LITERATURE CITED

Koch, M.S. and C.J. Madden. 2001. Patterns of Primary Production and Nutrient Availability in a Bahamas Lagoon with Fringing Mangroves. Marine Ecology Progress Series. 219:109-119.

Kristensen, E. 2008. Mangrovecrabs as ecosystem engineers; with emphasis on sediment processes. Journal of Sea Research 59:30-43.

Lambe, T. W. and R.V. Whitman. 1969. Soil Mechanics. John Wiley & Sons, New York, NY. pp. 553.

Lapointe, B.E. and B.J. Bedford. 2007. Drift rhodophyte blooms emerge in Lee County, Florida, USA: evidence of escalating coastal eutrophication. Harmful Algae 6:421-437.

Lee, K.S., Dunton, K.H., 1997. Effects of in situ light reduction on the maintenance, growth and partitioning of carbon resources in *Thalassia testudinum* Banks ex Konig. J. Exp. Mar. Biol. Ecol. 210, 53–73.

Lee, K.S., Dunton, K.H., 2000. Effects of nitrogen enrichment on biomass allocation, growth, and leaf morphology of the seagrass *Thalassia testudinum*. Mar. Ecol. Prog. Ser. 196, 39–48.

Lindquist, E.S., Krauss, K. W., Green, P.T., O'Dowd, D. J., Sherman, P.M. and Smith, T. J. III. 2009. Land crabs as key drivers in tropical coastal forest recruitment. Biol. Rev. 84: 203–223.

Lirman, D., G. Deangelo, J. Serafy, A. Hazra, D. Smith Hazra, J. Herlan, J. Luo, S. Bellmund, J. Wang, and R. Clausing. 2008. Seasonal changes in the abundance and distribution of submerged aquatic vegetation in a highly managed coastal lagoon. Hydrobiologia 596:105-120.

Livingston, R.J., S.E. McGlynn, and X. Niu. 1998. Factors controlling seagrass growth in a gulf coastal system: water and sediment quality and light. Aquatic Botany 60:135-159.

Marques-Silva, N.S., Beasley, C.R., Paiva Gomes, C., Lima Gardunho, D.C., Tagliaro, C.H., Schories, D., and Mehlig, U. 2006. Settlement dynamics of the encrusting epibenthic macrofauna in two creeks of the Caete´ mangrove estuary (North Brazil). Wetlands Ecology and Management 14: 67–78.

Marsden , D. and Maclaren, S.R. 2010. Short-term study testing the resilience of an estuarine bivalve to macroalgal mats Resilience of an estuarine bivalve. Hydrobiologia 649:217–229.

McGlathery, K.J. 2001. Macroalgal blooms contribute to the decline of seagrass in nutrient-enriched coastal waters. Journal of Phycology 37:453-456.

LITERATURE CITED

Mchenga, I.S.S.., Mfilinge, P. L., and Tsuchiya, M. 2007. Bioturbation activity by the grapsid crab Helice formosensis and its effects on mangrove sedimentary organic matter. Estuarine, Coastal and Shelf Science 73: 316-324.

Melville, F. and Pulkownik. 2006. Investigation of mangrove macroalgae as bioindicators of estuarine contamination. Marine Pollution Bulletin 52:1260–1269.

Montague, C.L. and J.A. Ley. 1993. A possible effect of salinity fluctuation on abundance of benthic vegetation and associated fauna in northeastern Florida Bay. Estuaries 16:703-717.

Murrell, M.C., Campbell, J.G., Hagy, J.D III, and Caffrey, J. M. 2009. Effects of irradiance on benthic and water column processes in a Gulf of Mexico estuary: Pensacola Bay, Florida, USA. Estuarine Coastal and Shelf Science 81:501-512.

Nagelkerken, I, Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M. Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A. and Somerfield, P.J. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review. Aquatic Botany 89:155-185.

Nordhaus, I., Hadipudjana, F.A., Janssen, R. and Pamungkas, J. 2009. Spatio-temporal variation of macrobenthic communities in the mangrove-fringed Segara Anakan lagoon, Indonesia, affected by anthropogenic activities. Reg Environ Change 9:291–313.

Ogilby, R.R. 1972. Investigation of the Bottom Sediments in the Clam Bay System. Prepared for the Collier Company at Clam Pass Properties. Tri-County Engineers Inc. pp.22.

Österling, M. and L. Pihl. 2001. Effects of filamentous green algal mats on benthic macrofaunal functional feeding groups. Journal of Experimental Marine Biology and Ecology 263:159-183.

PBS&J. 2008. Clam Bay Seagrass Assessment. Prepared for: Collier County Coastal Zone Management Department. PBS&J. Tampa, Florida. pp. 75.

PBS&J, 2009. Clam Bay System Data Collection & Analysis. Prepared for: Collier County Coastal Zone Management Department. PBS&J. Tampa, Florida. pp 75.

Phillips, R.C. 1960. Observations on the ecology and distribution of Florida seagrasses. Florida State Board of Conservation, Professional Papers Series No. 2. pp.72.

Phillips, R. C., and R. R. Lewis. 1983. Influence of environmental gradients on variations in leaf widths and transplant success in North American seagrasses. J. Mar. Tech Soc. 17(2)59-68.

Phillips, R.C. and E.G. Meñez. 1988. Seagrasses. Smithsonian Contributions to the Marine Sciences, Number 34. pp. 104.

LITERATURE CITED

Powell, G.V.N., W.J. Kenworthy, and J.W. Fourqurean. 1989. Experimental evidence for nutrient limitation of seagrass growth in a tropical estuary with restricted circulation. Bulletin Marine Science 44:324-340.

Reid, D.G., Dyal, P., and Williams, S.T. 2010. Global diversification of mangrove fauna: a molecular phylogeny of Littoraria (Gastropoda: Littorinidae). Molecular Phylogenetics and Evolution 55: 185–201.

Robbins, B.D. 1997. Quantifying temporal change in seagrass areal coverage: the use of GIS and low resolution aerial photography. Aquatic Botany 58:259-267.

Schmid, J. R. 2000. Activity patterns and habitat associations of Kemp's ridley turtles, *Lepidochelys kempi*, in the coastal waters of the Cedar Keys, Florida. Ph.D. dissertation, University of Florida, Gainesville, Florida. http://www.uflib.ufl.edu/etd.html

Schmid, J.R., A.B. Bolten, K.A. Bjorndal, W.J. Lindberg, H.F. Percival, and P.D. Zwick. 2003. Home range and habitat use by Kemp's ridley turtles in west-central Florida. Journal of Wildlife Management. 67:197-207.

Schmid, J.R., K. Worley, D.A. Addison, A.R. Zimmerman, and A. Van Eaton. 2006. Naples Bay past and present: a chronology of disturbance to an estuary. Final Report to the City of Naples. pp. 58.

Schmid, J.R. 2009. Ecological Assessment and Calibration of Water Quality in Estero Bay, Florida. Final Report to Environmental Protection Agency Gulf of Mexico Program Office for Contract Agreement No. MX- 96422705. Conservancy of Southwest Florida. pp. 89.

Stickney, R.R. 1984. Estuarine Ecology of the Southeastern United States and Gulf of Mexico. Texas A&M University Press, College Station, TX. pp. 310.

Tabb, D.C., D.L. Dubrow, and R.B. Manning. 1962. The ecology of northern Florida Bay and adjacent estuaries. State of Florida Board of Conservation, Technical Series No. 39. pp. 81.

Tolley, S.G., A.K. Volety, and M. Savarese. 2005. Influence of salinity on the habitat use of oyster reefs in three southwest Florida estuaries. Journal of Shellfish Research 24:127-137.

Tomasko, D.A. and Lapointe, B.E.. 1991. Productivity and biomass of *Thalassia testudinum* as related to water column nutrient availability and epiphyte levels: field observations and experimental studies. Marine Ecology Progress Series 75: 9-17.

LITERATURE CITED

Turrell & Associates, Inc. 1995. Clam Pass Inlet Management Plan, Interim Report NO. 1. pp 4:1 - 7:1.

Turrell & Associates, Inc. 2000. Clam Bay Restoration and Management. Biological Monitoring Report. Baseline and Time Zero Report.

Turrell & Associates, Inc. 2001. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 5. .

Turrell & Associates, Inc. 2002. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 6. .

Turrell & Associates, Inc. 2003. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 7.

Turrell & Associates, Inc. 2004. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 8.

Turrell & Associates, Inc. 2005. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 9.

Turrell & Associates, Inc. 2006. Clam Bay Restoration and Management. Biological Monitoring Report. Sixth Annual Report No. 9.

Turrell, Hall & Associates, Inc. 2007. Clam Bay Restoration and Management. Biological Monitoring Report. Eighth Annual Report No. 10.

Turrell, Hall & Associates, Inc. 2009. Clam Bay Restoration and Management. Biological Monitoring Report. Eighth Annual Report No. 11.

U.S. Fish and Wildlife Service. 1999. South Florida Multi-Species Recovery Plan. Atlanta, GA. pp 2172.

Valiela, I., J. McClelland, J. Hauxwell, P.J. Behr, D. Hersh, and K. Foreman. 1997. Macroalgal blooms in shallow estuaries: controls and ecophysiological and ecosystem consequences. Limnology and Oceanography 42:1105-1118.

Volety, A.K. 2008. Effects of salinity, heavy metals and pesticides on health and physiology of oysters in the Caloosahatchee Estuary, Florida. Ecotoxicology 17:579–590.

Wolfe, S. H. (Editor) 1990. An Ecological Characterization of the Florida Springs Coast: Pithlachascotee to Waccasassa Rivers. U. S. Dept. of Interior Biological Report 90(21). pp. 323.

LITERATURE CITED

Worley, K. and Gore, J. A. 1995. Status of the Clam Bay ecosystem - phase I. Technical report. The Conservancy, Inc. Naples, Florida. pp. 120.

Worley, K. 2005. Save the Bay Water Quality Report # 50. Conservancy of Southwest Florida. pp.5.

Worley K., 2005. Mangroves as an Indicator of Estuarine Conditions in Restoration Areas. In: Estuarine Indicators. S. A. Bortone (ed). CRC Press, Boca Raton, Fl. 16: 247-259.

Worley, K. 2006. Relating Mangrove Die-offs to Encroaching Human Development in Southwest Florida. NOAA Technical Report 160R2407. Conservancy of Southwest Florida. Naples, Florida. pp 59.

Yokel, B. 1979. Appendix E-Biology. *In*: B.L. Simpson, R. Aaron, J. Betz, D. Hicks, J. van der Kreeke, and B. Yokel. The Naples Bay Study. The Collier County Conservancy. Naples, Florida.

Zieman, J.C. 1982. The ecology of seagrasses of south Florida: a community profile. U.S. Fish and Wildlife Services, Office of Biological Services. FWS/OBS-82/25. pp. 158 .

Zieman, J.C. and R.T. Zieman. 1989. The ecology of the seagrass meadows of the west coast of Florida: a community profile. U.S. Fish and Wildlife Services Biological Report 85(7.25). pp 155.

Table 1. Percent composition of benthic substrates in portions of the Clam Bay complex. Secondary substrates include mud with high sand content (sandy mud) and sand with high mud content (muddy sand). Dominant substrates are indicated in bold.

Substrates	Upper Clam Bay	Upper Tributary	Inner Clam Bay	Lower Tributary	Lower Clam Bay
Primary					
Mud	**72.5**	**57.9**	**66.7**	2.4	**66.2**
Sand	25.5	34.2	32.9	**57.1**	32.6
Shell	2.0	7.9	0.5	40.5	1.2
Secondary					
Mud	**47.1**	26.3	18.5	0.0	**52.5**
Sandy mud	25.5	**31.6**	**48.1**	2.4	13.7
Muddy sand	24.2	28.9	32.4	9.5	11.6
Sand	1.3	5.3	0.5	**47.6**	21.0
Shell	2.0	7.9	0.5	40.5	1.2

Table 2. Percent composition of the biological assemblage components for assemblage sites in each portion of the Clam Bay complex.

Biological assemblage	Upper Clam Bay	Upper Tributary	Inner Clam Bay	Lower Tributary	Lower Clam Bay
Seagrasses					
Halodule beaudettei (shoal grass)	0.0	0.0	0.0	0.0	100.0
Halophila decipiens (paddle grass)	0.0	0.0	0.0	0.0	100.0
Green algae					
Green filamentous algae	0.9	0.0	59.7	0.0	39.4
Caulerpa sertularoides	0.0	0.0	0.0	0.0	100.0
Acetabularia crenulata	0.0	0.0	100.0	0.0	0.0
Red algae					
Unidentified spp.	0.0	0.0	0.0	0.0	100.0
Acanthophora spicifera	0.0	0.0	0.0	0.0	100.0
Polychaetes					
Unidentified worm tubes	0.3	2.5	41.8	0.3	55.1
Unidentified mud tubes	0.0	0.0	15.9	0.0	84.1
Shell-encrusted tubes	0.0	0.0	0.0	20.0	80.0
Pectinaria gouldi (trumpet worm) tubes	3.3	0.0	20.0	3.3	73.3
Molluscs					
Crassostrea virginica (American oyster)					
Shell	13.3	15.7	10.8	32.5	27.7
Living	10.0	0.0	0.0	10.0	80.0
Tagelus plebeius (stout razor clam)	78.8	9.6	10.6	0.0	1.0
Anomalocardia auberiana (pointed venus clam)					
Shell	0.0	0.0	50.0	0.0	50.0
Living	0.0	20.0	46.7	0.0	33.3
Bittiolum varium (grass cerith)	0.0	0.0	0.0	0.0	100.0
Melongena corona (Florida crown conch)					
Shell	0.0	0.0	100.0	0.0	0.0
Living	0.0	0.0	16.7	0.0	83.3
Echinoderms					
Moira atropos (heart urchin)	0.00	0.00	0.00	0.00	100.00
Ophiophragmus filograneus (brittlestar)	0.00	0.00	11.11	0.00	88.89

Table 3. Percent composition of the biological assemblage components for study area sites in each portion of the Clam Bay complex.

Biological assemblage	Upper Clam Bay	Upper Tributary	Inner Clam Bay	Lower Tributary	Lower Clam Bay
Seagrasses					
Halodule beaudettei (shoal grass)	0.0	0.0	0.0	0.0	6.4
Halophila decipiens (paddle grass)	0.0	0.0	0.0	0.0	0.2
Green algae					
Green filamentous algae	1.3	0.0	59.7	0.0	20.1
Caulerpa sertularoides	0.0	0.0	0.0	0.0	1.2
Acetabularia crenulata	0.0	0.0	5.1	0.0	0.0
Red algae					
Unidentified spp.	0.0	0.0	0.0	0.0	2.8
Acanthophora spicifera	0.0	0.0	0.0	0.0	1.4
Polychaetes					
Unidentified worm tubes	0.7	21.1	61.1	2.4	41.1
Unidentified mud tubes	0.0	0.0	6.0	0.0	16.3
Shell-encrusted tubes	0.0	0.0	0.0	4.8	1.9
Pectinaria gouldi (trumpet worm) tubes	0.7	0.0	2.8	2.4	5.2
Molluscs					
Crassostrea virginica (American oyster)					
Shell	7.2	34.2	4.2	64.3	5.4
Living	0.7	0.0	0.0	2.4	1.9
Tagelus plebeius (stout razor clam)	53.6	26.3	5.1	0.0	0.2
Anomalocardia auberiana (pointed venus clam)					
Shell	0.0	0.0	1.4	0.0	0.7
Living	0.0	7.9	3.2	0.0	1.2
Bittiolum varium (grass cerith)	0.0	0.0	0.0	0.0	6.1
Melongena corona (Florida crown conch)					
Shell	0.0	0.0	2.3	0.0	0.0
Living	0.0	0.0	0.5	0.0	1.2
Echinoderms					
Moira atropos (heart urchin)	0.0	0.0	0.0	0.0	2.4
Ophiophragmus filograneus (brittlestar)	0.0	0.0	0.5	0.0	1.9

Table 4. Percent composition of secondary benthic substrates for components of the seagrass assemblage in each portion of the Clam Bay complex.

	Halodule beaudettei (shoal grass)	*Halophila decipiens* (paddle grass)
Upper Clam Bay		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Upper Tributary		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Inner Clam Bay		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Lower Tributary		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Lower Clam Bay		
Mud	0.0	0.0
Sandy mud	11.1	100.0
Muddy sand	66.7	0.0
Sand	22.2	0.0
Shell	0.0	0.0

Table 5. Percent composition of secondary benthic substrates for components of the green and red algae assemblages in each portion of the Clam Bay complex.

	Green algae			Red algae	
	Green filamentous algae	*Caulerpa sertularoides*	*Acetabularia crenulata*	Unidentified spp.	*Acanthophora spicifera*
Upper Clam Bay					
Mud	0.0	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0	0.0
Muddy sand	100.0	0.0	0.0	0.0	0.0
Sand	0.0	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0	0.0
Upper Tributary					
Mud	0.0	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0	0.0	0.0
Sand	0.0	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0	0.0
Inner Clam Bay					
Mud	0.8	0.0	0.0	0.0	0.0
Sandy mud	53.5	0.0	54.5	0.0	0.0
Muddy sand	45.7	0.0	45.5	0.0	0.0
Sand	0.0	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0	0.0
Lower Tributary					
Mud	0.0	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0	0.0	0.0
Sand	0.0	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0	0.0
Lower Clam Bay					
Mud	35.3	40.0	0.0	66.7	0.0
Sandy mud	8.2	0.0	0.0	16.7	50.0
Muddy sand	11.8	40.0	0.0	8.3	0.0
Sand	43.5	20.0	0.0	8.3	33.3
Shell	1.2	0.0	0.0	0.0	16.7

Table 6. Percent composition of secondary benthic substrates for components of the tubiculous polychaete assemblage in each portion of the Clam Bay complex.

	Unidentified worm tubes	Unidentified mud tubes	Shell-encrusted tubes	*Pectinaria gouldi* (trumpet worm)
Upper Clam Bay				
Mud	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0
Muddy sand	100.0	0.0	0.0	100.0
Sand	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0
Upper Tributary				
Mud	0.0	0.0	0.0	0.0
Sandy mud	25.0	0.0	0.0	0.0
Muddy sand	75.0	0.0	0.0	0.0
Sand	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0
Inner Clam Bay				
Mud	3.0	15.4	0.0	16.7
Sandy mud	52.3	69.2	0.0	83.3
Muddy sand	44.7	15.4	0.0	0.0
Sand	0.0	0.0	0.0	0.0
Shell	0.0	0.0	0.0	0.0
Lower Tributary				
Mud	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0	0.0
Sand	100.0	0.0	50.0	100.0
Shell	0.0	0.0	50.0	0.0
Lower Clam Bay				
Mud	62.6	92.8	0.0	31.8
Sandy mud	12.6	7.2	37.5	9.1
Muddy sand	5.7	0.0	12.5	31.8
Sand	19.0	0.0	50.0	27.3
Shell	0.0	0.0	0.0	0.0

Table 7. Percent composition of secondary benthic substrates for components of the bivalve mollusc assemblage in each portion of the Clam Bay complex.

	Crassostrea virginica (American oyster)		*Tagelus plebeius* (stout razor clam)	*Anomalocardia auberiana* (pointed venus clam)	
	Shell	Living	Shell	Shell	Living
Upper Clam Bay					
Mud	27.3	0.0	14.6	0.0	0.0
Sandy mud	36.4	0.0	40.2	0.0	0.0
Muddy sand	27.3	0.0	43.9	0.0	0.0
Sand	0.0	0.0	1.2	0.0	0.0
Shell	9.1	100.0	0.0	0.0	0.0
Upper Tributary					
Mud	23.1	0.0	20.0	0.0	33.3
Sandy mud	38.5	0.0	40.0	0.0	33.3
Muddy sand	15.4	0.0	30.0	0.0	33.3
Sand	7.7	0.0	0.0	0.0	0.0
Shell	15.4	0.0	10.0	0.0	0.0
Inner Clam Bay					
Mud	22.2	0.0	27.3	0.0	0.0
Sandy mud	55.6	0.0	27.3	66.7	71.4
Muddy sand	0.0	0.0	45.5	33.3	28.6
Sand	11.1	0.0	0.0	0.0	0.0
Shell	11.1	0.0	0.0	0.0	0.0
Lower Tributary					
Mud	0.0	0.0	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0	0.0	0.0
Sand	51.9	0.0	0.0	0.0	0.0
Shell	48.1	100.0	0.0	0.0	0.0
Lower Clam Bay					
Mud	21.7	25.0	0.0	33.3	0.0
Sandy mud	39.1	12.5	0.0	0.0	0.0
Muddy sand	17.4	25.0	0.0	0.0	20.0
Sand	21.7	0.0	100.0	66.7	60.0
Shell	0.0	37.5	0.0	0.0	20.0

Table 8. Percent composition of secondary benthic substrates for components of the gastropod mollusc assemblage in each portion of the Clam Bay complex.

	Bittiolum varium (grass cerith)	*Melongena corona* (Florida crown conch)	
		Shell	Living
Upper Clam Bay			
Mud	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0
Sand	0.0	0.0	0.0
Shell	0.0	0.0	0.0
Upper Tributary			
Mud	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0
Sand	0.0	0.0	0.0
Shell	0.0	0.0	0.0
Inner Clam Bay			
Mud	0.0	40.0	0.0
Sandy mud	0.0	60.0	100.0
Muddy sand	0.0	0.0	0.0
Sand	0.0	0.0	0.0
Shell	0.0	0.0	0.0
Lower Tributary			
Mud	0.0	0.0	0.0
Sandy mud	0.0	0.0	0.0
Muddy sand	0.0	0.0	0.0
Sand	0.0	0.0	0.0
Shell	0.0	0.0	0.0
Lower Clam Bay			
Mud	0.0	0.0	0.0
Sandy mud	15.4	0.0	0.0
Muddy sand	19.2	0.0	20.0
Sand	65.4	0.0	80.0
Shell	0.0	0.0	0.0

Table 9. Percent composition of secondary benthic substrates for components of the echinoderm assemblage in each portion of the Clam Bay complex.

	Moira atropos (heart urchin)	*Ophiophragmus filograneus* (brittlestar)
Upper Clam Bay		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Upper Tributary		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Inner Clam Bay		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	100.0
Sand	0.0	0.0
Shell	0.0	0.0
Lower Tributary		
Mud	0.0	0.0
Sandy mud	0.0	0.0
Muddy sand	0.0	0.0
Sand	0.0	0.0
Shell	0.0	0.0
Lower Clam Bay		
Mud	80.0	62.5
Sandy mud	20.0	12.5
Muddy sand	0.0	12.5
Sand	0.0	12.5
Shell	0.0	0.0

Table 10. Percent biological assemblages on mangrove prop roots for study area sites and assemblage sites in the Clam Bay complex.

Biological assemblage	Upper Clam Bay	Upper Tributary	Inner Clam Bay	Lower Tributary	Lower Clam Bay
Study area sites					
Unidentified mussel spp.	100.0	16.71	0.0	0.0	0.0
Unidentified barnacle spp.					
Shell	3.1	0.0	7.1	0.0	0.0
Living	81.3	66.7	82.1	85.7	88.5
Crassostrea virginica (American oyster)					
Shell	0.0	5.6	10.7	4.8	3.8
Living	3.1	0.0	7.1	66.7	50.0
Littoraria angulifera (mangrove periwinkle)	0.0	0.0	14.3	76.2	11.5
Green filamentous algae	21.9	5.6	17.9	14.3	9.6
Unidentified red algae spp.	0.0	0.0	0.0	0.0	3.8
Mangrove crab	3.1	0.0	7.1	9.5	5.8
Melongena corona (Florida Crown Conch)	0.0	0.0	0.0	9.5	0.0
Assemblage sites					
Unidentified mussel spp.	91.4	8.6	0.0	0.0	0.0
Unidentified barnacle spp.					
Shell	33.3	0.0	66.7	0.0	0.0
Living	21.0	8.9	18.5	14.5	37.1
Crassostrea virginica (American oyster)					
Shell	0.0	14.3	42.8	14.3	28.6
Living	2.2	0.0	4.7	32.6	60.5
Littoraria angulifera (mangrove periwinkle)	0.0	0.0	15.4	61.5	23.1
Green filamentous algae	33.3	4.8	23.8	14.3	23.8
Unidentified red algae spp.	0.0	0.0	0.0	0.0	100.0
Mangrove crab	12.5	0.0	25.0	25.0	37.5
Melongena corona (Florida Crown Conch)	0.0	0.0	0.0	100	0.0

Table 11. Incidental species sampled or observed during sampling in Clam Bay

Species		Sampled	Obs	Upper Clam Bay	Upper Tributary	Inner Clam Bay	Lower Tributary	Lower Clam Bay
Sponge	*Porifera*	X						X
Atlantic Bay Scallop	*Argopecien irradians*	X				X		
Portunid Crab	*Crustacea*	X						X
Blue-green algae	*Cyanobacteria*	X						X
Unidentified Bivalves	*Mullusca*	X	X	X	X	X		X
Glass eel	*Anguilla rostrata*	X						X
Mussels	*Mytildae*	X		X	X	X		
Shrimp	*Penaeidea*	X						X
Quahog	*Mercenaria mercenari*	X						X
Atlantic Oyster Drill	*Urosalpinx cinera*	X						X
Duckweed	*Lemnaoidae*	X				X	X	X
Whelk	*Melongenidae*		X	X				
West Indian Worm Snail	*Vermicularia fargoi*		X					X
Clam Shell	*Mullusca*		X	X		X		X
Lace Murex	*Chicoreua florifer dilectus*		X					X
Florida Fighting Conch	*Strombus alatus*		X				X	X
Horse Conch	*Pleuroploca gigantea*		X					X
Blue Crab.	*Callinectes sapidus*		X					
Various Crabs	*Crustacea*		X	X		X	X	X
Tunicates	*Ascidiacia*		X					X
Algae, Bacteria, Epiphyton		X		X	X	X	X	X

Figure 1. Map of the Clam Bay estuarine complex in eastern Collier County, Florida. The green polygons and lines delineate the benthic habitat study area.

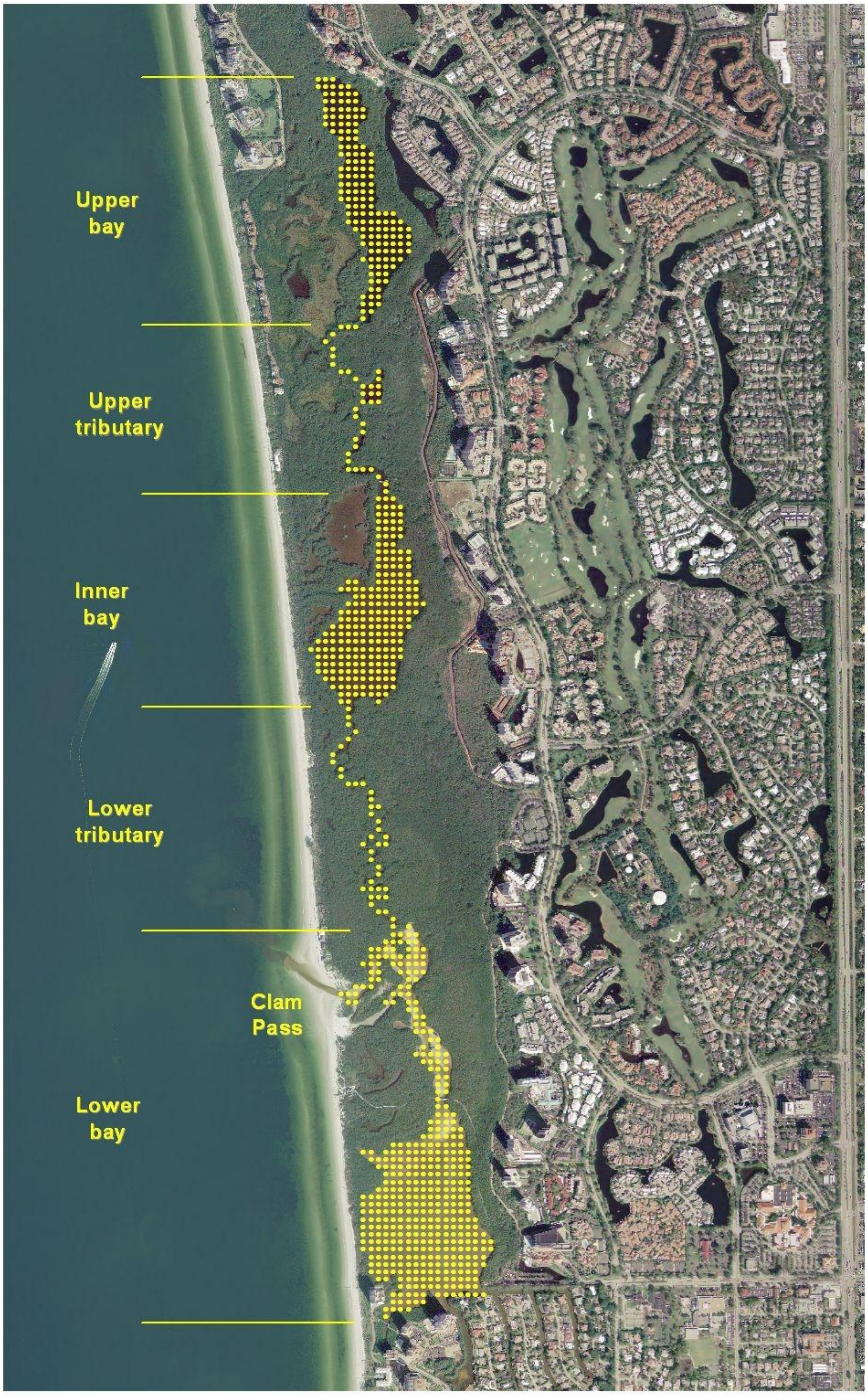


Figure 2. Sampling Sites

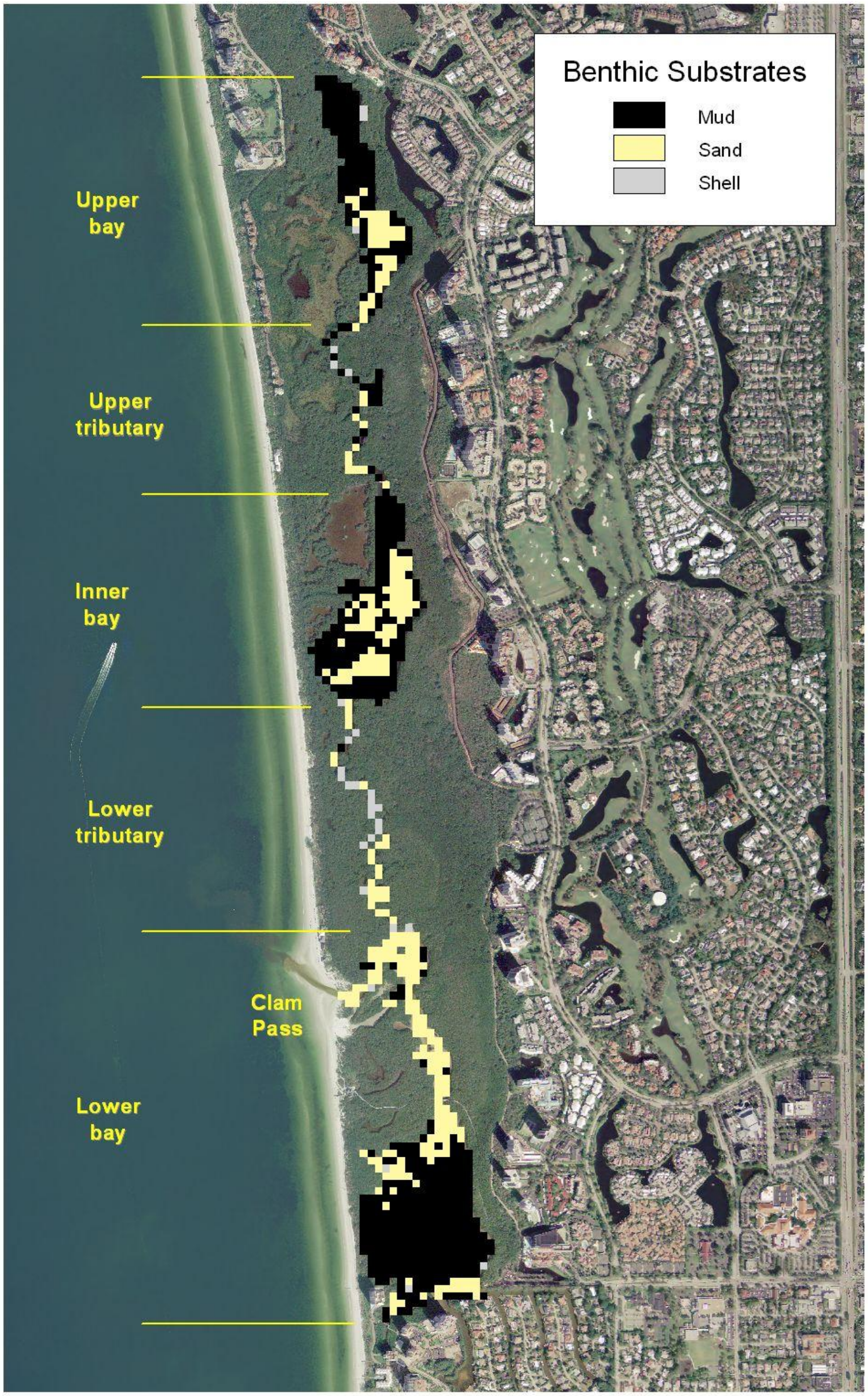


Figure 3. Habitat map of primary benthic substrates in the Clam Bay estuarine complex.

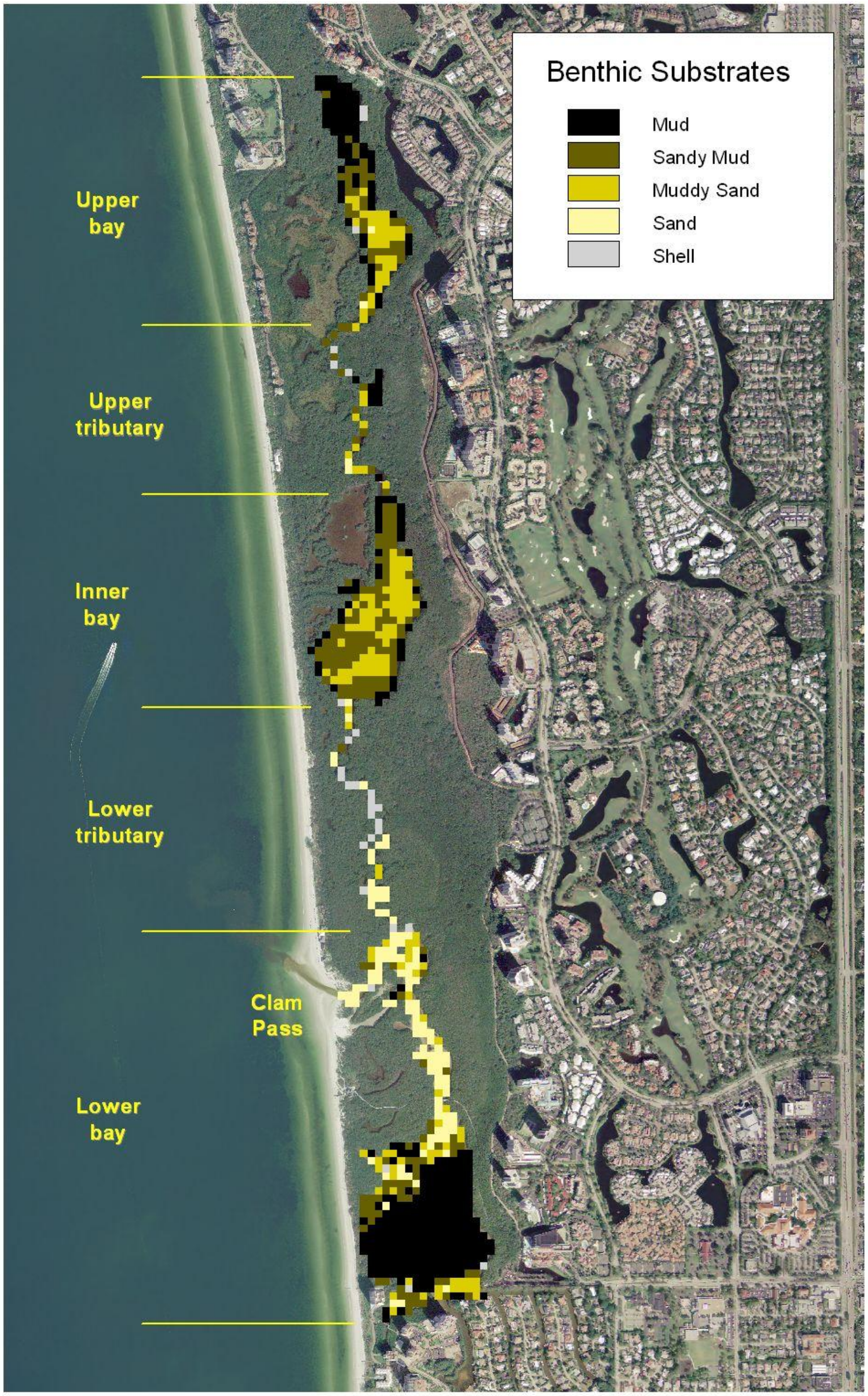


Figure 4. Habitat map of benthic substrates in the Clam Bay complex including secondary substrates of sandy mud (mud with 30-40% sand content) and muddy sand (sand with 30-40% mud content).

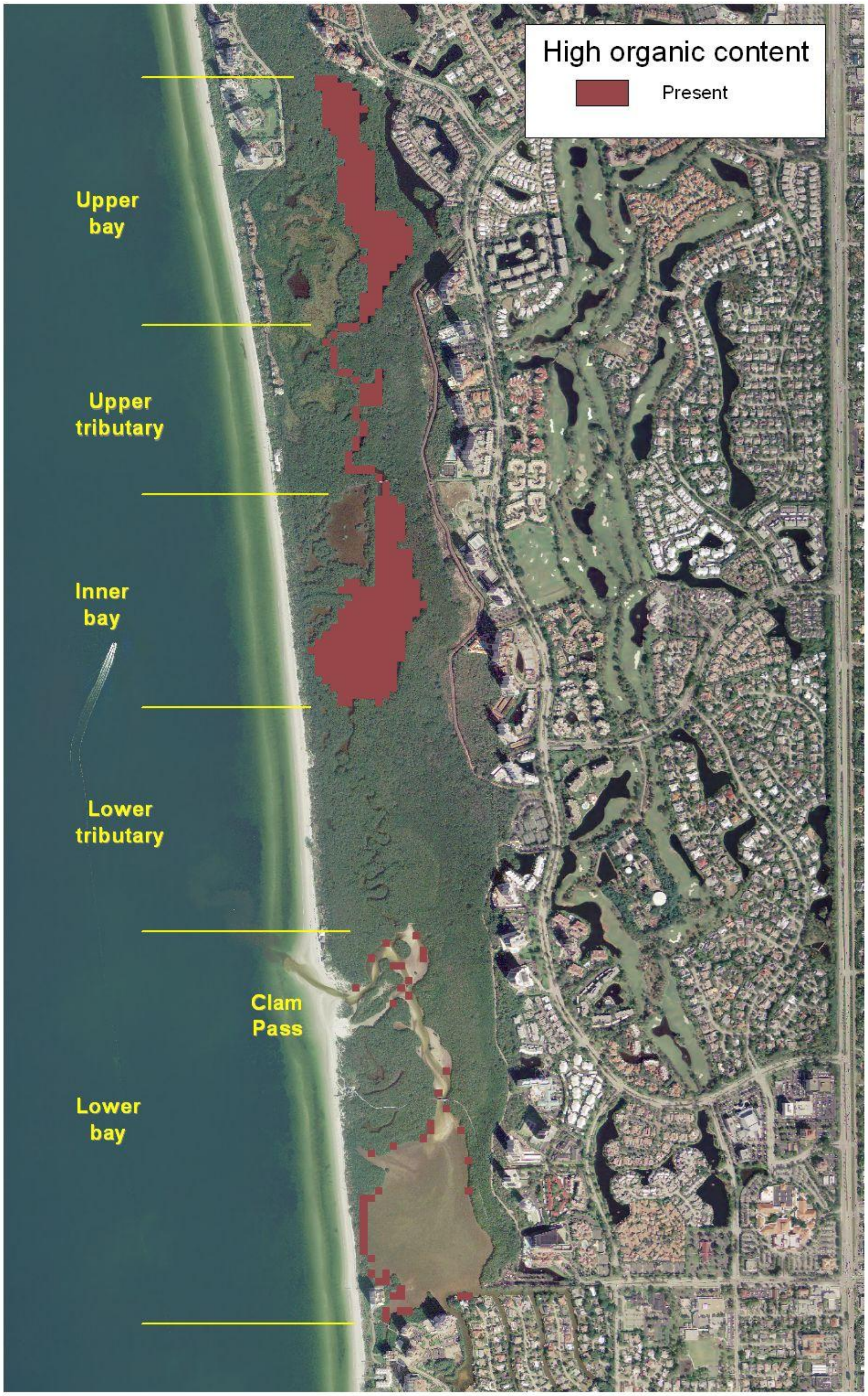


Figure 5. Distribution of sample sites with high organic content (i.e., detritus and/or mangrove leaf litter) in the Clam Bay study area.

Figure 6. Distribution of shoal grass (*Halodule beaudettei* syn. *Halodule wrightii*), and paddle grass (*Halophila decipiens*) in the Clam Bay study area.

Figure 7. Distribution of filamentous green algae, *Acetabularia crenulata, and Caulerpa sertularoides* in the Clam Bay study area.

Figure 8. Distribution of unidentified species of red algae and *Acanthophora spicifera* in the Clam Bay study area.

Figure 9. Distribution of unidentified polychaete worm tubes and mud tubes in the Clam Bay study area.

Figure 10. Distribution of shell-encrusted polychaete tubes and trumpet worm (*Pectinaria gouldi*) tubes in the Clam Bay study area.

Figure 11. Distribution of American oyster (*Crassostrea virginica*), pointed venus clam (*Anomalocardia auberiana*) and stout razor clam (*Tagelus plebeius*) in the Clam Bay study area.

Figure 12. Distribution of Florida crown conch (*Melongena corona*) and grass cerith (*Bittiolum varium*) in the Clam Bay study area.

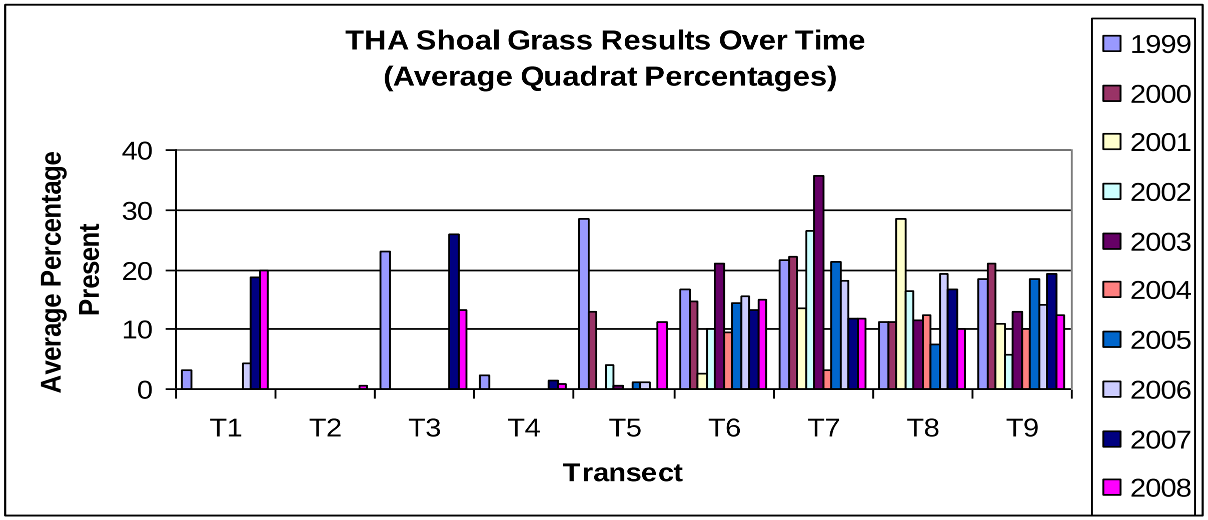
Figure 13. Distribution of heart urchin (*Moira atropos*) and brittlestar (*Ophiophragmus filograneus*) in the Clam Bay study area.

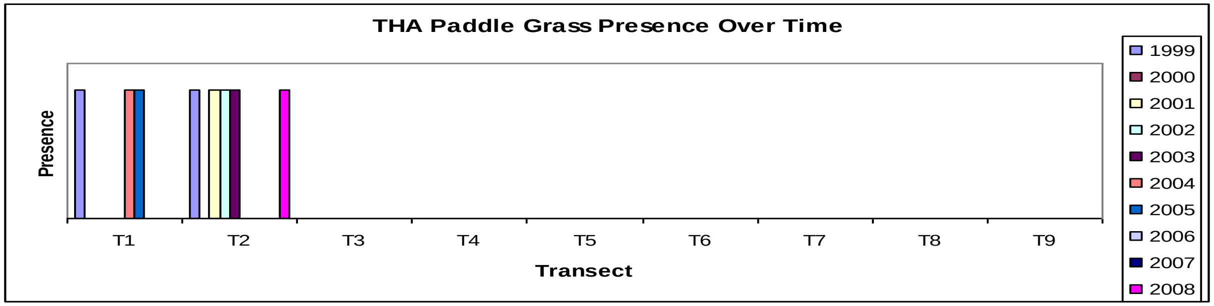
Figure 14. Distribution of unidentified species of mussel and American oyster (*Crassostrea virginica*) on mangrove prop roots in the Clam Bay study area.

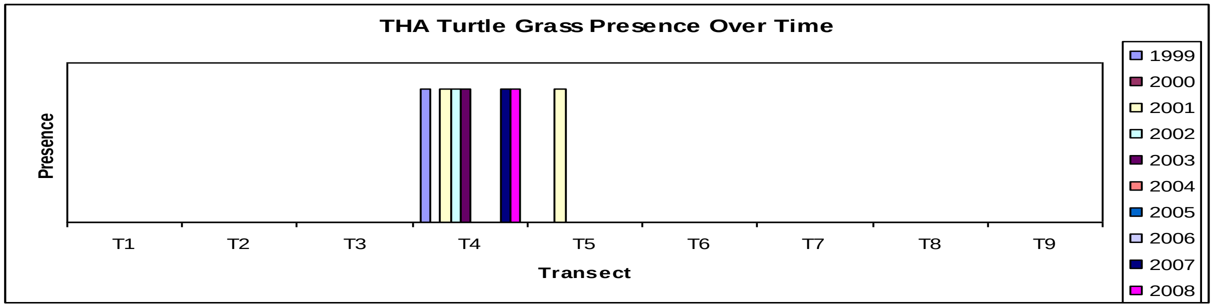
Figure 15. Distribution of mangrove periwinkle (*Littoraria angulifera*) on mangrove prop roots in the Clam Bay study area.

Figure 16. Distribution of filamentous green algae and unidentified species of red algae on mangrove prop roots in the Clam Bay study area.

Figure 17. Distribution of unidentified species of barnacle and mangrove crab on mangrove prop roots in the Clam Bay study area.







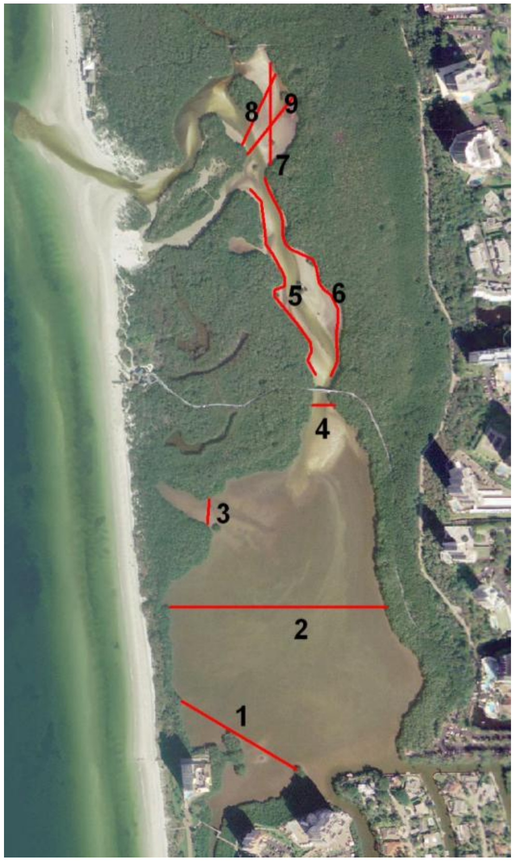


Figure 18: THA Seagrass Results Overtime.

Extrapolated from THA Clam Bay Restoration and Management. Biological Annual Monitoring Reports.

Figure 19. Clam Bay Seagrass Mapping Over the Years 1992-1999

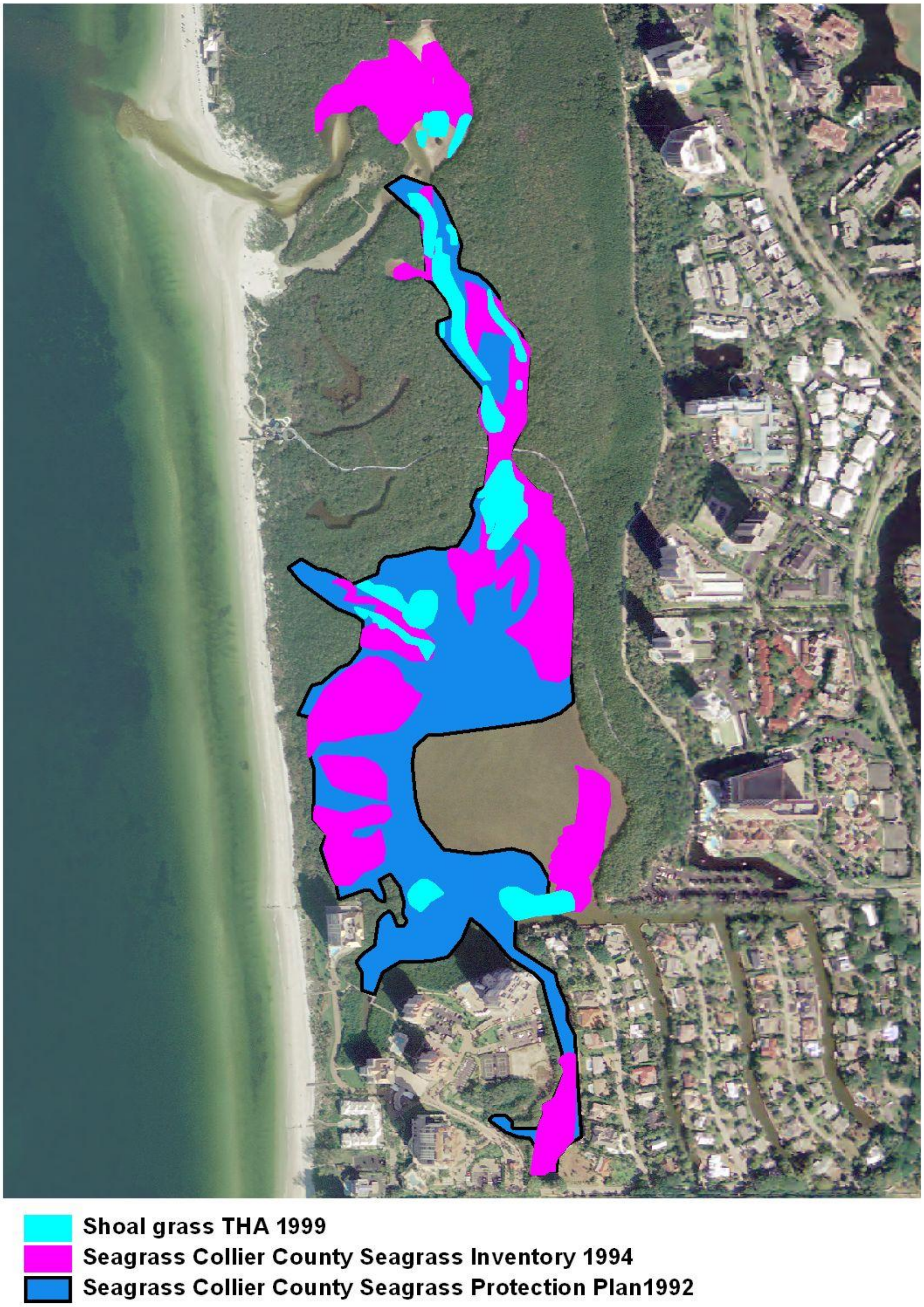


Figure 20. Clam Bay Seagrass Mapping Over the Years 2007 – 2010.

Appendix 1: Documented Species

The following appendix describes the macrobenthic species that were sampled or observed during this study.

The following references were used as source material in compiling this Appendix:

Alfaro, A.C. 2006. Benthic macro-invertebrate community composition within a mangrove seagrass estuary in northern New Zealand. Estuarine, Coastal and Shelf Science 66: 97-110.

Biber, P.D. 2007. Short Communication Hydrodynamic transport of drifting macroalgae through a tidal cut. Estuarine, Coastal and Shelf Science 74: 565-569.

Bright, D.B. and Hogue, C.J. 1972. A Synopsis of the Burrowing Land Crabs of the World and List of their Arthropod Symbionts and Burrow Associates. Natural History Museum Los Angeles. Number 220.

Burkholder, J.M., Tomasko, D.A. and Touchette, B.W. 2007. Seagrasses and eutrophication. Journal of Experimental Marine Biology and Ecology 350: 46–72.

Cannicci, S., Burrows, D., Fratini, S., Smith III, T.J., Offenberg, J. and Dahdouh-Guebas, F. 2008. Review Faunal impact on vegetation structure and ecosystem function in mangrove forests: A review. Aquatic Botany 89: 186–200.

Chen, J., Ye, Y and Lu, Chang-Yi. 2007. Changes of macro-benthic faunal community with stand age of rehabilitated *Kandelia candel* mangrove in Jiulongjiang Estuary, China. ecological engineering 3 1: 215–224.

Collado-Vides, L., Caccia, V.G., Boyer, J.N. and Fourqurean, J.W. 2007. Tropical seagrass-associated macroalgae distributions and trends relative to water quality. Estuarine, Coastal and Shelf Science 73: 680-694.

Gosner, K. 1976. A Field Guide to the Atlantic Seashore. Houghton Mifflin Co. Boston, MA. pp. 329.

Hillson, C.J. 1977. Seaweeds. Keystone Books. The Pennsylvania State University Press. University Park and London. pp.194.

Iez, D., Secilla, A., Santolaria, A. and Gorostiaga, J.M. 1999. Phytobenthic Intertidal Community Structure Along an Environmental Pollution Gradient. Marine Pollution Bulletin Vol. 38, No. 6, pp. 463 -472.

Kaplan, E. H. 1988. Peterson Field Guide: Southeastern and Caribbean Seashores. Houghton Mufflin Company. New York, NY. pp. 425.

Lindquist, E.S., Krauss, K. W., Green, P.T., O'Dowd, D. J., Sherman, P.M. and Smith, T. J. III. 2009. Land crabs as key drivers in tropical coastal forest recruitment. Biol. Rev. 84: 203–223.

Littler, D.S, Littler, M.M., Bucher, K.E., and Norris, J.N. 1989. Marine Plants of the Caribbean. A Field Guide from Florida to Brazil. Smithsonian Institution Press, Washington D.C. pp 263.

Marsden D. and Macleren, S.R., 2010. Short-term study testing the resilience of an estuarine bivalve to macroalgal mats Resilience of an estuarine bivalve. Hydrobiologia 649:217–229.

Nagelkerken, I, Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M. Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A. and Somerfield, P.J. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review. Aquatic Botany 89:155-185.

Overton, A.S. and Rulifson, R.A. 2009. Annual variability in upstream migration of glass eels in a southern USA coastal estuary. Environ. Biol. Fish. 84:29-37.

Rehder, H.A.. Carmichael, J.H., Nehring, C. and Brewer, M.B. 1981. National Audubon Society Field Guide to Norht American Seashells. Chanticleer Press. Alfred A Knopf, Inc. New York. pp. 894.

Reid, D.G., Dyal, P., and Williams, S.T. 2010. Global diversification of mangrove fauna: a molecular phylogeny of Littoraria (Gastropoda: Littorinidae). Molecular Phylogenetics and Evolution 55: 185–201.

Rookery Bay National Estuarine Research Reserve. 1996. Effects of mosquito control pesticides on the survival of fiddler crabs. Available: http://www3.csc.noaa.gov/rookerybay/rsrcmgt/enviro/methods.htm.

Sweat, L.H. 2009. Species Inventory Smithsonian Marine Station at Fort Pierce. Smithsonian Institution.

Turner, R.L. and Meyer, C.E., 1980. Salinity Tolerance of the Brackish-Water Echinoderm *Ophiophragmus filograneus* (Ophiuroidea). Marine Ecology – Progress Series Vol 2: 246-256.

Volety, A.K . 2008. Effects of salinity, heavy metals and pesticides on health and physiology of oysters in the Caloosahatchee Estuary, Florida Ecotoxicology 17:579–590.

Volety, A.K., Savarese, M., Tolley, G., Arnold, W.S., Sime, P, Goodman, P, Chamberlain, R. H., and Doering, P. H. 2009. Eastern oysters (*Crassostrea virginica*) as an indicator for restoration of Everglades Ecosystems. Ecological Indicators 9: 120-136.

Wang, C. and Tzeng, W. 1998. Interpretation of geographic variation in size of the American eel *Anguilla rostrata* elvers on the Atlantic coast of North America using their life history and otolith aging.). Marine Ecology – Progress Series Vol 168: 35-43.

Williams, W. 2008. Florida's Fabulous Seashells and Seashore Life. World. Publications. Hawaiian Gardens, CA. pp. 112.

Witherington, B. and Witherington, D. 2009. Florida's Living Beaches. Pineapple Press Inc. Sarasota, FL. pp 325.

SEAGRASSES

SHOAL GRASS: (*Halodule beaudettei* **AKA** *Halodule wrightii***):**
PADDLE GRASS: *(Halophila decipiens)*
TURTLE GRASS: (*Thalassia testudinum*)

Locations Sampled or Observed:

	UCB	UT	ICB	LT	LCB
Shoal grass					X
Paddle grass					X
Turtle grass					

Geographic Range: Shoal grass is found south from North Carolina, along the Atlantic and Gulf Coast, Caribbean, South America, northwest Africa and it has been reported in the Pacific Coast of Mexico and the Indian Ocean. This seagrass typically occurs in calm waters (up to 6 ft) and can tolerate a broad range of light conditions, salinity (up to 60 ppt; optimal range 10-25 ppt) and temperatures (optimal range 20º - 30º C). This species of seagrass is the most euryhaline of the species and can better tolerate salinity and temperature fluctuations and lower light conditions that other seagrasses. It tends to dominate subtidal areas and can tolerate brief periods of exposure. This seagrass can be found on a variety of strata ranging from silty mud to coarse sand and tends to be a pioneer species. Shoal grass often colonizes disturbed areas where conditions are too harsh for turtle and manatee seagrasses to occur.

SHOAL GRASS

Paddle grass occurs in the Gulf of Mexico, West Indies and the Indo-Pacific region, although very little is known about the extent of its distribution since it can exist in very deep waters. These grasses have been reported at depths of 100 meters and can exist in deeper waters than the other seagrass species, although is usually found at a depth of 10-30 meters. This seagrass is stenothermal and can tolerate a broad range of light conditions.

PADDLE GRASS

Turtle grass is found in Florida, Gulf of Mexico, Bermuda, West Indies and Venezuela, and seems

TURTLE GRASS

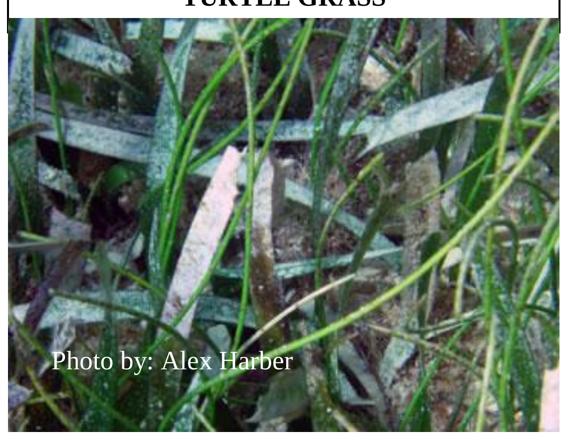


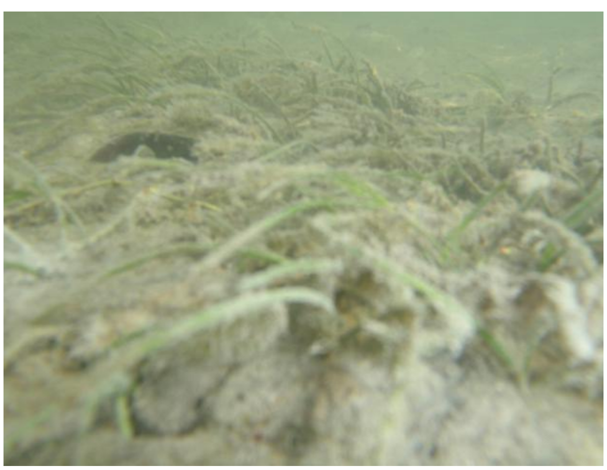
Photo by: Alex Harber

to show a preference for sand and mud, but colonizes on courser substrates. This seagrass is not very tolerant of high turbidity or low salinity and tends to avoid areas of strong wave action. It has been found in depths of as deep as 100 ft in clear water and up to 6 ft in murky conditions. Water clarity is the most important factor in determining the distribution of turtle grass. It can be found in shallow water but tends to dislike areas that are exposed at low tide. It is typically a climax species. Turtle grass is likely limited in its northern distribution by temperature. In the Gulf of Mexico this grass can endure warm waters, but along the eastern seaboard temperatures of greater 40ºC will kill the leaves. The optimal temperature range for this species is estimated at 30º C. This species does not tolerate extreme salinity fluctuations and salinity less than 20 ppt will have negative impacts and although this is a stenohaline species, the optimal range seems to vary with location.

Description: Shoal grass has long stalks that branch into clusters of flat grasslike leaves that extend to approximately 40 cm long, often with broken tips. Paddle grass consists of tiny thin stems that arise from rhizomes, each with two paddle shaped leaves that have a conspicuous mid rib. Turtle grass is the largest species found in Florida, consisting of clumps of broad flat leaves that often extend 30 cm or more from a dense rhizome system.

Ecology: Seagrasses are autotrophs that depend on light for photosynthesis. They are a major source of primary production and function as habitat, nursery areas, shelter and food for various ecologically important flora and fauna including over 120 macroalgal species, macrobenthos (decapods, amphipods, and epiphytes), seaturtles, parrotfish, sturgeon, sea urchins, queen conchs and manatees. Seagrasses also help to promote water clarity as the roots and rhizomes stabilize bottom sediments.

Seagrasses are an extremely important to estuary ecosystems and are one of the most productive areas in the oceans, functioning at the base of the food chain. Anthropogenic disturbances have increased nutrient eutrophication that has degraded many coastal waters and has been linked with seagrass disappearance worldwide. Compounding the problem sediment loading and resuspension often accompanies nutrient enrichment causing decreased light conditions, which has adverse impacts on seagrass beds.



Shoal Grass in Lower Clam Bay

MACROALGAE

GREEN ALGAE :
Green filamentous algae (unknown sps.)
Caulerpa sertularoides
Acetabularia crenulata

Locations Sampled or Observed:

	UCB	UT	ICB	LT	LCB
Green filamentous algae	X	X	X	X	X
Caulerpa sertularoides					X
Acetabularia crenulata			X		


GREEN FILAMENTOUS ALGAE

Geographic Range:
Green algae are typically found in the tropics and tend to proliferate on reefs and prop roots or in areas where nutrients are high and waves are low. They are tolerant of stressful conditions and they can be used as indicators of freshwater inflows or pollution. ***Caulerpa sertularoides*** is typically found in Florida and south to the tropics. It can form large colonies in sandy areas and is usually found in shallow water, but can exist in deep water. ***Acetabularia crenulata*** commonly occurs in shallow waters in protected areas of mangrove forests and can become established on mangrove roots, seagrass blades, limestone, shells, coral or stones.

Caulerpa sertularoides

Photo By: Aqua Guide.net

Description: Green Algae comprise a group of autotrophs that contain many species and have variable green coloration. Green algae have chloroplasts containing chlorophyll a and b which gives the plant its green coloration. ***Caulerpa sertularoides*** has featherlike flat branches that are dark to olive green in color. ***Acetabularia crenulata*** is often referred to as mermaid's wineglass as it has long stalks upon which branchlets form delicate tiny cups or delicate funnel-like discs. Their stalks have a tendency to become encrusted, which allow the stalks to sit upright and give them a whitish green coloration.

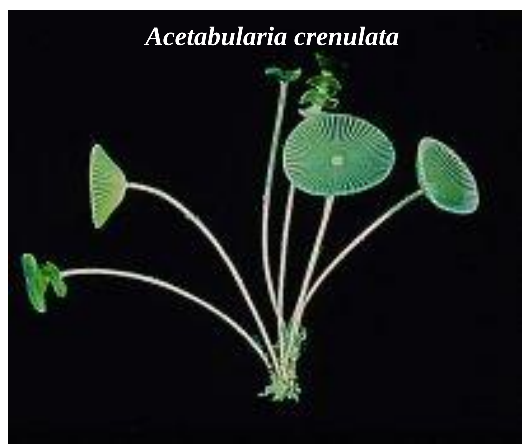

Acetabularia crenulata

Photo by: BeyondtheOrdinary.net

Ecology: Macroalgae are a fast growing species that react rapidly to increases in nutrients. If this happens the balance shifts in an estuary and macroalgae can replace seagrasses, which are a slower growing species. Macroalgal mats can occur seasonally in some estuaries, although their short or long-term effects on the estuary and other benthic macrofauna is unknown. What is known is that worldwide the presence of algal mats in estuaries has increased in the last 25 years, which could lead to hypoxia, alter the sediment properties and affect the distribution and abundance of macrofauna. Conversely, it has been suggested that low levels of algal mats can actually be good for macrofauna, implying there is a level of mats that becomes detrimental to the benthic community. They are autotrophs that obtain food from photosynthesis.

Green Algae, Epiphytes and Periphyton on Mangrove Prop Roots in Upper Clam Bay

MACROALGAE

RED ALGAE :
Red Drift Algae (*Rhodophyta sps*.)
Spiny Seaweed *Acanthophora spicifera*

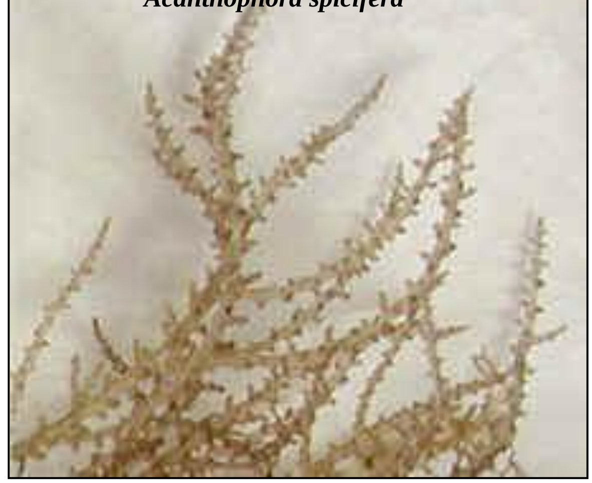
Locations Sampled or Observed:

	UCB	UT	ICB	LT	LCB
Red Drift Algae					X
Acanthophora spicifera					X

RED DRIFT ALGAE

Geographic Range: Rhodophyta can exist in both marine and freshwater habitats although mostly marine. Spiny seaweed is a member of the Rhodophycean alga's that has a wide distribution in the tropics and subtropics in the tidal and subtidal zones. It can occur on a variety of strata from hard bottom to epiphytic on other algae to free drifting. It can occur as a single component or a large mass. It is widely found on Florida's shallow reef flats or in shallow waters of 1-8 meters in depth. It can tolerate high salinity, but generally increases at lower salinities and is commonly found in saline waters of 32-35 ppt.

Description: Red algae are one of the oldest groups of eukaryotic algae made up of multicellular, mostly marine species, including seaweeds. They possess phycobiliproteins, which are accessory pigments that give them their red coloration and a double cell wall often made of pectin, which is used in the manufacturing of agar.



Acanthophora spicifera

Photo by: K. Hill

Spiny seaweed consists of irregularly shaped branchlets that are hooklike. These branches are very brittle and break off easily. This seaweed is highly variable in color and is usually red, purple or brown and is usually around 25 cm in length. Its abundance is based on nutrient availability and herbivory. This seaweed can be invasive as it can adapt to a wide range of hydrologic conditions.

Ecology: Red drift algae and spiny seaweed are autotrophs that obtain and store starches from photosynthesis. They are commonly found in south Florida estuaries. These algal species move in accordance with tidal and wind currents and typically have their own invertebrates and fish species that are found in association and thus drift along with the algae. This passive movement creates an important dispersal mechanism for both the plants themselves and their associated fauna. Increases in communities of unattached drift algae are common in areas of high nutrients, light and low energy conditions common to sheltered bays and estuaries.

Red algae are primary producers and provide habitat and food for a variety of organisms. Additionally red algae are important sources of food, particularly for Southeast Asians, and also suspected of having medicinal benefits.

ECHINODERM

HEART URCHIN: *Moira atropos*

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: This urchin is found north to Cape Hattaras, N.C. and south into the tropics. It is found in shallow water burrowed in substrates of mud or sand (prefers soft mud).

Description: The heart urchin is an egg or heart shaped echinoderm. Its test (exterior covering) is very fragile made of ten fused plates scattered with tiny holes and has five radiating grooves. In life it has a layer of short gray to brownish fine spines that form bumps once the spine has been discarded or broken off and in death its tests are white.

Ecology: Urchins are primarily particulate feeders, but can consume small polychaete worms and small crustations. They are also scavengers and have been known to intake small bits of shrimp. These urchins filter the water by trapping debris in their mucus and are known to clean algae off the surface of aquariums. Urchins in general are popular food sources in Japan, Caribbean and Florida Keys and their tests are often sold as decorative items.

BRITTLE STARS: *Ophiophragmus filograneus*

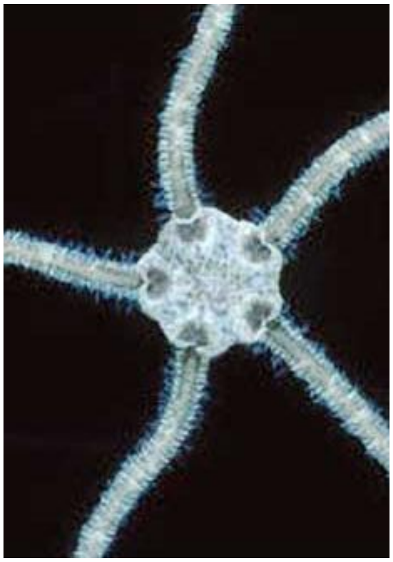


Photo by: D. Pawson

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay: X

Geographic Range: Although Brittle Stars are found worldwide, the species *Ophiophragmus filograneus* is exclusively subtropical and has only been reported in shallow brackish waters estuaries of Florida in association with mud or sand, under rocks and occasionally seagrass beds. They can tolerate brackish water, which is not common in other echinoderms.

Description: The brittle star is an echinoderm that has five long thin serpentine arms attached to a pentagram shaped center and are closely related to starfish. They are green or gray and sometimes yellow or black with darker highlights and arm bands. They are mobile and can crawl along the sediment or use their flexible regenerative arms to "swim".

Ecology: Brittle stars are both predatory in nature consuming polychaete worms and small crustations, deposit detritus feeders, and scavengers. *Ophiophragmus filograneus* is an important component in the diet of many benthic-feeding organisms such as stingrays, shrimp, crabs, flatfish and other benthic predators.

MULLUSCS

OYSTERS: *Crassostrea virginica*

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: The American Oyster is found throughout temperate and subtropical latitudes of the western Atlantic and Gulf of Mexico and occurs over a broad range of temperatures and salinities (0-42 ppt (optimum 14-28 ppt)).

Description: The oyster is a bivalve gastropod mollusc that has a hard calcium-carbon shell that protects it from predation. The shell is variable in shape, rough and uneven and the lower valve cements itself to hardened material. The shell is grayish to yellow-white, sometimes with red-purple rays.

Ecology: Oysters are filter feeders and provide shelter and habitat for other organisms as they create reef habitat. Oysters provide a food source for other organisms (over 303 species that depend, either directly or indirectly, on oyster reefs for sustenance). Oysters can filter 4–40 liters of water per hour per oyster, thereby removing contaminants, organic debris and sediment from the water column and in the process increasing light penetration and helping to maintain water quality. Oysters have important commercial value in many parts of the world and provide habitat for many species that have commercial and recreational value in Southwest Florida.

MUSSELS: *Mytildae*

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay:

Geographic Range: Marine mussels are found globally in the low and mid tidal zone of temperate and tropical seas and intertidal areas, quiet bays, saltmarshes and some species are even found in hydrothermal vents.

Description: The mussel is a bivalve mollusc that has a thin-shelled calcium-carbon shell that protects it from predation and desiccation. The shell is made of two hinged halves joined together by a ligament and can be ovate, fan shaped or elongate or oblong, smooth or radially ribbed. They can live in the open, attached to hardened material, while others burrow into rocks, sand or gravel. They attach to firm surfaces by means of strong byssal threads and can attach themselves to pilings and roots. Mussels are often found in clumps and tend to reside lower in the water in complex assemblages of bivalves.

Ecology: Mussels are filter-feeders that feed on plankton and other microscopic organisms which are floating in the water. They can be an indicator of degraded environmental conditions as they can proliferate in these areas that other mulluscs tend to avoid. Mussels provide a food source for other organisms such as seastars, predatory marine mulluscs, otters, raccoons, and some bird species. Mussels have important commercial value in many parts of the world and provide habitat for many species that have commercial and recreational value in Southwest Florida.

CLAMS

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary:
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay: X

Geographic Range: Clams are found worldwide.

Description: Clams are bivalve mulluscs that burrow in the sediment and respire by means of siphons. Water containing oxygen and food particles enters through an incurrent siphon and waste-containing water is expelled through an excurrent siphon. The shell can vary in shape but has two matching sides that are held together by a hinge joint and ligament.

Ecology: These bivalves are filter feeders. Clams have important commercial value in many parts of the world and provide habitat for many species that have commercial and recreational value in Southwest Florida.

RAZOR CLAMS: *Tagelus plebeius*
Aka Stout tagelus clam

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay: X

Geographic Range: The Razor Clam is found from southern Massachusetts to the West Indies and Brazil, but prefer warmer waters.

Description: Razor clams are bivalve molluscs that have a hard calcium-carbon shell that protects it from predation. It has an elongated shell with rounded ends that is thick and lumpy with smooth growth lines and can be white, ivory or light gray in color. These clams frequent sand and/or mud substrates and prefer closed lagoon systems.

Ecology: Razor clams are particulate filter feeders that filter out suspended particles from the water column improving water quality and are prey for fish and other gastropods.

POINTED VENUS CLAMS:

Anomalocardia amberiana
These clams are sometimes referred to as cockles.

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay: X

Geographic Range: The Pointed Venus Clam is found from southern Florida to Texas and Mexico in intertidal waters.

Description: Pointed Venus Clams are bivalve molluscs that have a hard calcium-carbon shell that protects it from predation. It has an elongate ovate shell with a pointed posterior (somewhat triangular in shape) with concentric ribs that is glossy greenish white to grey or tan or brownish white often with grey or blue with a white brown or pale lavender interior. These clams prefer to burrow in muddy sands of coastal lagoon mangrove systems.

Ecology: Pointed Venus clams are particulate filter feeders that filter out suspended water from the water column improving water quality and are prey for fish and gastropods.

SCALLOPS:
Argopecien irradians

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay:

Geographic Range: Scallops are found worldwide and occur in muddy sands and seagrasses in shallow waters.

Description: American Bay scallops are free swimming bivalves that have a hard calcium-carbon shell that protects it from predation. They have fan shaped, broadly ovate shells with 17-18 ribs that appear as a fluted pattern and come in a variety of colors although white, gray-brown or orange are the most common. Some scallops are active swimmers, some of which migrate, while other species are more sedimentary and attach themselves to substrate.

Ecology: Scallops are scarce in Florida due to overharvest and habitat loss and thus are not a viable commercial enterprise anymore, although they are still a commercial venture in other parts of the world. Scallops are filter feeders that prey upon plankton and remove organic debris from the water improving water quality. Scallops provide a food source for other organisms such as gastropods, squid, seastars, rays and crabs. Scallop populations have declined in the United States due to a variety or combination of factors including: degraded water quality, coastal development, reduction in seagrasses and overfishing of sharks (as sharks decline, rays increase and consume more scallops). The Atlantic sea scallop is currently recovering from over fishing.

QUAHOG: *Mercenaria mercenari*

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: Quahogs are found from Canada to Florida and prefer salinities of 18-26 ppt. These clams are found in sand or mud in shallow bays, lagoons or inlets

Description: Quahogs are bivalve molluscs that have a thick hard calcium-carbon ovate shell that protects it from predation. These clams are large and can reach sizes of up to 4 inches or more. Its age can be determined by counting the number of growth rings on the shell. The shell is white or grayish yellow often with brown rings.

Ecology: Quahogs are filter feeders sieving microscopic plankton and provide a food source for fishes and crustaceans. Quahogs can filter a gallon of water per hour per clam, thereby removing contaminants, organic debris and sediment from the water column and in the process increase light penetration and help to maintain water quality. Quahogs have important commercial value in many parts of the world and provide habitat and a food source for many species that have commercial and recreational value in Southwest Florida.

GRASS CERITH: *Bittiolum varium:*

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: The Grass Cerith is a subtropical to tropical species that is found on the east coast of the United States from Maryland to the Keys, from the Gulf Coast to Texas and south to Caribbean and Brazil. It occurs in lagoons and estuaries with subtidal sandy bottoms or seagrass. The Grass Cerith is one of the two most abundant mulluscs in Florida. These ceriths seem to be temperature driven as they burrow into the bottom sediments during the winter months. They can tolerate salinity as low as 10 ppt.

Description: The grass cerith is a small cerithiid gastropod mollusc with an elongated slender or turreted shell with whirls and a pointed spire that protects it from predators. The intersections of the spiral lines form raised nodes. Coloration is varied from reddish to bluish-black to gray-white to light to dark browns.

Ecology: The grass cerith is a micrograzer that feeds on diatoms, algae, detritus and other epiphytes found in seagrass and the sediment and are a primary and preferred food source for juvenile blue crabs. Due to their high abundance ceriths are important grazing faunal part of the benthic community and is also a dietary resource for benthic predators**.**

FLORIDA CROWN CONCH: *Melongena corona*

Photo by Lynn Zurik

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay: X
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: The Florida Crown Conch is found in the subtropics of Florida and eastern Alabama, throughout the West Indies and South America. It occurs in muddy sand of shallow, quiet bays often in intertidal areas among mangroves. It is very cold sensitive and dislikes high energy areas.

Description: The crown conch is a carnivorous gastropod with a large body whirl and a wide aperture that tapers into the siphon canal. It has one or more rows of spines that are crown-like in appearance. The shell has spiral bands of blue-gray or brown and has hollow spikes that may appear as nubs, although they are usually spiky.

Ecology: Crown conchs are opportunistic scavengers that feed on dead fish, crabs, other mulluscs and detritus. It also attacks and feeds on living bivalves. In turn this conch is preyed upon by larger gastropods such as the Florida horse conch and lace murex.

FLORIDA FIGHTING CONCH:
Strombus alatus

Photo by: Seashell.com

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: Florida Fighting Conchs are found from North Carolina to Florida, the Gulf Coast to Texas and Mexico in sandy shallows often near seagrasses on low energy beaches and estuaries.

Description: The Fighting Conch is a gastropod that has a stout thick shell that varies in color from pale yellow to chestnut brown and can have scattered spots or zigzags. The shell whirl has blunted knobs on fine spiral cords.

Ecology: Fighting conchs are herbivorous and feed on detritus and algae, sometimes in “herds” or large colonies.

HORSE CONCH: *Pleuroploca gigantea*

Photo by: Seashell.com

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: The Horse conch is found along the Atlantic Coast from North Carolina south to the Gulf and Yucatan. It prefers to live in sand, but is also found in weeds or mud flats in the low intertidal to shallow subtidal areas.

Description: The horse conch is not actually a conch but a member of the tulip family. It is a spindle-shaped, extremely large marine gastropod mollusc that is grayish white to salmon orange. The horse conch has a hard calcium-carbon shell with knobby whirls and a long conical spire that protects it from predation. It is the largest snail in North America.

Ecology: Horse conchs are predatory carnivorous animals that feed on other marine gastropods such as whelks, murex, pen shells and other conchs. At times this species can be cannibalistic. Its shell is popular for shell collectors and is the Florida state seashell. This animal is also sometimes used for human consumption.

LACE MUREX
Chicoreua florifer dilectus

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: Lace Murex prefers sandy, muddy or coral rubble and is found intertidally or in shallow water. This species ranges from North Carolina to Florida and the Gulf Coast to Panama.

Description: The murex is a gastropod whose shell is elongated with a conical spire. It has body whorls adorned with three varices with hollow spires that are frond-like and resemble lace. This murex shell is usually white to brown and the soires range in color from white to black.

Ecology: These gastropods are carnivorous and feed on other gastropods, worms, corals and other invertebrates and barnacles by boring holes in their preys outer shell or carapace.

WHELK: *Melongenidae*
Commonly referred to a sea snails

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay:

Geographic Range: Whelks are found in temperate and tropical waters in sandy shallows or sandy muddy bays.

Description: Whelks are medium to large sized gastropod mulluscs, with both axial and spiral ridges on their shells. They have large body whirls that are knobbed with a wide aperture tapering to a long siphon canal and come in a variety of coloration patterns with usually a white background.

Ecology: Whelks are scavengers and some prey on bivalves such as oysters and other mulluscs. Historically whelks were a main source of food for humans and is still today. They also are prey items for fish and sea stars.

WEST INDIAN WORM SNAIL:
Vermicularia fargoi aka Vermicularia spirata

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: These gastropods range from Southwest Florida to the Caribbean. They are not anchored and move freely in the sediment.

Description: These worm snails make coiled auger-like shells much like the tube-building annelid worms, except their shells have 3 layers with a glossy nacre on the inside of the shell. The shell coils separate as they grow.

Ecology: These worms feed on tiny food particles found in the water.

ATLANTIC OYSTER DRILL:
Urosalpinx cinera

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X


Photo by: Andrew Cohen

Geographic Range: The American Oyster Drill native range extends from the Gulf of St. Lawrence in the northwest Atlantic to south Florida, but has been introduced and spread from British Columbia to England and Washington to California. It typically occurs intertidally in shallow waters of bays and estuaries on oyster reefs, rocks, pilings and seagrass beds.

Description: The oyster drill is a small gastropod that has an oval shaped shell with a pointed spire approximately half the length of the shell and varies in color from gray to purple or yellowish white with brown spiraling ribs.

Ecology: Oysters drills mainly feed on oysters, mussels and barnacles by drilling pin sized holes in the shell. It also feeds on other gastropods and even crabs. Shells found on beaches with circular holes likely were caused by oyster drills. Drills have the potential to impact oyster beds, but they are usually kept in check by factors such as lower salinity. Drills are often credited with keeping the barnacle population in check.

PERIWINKLES:
Littoraria scabra anguliflera

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay: X
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: The periwinkle is found in brackish waters of Southern Florida to Texas, Brazil and the West Indies.

Description: Periwinkles are a mulluscs that are closely associated with mangroves and often referred to as marine snails. They are found on the trunks, branches, roots and foliage of mangroves or other salt tolerant plants where they depend upon the trees for food, shelter, substrate and shade. They can be described as facultative wood-dwellers, as they have a broader range of habitat than other marine snails and can reside on driftwood and sheltered rocks. Their shell is broadly ovate, large, sharp-spiraled, and has yellowish-white to reddish-brown spiral bands.

Ecology: Periwinkles feed on mangrove leaf litter, propagules and algae found on mangrove prop roots and rocks. These snails are an important link in the food chain between estuarine flora and crabs, fish and birds, which prey on them.

CRUSTACEA

PORTUNIDS (Crabs)

More than 70 crab species have been documented along Florida's coastline. Common crabs seen in or near shorelines, estuaries, and the mangrove community include mangrove, fiddler, mud and blue crabs which are usually seen on sandy or muddy areas or mangrove trees, and in marine and estuarine waters. Crabs form an important component of commercial fisheries worldwide. Mangrove crabs are among one of the most ecologically important species in the mangrove forests. Mud crabs, also known as swimmer crabs, and are found mainly on muddy substrates of coastal mangrove systems. Mud crabs are xanthids that encompass a large group of species and families that are found in estuaries, some of which are detailed below.

CRABS: Crustacea

Common Mud Crab: *Panopeus herbstii*
Depressed Mud Crab: *Eurypanopeus depressus*
White Fingered Mud Crab: *Rhithropanopeus harrisii*
Mangrove or Mud Crab: *Ocypodidae (Ucides); Grapsidae;* and *Coenobitidae*
Fiddler Crab: *Uca sps.*
Blue Crab: *Callinectes sapidus*

Locations Sampled or Observed:

	UCB	UT	ICB	LT	LCB
Common Mud Crab				X	X
Depressed Mud Crab					X
White Fingered Mud Crab					X
Mangrove Crab	X		X	X	X
Fiddler Crab					X
Blue Crab				X	X

COMMON MUD CRAB: *Panopeus herbstii*
Also known as the Black-Fingered Mud Crab or Atlantic Mud Crab.

Photo By: of Kathy Hill, Smithsonian

Geographic Range: Common Mud Crabs are found in estuaries and oceans from Massachusetts to Brazil. These crabs prefer muddy substrates in mangrove swamps and oyster beds, but can also be found on jetties, shell or cobble substrates.

Description: This crab is a crustacean that typically has a brownish green or dull grey/brown carapace or exoskeleton that is rounded in front with 4 well developed pairs of legs and 2 stout claws. The appendages that attach to the claws are often spotted and the top and bottom of the claws are usually black to brown and of unequal size. Other types of mud crabs such as the Florida stone crab (*Menippe mercenaria*), strongtooth mudcrab (*Panpeus bermudensis*), Florida grassflat crab (*Neopanope packardii*) are often confused with the Atlantic mud crab due to similarities in appearance.

Ecology: Common Mud Crabs can be solitary or aggregated and are primarily carnivorous preying on species such as oysters, clams, crustaceans, worms, small fish, and periwinkles, although like most mud crabs it is also a scavenger. In turn these crabs are preyed upon by larger fish, birds, and other larger crustaceans.

DEPRESSED MUD CRAB: *Eurypanopeus depressus*
Also known as the Flatbacked Mud Crab

Geographic Range: The Depressed Mud Crab is found in estuaries around the eastern and gulf coasts of the United States and also in Bermuda, the West Indies and Uruguay.

Description: This crab is a crustacean that typically has a carapace or exoskeleton with 4 well developed pairs of legs and 2 claws. Depressed mud crabs are small and sport an oval flattened carapace that is grayish to brown in color. These crabs tend to associate with oyster reefs, which they use to hide from direct sunlight and predators. They prefer shallow water, but are sometimes seen on land.

Ecology: Depressed mud crabs are omnivores that typically feed on detritus, algae, polychaetes, sponges, other crustaceans, amphipods and oyster spat. They are a euryhaline species that tolerates low salinity. They also are known to prey on barnacles, which helps to keep this fouling species in check and in turn these crabs are preyed upon by a variety of species.

WHITE FINGERED MUD CRAB: *Rhithropanopeus harrisii*

Photo: http://www.tarleton.edu/Faculty/dekeith/MudCrab.html

Geographic Range: The White Fingered Mud Crab is found in fresh to brackish water intertidally from Cape Cod to Brazil in shallow water on muddy and sandy substrates. Reports have indicated that this species has spread to European shores along the North Sea.

Description: The crab is a crustacean that typically has a carapace or exoskeleton with 4 well developed pairs of legs and 2 claws (one larger than the other). White Fingered Mud Crabs are non-descript brown to olive-green crabs that can be identified by their white "fingers".

Ecology: White Fingered Mud Crabs are important predators on young oysters, clams and barnacles and in turn are preyed upon by a variety of species. These crabs tend to be more aggressive and can outcompete other crabs for habitat.

MANGROVE MUD CRAB: *Ocypodidae (Ucides); Grapsidae;* and *Gecarcinidae*
Also Known as Land Crabs

Photo by: Anne Kolb

The dominant members of land crabs that reside in the mangroves belong to the families Grapsidae and Ocypodidae, Gecarcinidae. In the Atlantic and Caribbean the Ocypodids (e.g. Ucides spp.) and Gecarcinids (e.g. Cardisoma sps.) are more common than the Grapsids.

Geographic Range: Mangrove Crabs are land crabs that are found worldwide in tropical coastal ecosystems living among the mangroves burrowing in the mud and climbing trees and prop roots. These crabs can stay out of the water for extended periods of time due to physiological, morphological, ecological and behavioral adaptation to terrestrial environments.

Graspids are found in tropical and subtropical coastal areas of mud along mangroves and lagoons, mudflats, coastal marshes and the banks of drying streams. Ocypodids are found typically in tropical and subtropical coasts on sandy beaches, sand-mud and gravel areas from Rhode Island to Brazil, the Mediterranean Sea, and the coasts of Africa, Red Sea, Indo-Pacific, and eastern Pacific from California to Chile. Gecarcoidids are generally found in the Indo-Pacific Islands, tropical and subtropical America, and West Africa in moist or muddy substrates.

Description: The term land crab refers to a group of tropical species which dig well-defined burrows above the normal flooding and flushing action of the tides. Land crabs reduce water loss by creating and inhabiting damp, deep burrows, being active at night or in high humidity. These crabs also have developed respiratory enhancements. Part of their carapace covering the gills can be inflated, and since it is equipped with blood vessels, operates in a way similar to lungs. Graspids generally have a squarish carapace with sides that are usually straight and parallel. They have thick claws that are unequal in size in the male, and the third pair of legs is the longest. Ocypodids have a deep carapace deep that is slightly broader than long or squarish. Their claws are unequal in length and shorter than their legs, and the fourth pair of legs is shorter and thinner than the others. Gecarcoidids are square bodied crabs with stout legs and their claws are equal or nearly equal in size in both sexes.

Ecology: Graspids usually have well defined burrows in muddy, sand or mud-gravel areas that extend from the surface an estimated one meter down to the water table. Some do not construct burrows but live under debris (rocks and roots). Most individuals are solitary, although juveniles can live in the same burrow as an adult. Ocypodids can construct simple to complex burrows in the soft substrates. Gecarcoidids have shallow burrows that are usually not well developed. Land crabs are generally omnivores and can tolerate areas that are high in nutrient concentrations specifically nitrogenous compounds.

Mangrove Crabs are considered a keystone species that are ecologically significant in many different ways. These crabs influence the mangrove community by functioning as ecological filters and influencing community dynamics and forest structure; soil nutrient and carbon availability; decomposition of organic matter, microtopography, soil aeration; nutrient, chemical and physical environmental gradients; and play many other significant roles (Lindquist, et al., 2008).

FIDDLER CRAB: *Uca sps.*

Geographic Range: Fiddler crabs are land crabs that are found from Massachusetts to Florida and are more common in beaches, estuaries and coastal marsh environments.

Photo by: Anne Kolb

Description: Fiddler crabs are crustaceans whose body is usually flat, wide and squarish with a reduced abdomen that lacks a fan tail and has 5 pairs of walking legs 2 of which have claws with one of the claws significantly larger than the other comprising an estimated 65% of its body weight. Their carapace can range in color. Mud fiddlers are usually brown in color with the larger claw having yellowish white to orange coloration; sand fiddlers are pinkish purple with a bright purple patch toward the center of the carapace; and red jointed fiddlers are larger than the other 2 species with a large red claw.

Ecology: Fiddler crabs play a key role in the ecology as they are sensitive to environmental contaminants, particularly insecticides some of which are used for mosquito control. Fiddler crabs are bioaccumulators of contaminants including PCB's, insecticides and fertilizers. These crabs dine on algae and decomposed matter. They are burrowers and like mangrove crabs serve a variety of functions including: soil nutrient availability and mineralization, soil aeration, cordgrass production and decomposition, and they serve as prey items for many species of birds (such as herons and ibis) and fish (such as snook and redfish) and blue crabs.

BLUE CRAB: *Callinectes sapidus*

Photo: http://lobsterfacts.livelob.com

Geographic Range: The Blue Crab is commonly found along the coasts from Massachusetts to Texas although they have also been observed as far north as Nova Scotia and as far south as Uruguay. It resides on the bottom of inshore brackish waters and requires high salinity ocean waters to complete its lifecycle.

Description: The blue crab is a crustacean that has paddle shaped posterior legs and a shell that is twice as wide as it is long with pointed projections on the sides of its carapace. It can live up to three years and it is usually olive or bluish green on the dorsal side and paler on the anterior side with bright blue claws. Their coloration stems from a combination of red and cyan pigments which create the bluish-green color. Blue crabs are quick and can be aggressive when caught. In the winter they migrate from estuaries into deep waters to spawn.

Ecology: Blue crabs like so many portunids are opportunistic scavengers, they are omnivores that will eat both plants and animals. However the blue crab is also known to be a swift predator that consumes mulluscs, fishes, shrimp, lobster, worms and other crabs. Blue Crabs provide a food source for other organisms such as fish, jellyfish, planktivores, birds, and even other blue crabs and they form an association with barnacles that use their shell as substrate. Natural predators of the crab include eels, trout, some sharks, drum, rock fish, cownose stingrays and humans. Blue crabs are harvested commercially for human consumption. They are most valuable commercial species for the Gulf States including Louisiana, West Florida, Texas, Alabama, and Mississippi and are the heaviest harvested crab in the world.

BARNACLES:

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: Barnacles are common and occur worldwide over a broad range of salinities and temperatures.

Description: The barnacle is a type of arthropod belonging to the subphyla crustacea that has a shell of interlocking calcareous plates that conceals the animal and protects it against desiccation. Barnacles cement themselves to a wide range of surfaces from prop roots, leaves, trunks, and twigs to ship bottoms. Barnacles are encrusters in that they permanently attach themselves to hard substances. Barnacle plates are usually whitish, bluish gray or purple in color with darker ridges.

Ecology: Barnacles are suspension feeders that extend feathery appendages into the water column and draw in plankton and detritus to feed upon. They can be indicators of degraded water conditions as they can proliferate in degraded environments. Barnacles are often thought of as a member of the "fouling community" as in overabundance they can negatively affect mangrove prop root growth and can weaken the structural integrity of water craft. Barnacles have a tendency to be outcompeted for substrate by mussels and have adapted to reside higher in the water column where mussels tend to avoid. Barnacles provide a food source for other organisms such as whelks and their larvae are eaten by mussels.

Note: Barnacles residing on the upper part of the prop root and mussels closer to the bottom in Upper Clam Bay

POLYCHAETES

WORM and MUD TUBES:
Polychaeta

Locations Sampled or Observed:
Upper Clam Bay: X
Upper Tributary: X
Inner Clam Bay: X
Lower Tributary: X
Lower Clam Bay: X

Geographic Range: Tube worms are found world wide and can tolerate a broad range of salinities and temperatures.

Shell Encrusted Worm Tube

Description: Worm tubes are prickly, segmented worms with bristles. There are many types of worms and most tend to stay out of sight in bays and burrow in the sand and sediment. **Parchment worm tubes**, (*Chaetopterus variopedatus),* leave behind a whitish, limp, curved paper-like tube that can be up to a foot long when they abandon their casing. Tube worms such as plumed worms (*Onuphidae*) live in soda straw sized tubes that are encrusted with shell and other debris and are referred to as **shell encrusted worm tubes.** Some worms that form short conical tubes of sand or gravel and are open at both ends are referred to as **conical sand tubes.** **Trumpet worm tubes,** *(Pectinaria gouldii)*, also known as ice cream cone worms have a tusk-shaped, tapering sand tube that is very fragile and composed of a single layer of sand grains cemented together with a protein glue. These worms are usually found in the intertidal and subtidal areas of mudflats and are more common in shallow water from the Caribbean to Massachusetts. **Mud tubes** are made from sediments and mucus and are inhabited by a host of different polychaetes.

Ecology: Worm and mud tubes create habitat and food for many organisms such as mulluscs, fish and even sea turtles. Worms are usually filter or deposit feeders that keep the substrate open and free of accumulation of wastes and other solid matter that can accumulate in the water. Shell encrusted worm tubes provide substrate for many benthic species.

Mud Tube

Parchment Worm Tube
Photo by: Joel Wooster

TUNICATES: *Ascidiacia*
Also known as Urochordates and commonly referred to as sea squirts *(Molgula sps.)* and sea pork (*Aplidium stellatum*).

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Photo by: Gulf Specimen.org

Geographic Range: Tunicates are found in seas and in intertidal areas. Tunicates are sessile organisms that commonly attach themselves to pilings, jetties, hulls, rocks, reefs, the backs of large seashells or crabs and can live as an individual or in a colony.

Description: Tunicates have a outer protective covering or tunic that is yellowish green, white, pink, red or purple and usually round and leathery in appearance with two large pores or siphons that form an entrance and exit for water to enter and leave the body cavity. If prodded these organisms will usually squirt water at you.

Ecology: Tunicates are filter feeders that remove food and oxygen from the water current along with detritus and plankton. They are a food source for sea turtles, stingrays and tulip snails. These organisms are very tolerant of polluted water and remove pollutant material from the water column that helps in maintaining water quality. They can remove 95% of the suspended bacteria from the water they filter.

SPONGES: *Porifera*

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: Sponges occur worldwide over a broad range of habitats, salinities, sedimentation and temperatures. They attach themselves to stones, coral or fixed objects.

Photo By; Boris Masis

Description: Sponges are porous multicellular soft-bodied organisms that consist of a jelly like mesohyl material sandwiched between layers of cells. They lack specialized internal organs and rely upon a constant flow of water to obtain food and oxygen and remove wastes. Their "skeletons" are made of glassy spicules made from calcium carbonate or a form of collagen known as spongin. They are sessile organisms that can exist from the intertidal zones to depths of 5 miles or more. Sponges have regeneration properties and are able to reform fragments that have broken off from the main body of the organism. Sponges that inhabit estuaries reside primarily on seagrass, hardbottom and reefs, but can attach to mangrove roots.

Ecology: Sponges are filter feeders that strain out plankton and organic particulates from the water column through a unique method of drawing in water through their pores. Sponges provide food for seastars, sea turtles and fish. Mangroves and sponges have developed a mutualistic relationship that offsets the negative fouling capabilities of sponges. Mangroves provide substrate for the sponge, while the sponge protects the mangrove roots from isopod boring and can increase tree growth by encouraging the formation of adventurous rootlets. Sponges tend to proliferate in degraded environmental conditions. Sponges are often thought as a member of the "fouling community" as in overabundance they can negatively affect mangrove prop root growth.

.

DECOPOD

PENAEID SHRIMP: *Penaeidea*

Photo By: Gulf Specimen Marine Lab

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

Geographic Range: These shrimp tend to prefer muddy or peaty bottoms rich in decaying matter in nearshore waters. Three penaeid species are restricted to the Atlantic seaboard and the Gulf of Mexico.

Description: Shrimp are decapod crustaceans that have a well developed abdomen and fan-like tail with a carapace covering the head and thorax. Penaeids are distinguished from other shrimp in that they have 3 pairs of legs with sharp pincers. Commonly referred to as pink, white or brown shrimp according to its color.

Ecology: These shrimp feed on a variety of different items as they are omnivorous scavengers and opportunists, carnivores, detritus feeders and insectivores dependant on local availability. They are bottom feeders which in turn are fed upon by a wide variety of fish species.

FISH

AMERICAN EEL: *Anguilla rostrata*

The American eel has several distinct developmental stages that include:

- Leptocephali – larva
- Glass eel – juvenile
- Elvers – juvenile
- American eel - adult

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay:
Lower Tributary:
Lower Clam Bay: X

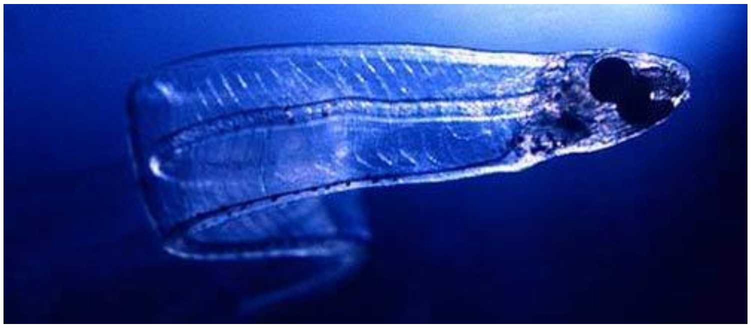


Photo by USFWS

Geographic Range: The American Eel is a catadromous fish found throughout rivers of eastern North and Central America and migrates to the Sargasso in the Atlantic Ocean to spawn. Leptocephali migrate to the continental shelf where they drift in the Florida Current and Gulf Stream. Leptocephali morph into glass eels and enter coastal waters, bays and inlets. Glass eels become elvers in estuaries and enter rivers as adults.

Description: The **glass eel** is wormlike in appearance and is transparent to yellowish brown in color and at this stage is usually less than 4 inches.

Ecology: American eels are declining in response to habitat loss and overfishing. Eels have important commercial value in many parts of the world including Florida and provide food for many species that have commercial and recreational value in Southwest Florida.

AQUATIC VEGETATION

DUCKWEED: *Lemnaoideae*

Locations Sampled or Observed:
Upper Clam Bay:
Upper Tributary:
Inner Clam Bay: X
Lower Tributary:
Lower Clam Bay:

Geographic Range: Worldwide primarily in lakes as it is a fresh water species, but can live in estuaries at lower salinities.

Description: Duckweeds are aquatic plants that float on the water surface. They are simple plants that often lack obvious leaves, but rather employ a plate-like structure that floats on or just below the water surface, with or without rootlets.

Ecology: Duckweed is a high protein food source for many animals from waterfowl to humans as it contains more protein than soybeans. These plants provide cover for many juvenile fish species and aquatic insects. They can be useful in bioremediation as they remove minerals and nutrients (nitrogen and phosphorus) from the water, but if not checked can exponentially explode and can block light penetration needed for grass beds and cause noxious blooms and fish kills.

APPENDIX 2: DEFINITIONS

Abiotic	Non-living
Benthos	A community of organisms which live on, in, or near the sediment, also known as the benthic zone.
Bioindicator	Species that can be used to determine how various conditions in an environment change overtime.
Detritus	Non-living particulate organic material (as opposed to dissolved organic material) typically made up of fragments of dead matter as well as fecal material. Detritus is typically colonized by communities of microorganisms that act to decompose (or remineralize) the material. Detritus of aquatic ecosystems can consist of organic material suspended in water, including mangrove leaf litter.
Ecosystem	It is all the organisms in a given area, along with the nonliving (abiotic) factors with which they interact; a biological community and its physical environment.
Epiphyte	A plant that grows on - is not parasitic to, but rather depends upon another plant for structural support.
Estuary	Estuaries are formed when freshwater mixes with saltwater from the ocean. This mixing of fresh and saltwater creates a unique environment that supports a wide variety of organisms.
Euryhaline	Organisms that are tolerant to changes in salinity and can withstand salinity fluctuations.
Infaunal	Benthic animals that live in the substrate of a body of water, especially in a soft sea bottom. Infauna usually construct tubes or burrows and are commonly found in deeper and subtidal waters. Clams, tubeworms, and burrowing crabs are infaunal animals.
Intertidal	Relating to the region between the low and high tide marks.
Keystone Species	A species that has a disproportionate effect on its environment relative to its biomass. Such species play a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community.
Macroalgae	Multicellular algae (green, blue-green and red algae) having filamentous, sheet or mat-like morphology.
Macrobenthic	Organisms that live on or near the sediment that are larger than ~1mm and are large enough to be seen by the human eye.
Macrofauna	Animals that are larger than ~1mm and are large enough to be seen by the human eye.

Mangrove Fringe	Mangroves that occur in areas directly adjacent to a water body.
Meiofauna	Animals that range is size from ~ 0.1mm to 1mm that live within the sediments. Class size transition between micro and macro.
Microbenthic	Organisms that live on or near the sediment that are typically less than 0.1mm.
Microfauna	Microscopic animals that are typically less than 0.1mm and cannot be seen by the human eye.
Microphotobenthos	Microscopic flora that live on the bottom of a water body.
Productivity	The amount and rate of production which occurs in a given ecosystem over a given time period. It may apply to a single organism, a population, or entire communities and ecosystems. Productivity can be expressed in terms of dry matter produced per area per time (net production), or in terms of energy produced per area per time (gross production = respiration + heat losses + net production). In aquatic systems, productivity is often measured in volume instead of area.
Stenohaline	Organisms that cannot handle a wide fluctuation of salinity.
Subtidal	Marine zone below the intertidal zone that remains submerged at low tide; generally refers to near-shore or coastal areas.