Pinellas County Seagrass Resource Assessment & Monitoring Program

Status Report 1998-2010

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August 2011

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Acknowledgements

Thank you for all of your support, hard work, long days, and dedication!

Will Davis, Andy Squires, Craig Dye, Scott Deitche, Mark Flock, Eric Fehrman, Don Hicks, Robert McWilliams, Jim Meyer, Sue Myers, Cindy Meyer, Ryan Ryczek, Melanie Weed, Natasha Dickrell, Anamarie Rivera, Pamela Leasure, Angela Young, Nancy Page, Phillip Hoffman, and Alice Ketron,.

Walt Avery, Roger Johansson, and John Pacowta from the City of Tampa Bay Study Group;

Paul Carlson and Florida Wildlife Commission;

Kris Kaufman Southwest Florida Water Management District

Melissa Harrison assisting with seagrass assessment.

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Executive Summary

The seagrass resource provides essential functions to the marine ecosystem including nutrient cycling, detritus production, sediment formation, and shelter to increase the productivity of the ecosystem (Dawes et. al., 2004). In an effort to assess and monitor the seagrass resource, Pinellas County participates in a combination of transect monitoring and remote sensing programs. Since 1998, the Watershed Management Section of the Pinellas County Department of Environment and Infrastructure has conducted seagrass resource monitoring in Boca Ciega Bay (BCB) and Clearwater Harbor and St. Joseph Sound (CLW/SJS).

Pinellas County monitors 11 fixed transect sites in BCB in accordance with the Tampa Bay Estuary Program Interlocal Agreement. In CLW/SJS, Pinellas County monitored 14 fixed transect sites from 1998-2005. In 2006, Pinellas County replaced the 14 fixed transects with a stratified random transect monitoring design. The stratified random design included 63 sites in 2006, 65 sites in 2007, and 67 sites from 2008 to 2010. Fourteen of the stratified random transects remained stationary and intersect at the historical monitoring transects. All of the transects were monitored during September, October, and November of each year after the growing season ended. In addition to the transect monitoring program, Pinellas County participates in a cooperative aerial seagrass mapping program managed by the Southwest Florida Water Management District (SWFWMD). The aerial photointerpretation mapping provides acreage estimates for the seagrass resource bi-annually. Results of the seagrass assessment and monitoring program activities:

General Results:

- The prominent seagrass species in the BCB and CLW/SJS consisted of *Halodule wrightii, Syringodium filiforme,* and *Thalassia testudinum*. Various marine algae were also found including ten attached algae and four species of *Caluerpa.*
- The condition of the seagrass varied from poor-very good with the majority of the sites rated as fair-good.

Fixed Transect Results:

- The seagrass abundance and density along the fixed transects remained relatively stable along the BCB and CLW/SJS throughout the monitoring program.
- *Halophila engelmanni* was observed in CLW/SJS along two transects in 2001 and 2002.
- In BCB transects BCB-01 and BCB-04 the seagrass abundance and length of bed increased, and remained relatively stable along the other nine transects.
- In CLW/SJS the length of bed increased at CLW-08, decreased at CLW-04, varied at CLW-05, and remained stable at the other 11 transect locations.
- Some transects in BCB and CLW/SJS showed a temporary decrease in density from 2004-2005, most likely correlated with the hurricane events.

Stratified Random Transect Results

- The seagrass resource in CLW/SJS remained stable and in good condition.
- Density of the seagrass showed little variation.
- The geographic extent of the seagrass resource expands beyond the aerial mapping estimations.
- The study statistically supports the detection of spatial distribution and ecotone by strata, depth zone, and species.

Overall, the Pinellas County seagrass assessment and monitoring activities suggest that the seagrass resource remained stable in BCB and CLW/SJS from 1998-2010. This does not discount the indications of positive and negative variation within the resource. Further information is necessary to determine the spatial and temporal changes in the seagrass resource in relation to water quality, especially in the unstable areas of the resource. This report summarizes the information from the fixed transect and stratified random transect

monitoring activities. It is the recommendation of the Pinellas County Watershed Management staff to continue both the BCB fixed station and SJS and CLH stratified random transect monitoring activities. The SJS and CLH monitoring activities provide important information regarding geographic extent of the seagrass meadows as well as species, epiphyte, density, and length data that are important components for understanding overall health and community structure. This report represents the culmination of a five year pilot study of seagrass conditions using a stratified random design off of the west coast of Pinellas County, Florida.

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Seagrass bed in St. Joseph Sound, Pinellas County, FL.

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Acronyms

BCB	Boca Ciega Bay
CLW	Clearwater Harbor
CLWN	Clearwater Harbor North
CLWS	Clearwater Harbor South
COT	City of Tampa
SJS	Saint Joseph Sound
SWFWMD	Southwest Florida Water Management District
TBEP	Tampa Bay Estuary Program

1.0 Background

In the early 1990s the Tampa Bay Estuary Program (TBEP) addressed the importance of monitoring trends and conditions of seagrass beds in Tampa Bay as an indicator of bay wide health. The Technical Advisory Committee of TBEP outlined an extensive bay wide seagrass monitoring program in 1994 (Coastal Environmental, Inc., 1994.) This was accomplished by monitoring fixed transects at various locations throughout the Tampa Bay area. Objectives of the seagrass transect monitoring program:

- Determination of temporal and spatial seagrass species zonation, water depth, and seagrass density along transect (Braun-Blanquet rating);
- Determination of relevant water quality and water column light attenuation data (Avery and Johansson, 2001) at each transect; and
- Measurement of epiphyte/epifauna types and density on seagrass blades.

In 1997, the City of Tampa's (COT) Bay Study Group set up the first transects. After completion, COT presented preliminary results to the Tampa Bay Interagency Seagrass Monitoring Program (Avery and Johansson, 2001). In 1998, Pinellas County began seagrass monitoring in accordance with the TBEP Interlocal Agreement. Other members of the Tampa Bay Seagrass Monitoring group include:

- City of Tampa Bay Study Group
- Tampa Bay Watch, Inc.
- Florida Fish and Wildlife Conservation Commission - Florida Wildlife Research Institute
- Environmental Protection Commission of Hillsborough County
- Manatee County Environmental Management Department
- Hillsborough County Cockroach Bay Aquatic Preserve
- Southwest Florida Water Management District

From 1998-2005, Pinellas County's seagrass monitoring program had 25 transects: 11 in Boca Ciega Bay (BCB) and 14 in Clearwater Harbor/St. Joseph Sound (CLW/SJS). The BCB transects were surveyed as part of the Tampa Bay-wide consortium of organizations that monitor seagrass transects in the bay to assess long-term and short-term trends in zonation, abundance, epibiont coverage, and species composition. Due to the extensive seagrass resource in CLW/SJS (14,700 acres), Pinellas County discontinued monitoring the 14 fixed transects, and implemented a stratified random monitoring program to increase the geographic extent.

2.0 Introduction

Seagrasses are flowering plants, angiosperms, specialized for living in marine nearshore environments (Short, 2001). Areas containing dense populations of seagrasses are considered seagrass habitat. Ecological functions provided by seagrass habitat include structural and physiological characteristics that support species living in the seagrass communities. Functions such as nutrient cycling, detritus production, sediment formation, and shelter increase the productivity of the ecosystem (Dawes et. al., 2004). Seagrass requires available light for photosynthesis. Thus, good water clarity is crucial to the persistence and growth of the seagrass beds. Disturbances in water quality such as nitrification, sediment re-suspension, and illicit discharges can negatively affect the water quality and clarity. Additionally, anthropogenic and natural stresses impact the health, sustainability, and persistence of the seagrass resource.

The complexity of the interacting anthropogenic and natural conditions adds to the intricate dynamics of the Pinellas County marine ecosystem. Managers acknowledge the relationship between the anthropogenic factors and the degradation of the seagrass resource and realize the importance of sustaining this valuable ecosystem (Chauvaud et al., 1998). Correlated with urbanization, anthropogenic factors such as stormwater pollution, hardened shorelines, development, eutrophication, and boat prop scarring cause direct and indirect damage to the nearshore habitats and seagrass resources. In turn, natural factors such as water circulation, beach erosion, climate change, and weather events may also cause changes to occur in the ecosystem. These interacting environmental issues present a challenge for resource managers to develop strategies to protect and sustain the quality of the ecosystem (Meyer, 2008). To protect and manage natural resources managers require reliable data (Mumby, 1999). It is therefore essential to conduct a monitoring program to gain understanding of the seagrass resource spatial distribution and characterization.

2.1 Study Area

The study area consists of two regions, Clearwater Harbor/ St. Joseph Sound (CLW/SJS) and Boca Ciega Bay (BCB). The northern region of the study area, CLW/SJS, occurs along the northwest coastline of Pinellas County (Figure 1). Approximately 30 km north of the mouth of Tampa Bay, CLW/SJS consists of open water regions bounded east and west by the coastal mainland shoreline and the barrier island chain, respectively. Of the 118 km^2 in CLW/SJS, expansive seagrass beds cover over 70 km^2 providing essential habitat for marine flora and fauna (Kaufman, 2011). CLW/SJS also encompasses Honeymoon Island and Caladesi Island State Parks. The southern region of the study area, BCB, occurs along the southwest coastline of Pinellas County (Figure 1). BCB consists of open water and intercoastal regions bounded on the west by the coastal mainland and on the east by the barrier island chain. The southern portion of BCB connects directly to the Gulf of Mexico near the mouth of Tampa Bay. Of the 91 km^2 in BCB, seagrass beds cover nearly 36 km^2 (Kaufman, 2009). BCB also includes Shell Key Preserve and Fort De Soto Park.

The study area has diverse natural and anthropogenic features. The ecosystem in BCB and CLW/SJS provide critical bird nesting areas, sessile algal communities, essential fishery habitats, marine mammal and turtle habitats, and numerous recreational opportunities. Anthropogenic features in the study area include dredge and fill operations, boat channels, spoil islands, finger canal systems, seawalls, and causeways. The complexity of the interacting anthropogenic and natural conditions adds to the intricate dynamics of the managing Pinellas County seagrass resource.

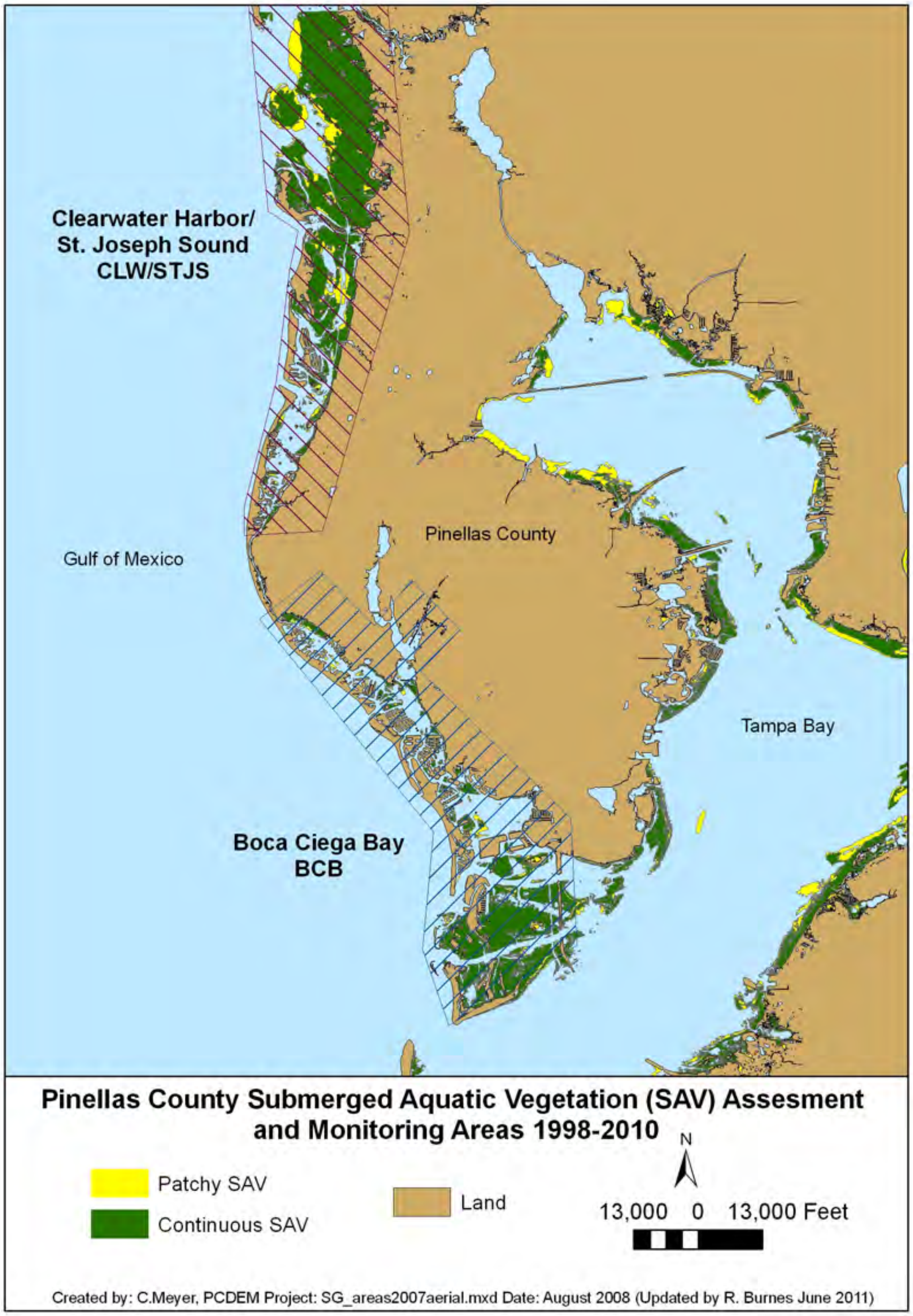

Figure 1. Map of Pinellas County Seagrass Areas

2.2 Aerial Seagrass Mapping

To assess the extent of the seagrass resource, Pinellas County participates in a cooperative remote sensing project managed by the Southwest Florida Water Management District (SWFMWD). The aerial photointerpretation mapping provides acreage estimates for the submerged aquatic vegetation (SAV) resource bi-annually. The SAV classification results from the inability of the photointerpretation method to discern seagrass from marine algae. The mapping resolution is 0.5 acres with an 80% ground-truth accuracy. The data can be used to calculate a rate of change (ROC) for the SAV:

$$\text{SAV ROC} = \frac{\text{"New Acreage"} - \text{"Old Acreage"}}{\text{"Old Acreage"}}$$

In 1950, the estimated SAV acreage in BCB was 10,800 acres as interpreted from single band photography. In 1982, the estimate dropped drastically to 5,770 acres (Table 1, Figure 2). From 1998-2006, the SAV increased to 8,961 acres. The estimated SAV acreage in BCB increased 16% from 1996-2008 (Table 2). However, improvements in technology and photointerpretation methods may have contributed to the variability.

The aerial photo-interpretation mapping for CLW/SJS took place from 1999-2010. The SAV acreage increased from 13,994 to17,491 acres (Table 1, Figure 2.) The overall change in estimated SAV acreage increased 25% from 1999-2010 (Table 2). Photointerpretation results may be limited by physical factors (e.g. tide stage, turbidity, wind direction and intensity) on the day of the flight. This is most likely the case for the large increase (16%) in seagrass between 2006 and 2008 (Table 2) and does not represent an actual increase in seagrass abundance by that factor. Rather it indicates further refinement of the photointerpreation which allows for the identification of seagrass beds previously missed.

The aerial photo-interpretation mapping project provides an estimate of the geographic extent of the SAV in the study area (Figure 3). The trends suggest an increase in the SAV which may be positively correlated with an increase in seagrass. To verify these trends resource managers will require more detailed information about the seagrass habitat.

Table 1. SAV acreage calculated from aerial photo-interpretation (Kaufman, 2011)

BAY SEGMENTS	YEAR												
	1950	1982	1988	1990	1992	1994	1996	1999	2002	2004	2006	2008	2010
BCB	10,800	5,770	6,258	6,805	6,952	7,116	7,699	7,464	7,673	7,731	8,961	8,457	8,554
CLW/STJS								13,994	13,393	14,200	14,982	17,422	17,491

Table 2. Change in SAV acreage calculated from aerial photo-interpretation (Kaufman, 2011)

BAY SEGMENTS	Rates of Change										
	82-88	88-90	90-92	92-94	94-96	96-99	99-02	02-04	04-06	06-08	08-10
BCB	8%	9%	2%	2%	8%	-3%	3%	1%	16%	-6%	1%
CLW/STJS							-4%	6%	6%	16%	4%

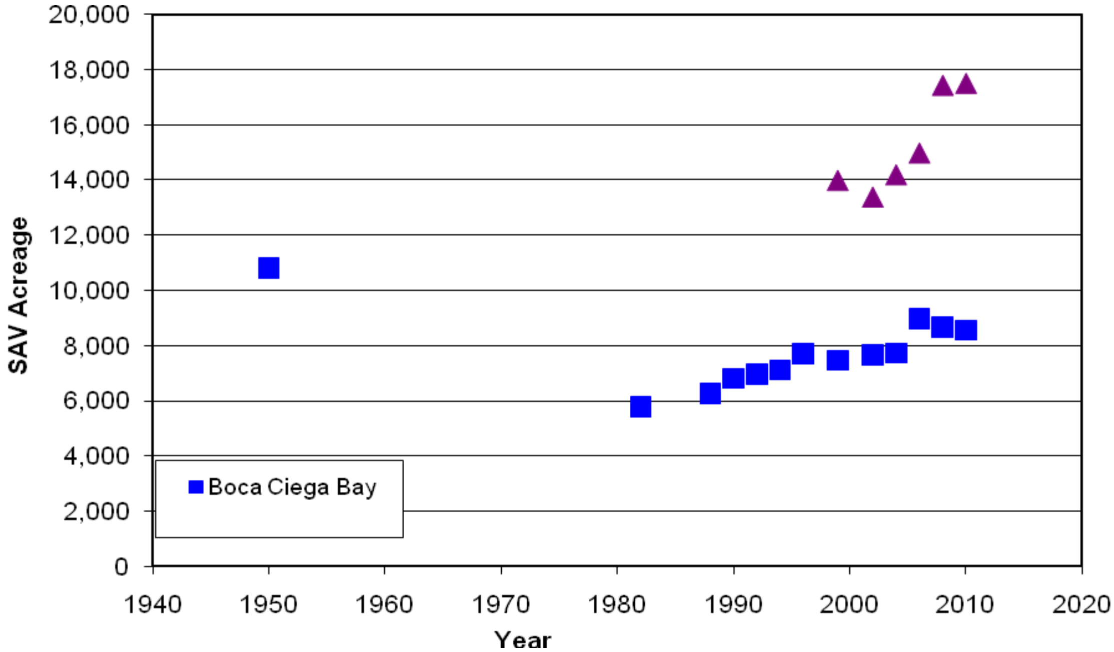

Figure 2. Estimated SAV acreages calculated from aerial photo-interpretation for BCB and CLW/SJS.

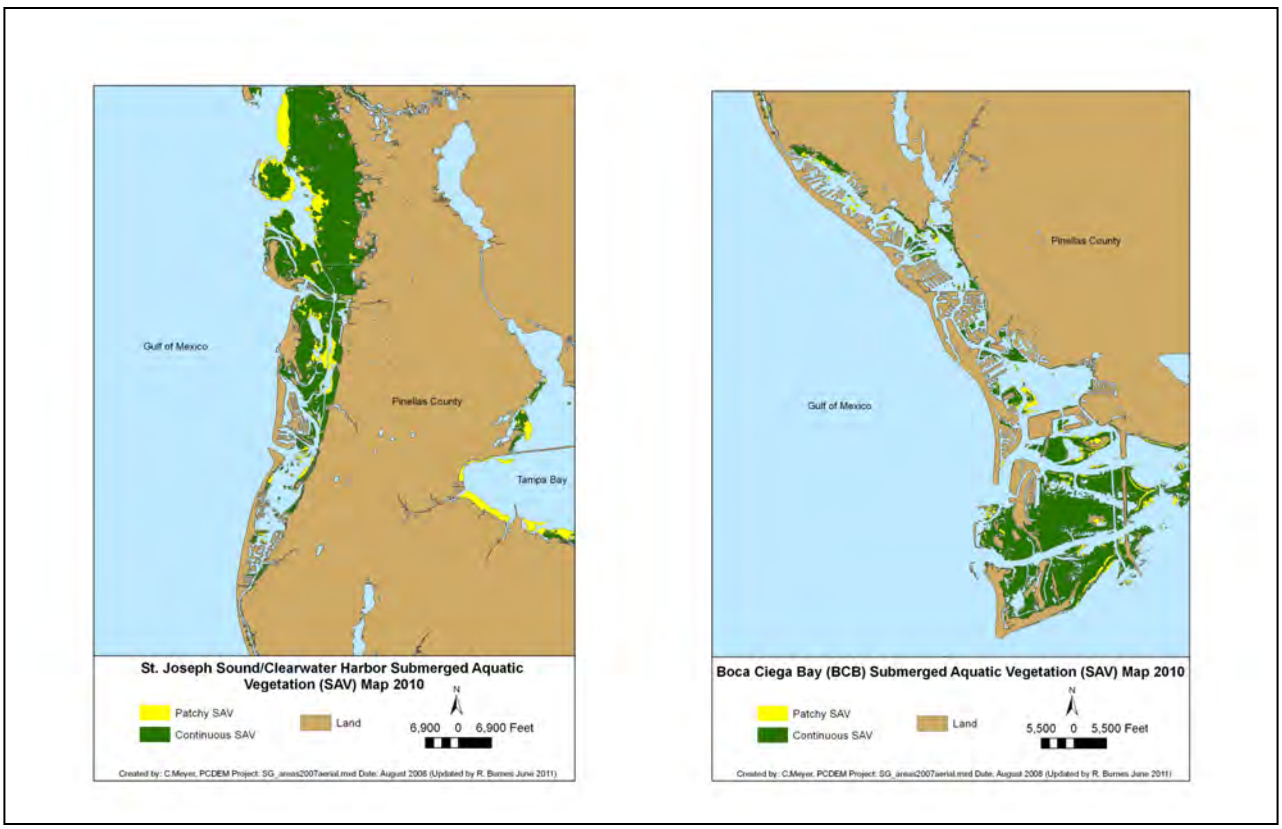

Figure 3. Submerged Aquatic Vegetation (SAV) mapped in 2010 (Kaufman, 2011).

2.3 Seagrass Habitat Components

The seagrass monitoring program provides specific information about the species composition, abundance, and condition of the resource. In Pinellas County the three prominent species are *Syringodium filiforme, Thalassia testudinum,* and *Halodule wrightii* (Figure 4) (Deitche and Meyer, 2003). The common names for the species are manatee, turtle, and shoal grass, respectively. Two additional species *Ruppia maritina* and *Halophila engelmanni* are occasionally observed in the area. In addition to the seagrass species, the SAV includes a variety of marine algae. Figure 5 shows seven marine algae and an invertebrate common in Clearwater Harbor and St. Joseph Sound. Field staff found the marine algae integrated with the seagrass species. The habitat also hosts numerous invertebrate taxa including the Bay Scallop (*Argopecten irradians).*

Figure 4. Prominent seagrass species in Pinellas County, FL (Meyer 2008)

Figure 5. Marine algae found in Clearwater Harbor and St. Joseph Sound, FL. (Meyer, 2008)

In the Tampa Bay area, epibionts, including both epiphytes and epifauna, commonly coexist on seagrass blades. The epibionts contribute to the primary production associated with the seagrass habitat. While certain epibionts may negatively impact the seagrass, others live symbiotically through a mutualistic or commensalistic relationship. Several epibionts found during seagrass monitoring include polycheates, attached algae, barnacle spat, coralline algae, and filamentous algae (Figure 6). A pilot study by Cho et al (2002) focused on the macroalgal epiphytes on *Thalassia*. The study identified 13 epiphytic species in dense seagrass beds and nine epiphytic species in sparse seagrass beds. The epiphytes include green, brown, and red algae with several species such as *Enteromorpha flexuosa*, *Sphacelaria rigidula*, *Ceramium gracillimum var. byssoideum*, *Herposiphonia tenella*, *Griffithsia*, and *Stylonema alsidii* (Cho et al., 2002).

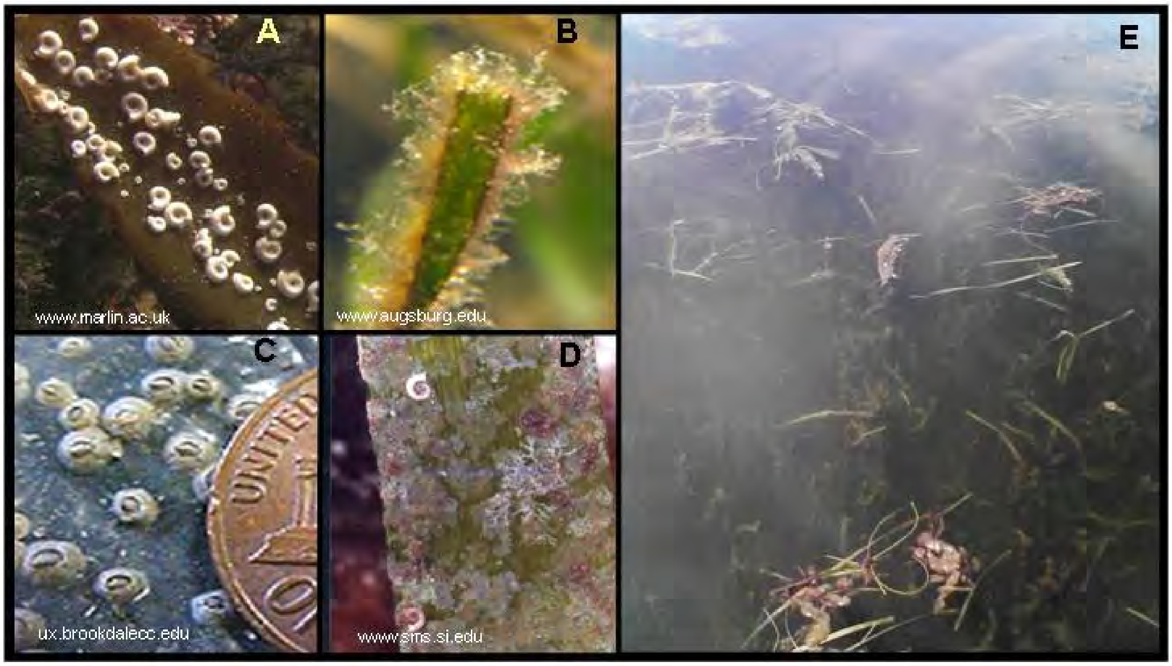

Figure 6. Common epibionts found on seagrass in Pinellas County, FL (A- *Spirorbis*, a filter-feeding polycheate, B- attached algae, C- barnacle spat, D- encrusting coralline algae, E- *Lyngbya*, filamentous algae)

2.4 Project Objectives

This report aims to review and synthesize the monitoring and mapping data from 1998-2010. The results will provide an assessment of the seagrass resource in BCB and CLW/SJS. The report is separated into two parts. Part I summarizes the data from the Fixed Transect Monitoring Program in BCB and CLW/SJS. Part II summarizes the Stratified Random Transect Program in CLW/SJS. An overview of the status of the seagrass resource, issues of concern, comparison of the sampling designs, and potential for future studies including the relationship of seagrass to water quality will be examined in section 6.

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3.0 Part I: Fixed Transect Monitoring

3.1 Methods: Fixed Transect Monitoring

Pinellas County monitored the fixed seagrass transects during October and November. This period marks the end of the growing season when seagrass biomass peaks. A PVC pole, imbedded in the bottom, marked the beginning of the transect (0m) and the end of the transect. In most cases the end of the transect coincided with the edge of bed. Transects are located using spatial coordinates from a Trimble® GPS unit. In most cases, the transects start on or near shore and then continued perpendicular to the shoreline (Deitche and Meyer, 2003).

After arriving on site and locating the transect 0m mark, staff swam along the transect line with a meter square frame (quadrat). For transects less than 100m, seagrass abundance was recorded every 10m. For transects greater than 100m, only the final 100m was recorded in 10m increments; the rest of the transect's seagrass abundance was recorded at 25m increments.

Individual seagrass species abundance was assessed using the Braun-Blanquet rating system (Braun-Blanquet, 1965):

- 0= no coverage
- 0.1= solitary short shoot
- 0.5= sparse or less than 1%
- 1= 1-5% coverage
- 2= 6-25%
- 3= 26-50%
- 4= 51-75%
- 5= 76-100%

Due to the stability of the seagrass resource determined by Levy et al (2003) the transects are monitored in Boca Ciega Bay every other year beginning in 2004. For Clearwater Harbor and St. Joseph Sound monitoring was conducted from 1995 to 2005. Starting in 2006 the County switched to a stratified random sampling design.

Other data collected include: water depth, sediment composition, seagrass condition, and algae occurrence. The sediment composition is qualitatively categorized as sand, sandy mud, mud, shelly mud, shelly sand, or hard bottom. The seagrass condition is qualitatively categorized as very good, good, fair, poor, or necrotic. Epibiont density on the seagrass blade was assessed using a numerical rating scale: 1= clean, 2= light coverage, 3= moderate, 4= heavy. At the transect's mid-bed and edge of bed, staff recorded shoot density and canopy height. Three density counts were made using either a 10x10cm or 25x25cm square frame. Also, five shoot lengths were recorded to the nearest centimeter. Samplers assess each species independently (Deitche and Meyer, 2003).

Chlorophyll-a, turbidity, Hydrolab®, and LICOR® readings were taken at mid-bed, edge of bed, and the 2m depth contour. Chlorophyll-a and turbidity samples were collected using a 125ml Nalgene® bottle. The bottles were placed on ice and transferred to COT for analysis. LICOR® readings were used to calculate water column photosynthetically active radiation (PAR) values for the transect. Since 2003, water samples are analyzed using a transmissometer to complement the LICOR® readings to determine relative water clarity and light attenuation. The Hydrolab® provides measurements of depth, pH, temperature, salinity, conductivity, and dissolved oxygen (Deitche and Meyer, 2003).

3.2 Results: Fixed Transect Monitoring

In general, the seagrass beds in BCB and CLW/SJS remained stable throughout the monitoring program in SJS. The species found along the transects were *Halodule wrightii, Thalassia testudinum, Syringodium filiforme, and Halophila engelmanni.* The summary results are shown in Table 3. The sediment composition ranged from mud to sand with most of the observations recorded sandy mud. The seagrass condition ranged from poor-very good with most of the observations recorded as good. The epibiont density ranged from light to heavy with the most prominent assemblages consisting of attached algae and polycheates. However, in 2002 and 2003, there was an increase in observations of barnacle spat and bryozoans in the CLW/SJS transects. In BCB, the two prominent seagrasses were *Halodule* and *Thalassia*. In CLW/SJS, the prominent seagrasses were mixed beds composed of *Halodule, Thalassia*, and *Syringodium*. The species composition varied throughout the monitoring program in several of the transects. The most apparent shifts occurred in CLW-08, CLW-10, CLW-11, and CLW-12. In 2001-2005, observers recorded an increase in the abundance and occurrence of *Syringodium* along the middle of the transects. The shift transitioned the species composition from *Halodule* and/or *Thalassia* to *Syringodium*. The seagrass abundance and length of the bed appeared to increase in BCB-11and CLW-08. The abundance and length of the bed appeared to decrease in BCB-01, BCB-08, and CLW-04. Overall, the transects in BCB and CLW represent a stable seagrass resource with few temporal trends in the data.

The following section summarizes the data collected from 1998-2010 separately for each fixed transects. The transects were grouped by bay segment, BCB (Figure 7) and CLW/SJS (Figure 8). Within a bay segment group, each transect was presented with a summary paragraph, aerial map, transect graphs, epibiont density graph, species mean canopy height graph, and species mean density graph. The summary paragraph includes the description of the transect along with a brief compilation of the qualitative data and a synopsis of the quantitative data. The transect graphs illustrate seagrass abundance by species along the transect line by year. The abundance was represented using the Braun-Blanquet rating system. In some years, data was not collected from certain points resulting in gaps between readings. The epibiont density graph displays the mean density for each year. The density found on each seagrass species was ranked on a scale of 1-4 reflecting the categories of clean, light, moderate, and heavy, respectively. The mean canopy height and mean density graphs were calculated from the readings collected at the mid bed and edge of bed. The results are presented for each seagrass species.

Table 3. Summary of fixed transect data for BCB during 1998-2010 and CLW during 1998-2005. (H=Halodule, T= Thalassia, S=Syringodium, HP= Halophila) (AA= attached algae, SP=spirorbis (polycheate), BN=barnacle, BRY=bryozoan, HDY=hydroid, HOLO=holothuroidian, LYN=lyngbia, TUN=tunicate).

Transect	Length (m)	Depth (cm)	Sediment Type	Seagrass Species	Prominent Species	Condition	Status	Edge of Bed	Epiphye/Epifauna Density	Epiphyte/Epifauna Type	Canopy Height (cm)	Shoot Density (per m2)
BCB-01	300	10-120	mud	H	Halodule	Fair-Good	Decreasing	40-223	light/moderate	AA, SP, BN	5-25	170-1800
BCB-02	230	35-140	mud/sand	H,T	Halodule	Fair-Good	Stable	133-137	light-heavy	AA,SP, BRY, BN	5-35	100-4000
BCB-03	50	10-90	sandy mud	H	Halodule	Poor-Fair	Stable/Decreasing	24-44	light-heavy	AA	5-35	200-850
BCB-04	50	50-140	mud/sandy mud	H	Halodule	Good	Stable/Increasing	33-40	light-heavy	AA, SP	10-45	150-1800
BCB-05	80	40-120	mud/sand	H,T	Halodule	Fair-Good	Stable	50-61	moderate/heavy	AA, SP, BN,BRY	5-40	50-5000
BCB-06	115	20-140	sandy mud/sand	H,T	Halodule	Poor-Good	Stable	100-115	light-heavy	AA, SP, BRY	10-40	25-7000
BCB-07	200	20-100	mud/sand	T,H,S	Thalassia	Poor-Very Good	Stable	193-200	moderate/heavy	AA, SP, BN,BRY, LYN	10-40	100-1000
BCB-08	150	10-225	sand	H,T,S	All	Fair-Very Good	Stable	100-150	light-moderate	AA, BRY, SP	20-50	50-1400
BCB-09	500	20-120	sandy mud	T,H	Thalassia	Fair-Good	Stable	499	moderate/heavy	AA, SP, BY, LYN, HYD	15-50	50-1400
BCB-10	150	30-140	sandy mud/sand	H,T	All	Fair-Good	Stable	142-150	light-heavy	AA,SP, BN	15-45	25-1600
BCB-11	100	5-80	sandy mud	H	Halodule	Fair-Good	Stable/Increasing	70-97	moderate/heavy	AA, SP, LYN	15-30	50-3000
CLW-01	200	30-110	sandy mud	H,T	Halodule	Good	Stable	180-200	light-heavy	AA,SP,BN, TUN	5-30	50-2500
CLW-02	230	40-110	sand/mud	T,H	Thalassia	Good	Stable	125-139	heavy-light	AA,SP,BN	18-32	25-1200
CLW-03	260	20-140	sand	T,H	All	Poor-Good	Stable	227-238	moderate-heavy	AA,SP, BN,BRY	20-40	25-1850
CLW-04	250	15-140	sandy mud/sand	H,T	Halodule	Poor-Good	Decrease	235-218	light-heavy	AA, SP	10-35	20-5200
CLW-05	90	45-200	sand	H,T,S	All	Good	Varies	50-80	clean-heavy	AA,SP,BRY	15-45	50-1200
CLW-06	100	5-150	sand/sandy mud	H,T	All	Good	Stable	60-100	moderate-heavy	AA, SP	15-45	100-3000
CLW-07	200	40-170	sandy mud	H,S	Halodule	Good	Stable	140-192	light-heavy	AA,SP,BRY,BN	15-35	50-2500
CLW-08	225	45-150	mud/sandy mud	H,T,S,HP	Halodule/Thalassia	Good	Increase	140-210	light-moderate	AA, SP	5-50	50-1400
CLW-09	150	40-150	sand/sandy mud	H,S	H	Fair-Good	Stable	117-141	moderate	AA, SP,BRY	15-45	100-2500
CLW-10	200	15-150	sandy mud	H,S	H	Good-Very Good	Stable	149-172	light-moderate	AA, SP, BRY, BN	20-40	250-1500
CLW-11	300	20-150	sandy mud	H,S	All	Good	Stable	220-290	light-heavy	AA,SP,BRY,BN	5-45	100-1100
CLW-12	300	30-160	sandy mud	H,S	All	Fair-Good	Stable	240-296	light-heavy	AA, SP, BRY, BN	10-45	50-5333
CLW-13	450	20-140	sandy mud	H,S,T,HP	Halodule/Syringodium	Fair-Good	Stable	270-422	light-heavy	AA, SP	20-40	100-1500
CLW-14	200	30-200	sand/sandy mud	S,H	Syringodium	Good	Stable	110-198	light-heavy	AA, BRY, HOLO, TUN	25-50	75-1400

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3.2.1 Transect sites in Boca Ciega Bay (BCB)

The fixed transect seagrass monitoring took place from 1998-2010 in Boca Ciega Bay (BCB). There are 11 transect locations. The BCB transects are included in the Tampa Bay Estuary Program Seagrass Monitoring Program.

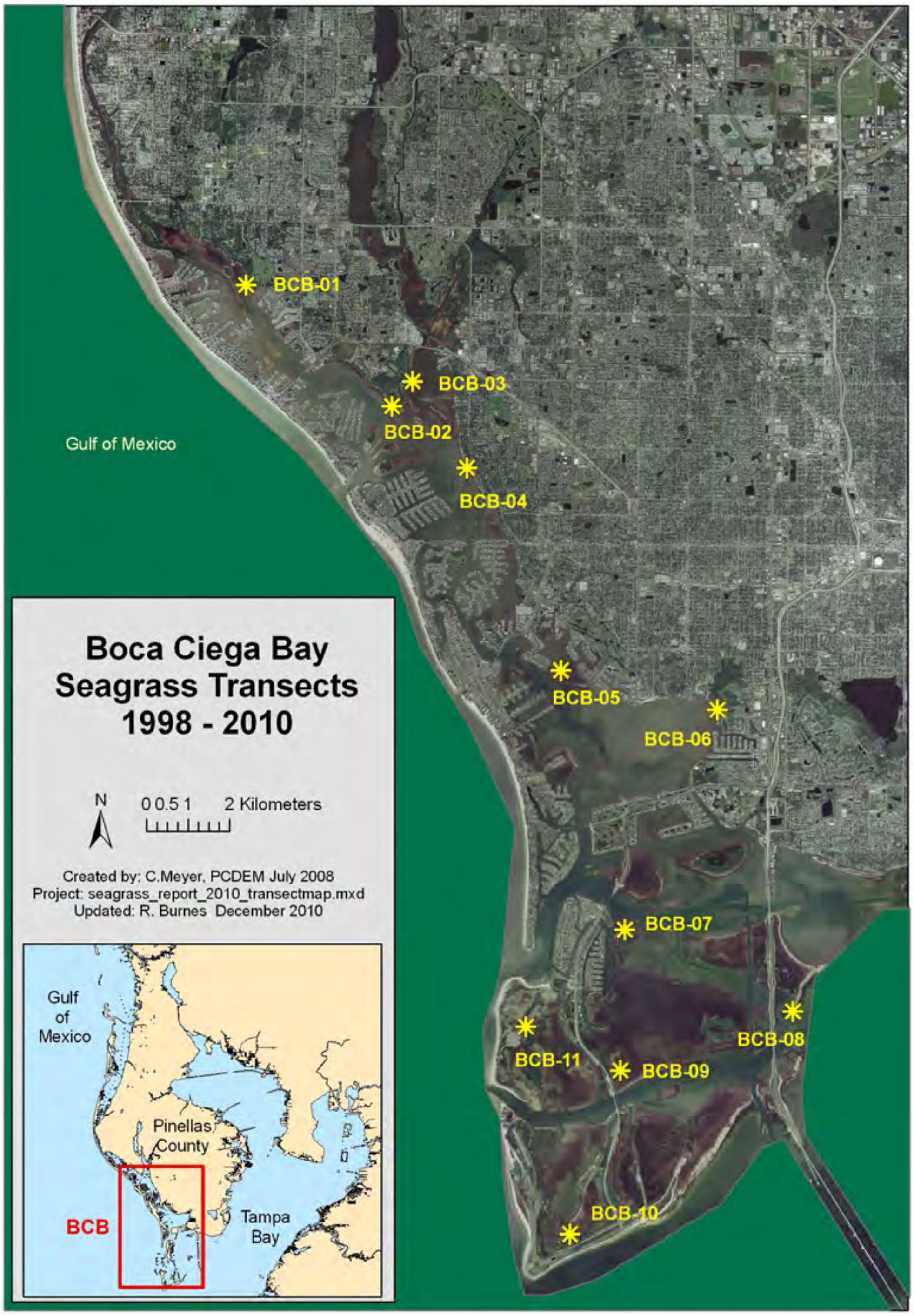

Figure 7. Location of Boca Ciega Bay fixed transects.

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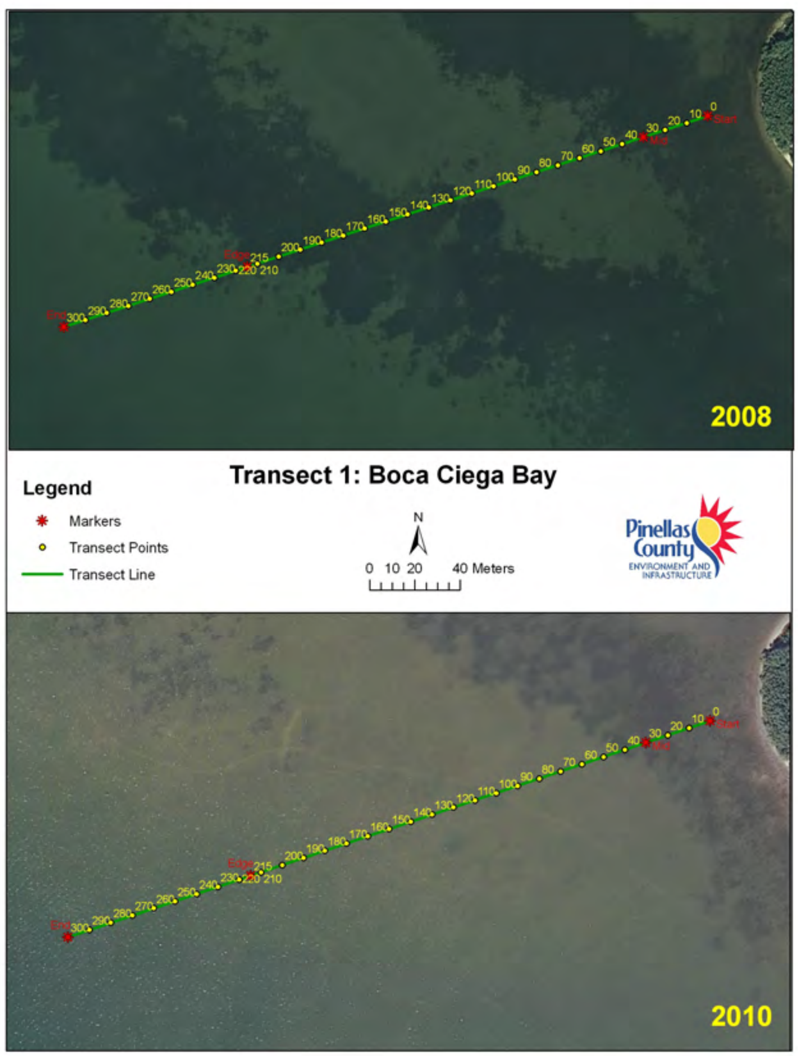
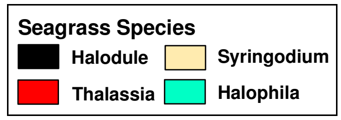
3.2.1.1 BCB-01

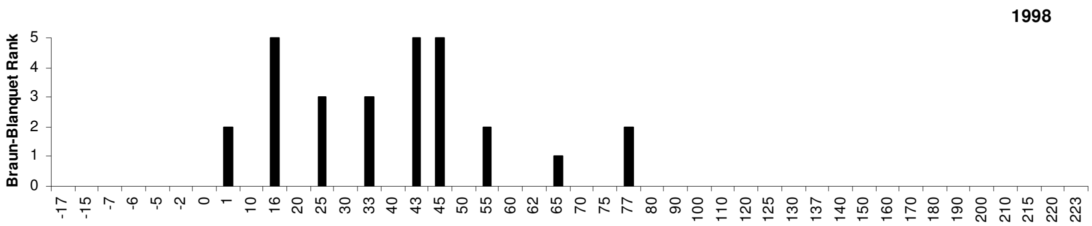
BCB-01 is located on the east side of the Intra-coastal Waterway (ICW) at the northern reach of Boca Ciega Bay. The transect extends 300m from the shore of a mangrove island to the edge of the ICW. The depth ranged from 10-120cm. The sediment composition consisted of mud along the transect. The prominent seagrass was *Halodule*. The condition of the seagrass varied from fair to good.

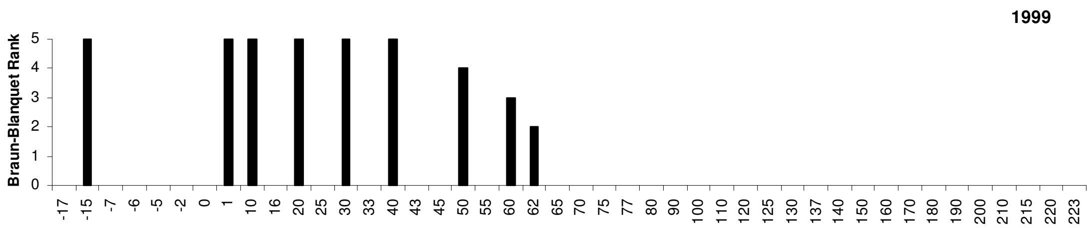
The length of the transect, BCB-01, expanded throughout most of the monitoring program. In 1998 the data indicated the edge of bed at 77m. By 2002, the bed extended to 143m continuing to 223m in the 2007 survey. However, in 2009 the seagrass bed receded greatly to 40m. The reason for this change is not certain; however, it is most likely due to sampler error in that they did not follow the same track as previous years. Further surveys are required to explain this regression. The epibiont density decreased slightly over the years to a light/moderate rating consisting mainly of attached algae, polycheates, and barnacles. The *Halodule* canopy height remained stable and ranged from 5-25cm. The shoot density ranged from 170-1150 shoots (per m^2) with the highest density of nearly 1800 shoots (per m^2) reported in 2001.

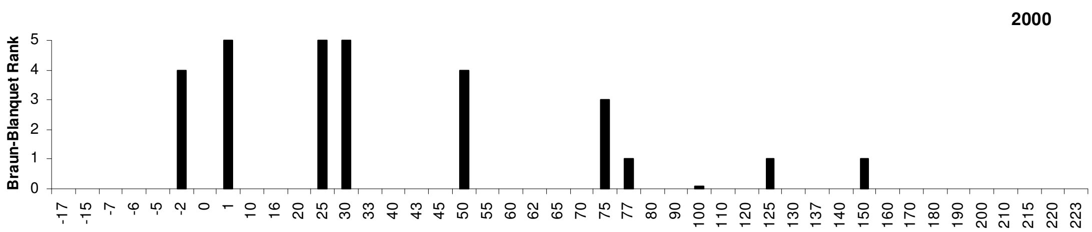


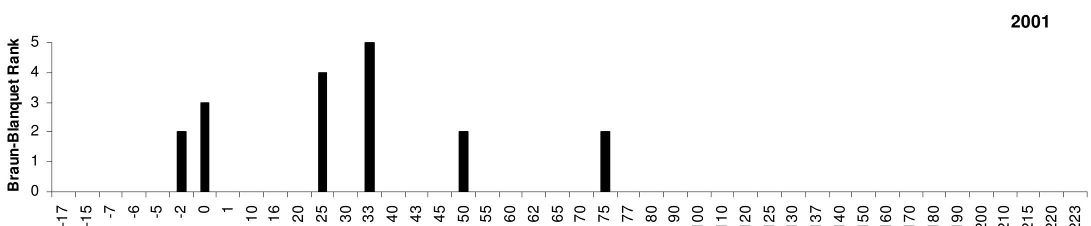


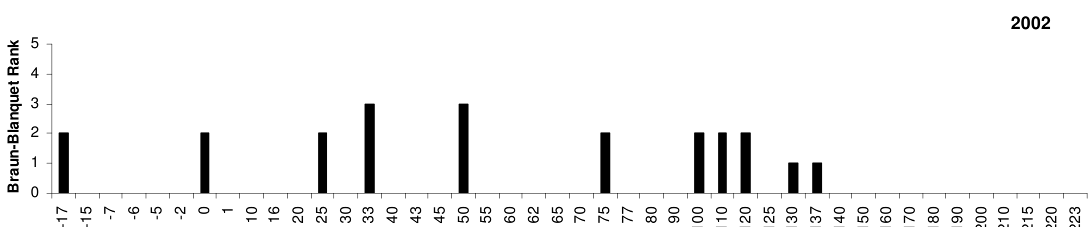
BCB-01 Transect Graphs

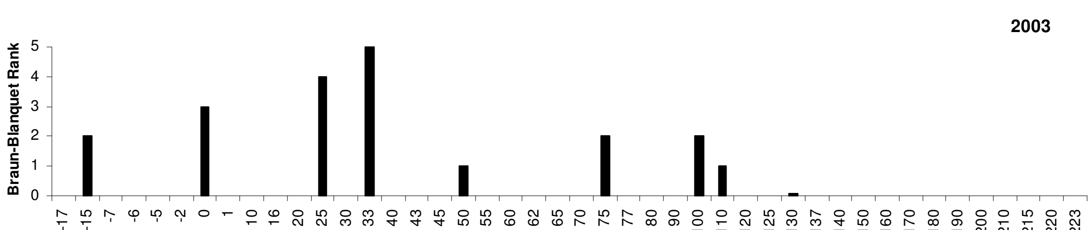


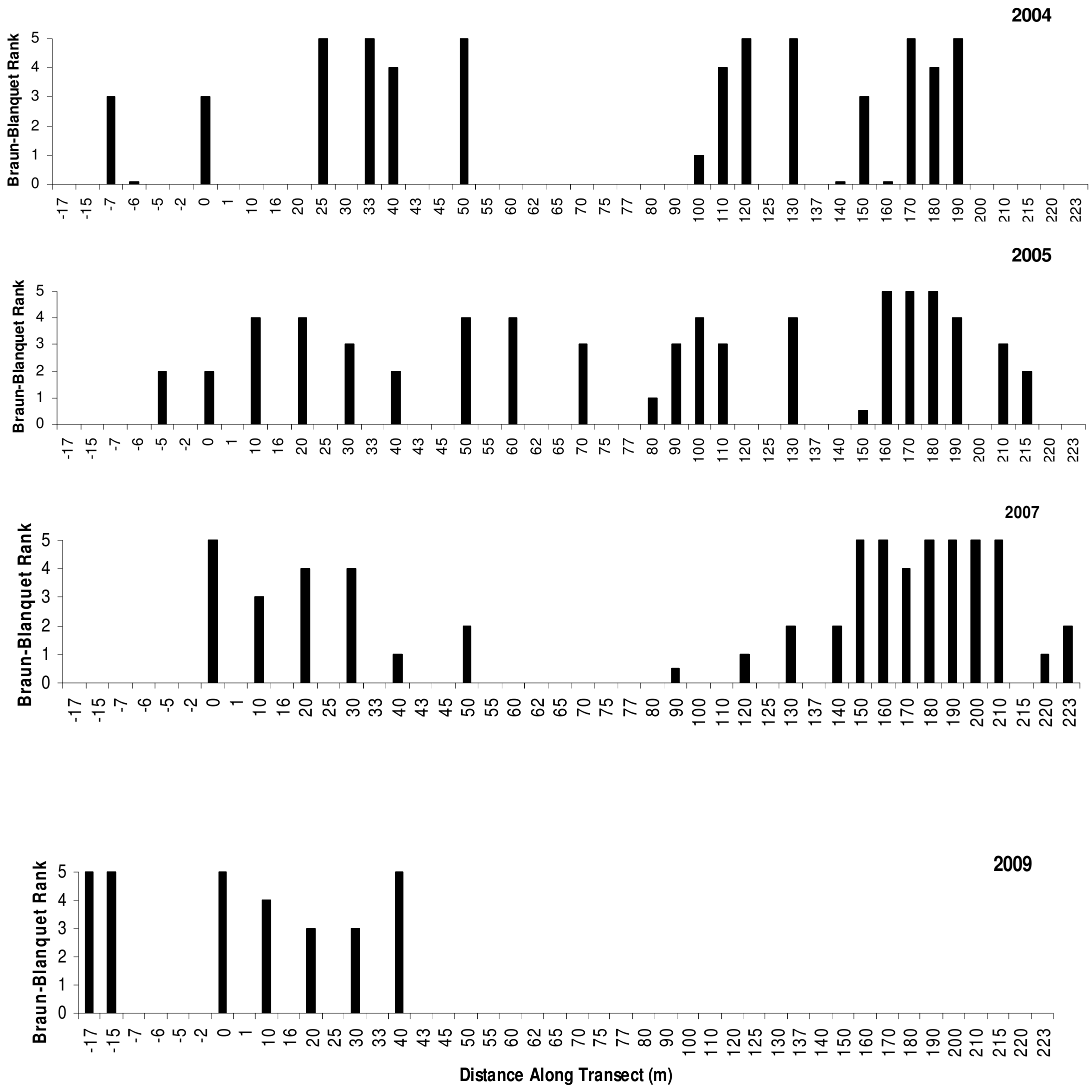




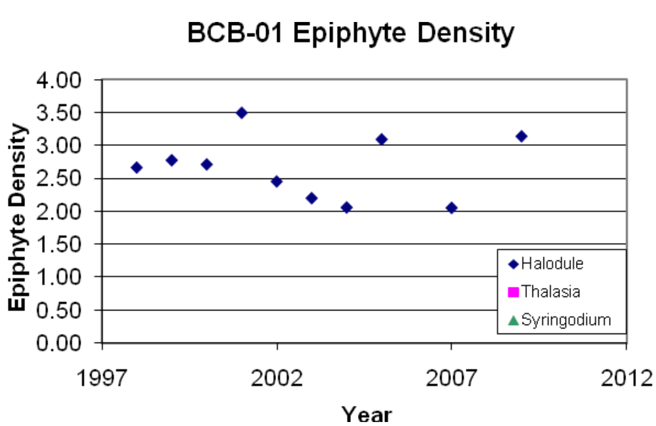




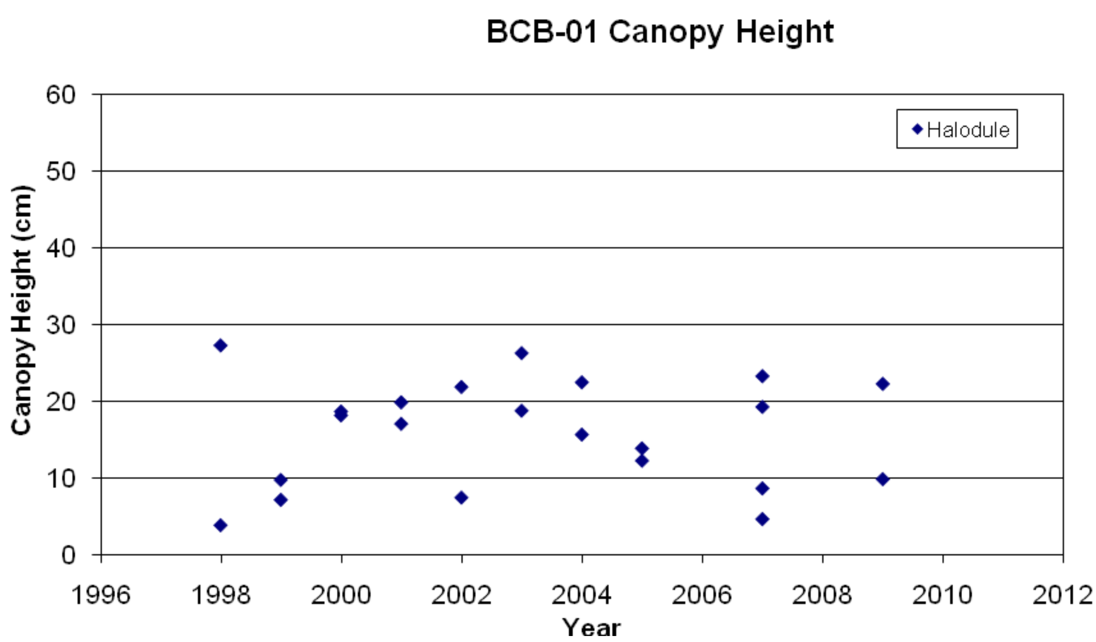




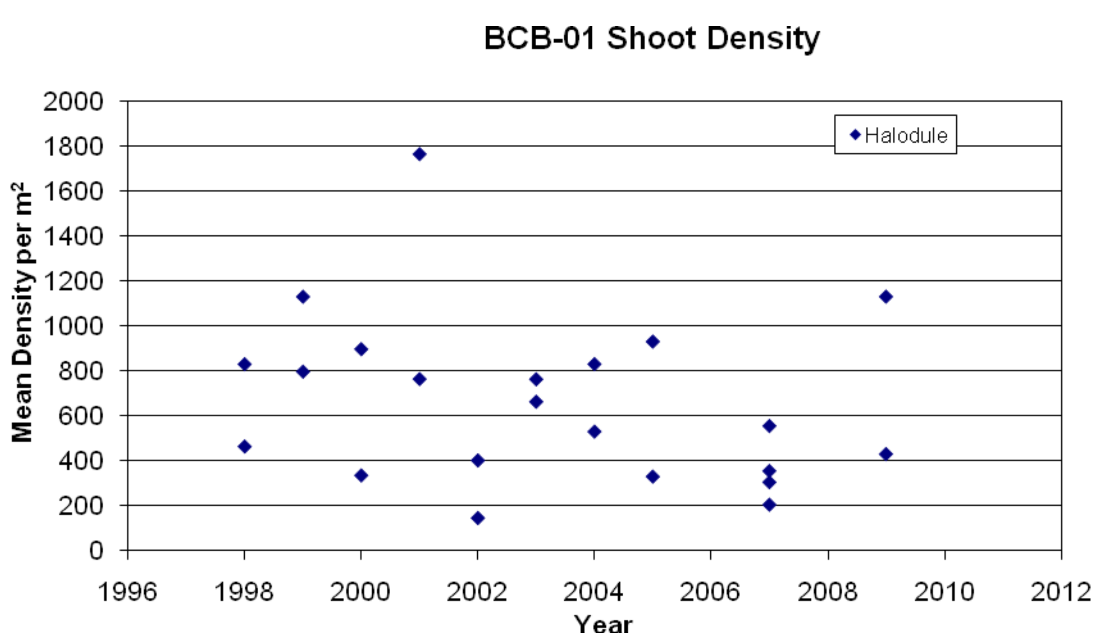
BCB-01 Epibiont Density Graph



BCB-01 Canopy Height Graph



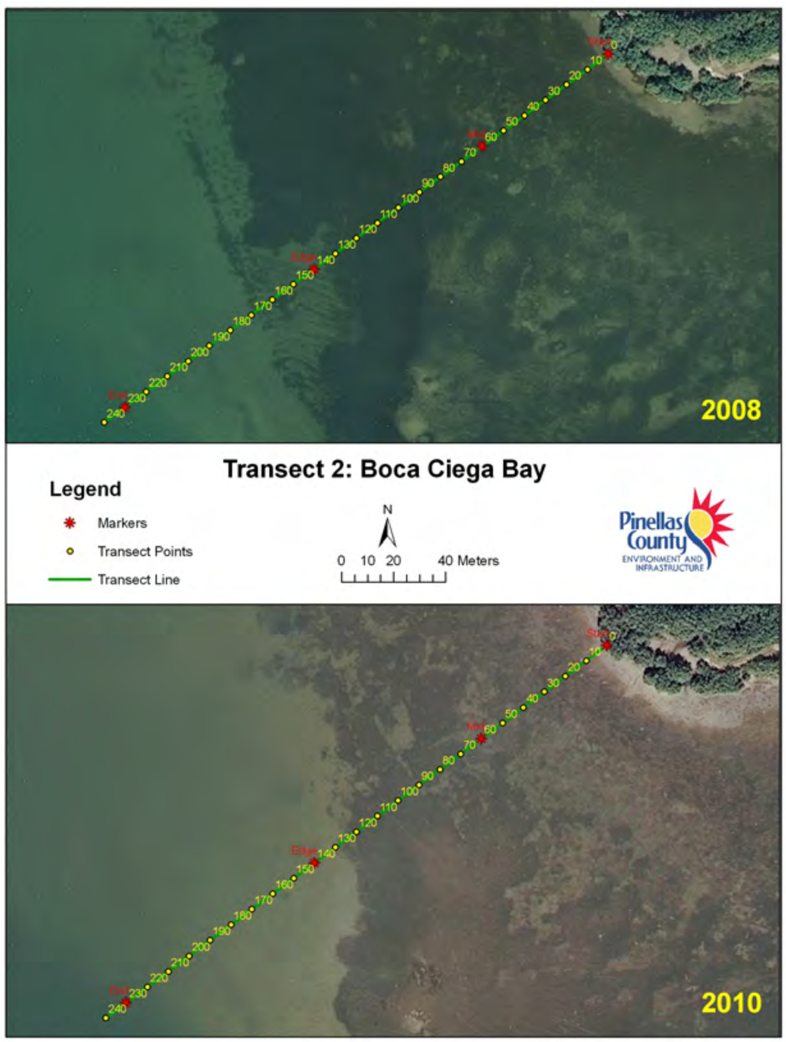
BCB-01 Shoot Density Graph

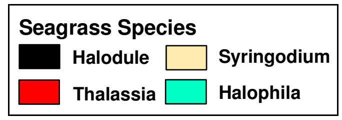


3.2.1.2 BCB-02

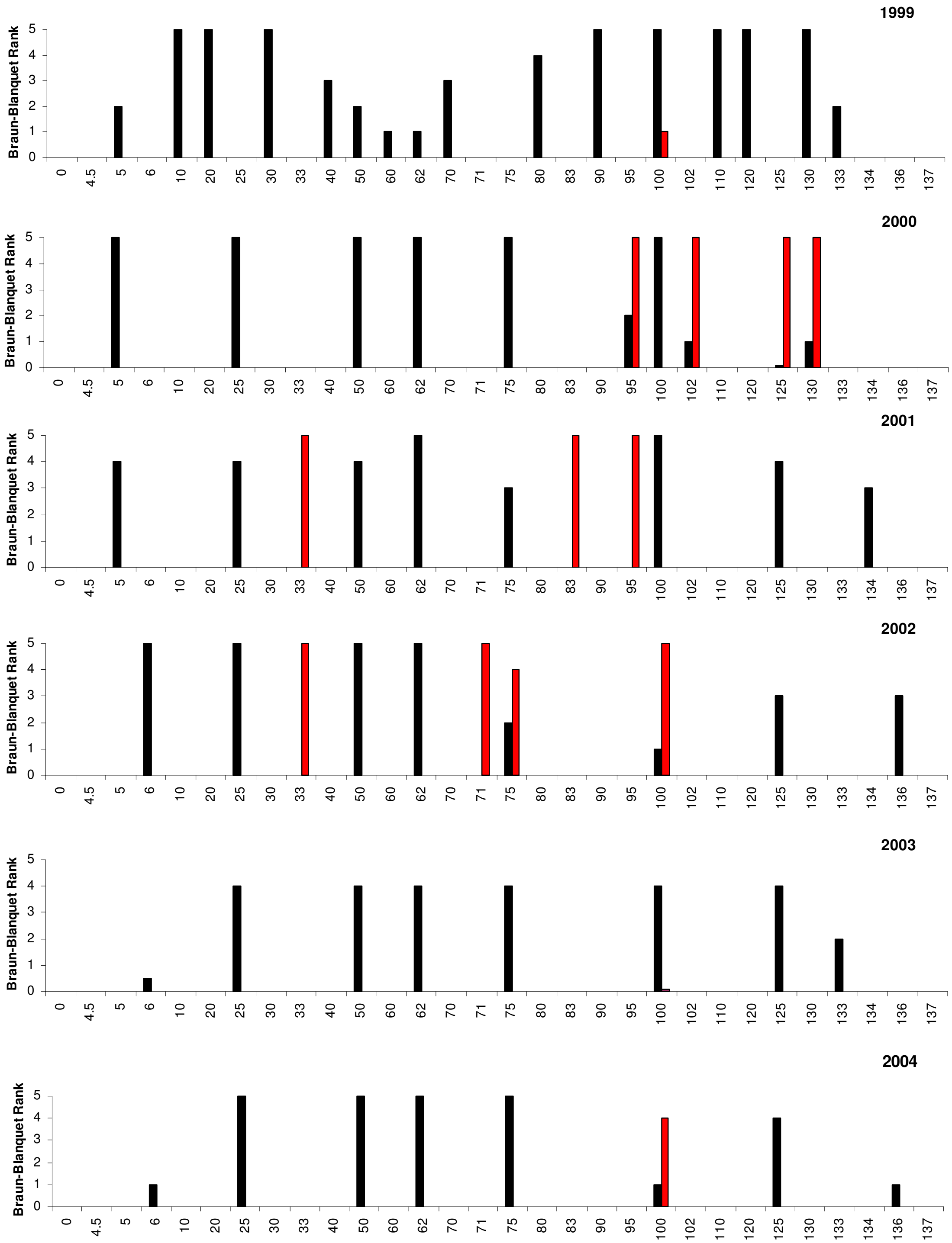
BCB-02 is located on the west side of Veterans Memorial Park in the ICW. The transect extends 230m from the shore to the edge of the boat channel. The depth ranged from 35-140cm. The sediment composition consisted of mud from 0-100 m; however, the sediment transitioned between 100m and 120m to shelly sand then to sand from 120m to 230m. The prominent seagrass was *Halodule* with occurrences of *Thalassia* between 70m-130m. The condition of the seagrass varied from fair to good.

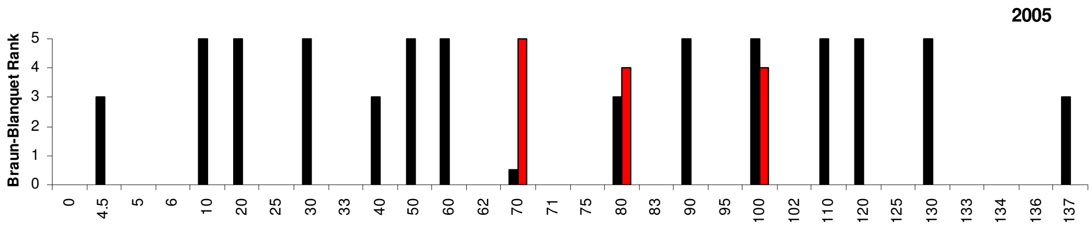
BCB-02 remained stable throughout the monitoring program. The data indicated that the edge of bed varied from 129m to 137m. The observation of Thalassia on the transect varied with a high abundance in 2000-2002, less abundance in 2003 and 2004, and then rebounding in 2005, 2006, and 2008. The epibiont density was light in 1999, heavy in 2000, and moderate but trending toward heavier assemblage from 2001 to 2010. The epibiont assemblages consisted of attached algae and polycheates with fewer bryozoans and barnacles. The canopy height remained stable from 5cm-35cm. The shoot density ranged from 100-1190 shoots (per m^2) with the highest *Halodule* density of nearly 4000 shoots (per m^2) recorded in 2000.

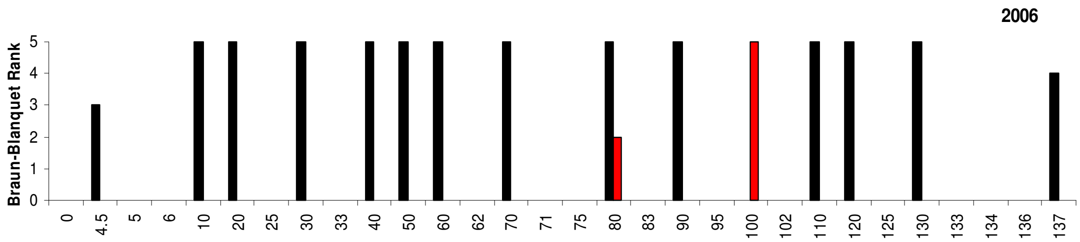


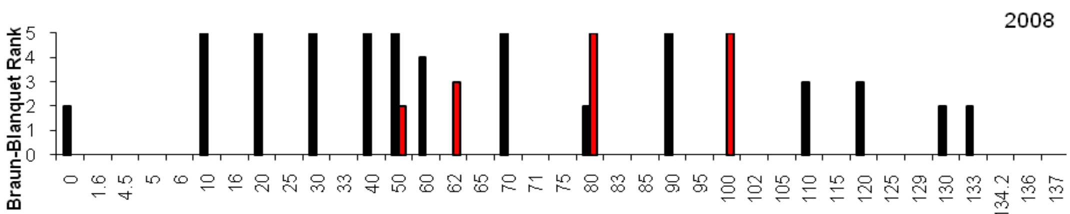


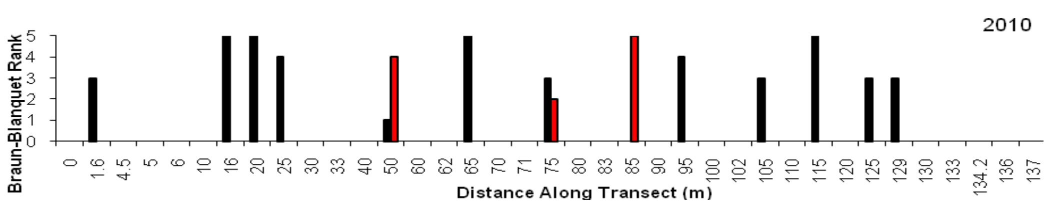
BCB-02 Transect Graphs



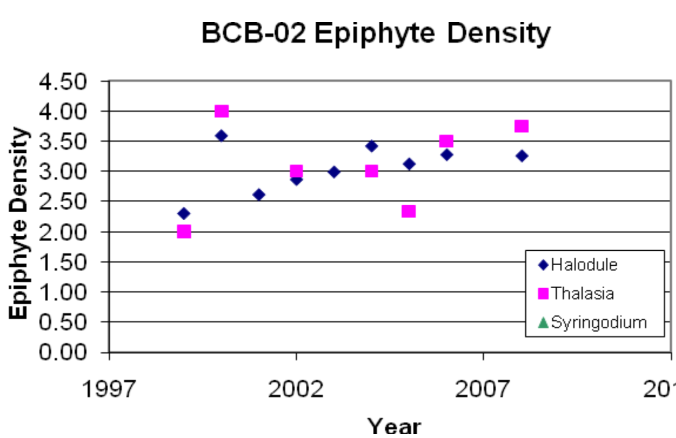




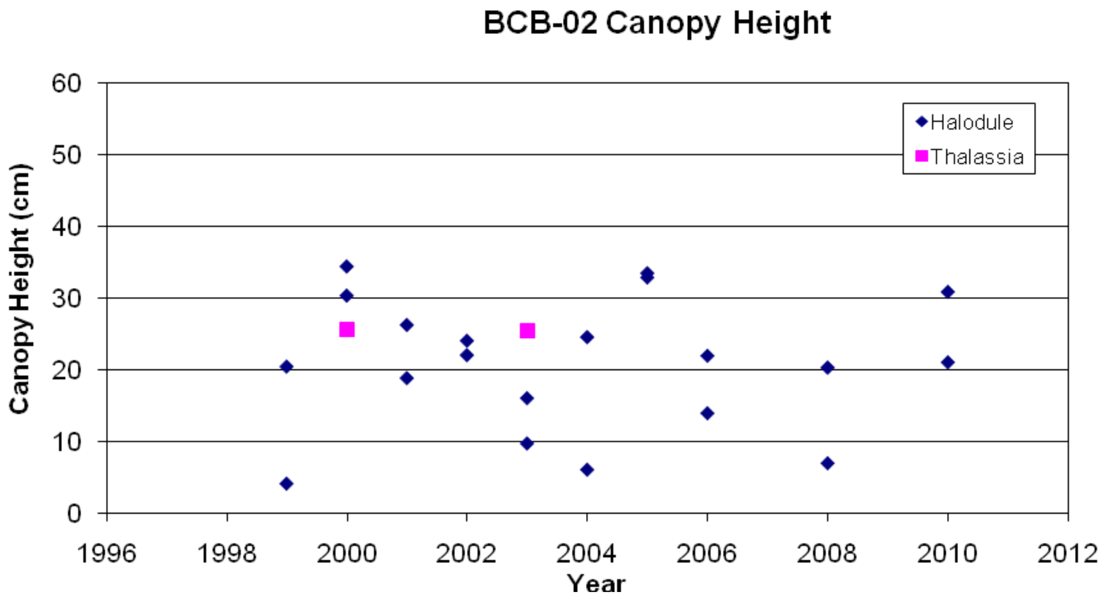




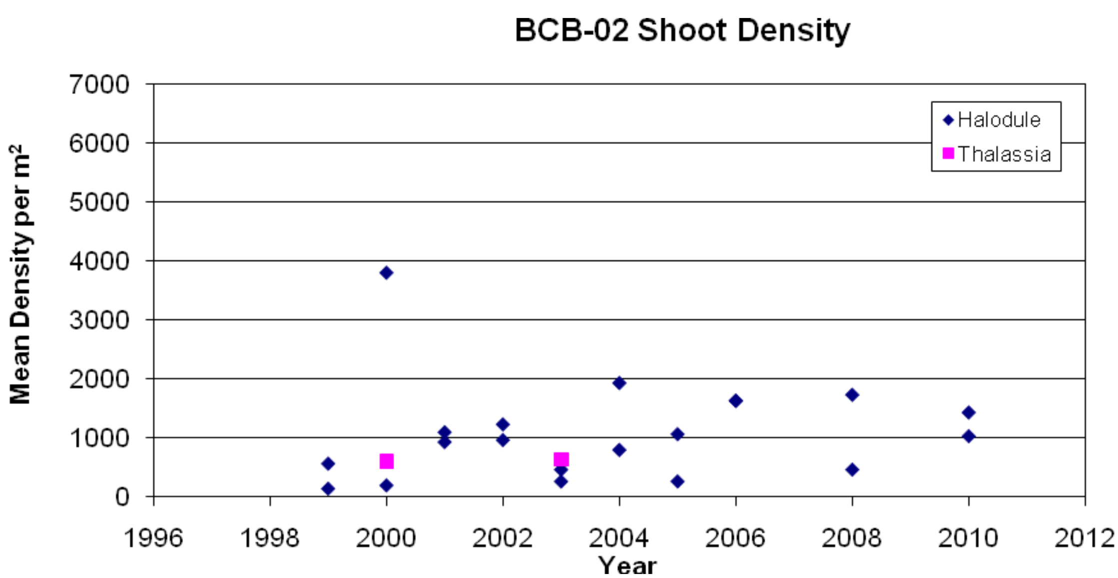
BCB-02 Epibiont Density Graph



BCB-02 Canopy Height Graph



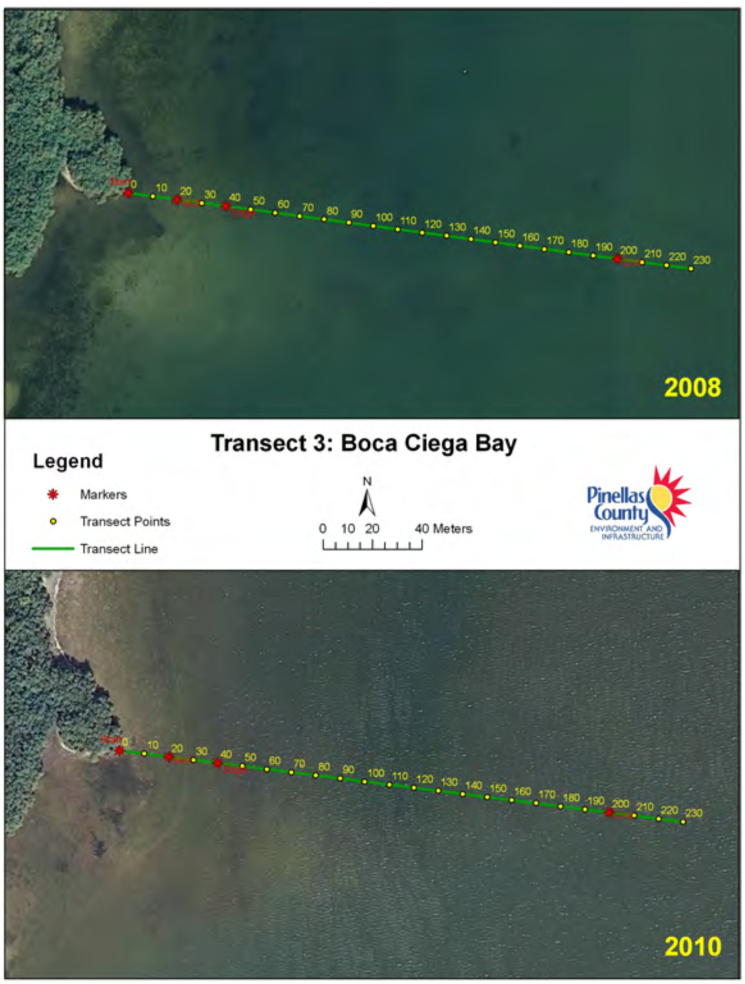
BCB-02 Shoot Density Graph



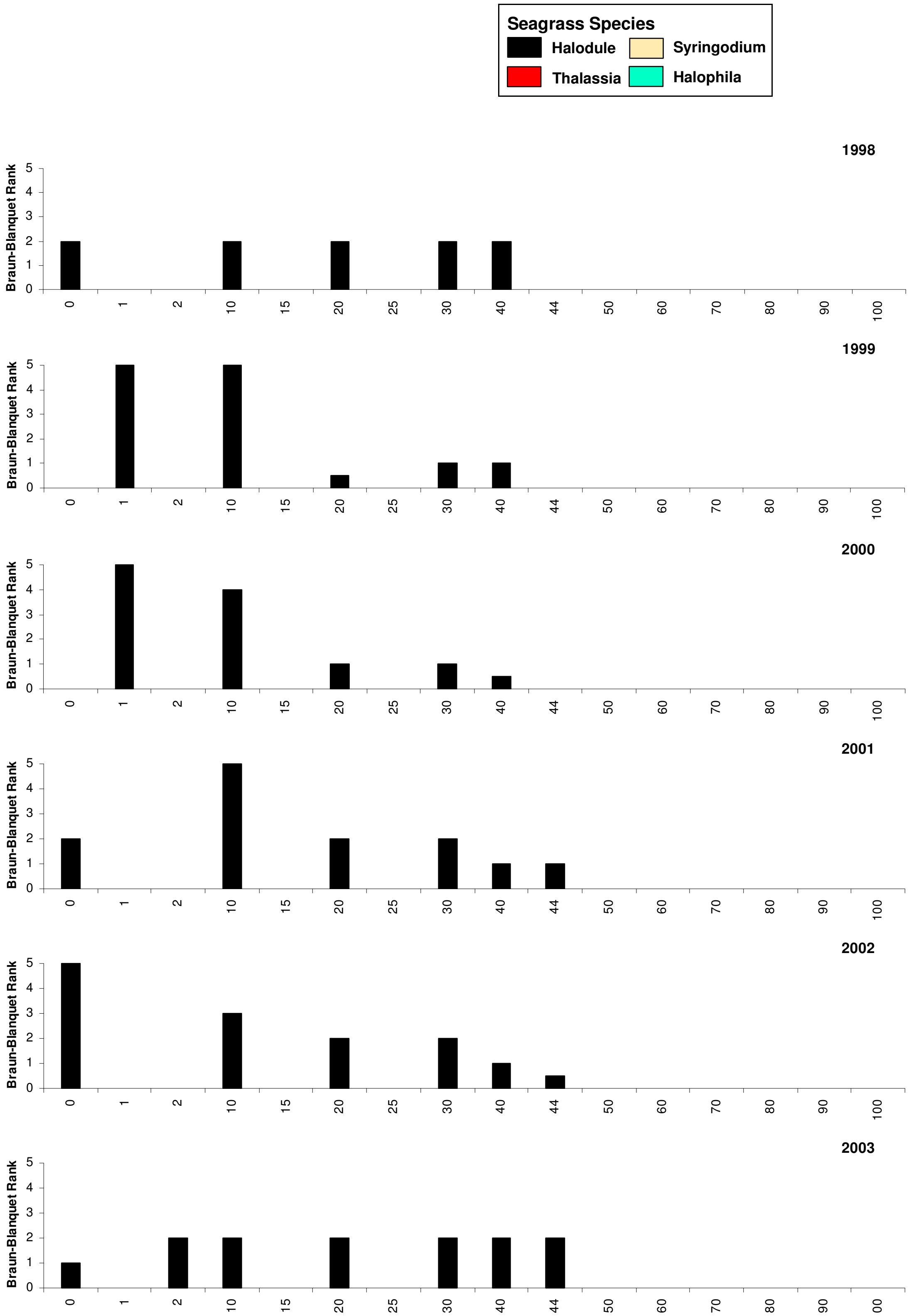
3.2.1.3 BCB-03

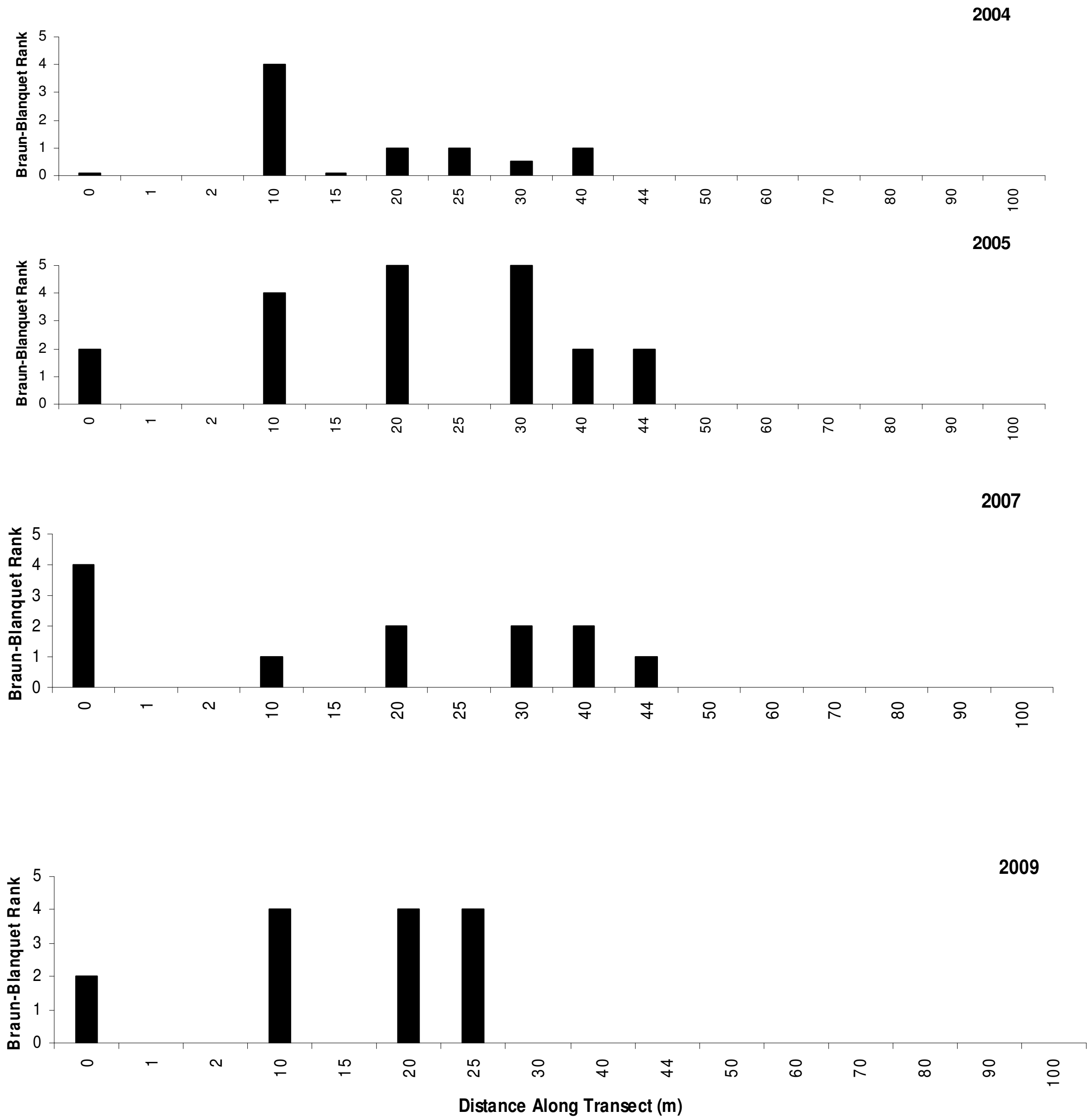
BCB-03 is located south of the Bay Pines boat ramp. The transect extends 50m from the mangrove shoreline towards the boat channel. The depth ranged from 10cm-90cm. The sediment composition was sandy mud along the transect. The prominent seagrass was *Halodule*. The condition of the seagrass varied between poor and fair with a few observations of good.

BCB-03 remained stable throughout most of the monitoring program. The data indicated that the edge of bed varied from 40m to 44m from 1998-2007. However, in 2009 the bed receded to 25m. The reason for this change is not certain; however, it is most likely due to sampler error in that they did not follow the same track as previous years. The abundance of *Halodule* varied along the transect. The epibiont density ranged from light to moderate with heavy coverage in 2005. The epibiont assemblages consisted of attached algae. The canopy height showed an increasing trend from 1998-2002 from 5cm to 20 cm. In 2004, the canopy height dropped to 5cm, recovered in 2005 to 25-35cm, and then drastically fell to 2-4cm in 2007. The canopy height rebounded some in 2009 to 8-16cm. Field comments from 2007 indicated the *Halodule* was buried under sediment. The shoot density ranged from 200-850 shoots (per m^2). The shoot density in 2001, 2005, and 2009 reflected the highest abundance recorded.

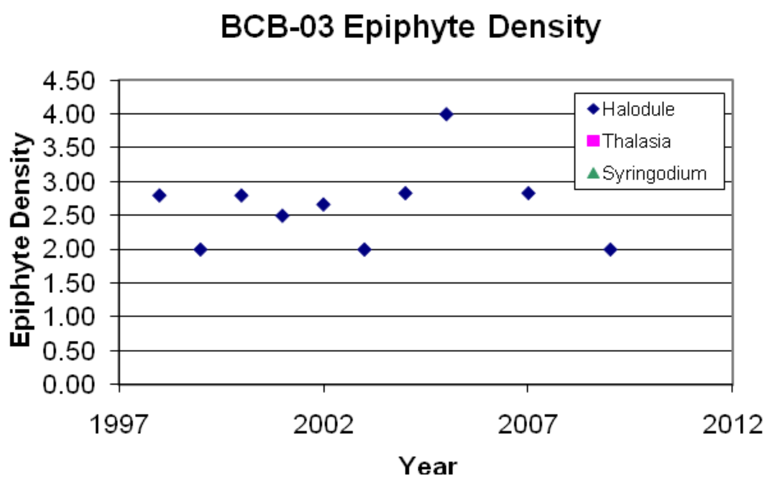


BCB-03 Transect Graphs

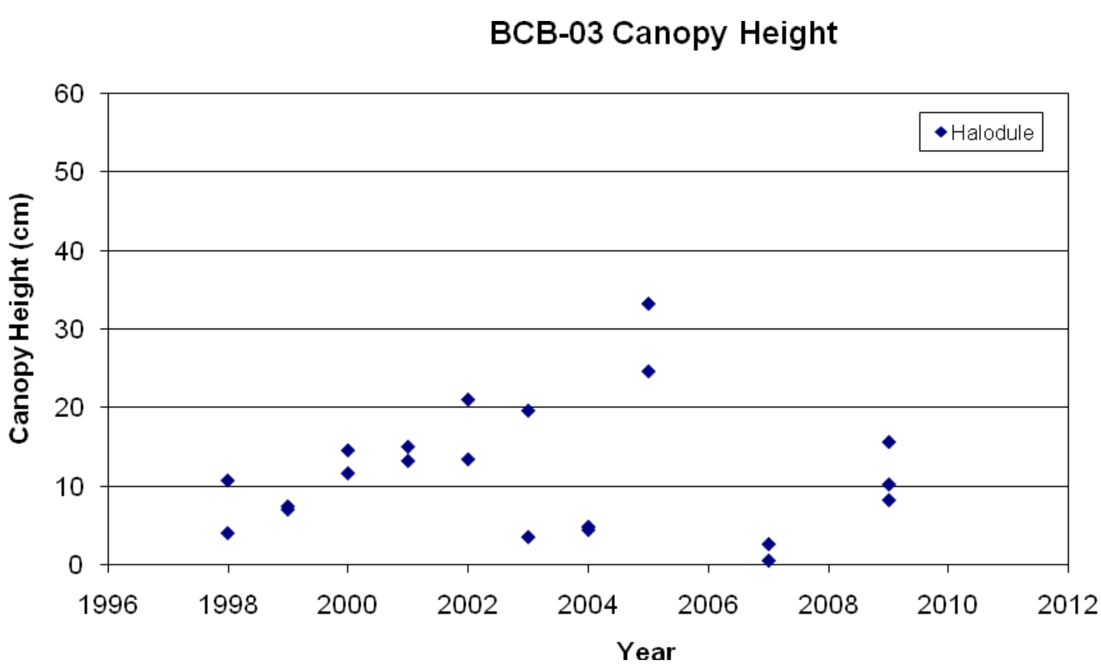



2004
2005
2007
2009
Braun-Blanquet Rank
0
1
2
3
4
5
0
1
2
10
15
20
25
30
40
44
50
60
70
80
90
100
Distance Along Transect (m)

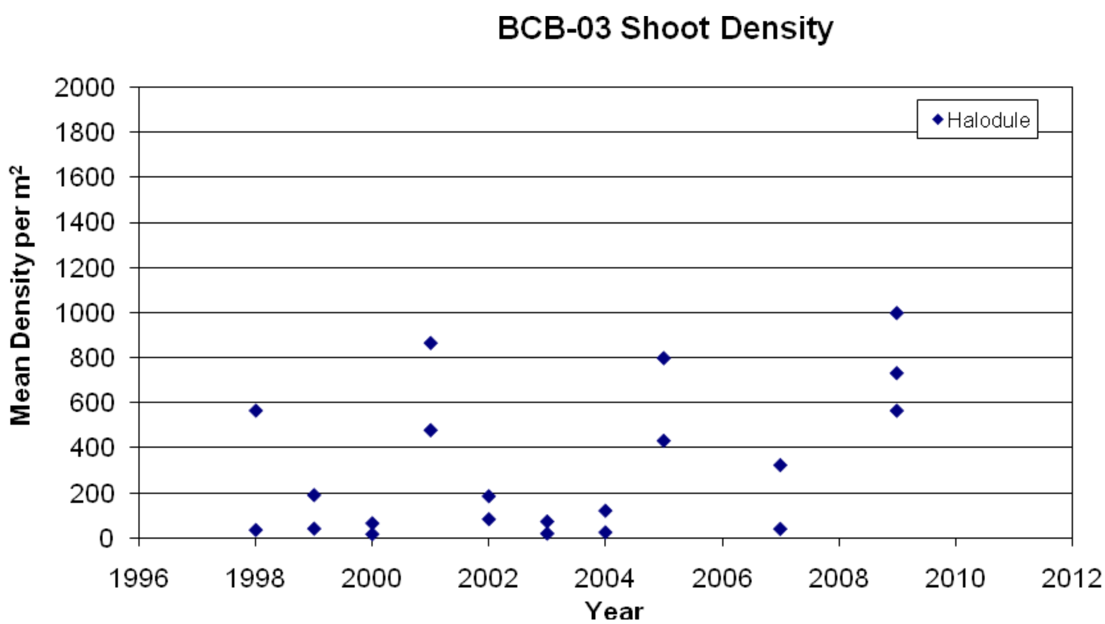
BCB-03 Epibiont Density Graph



BCB-03 Canopy Height Graph



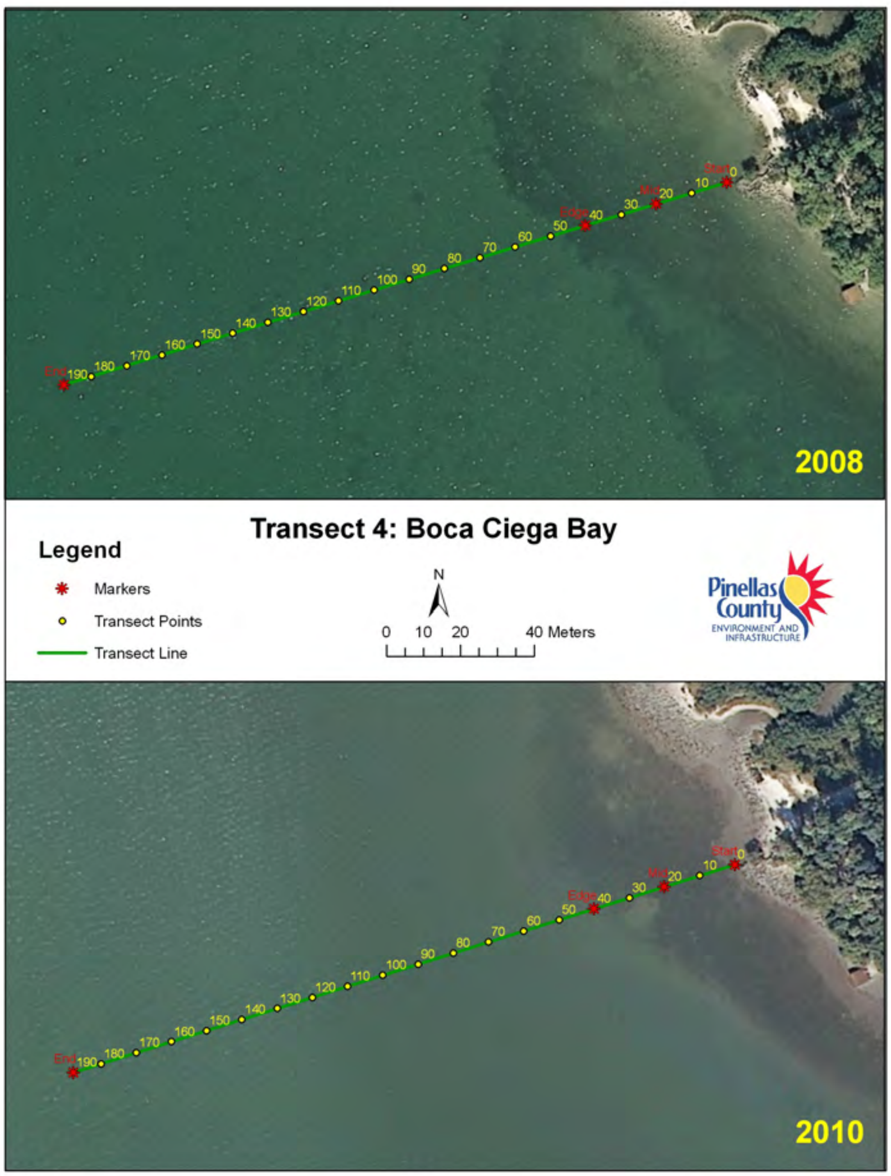
BCB-03 Shoot Density Graph

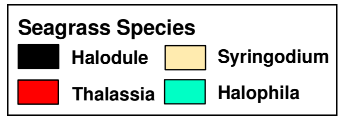


3.2.1.4 BCB-04

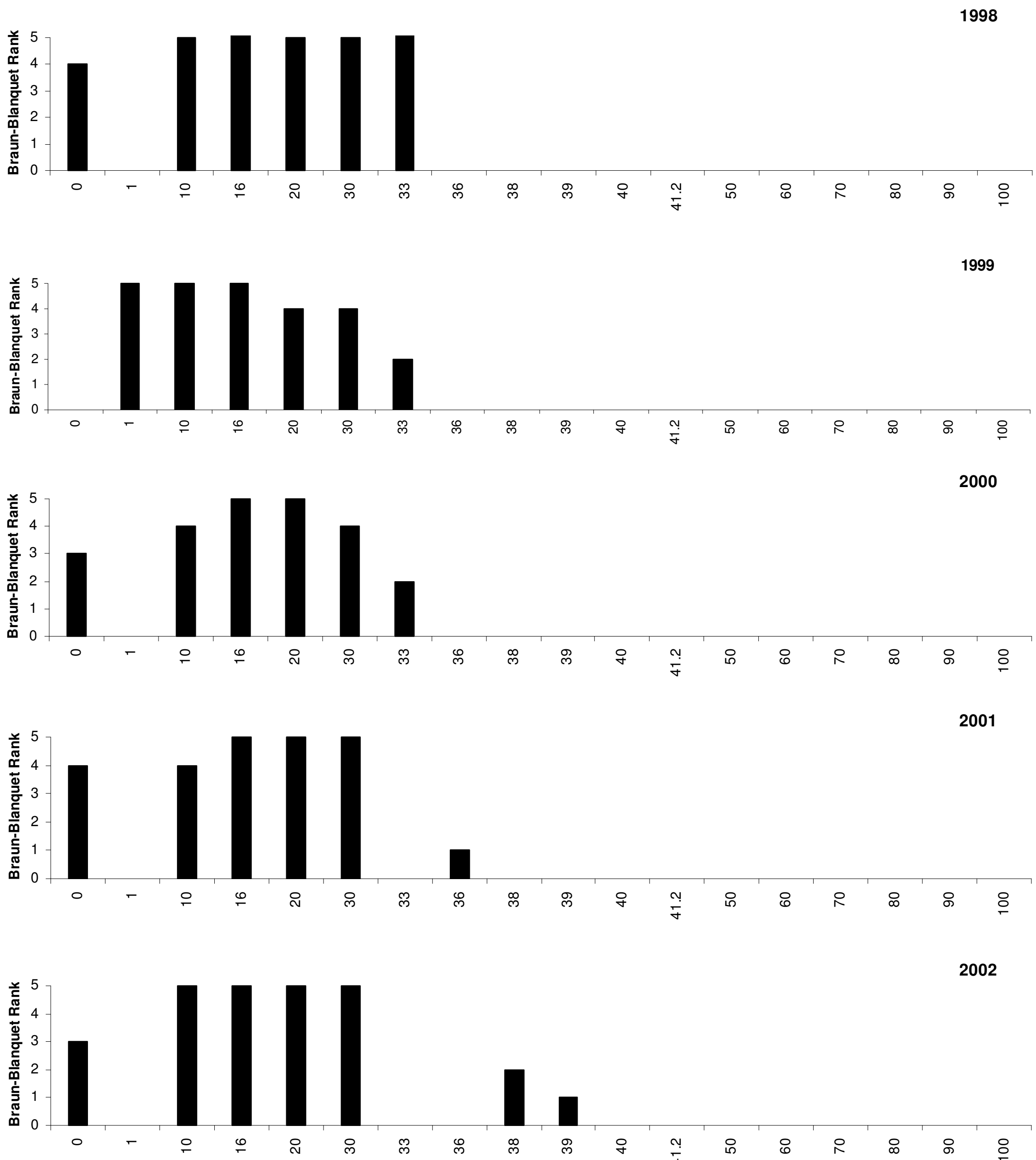
BCB-04 is located on the south side of Jungle Prada Park on the east edge of the ICW. The transect extends 50m from the shoreline towards the boat channel. The depth ranged from 50cm-140cm. The sediment composition shifted between mud and sandy mud. The prominent seagrass was *Halodule*. The condition of the seagrass was good with a few observations of fair.

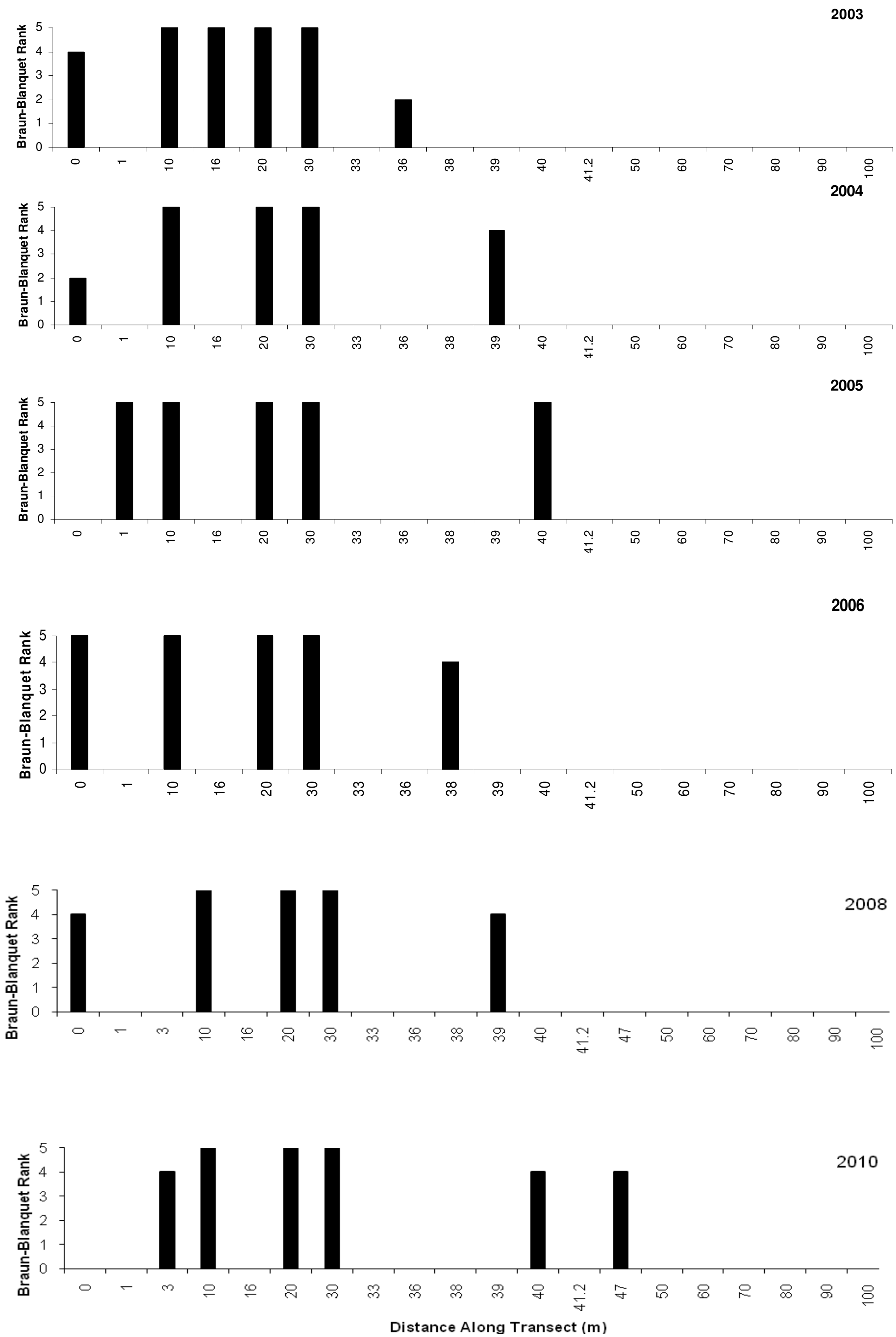
BCB-04 remained stable and possibly increased throughout the monitoring program. The data indicated that the edge of bed varied from 33m in 1998 to 47m in 2010. The epibiont density varied from light coverage in 2000, 2004, 2008, and 2010 to heavy coverage in 2001, 2002, and 2006. The epibiont assemblages consisted of attached algae and polycheates. The canopy height ranged from 10cm-45cm with a median observation of 30cm. The shoot density ranged from 150 shoots (per m^2) in 1998 to 1800 shoots (per m^2) in 2004 with no apparent trend.



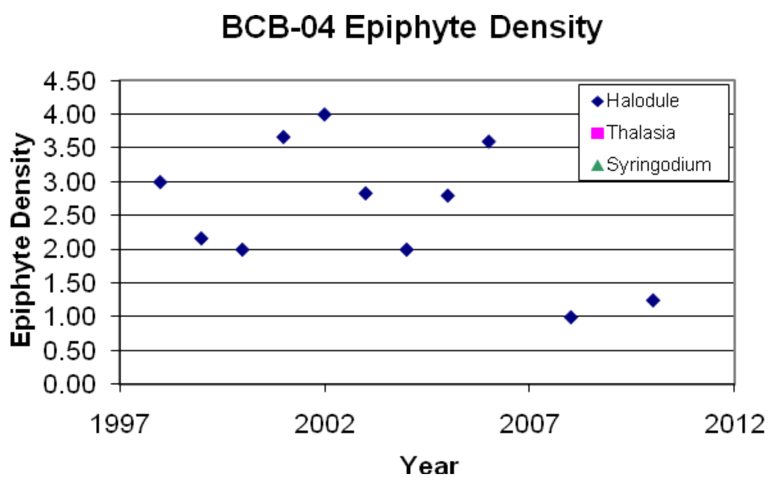


BCB-04 Transect Graphs

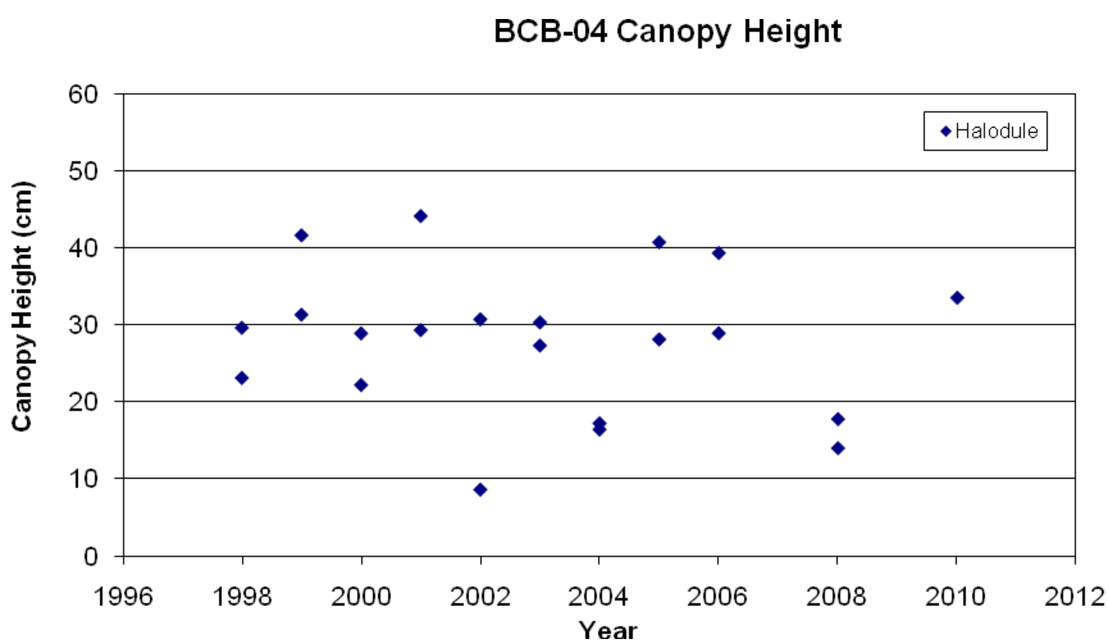



2003
2004
2005
2006
2008
2010
Braun-Blanquet Rank
0
1
2
3
4
5
0
1
3
10
16
20
30
33
36
38
39
40
41.2
47
50
60
70
80
90
100
Distance Along Transect (m)

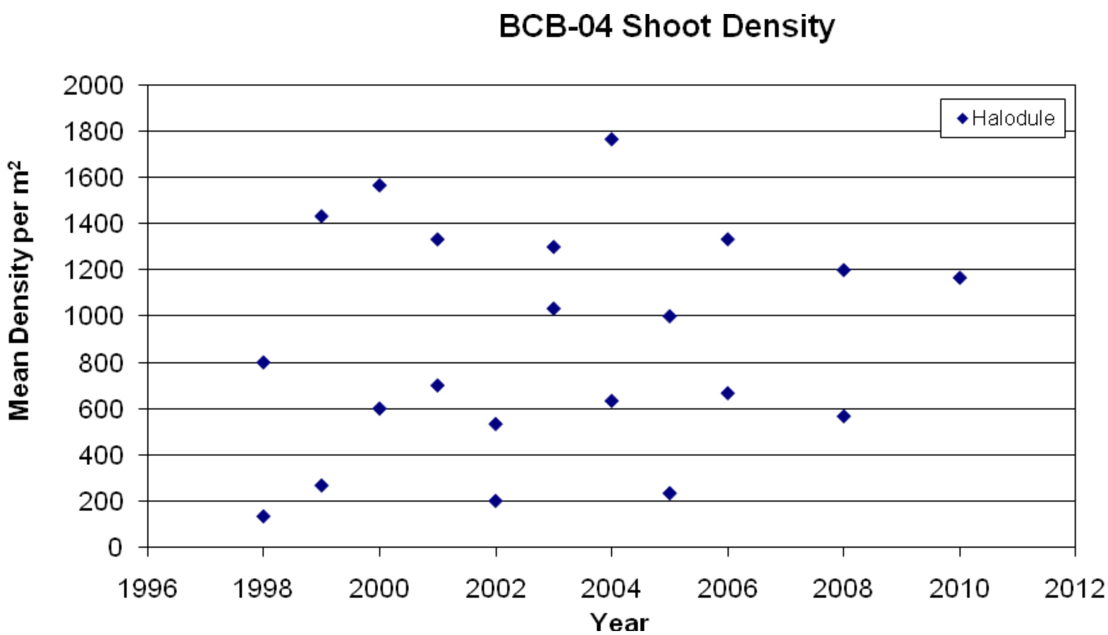
BCB-04 Epibiont Density Graph



BCB-04 Canopy Height Graph



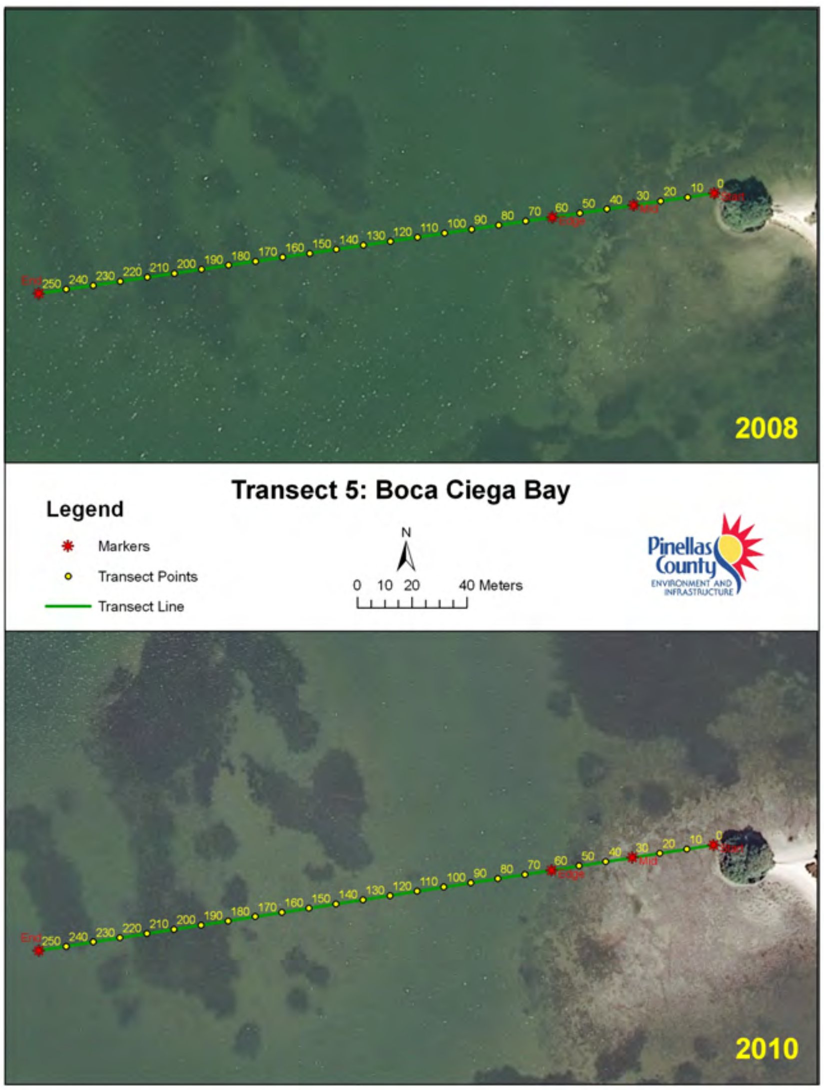
BCB-04 Shoot Density Graph

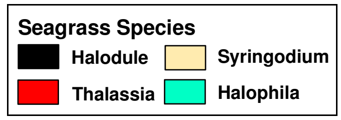


3.2.1.5 BCB-05

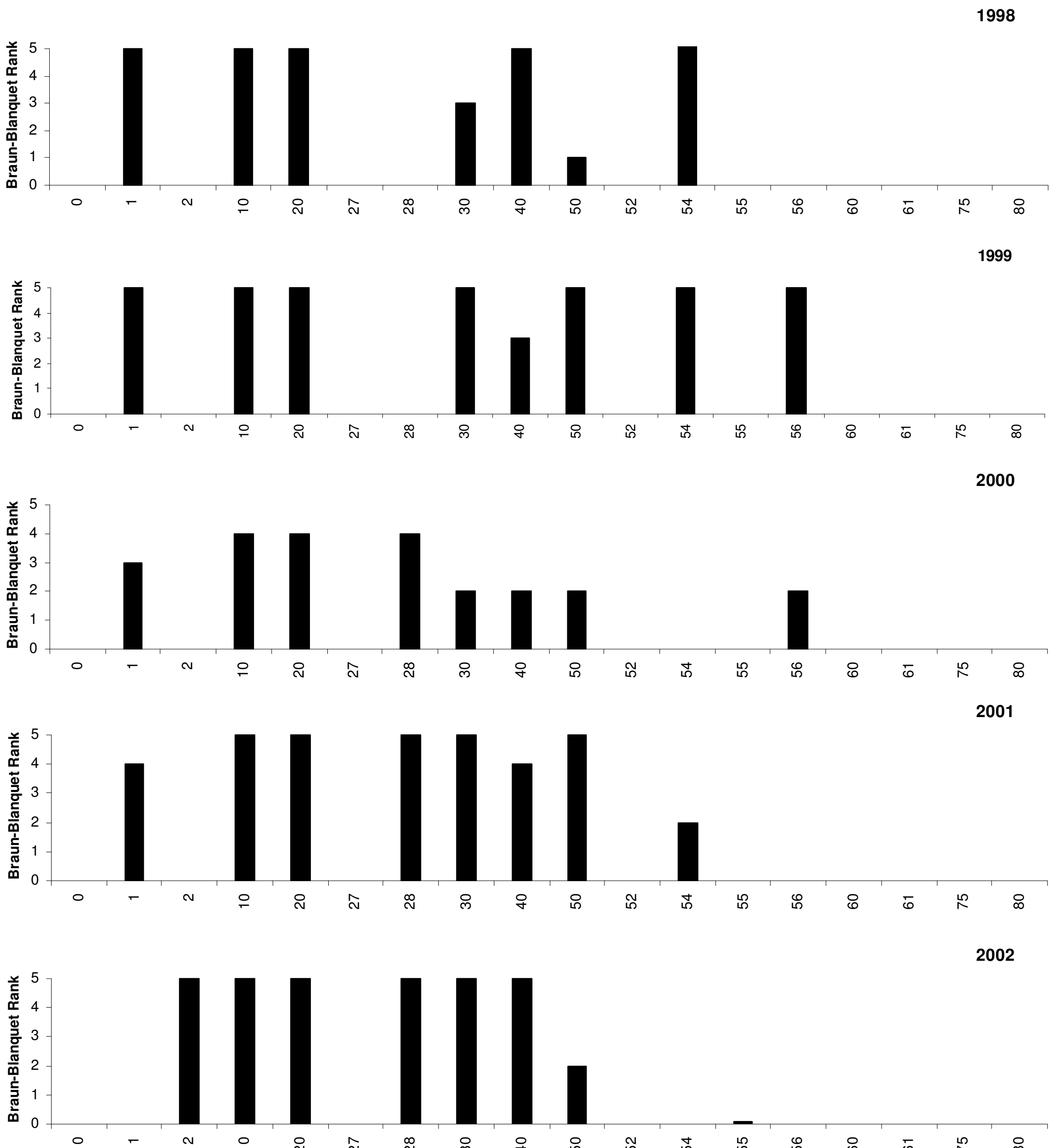
BCB-05 is located in the central portion of Boca Ciega Bay. The transect extends 80m towards the ICW and Pasadena Island. The depth ranged from 40cm-120cm. The sediment composition was mud from 0-50m then shifted to sand for the remainder of the transect. The prominent seagrass was *Halodule*. The condition of the seagrass was rated as fair to good.

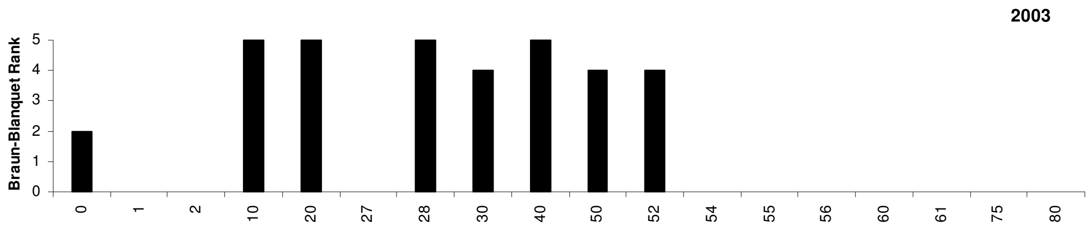
BCB-05 remained stable with some variation on the nearshore edge and edge of bed. The data indicated that the edge of bed fluctuated between 50m in 2002 to 61m in 2007. The abundance of *Halodule* was high along the transect. The 2009 survey exhibited the first recording of *Thalassia* along the transect. The epibiont density varied from moderate to heavy with assemblages consisting of attached algae, polycheates, barnacles, and bryozoans. The canopy height ranged from 5cm to 40cm. The canopy height steadily increased from 15cm in 2000 to 40cm in 2006, then dropped to 25cm in 2007 and rose slightly again in 2009. The shoot density ranged from 50 shoots (per m^2) to over 5000 shoots (per m^2) with most of the recorded density values between 500-2000 shoots (per m^2).

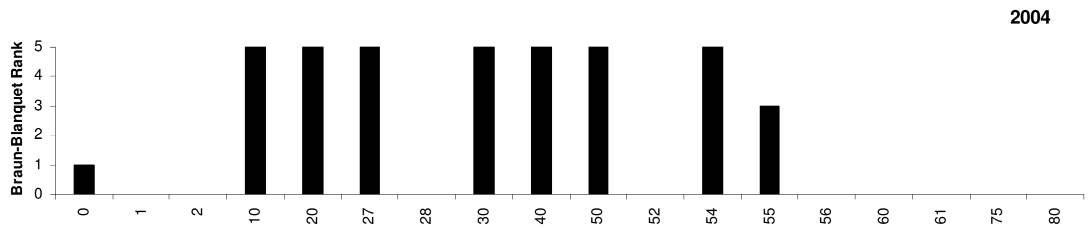


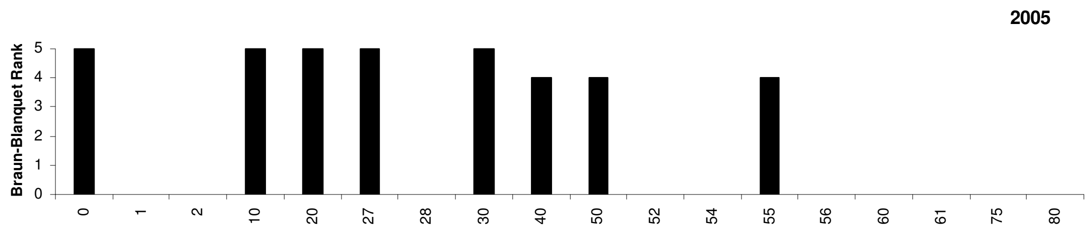


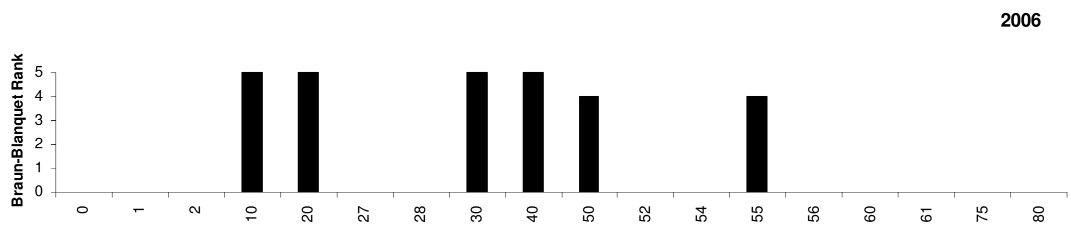
BCB-05 Transect Graphs

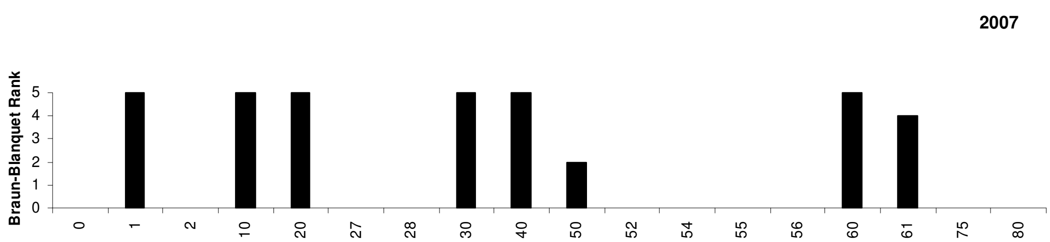


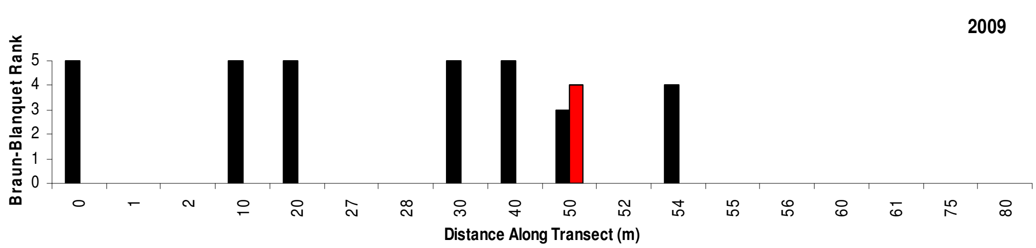

2003
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80


2004
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80

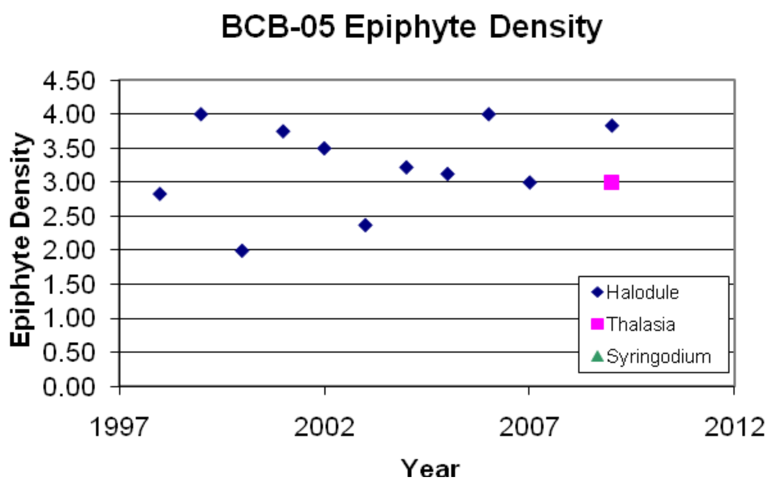

2005
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80


2006
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80

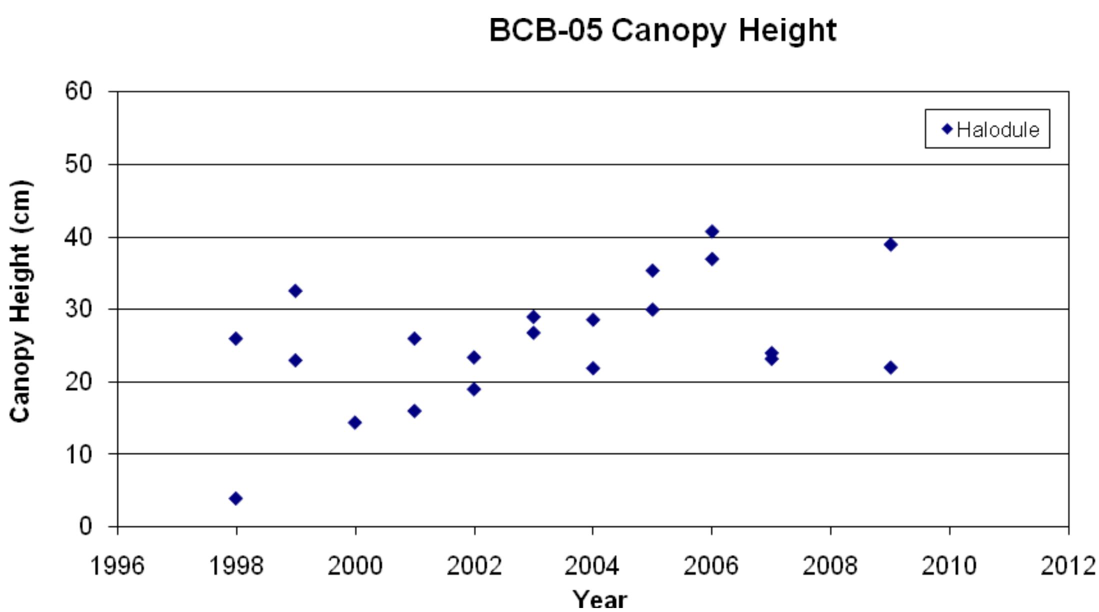

2007
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80


2009
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 2 10 20 27 28 30 40 50 52 54 55 56 60 61 75 80
Distance Along Transect (m)

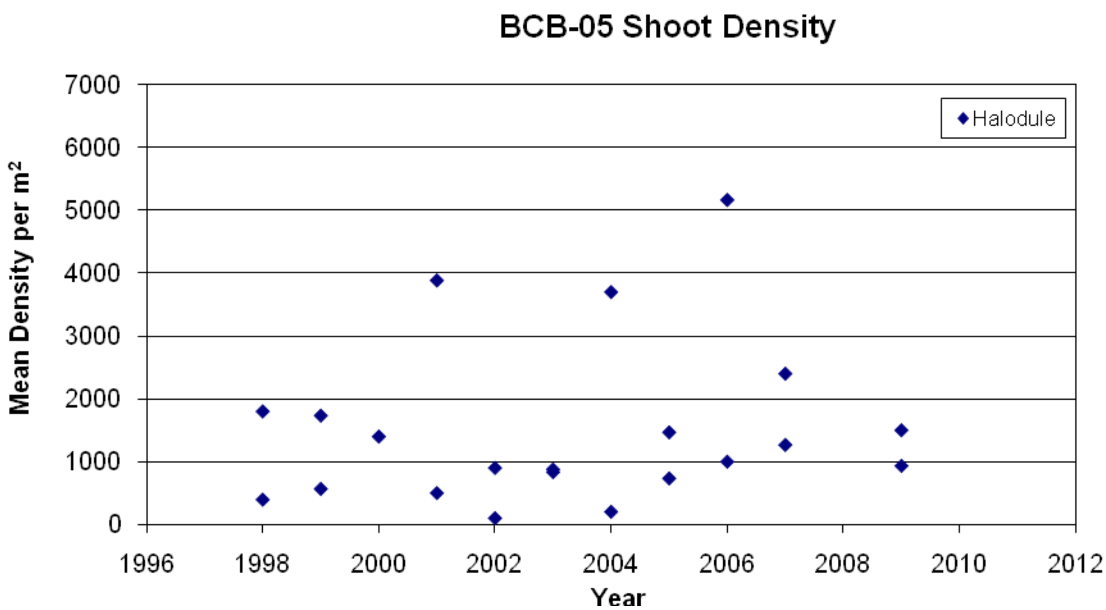
BCB-05 Epibiont Density Graph



BCB-05 Canopy Height Graph



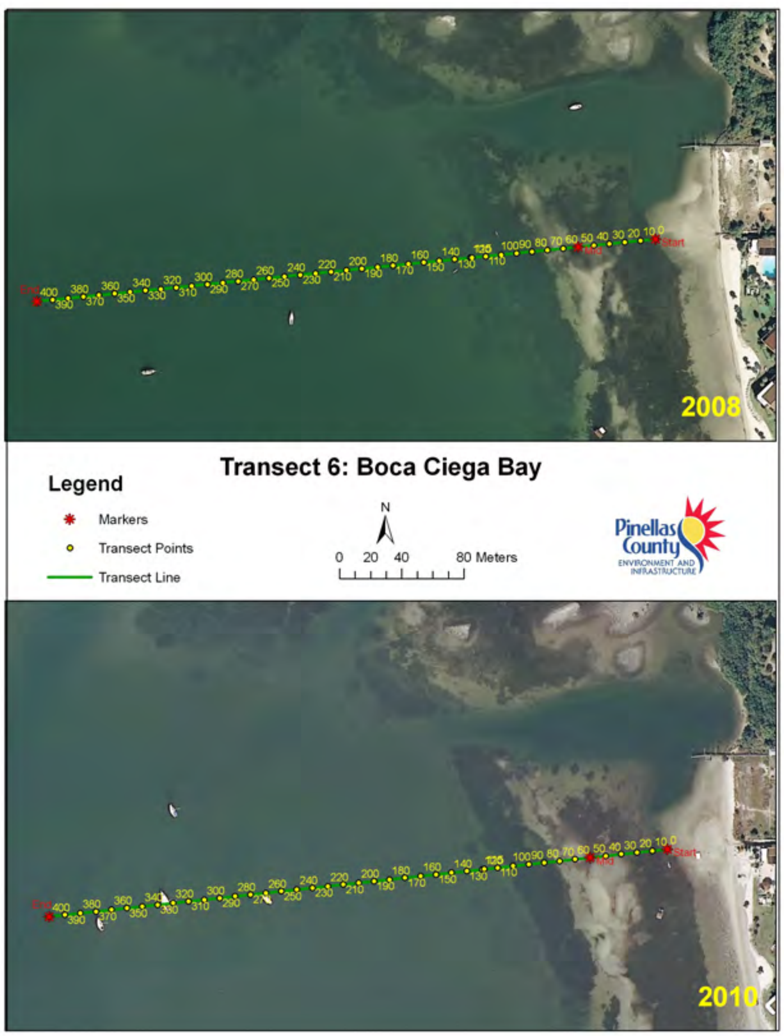
BCB-05 Shoot Density Graph

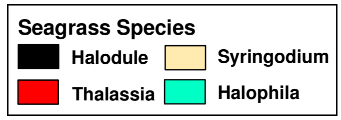


3.2.1.6 BCB-06

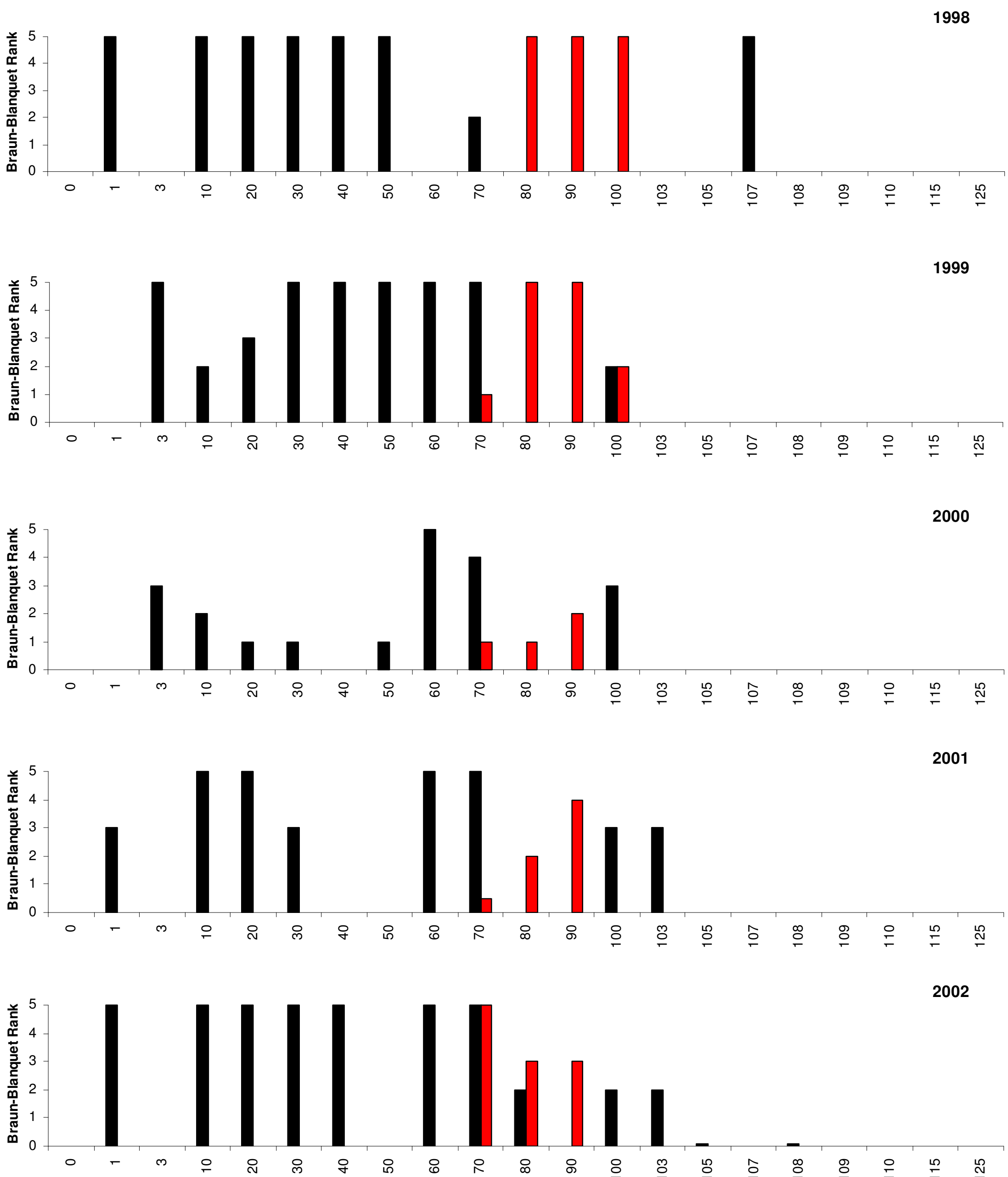
BCB-06 is located near Gulfport just south of the mouth of Clam Bayou. The transect extends 115m west from the shoreline. The depth ranged from 20cm-140cm. The sediment composition shifted between sandy mud and sand throughout the transect. There appeared to be a trend in the sediment between 0m-30m from sandy mud to mud. The prominent seagrass was *Halodule* with *Thalassia* consistent from 70m to 100m. The condition of the seagrass varied greatly from poor to good.

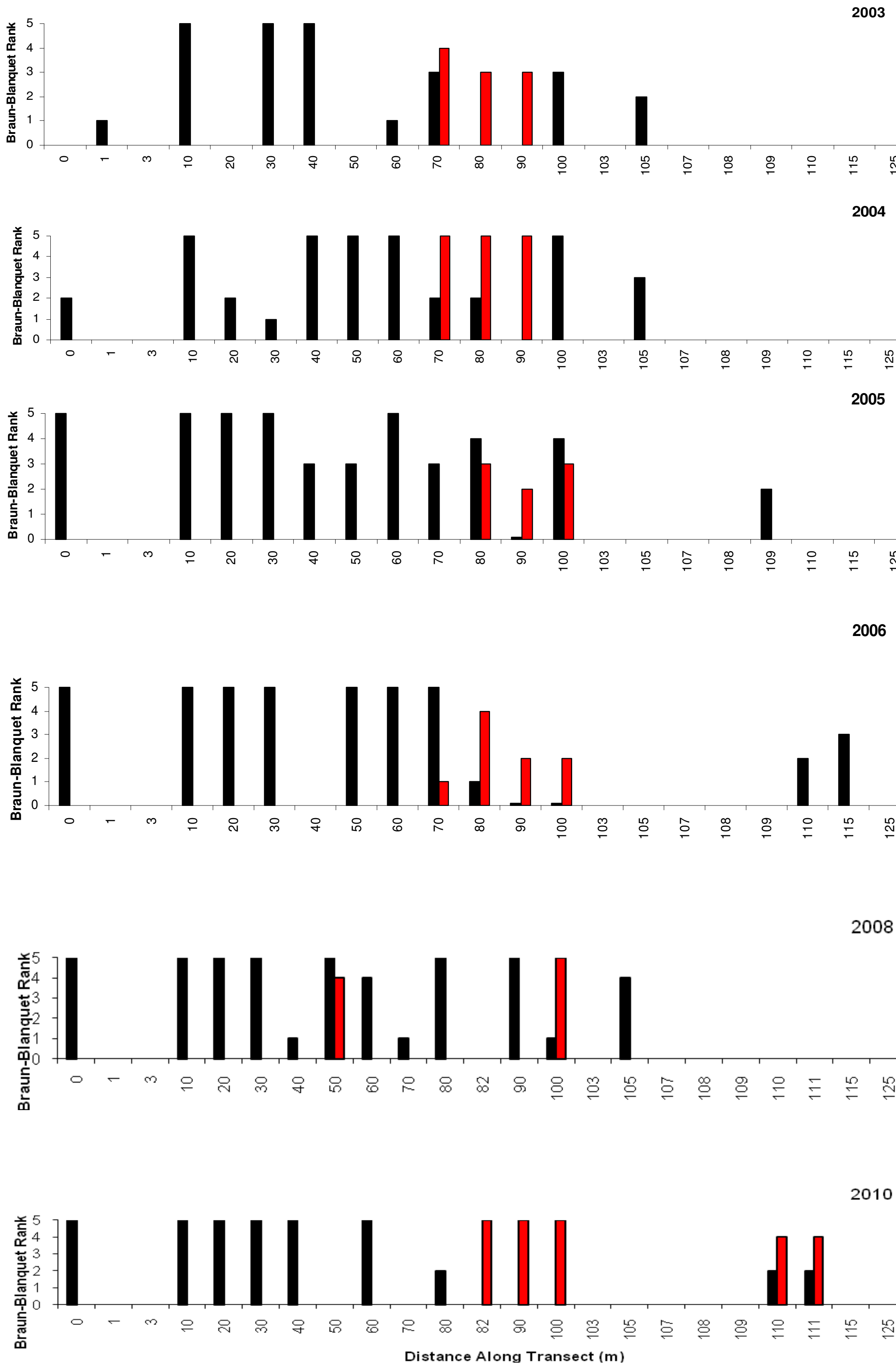
BCB-06 remained relatively stable throughout the monitoring program with the exception of 2000 when the abundance of seagrass dropped significantly. The data indicated that the edge of bed decreased from 107m in 1998 to 100m in 2000 then increased steadily to 115m in 2006 receded to 105 in 2008 but then expanded to 111m in 2010. The epibiont density varied from light to heavy on the *Halodule* and *Thalassia* with assemblages consisting mainly of attached algae, polycheates, and bryozoans. The epibiont density trended downward over recent years (2002-2010). The canopy height ranged from 10cm to 40cm with *Thalassia* being the tallest in 2008 and 2010. The shoot density varied greatly from 25 shoots (per m^2) to nearly 7000 shoots (per m^2).



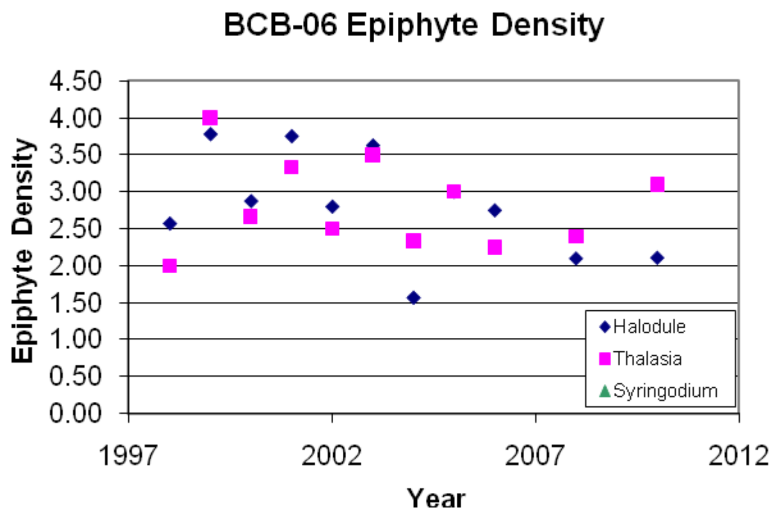


BCB-06 Transect Graphs

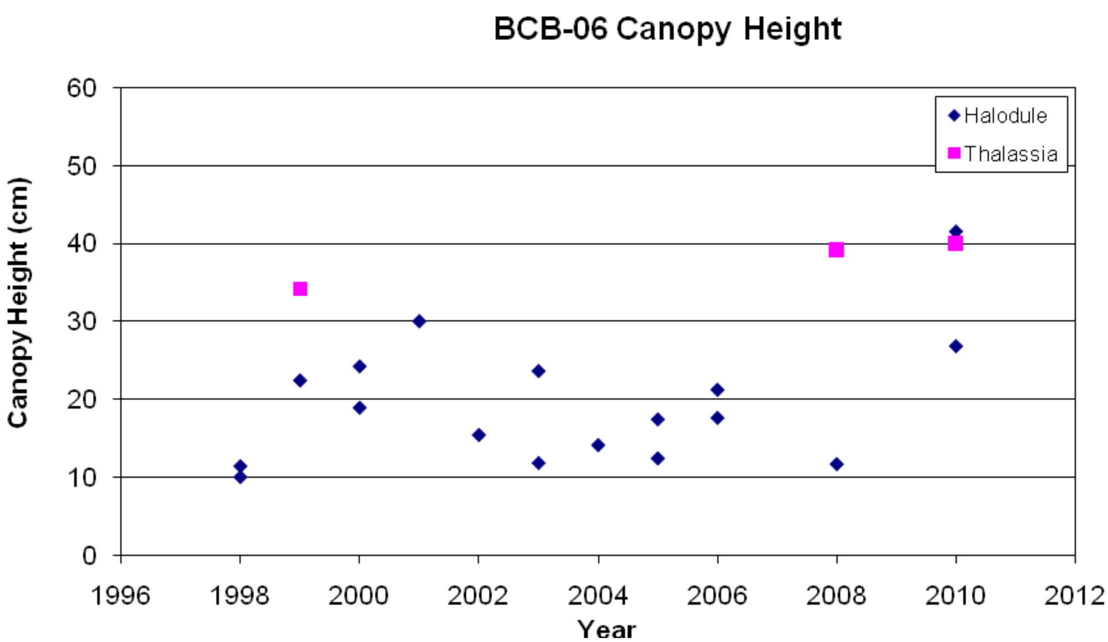



2003
Braun-Blanquet Rank
2004
Braun-Blanquet Rank
2005
Braun-Blanquet Rank
2006
Braun-Blanquet Rank
2008
Braun-Blanquet Rank
2010
Braun-Blanquet Rank
Distance Along Transect (m)

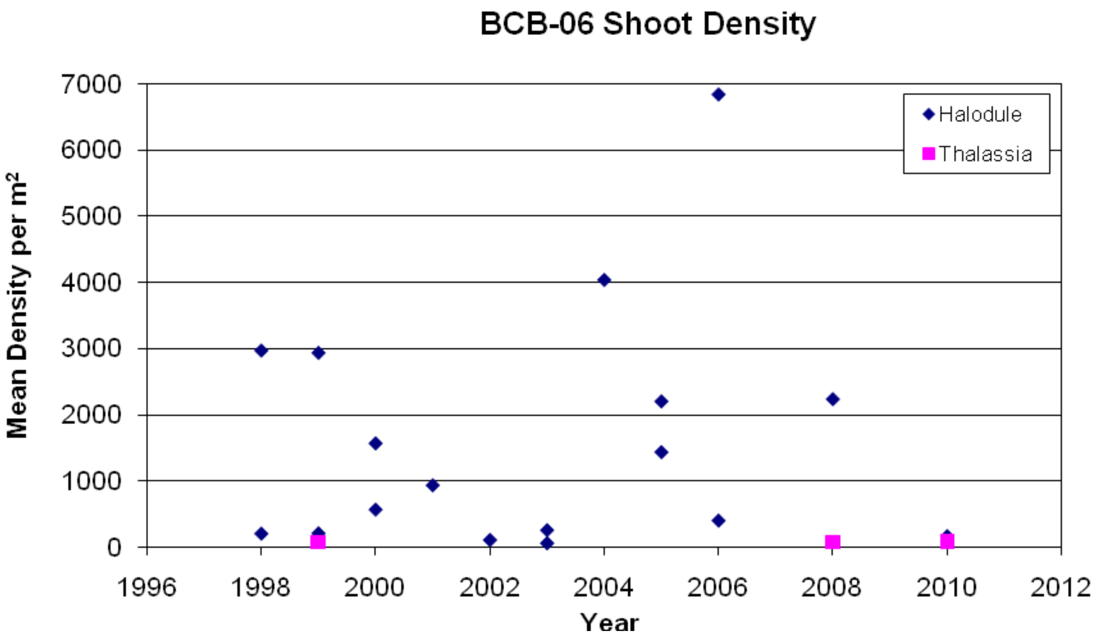
BCB-06 Epibiont Density Graph



BCB-06 Canopy Height Graph



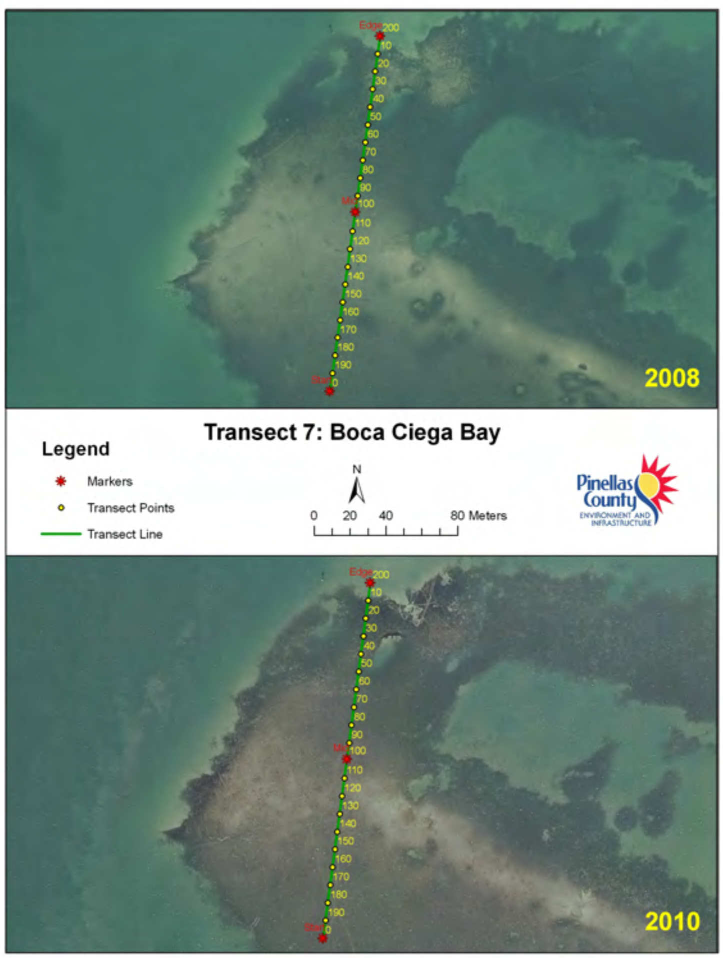
BCB-06 Shoot Density Graph



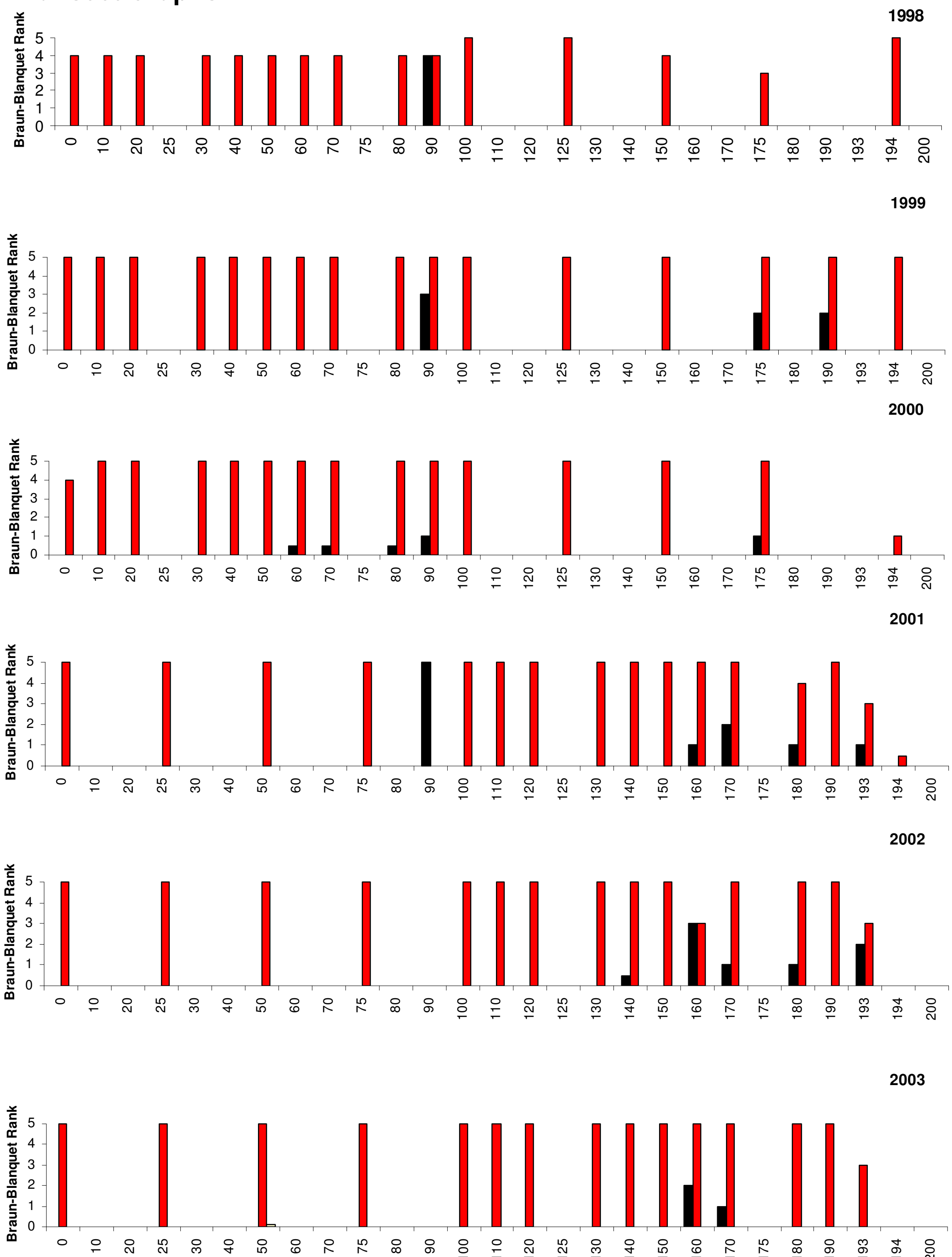
3.2.1.7 BCB-07

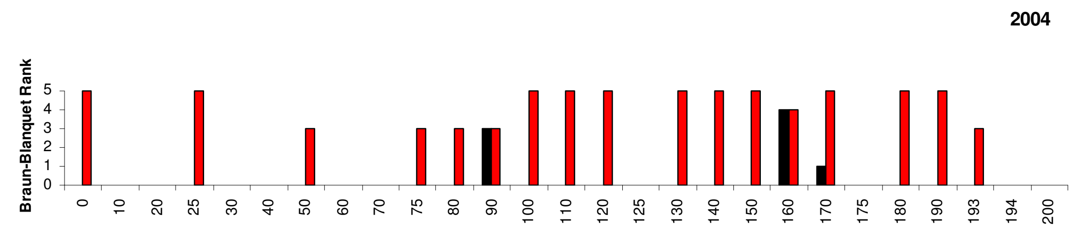
BCB-07 is located on the southeast side of the Tierra Verde Bridge. The transect extends north 200 m from the middle of the seagrass bed towards the ICW. Strong currents influence the north edge of the transect. The depth ranged from 20cm-100cm. The sediment composition varied from mud to sand throughout the monitoring program. Boat propeller scars were recorded in the comments increasing in frequency throughout the monitoring program. The prominent seagrass was *Thalassia* with occasional *Halodule* and sparse *Syringodium*. The condition of the seagrass varied from fair to very good. In 2005, the condition of the seagrass appeared necrotic to poor most likely due to the combination of heavy epibiont densities, very low tides, and below normal temperatures of 40-50 degrees Fahrenheit the week prior to the field survey.

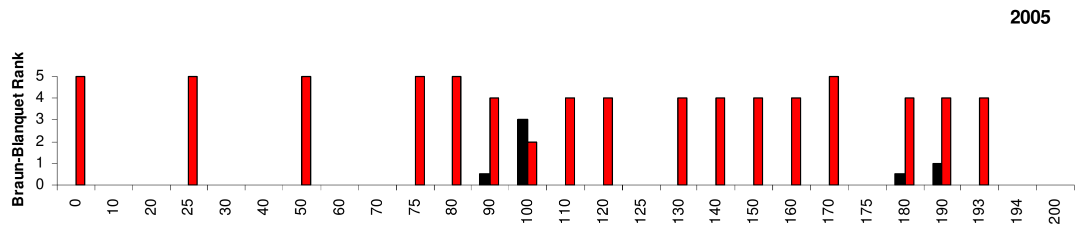
BCB-07 remained stable throughout the monitoring program. The data indicated that the edge of bed was consistently at 193m-194m. The epibiont density was moderate to heavy on the *Thalassia*, and light to moderate on the *Halodule* and *Syringodium* with assemblages consisting of attached algae, polycheates, bryozoans, and barnacles. In 2005, *Lyngbya sp.* covered a large portion of the seagrass bed. The canopy height ranged from 10cm to 40 cm. The shoot density ranged from 100-1000 shoots (per m^2). The shoot density for *Thalassia* decreased from 1998-2003 then increased from 2004 to 2009 with 2000 having the highest shoot density recorded of 1100 (per m^2).

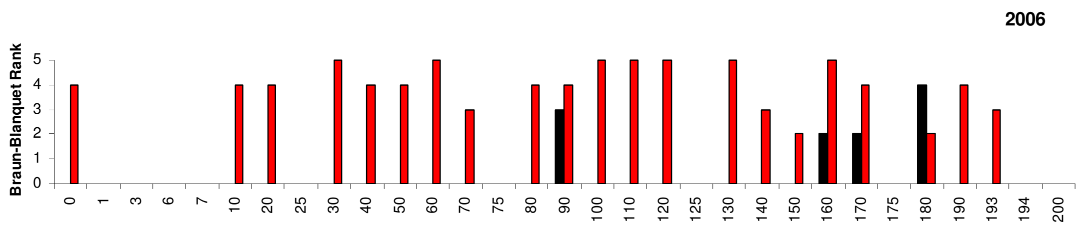


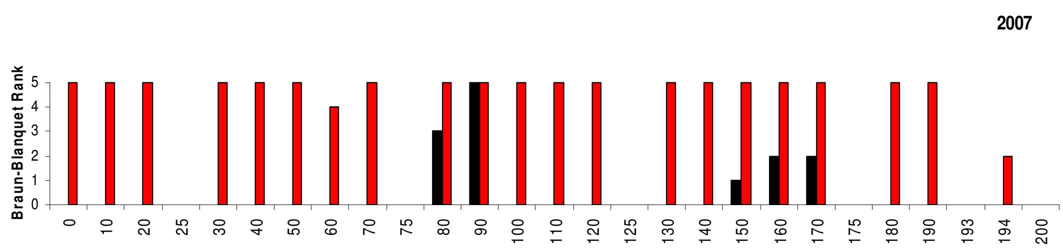
BCB-07 Transect Graphs

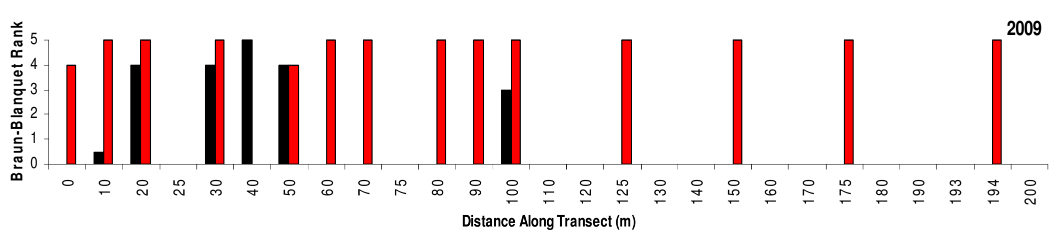



2004
Braun-Blanquet Rank
0 1 2 3 4 5
0 10 20 25 30 40 50 60 70 75 80 90 100 110 120 125 130 140 150 160 170 175 180 190 193 194 200

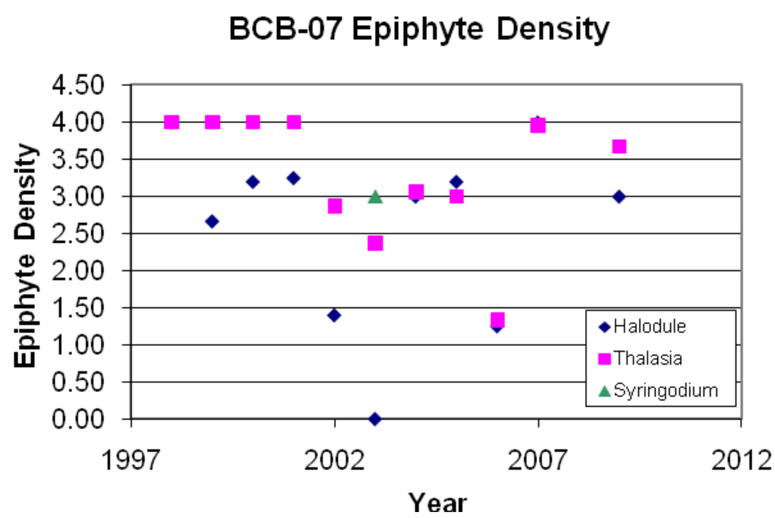

2005
Braun-Blanquet Rank
0 1 2 3 4 5
0 10 20 25 30 40 50 60 70 75 80 90 100 110 120 125 130 140 150 160 170 175 180 190 193 194 200


2006
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 3 6 7 10 20 25 30 40 50 60 70 75 80 90 100 110 120 125 130 140 150 160 170 175 180 190 193 194 200

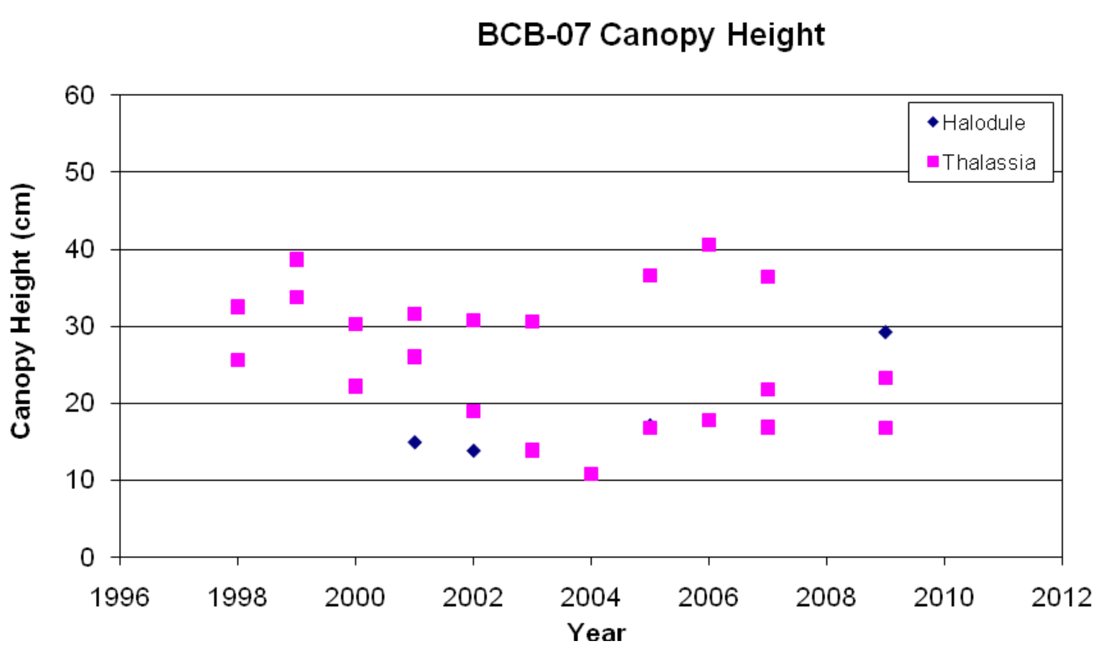

2007
Braun-Blanquet Rank
0 1 2 3 4 5
0 10 20 25 30 40 50 60 70 75 80 90 100 110 120 125 130 140 150 160 170 175 180 190 193 194 200


2009
Braun-Blanquet Rank
0 1 2 3 4 5
0 10 20 25 30 40 50 60 70 75 80 90 100 110 120 125 130 140 150 160 170 175 180 190 193 194 200
Distance Along Transect (m)

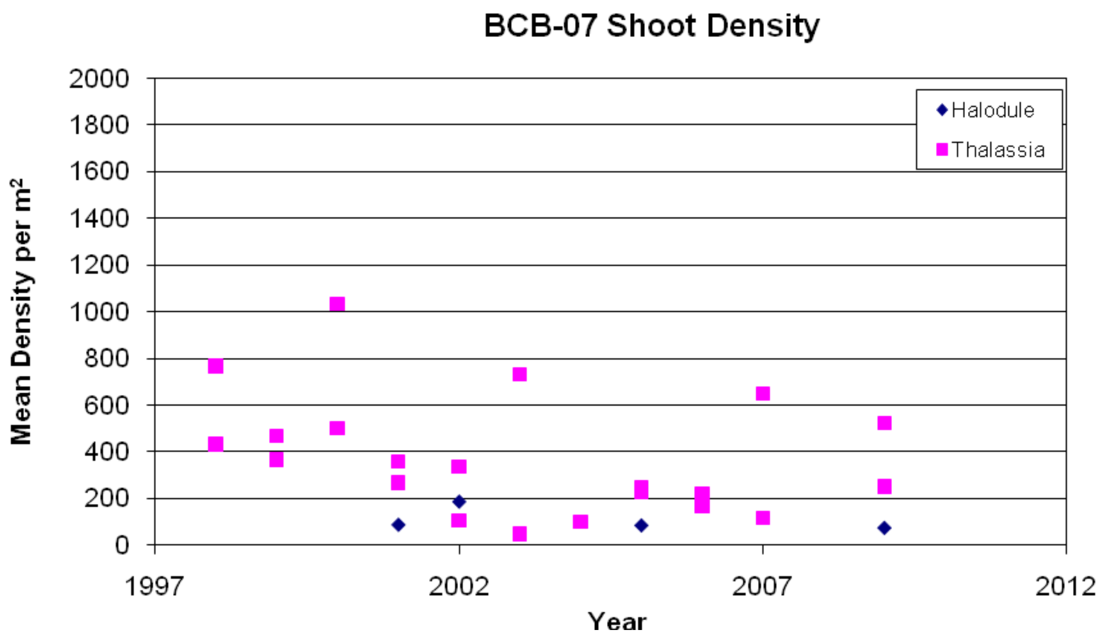
BCB-07 Epibiont Density Graph



BCB-07 Canopy Height Graph



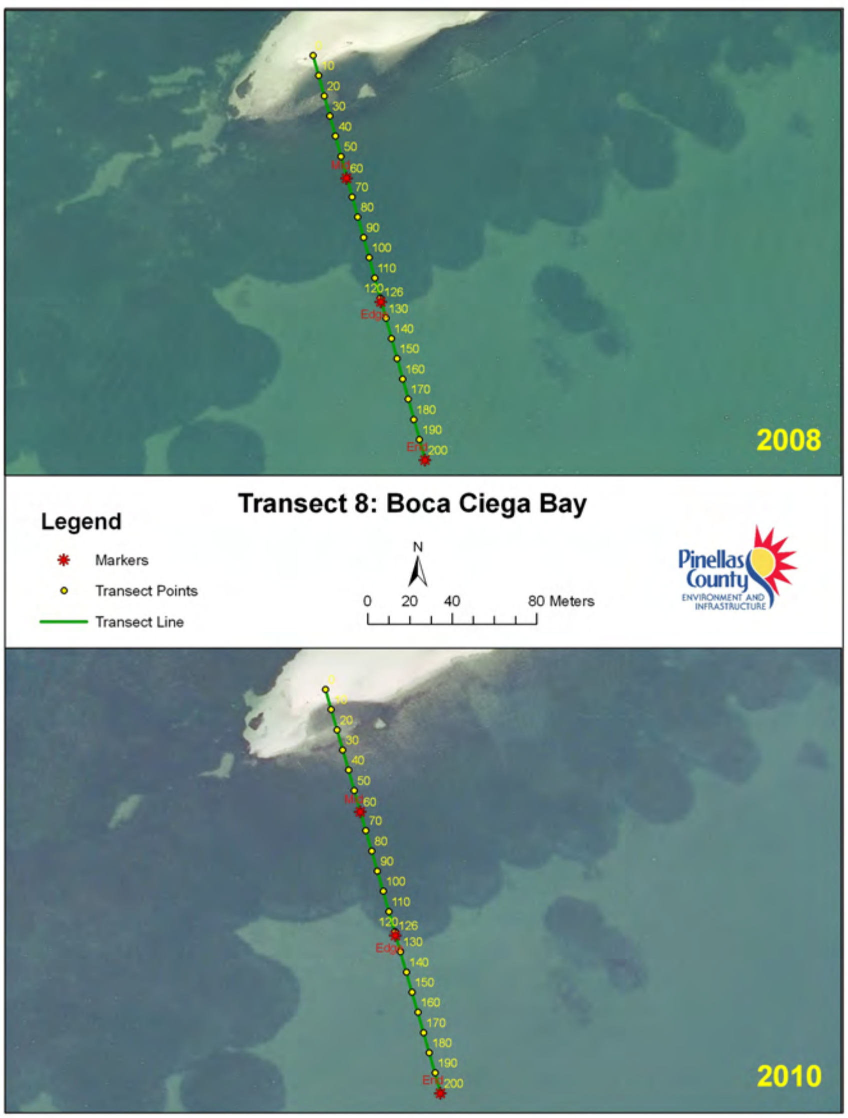
BCB-07 Shoot Density Graph

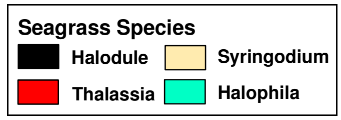


3.2.1.8 BCB-08

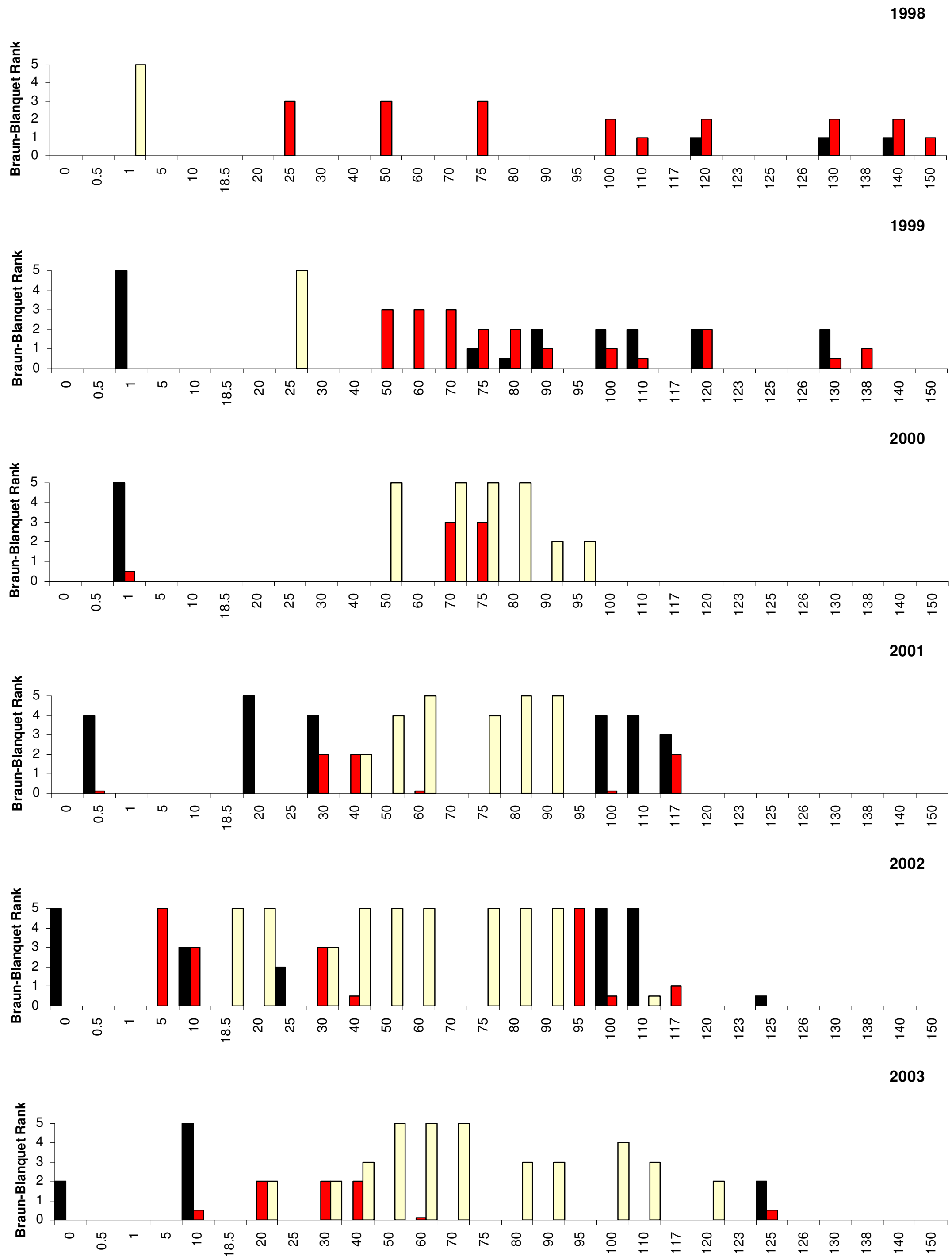
BCB-08 is located on the east side of the Skyway bridge causeway south of Pinellas Point. The transect extends 150m from a sand bar towards the boat channel. The depth ranged from 10cm-225cm. The sediment composition was sand. The seagrass species along the transect consisted of *Halodule, Thalassia*, and *Syringodium*. The condition of the seagrass varied from fair to very good for all three species.

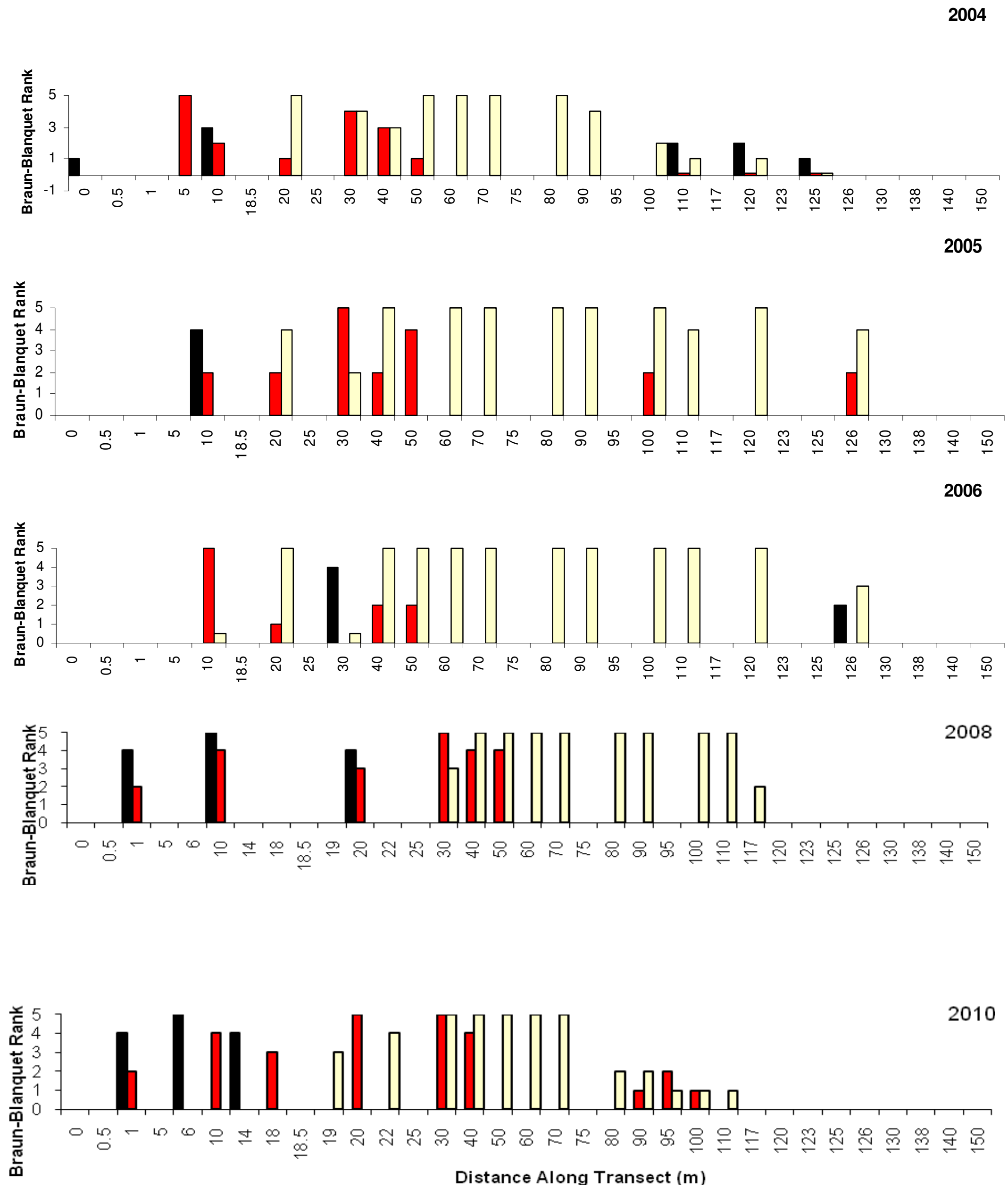
BCB-08 remained mostly stable throughout the monitoring program; however, the distribution of seagrass species along the transect fluctuated. The data indicated that the edge of bed decreased from 150m in 1998 to 100m in 2000 then increased and stabilized at 125m in 2002. However, in 2008 the bed receded to 119m and then to 117m in 2010. The epibiont coverage was light to moderate and trending towards lighter coverage with assemblages consisting of attached algae, bryozoans, and polycheates. The canopy height ranged from 20cm to 50 cm and has been trending upward since 2004. The shoot density ranged from 50-1400 shoots (per m^2).



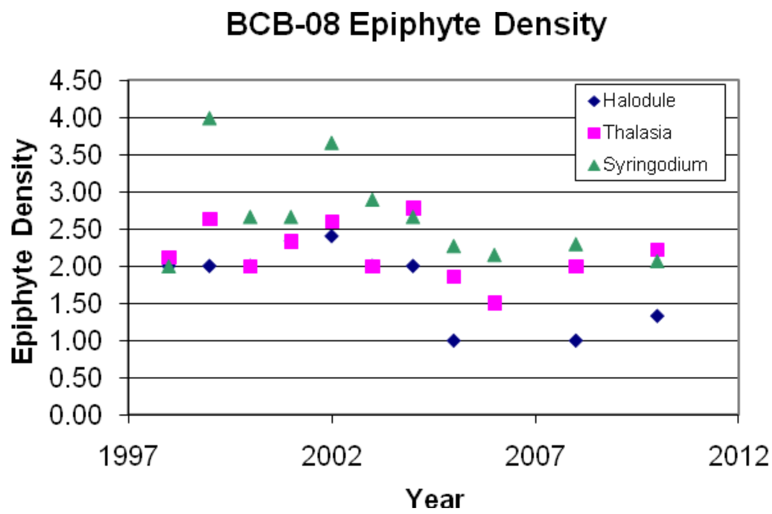


BCB-08 Transect Graphs

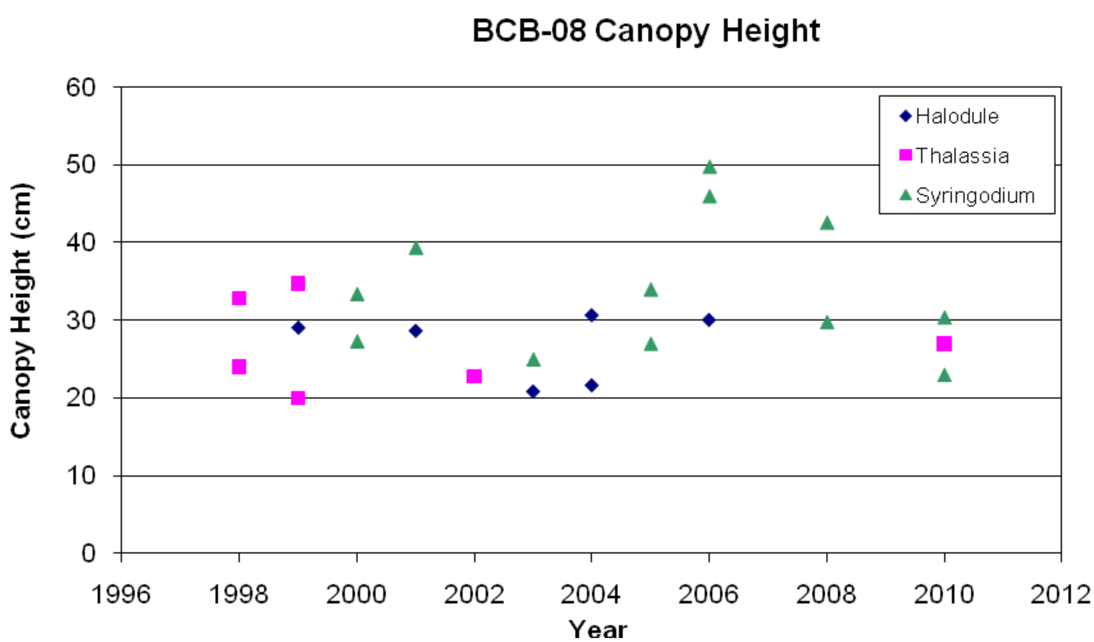



2004
Braun-Blanquet Rank
5
3
1
-1
0 0.5 1 5 10 18.5 20 25 30 40 50 60 70 75 80 90 95 100 110 117 120 123 125 126 130 138 140 150
2005
Braun-Blanquet Rank
5 4 3 2 1 0
0 0.5 1 5 10 18.5 20 25 30 40 50 60 70 75 80 90 95 100 110 117 120 123 125 126 130 138 140 150
2006
Braun-Blanquet Rank
5 4 3 2 1 0
0 0.5 1 5 10 18.5 20 25 30 40 50 60 70 75 80 90 95 100 110 117 120 123 125 126 130 138 140 150
2008
Braun-Blanquet Rank
5 4 3 2 1 0
0 0.5 1 5 6 10 14 18 18.5 19 20 22 25 30 40 50 60 70 75 80 90 95 100 110 117 120 123 125 126 130 138 140 150
2010
Braun-Blanquet Rank
5 4 3 2 1 0
0 0.5 1 5 6 10 14 18 18.5 19 20 22 25 30 40 50 60 70 75 80 90 95 100 110 117 120 123 125 126 130 138 140 150
Distance Along Transect (m)

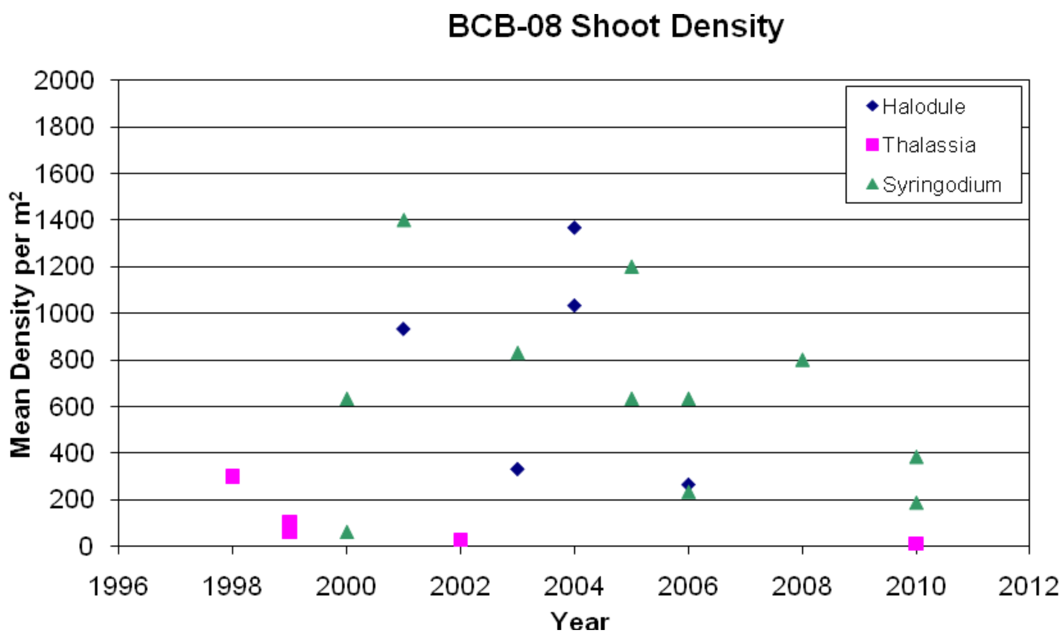
BCB-08 Epibiont Density Graph



BCB-08 Canopy Height Graph



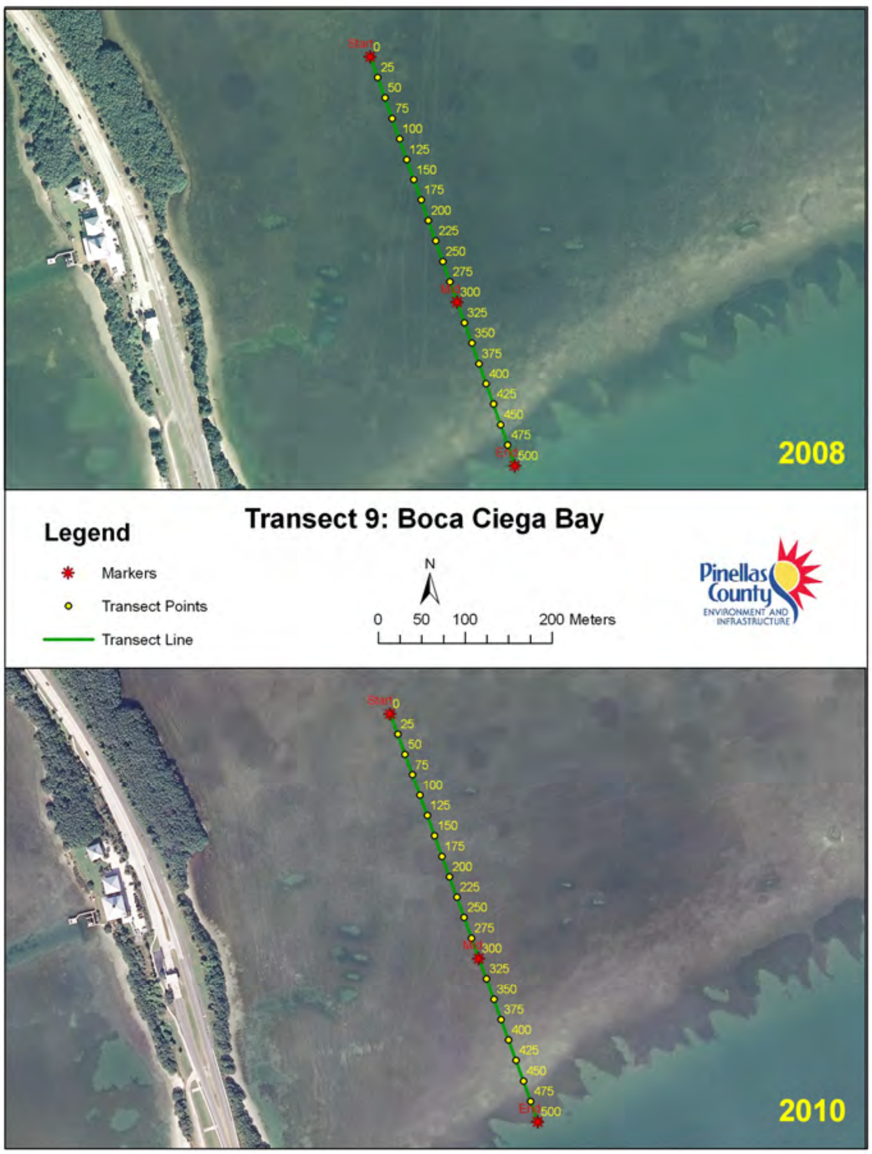
BCB-08 Shoot Density Graph

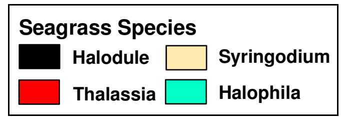


3.2.1.9 BCB09

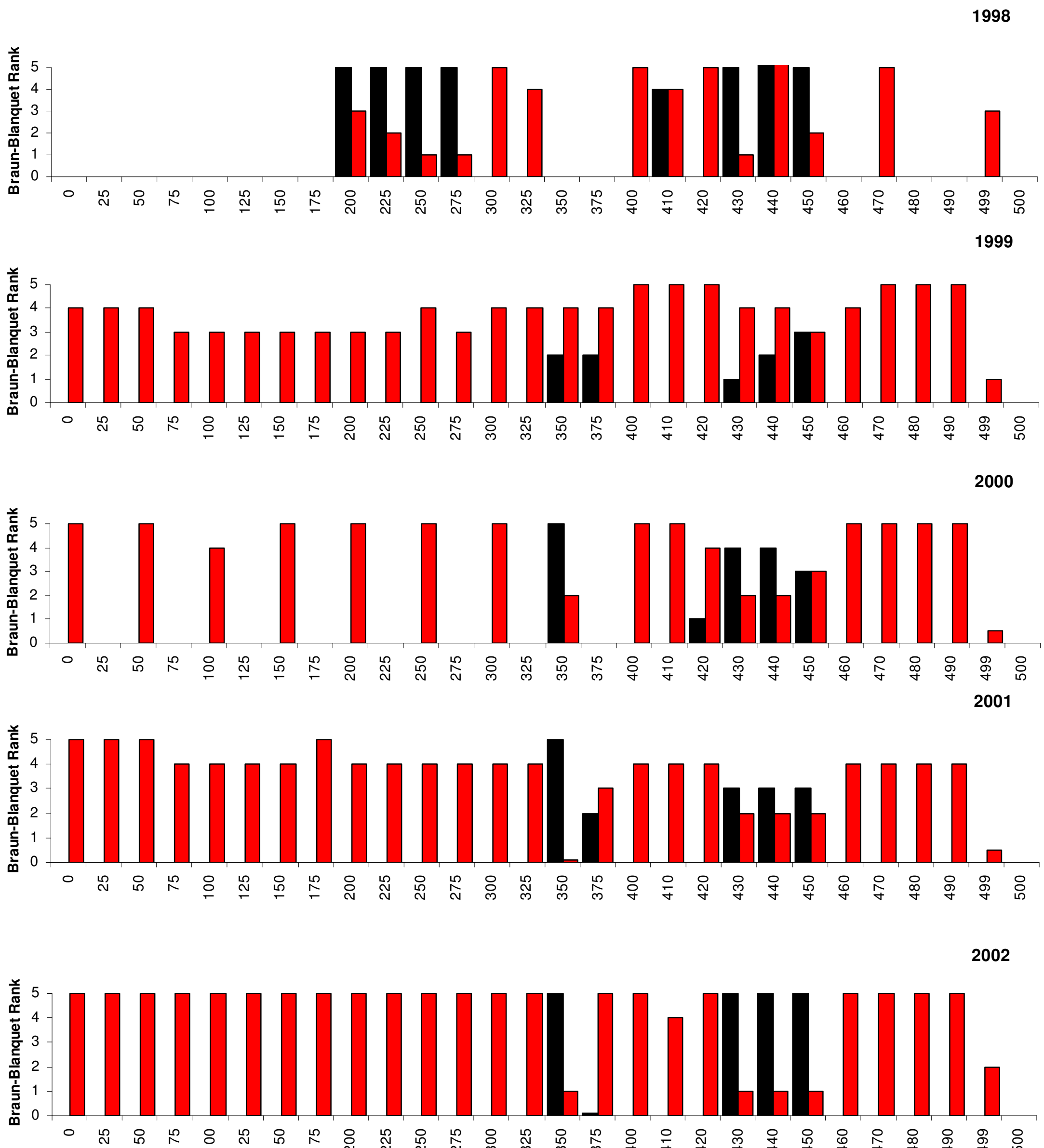
BCB-09 is located east of the Fort Desoto Bridge and north of the boat channel. The transect extends south 500m from the middle of the seagrass bed towards the boat channel. The depth ranged from 20cm-120cm. The sediment composition was sandy mud. The prominent seagrass species was *Thalassia* with occasional *Halodule*. The condition of the seagrass varied from fair to good.

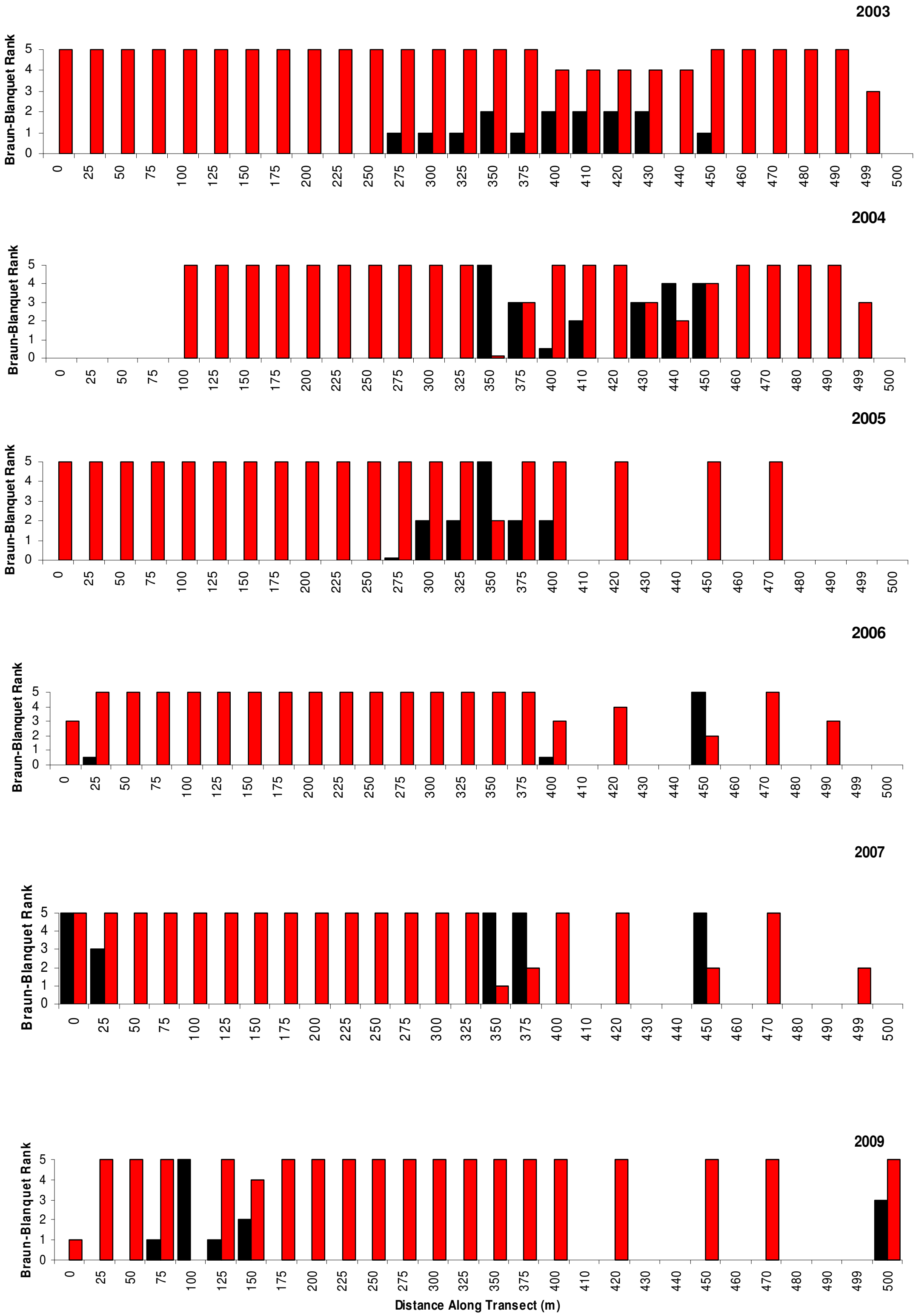
BCB-09 remained stable throughout the monitoring program. The data indicated that the edge of bed is consistent at 499m. However, the beds became patchier along the transect over time. The epibiont density trended toward heavier assemblages over the study. The epibiont density was moderate to heavy with assemblages consisting of attached algae, polycheates, and bryozoans along with hydroids and Lyngbya sp. The canopy height ranged from 15cm to 50cm. The shoot density ranged from 50-1400 shoots (per m^2).



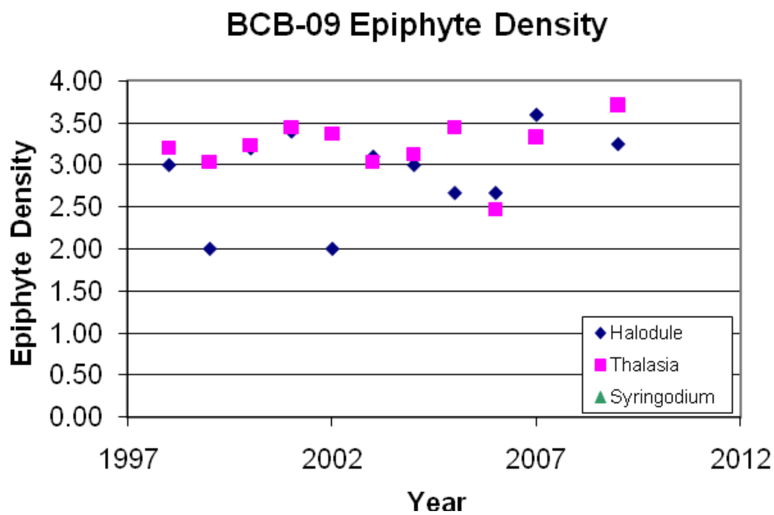


BCB-09 Transect Graphs

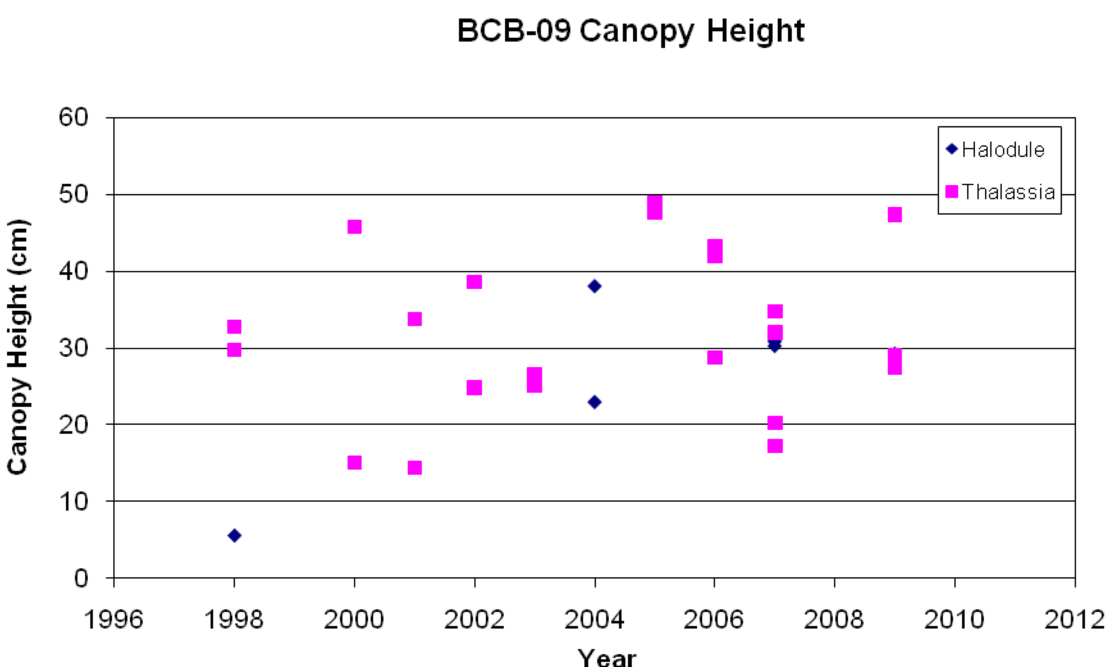



2003
2004
2005
2006
2007
2009
Braun-Blanquet Rank
Distance Along Transect (m)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
410
420
430
440
450
460
470
480
490
499
500

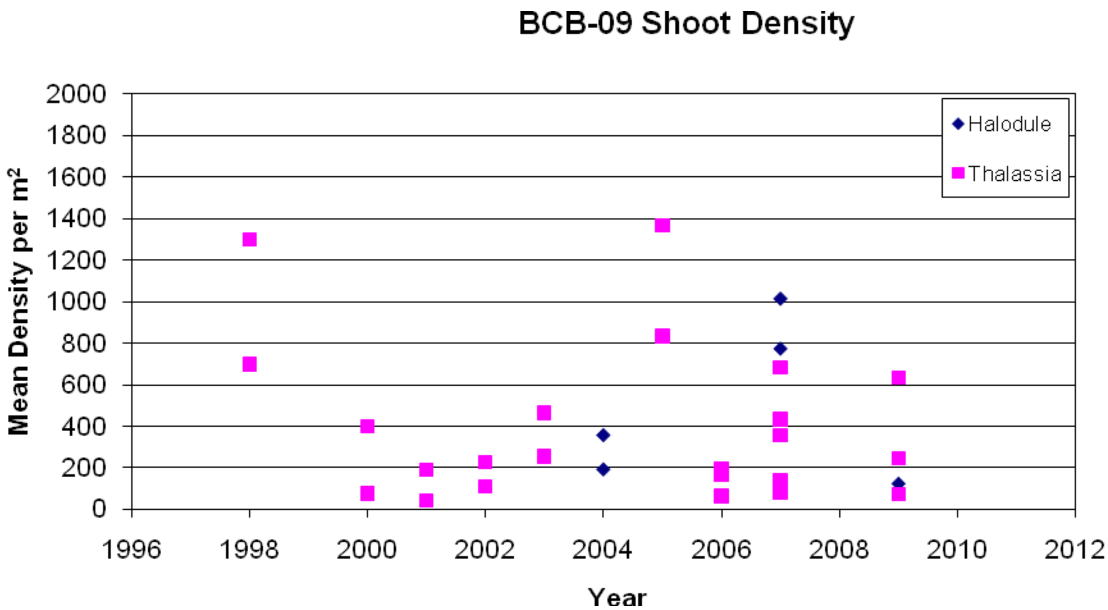
BCB-09 Epibiont Density Graph



BCB-09 Canopy Height Graph



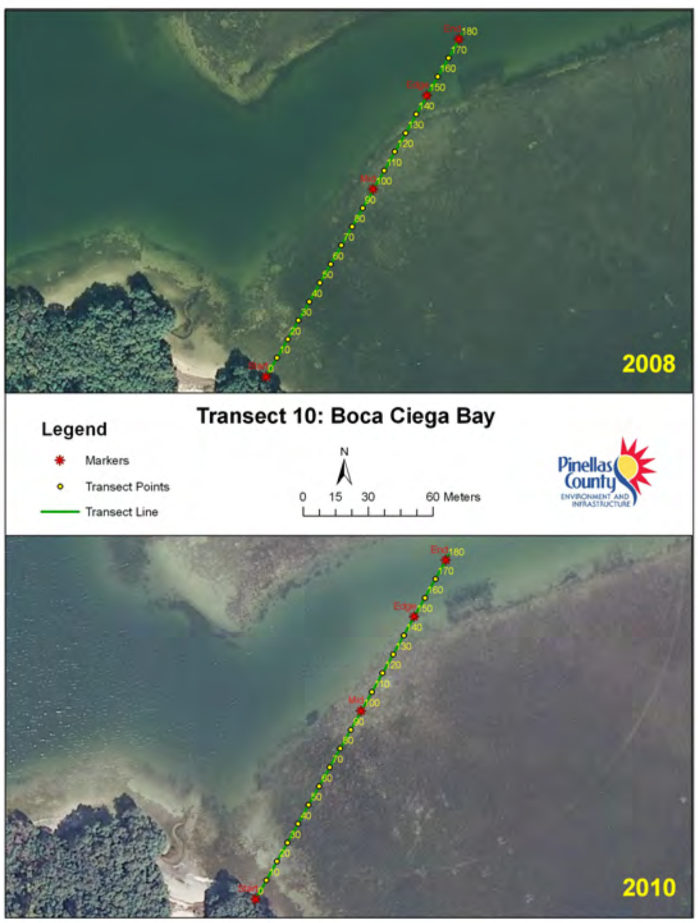
BCB-09 Shoot Density Graph

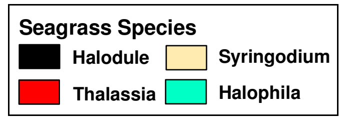


3.2.1.10 BCB10

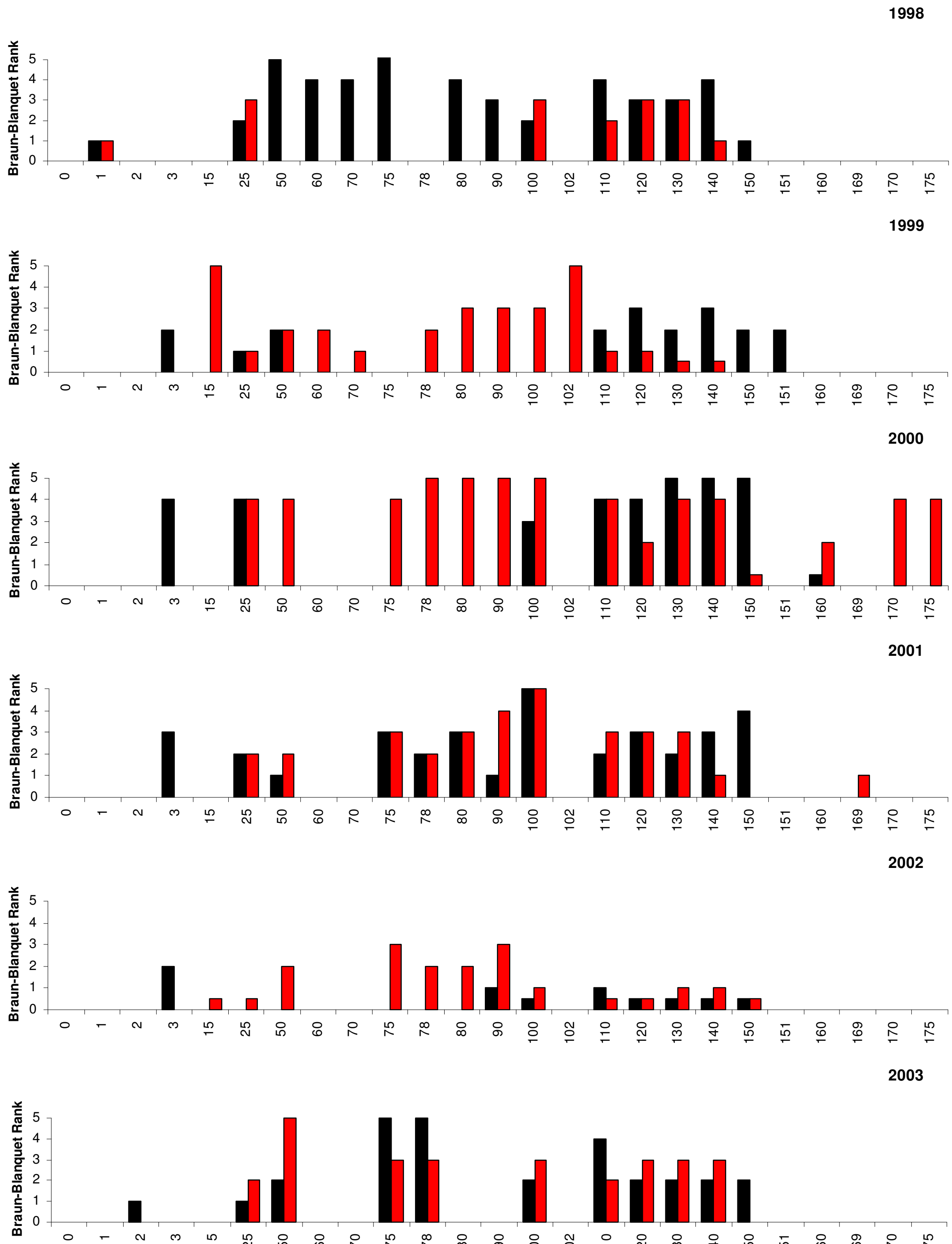
BCB-10 is located in South Mullet Key Bayou. The transect extends northeast 150m from the mangrove shoreline towards the boat channel. The depth ranged from 30cm-140cm. The sediment composition was sandy mud. The seagrass bed was a mixture of *Halodule* and *Thalassia*. The condition of the seagrass varied from fair to good.

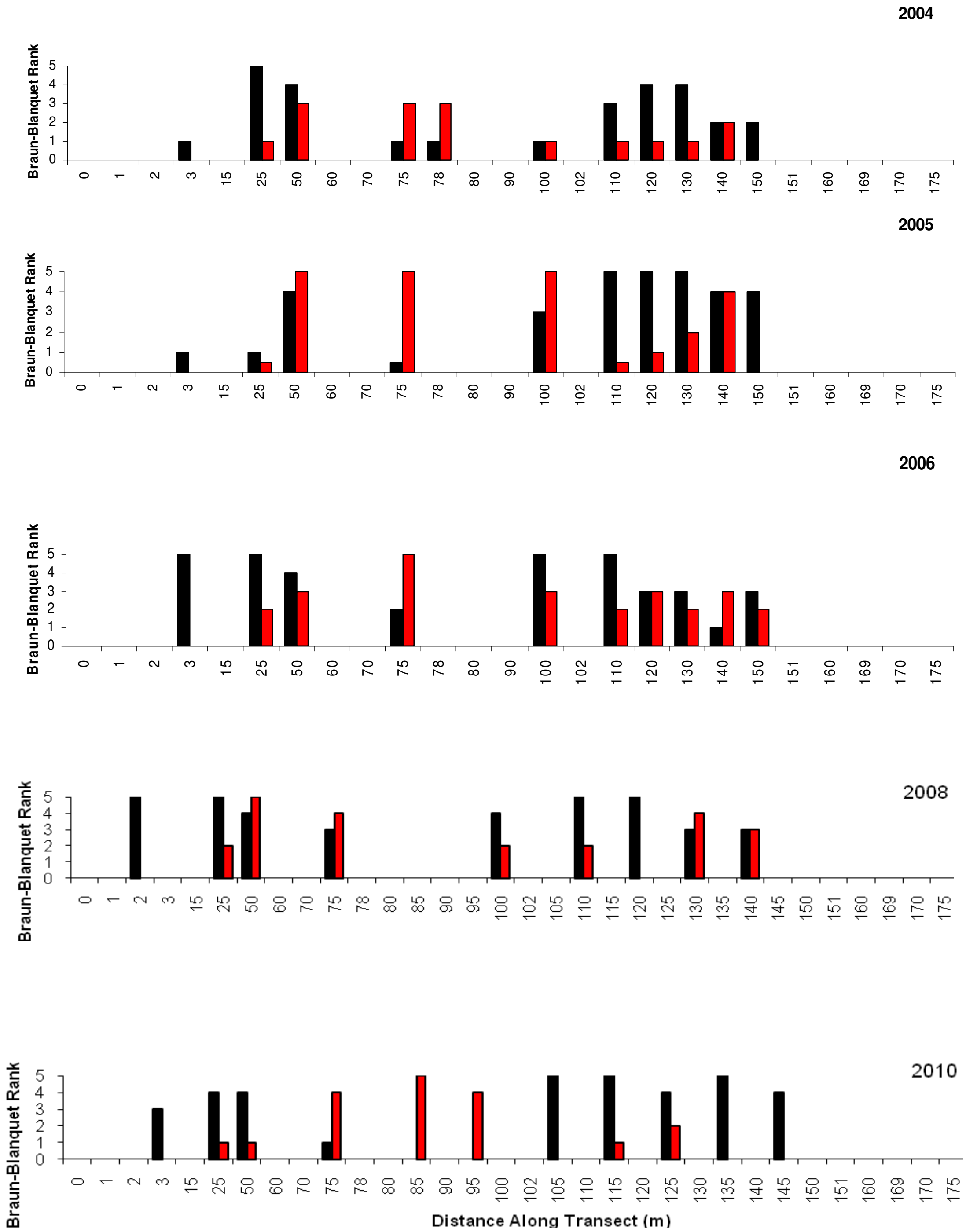
BCB-10 varied in species composition and abundance while maintaining a stable seagrass bed. The data indicated that the edge of bed is consistent at 150m throughout the monitoring program. In 1998 the prominent seagrass was *Halodule*. In 1999-2000, *Thalassia* increased in abundance becoming the prominent seagrass. By 2001, *Halodule* and *Thalassia* were both prominent species along the transect. The abundance of both seagrasses decreased in 2002, and then increased slightly through 2003-2004. The abundance of the *Halodule* increased in 2005-2006 and held that level in 2008. In November 2004, the Fort De Soto Recirculation Project restored the connection between the east and west side of the causeway. Improved circulation may have contributed to the increase in seagrass abundance along the transect. The epibiont density was light to heavy consisting of attached algae, polycheates, and barnacles. Since 2005 the epibiont density has been decreasing. The canopy height ranged from 15cm-38cm with *Thalassia* consistently higher than the *Halodule*. The shoot density showed separate trends for the species. The *Thalassia* ranged from 25-200 shoots (per m^2) with a decreasing density. The *Halodule* ranged from 25-1600 shoots (per m^2) with a exponential increase in density from 2004-2006.



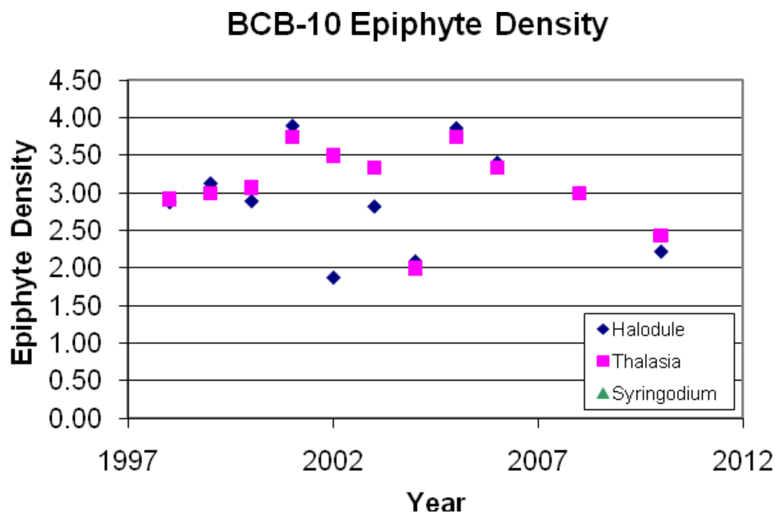


BCB-10 Transect Graphs

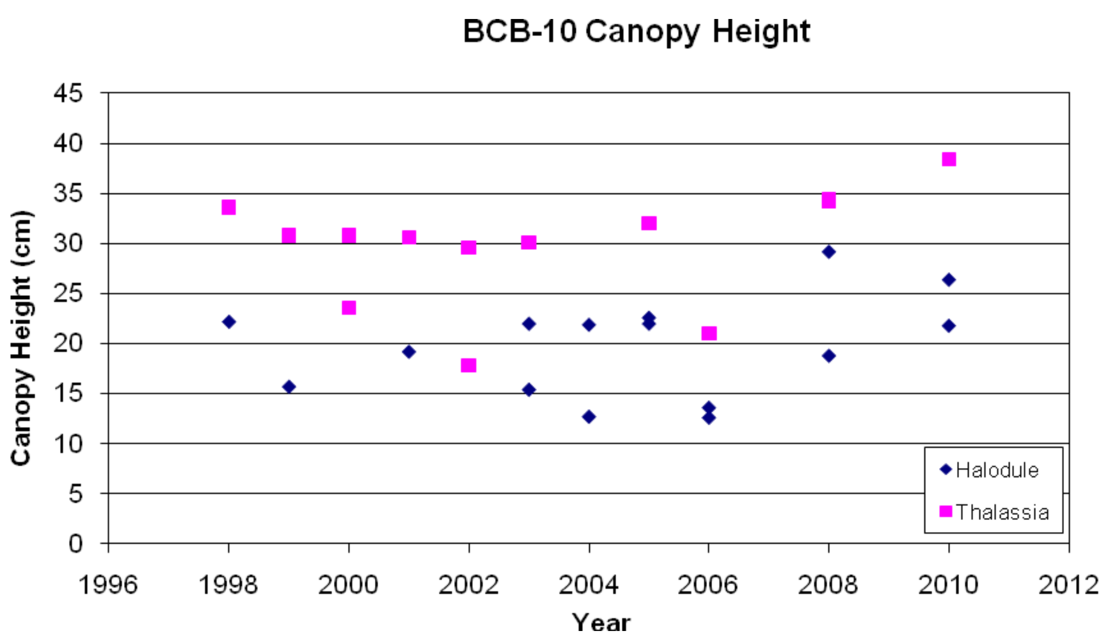



2004
Braun-Blanquet Rank
2005
Braun-Blanquet Rank
2006
Braun-Blanquet Rank
2008
Braun-Blanquet Rank
2010
Braun-Blanquet Rank
Distance Along Transect (m)

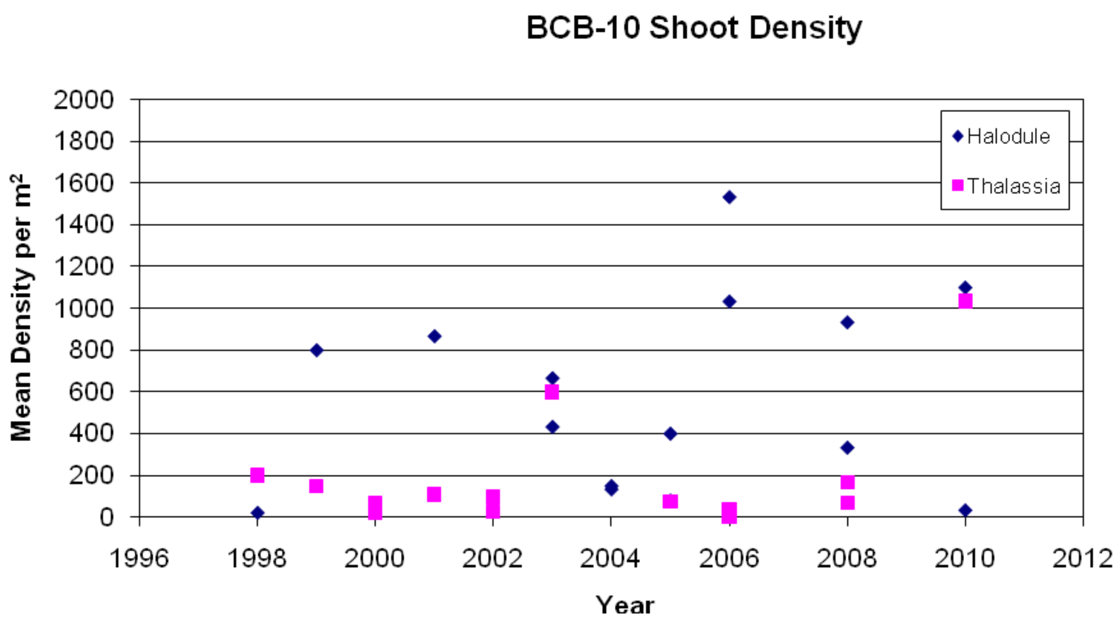
BCB-10 Epibiont Density Graph



BCB-10 Canopy Height Graph



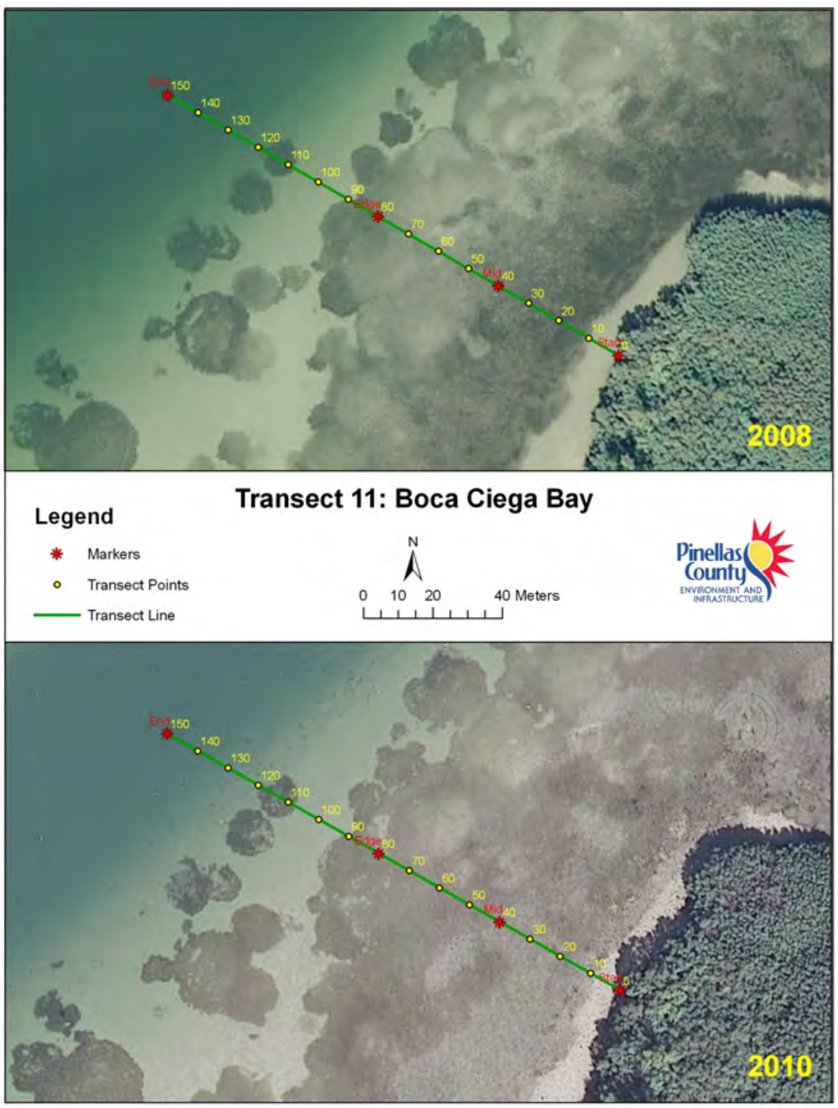
BCB-10 Shoot Density Graph

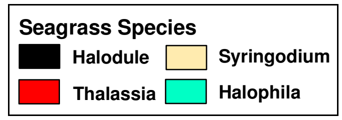


3.2.1.11 BCB11

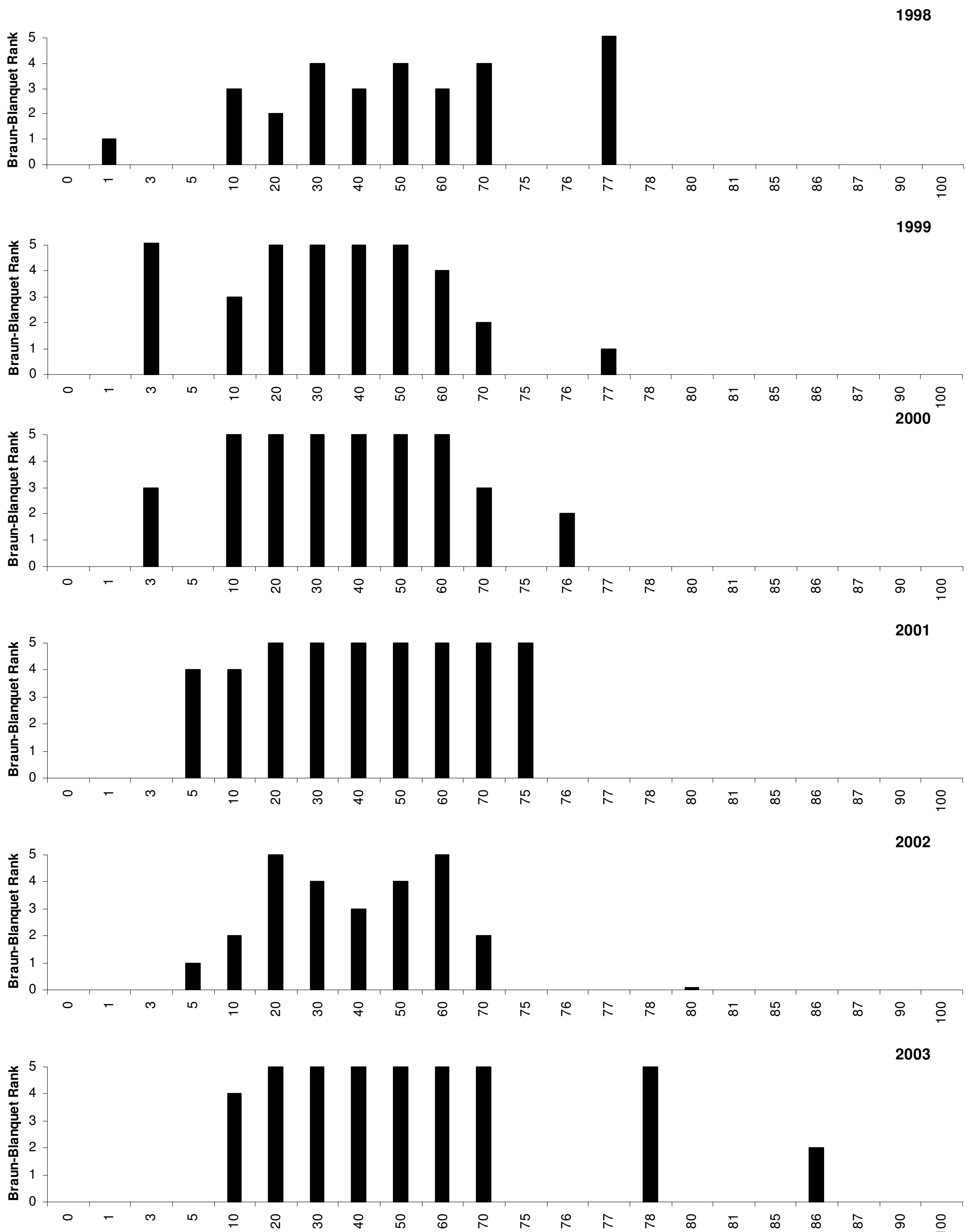
BCB-11 is located on the southeast side of Shell Key. The transect extends 100m from the mangrove island towards Shell Key. The area experiences dynamic circulation and sedimentation patterns due to the long shore currents and geographic orientation between two significant passes. The depth ranged from 5cm-80cm. The sediment composition was sandy mud from 0m-70m. The sediment composition shifted to sand from 70m-100m. The prominent seagrass was *Halodule*. The condition of the seagrass varied from fair to good.

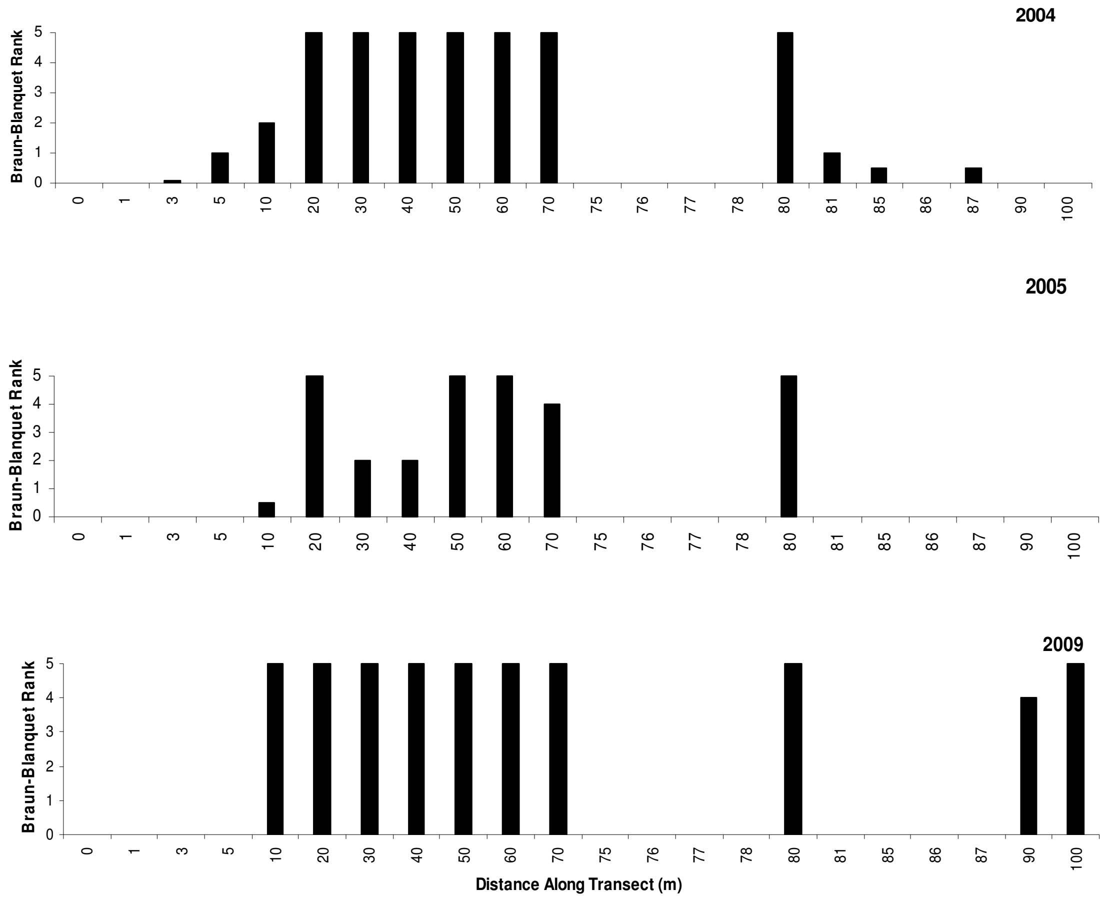
BCB-11 remained stable throughout the monitoring program. The data indicated that the edge of bed varied from 70m-77m from 1998-2002, then increased to 80m-87m in 2003-2005, and finally increased to 100m in 2009. The epibiont density was moderate to heavy with assemblages consisting of attached algae, polycheates, and *Lyngbya sp*. The canopy height ranged from 15cm-30cm. The shoot density ranged from 50-3000 shoots (per m^2) averaging near 1000 shoots (per m^2).



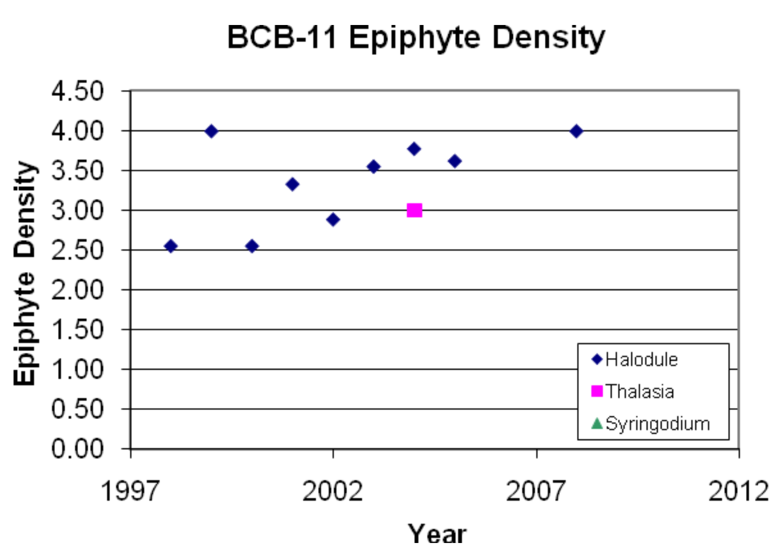


BCB-11 Transect Graphs

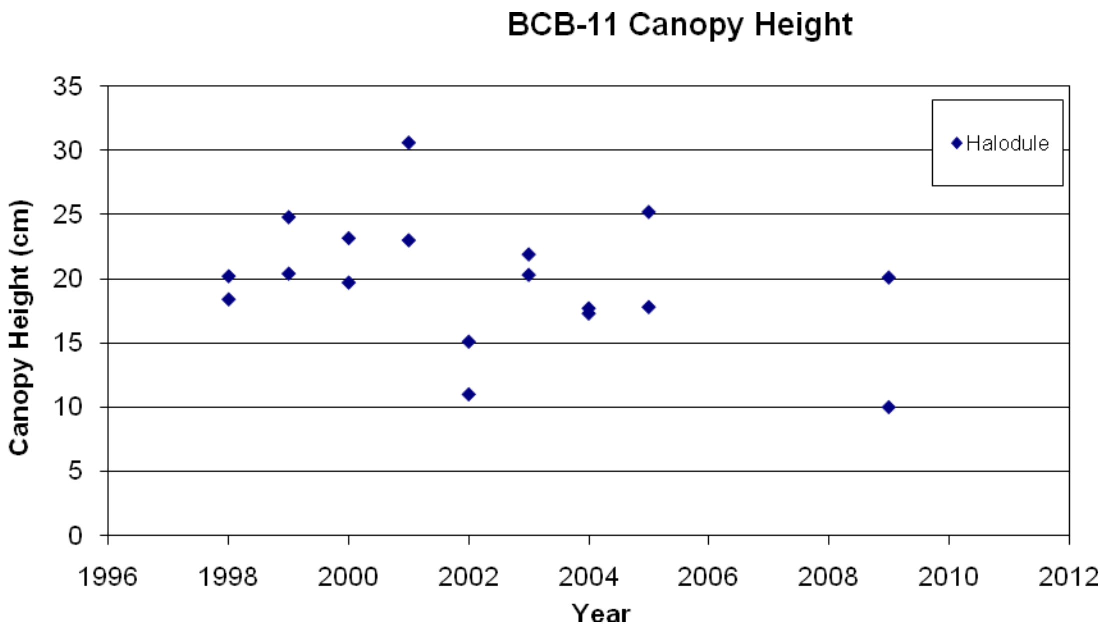




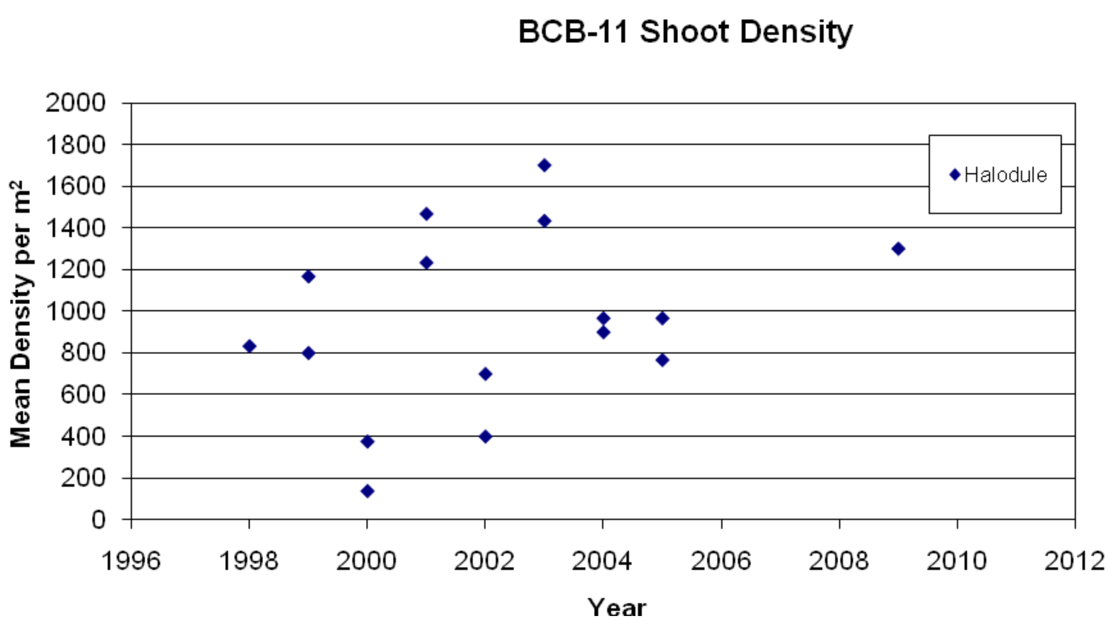
BCB-11 Epibiont Density Graph



BCB-11 Canopy Height Graph



BCB-11 Shoot Density Graph



3.2.2 Transects in Clearwater Harbor and St. Joseph Sound (CLW/SJS)

The fixed transect seagrass monitoring program took place from 1998-2005 in CLW/SJS. There were 14 transect locations. The transect names were abbreviated as CLW-01 through CLW-14. Only one transect, CLW-14, was located in SJS. The program was discontinued in 2006 and replaced with a different monitoring design to increase geographic coverage.

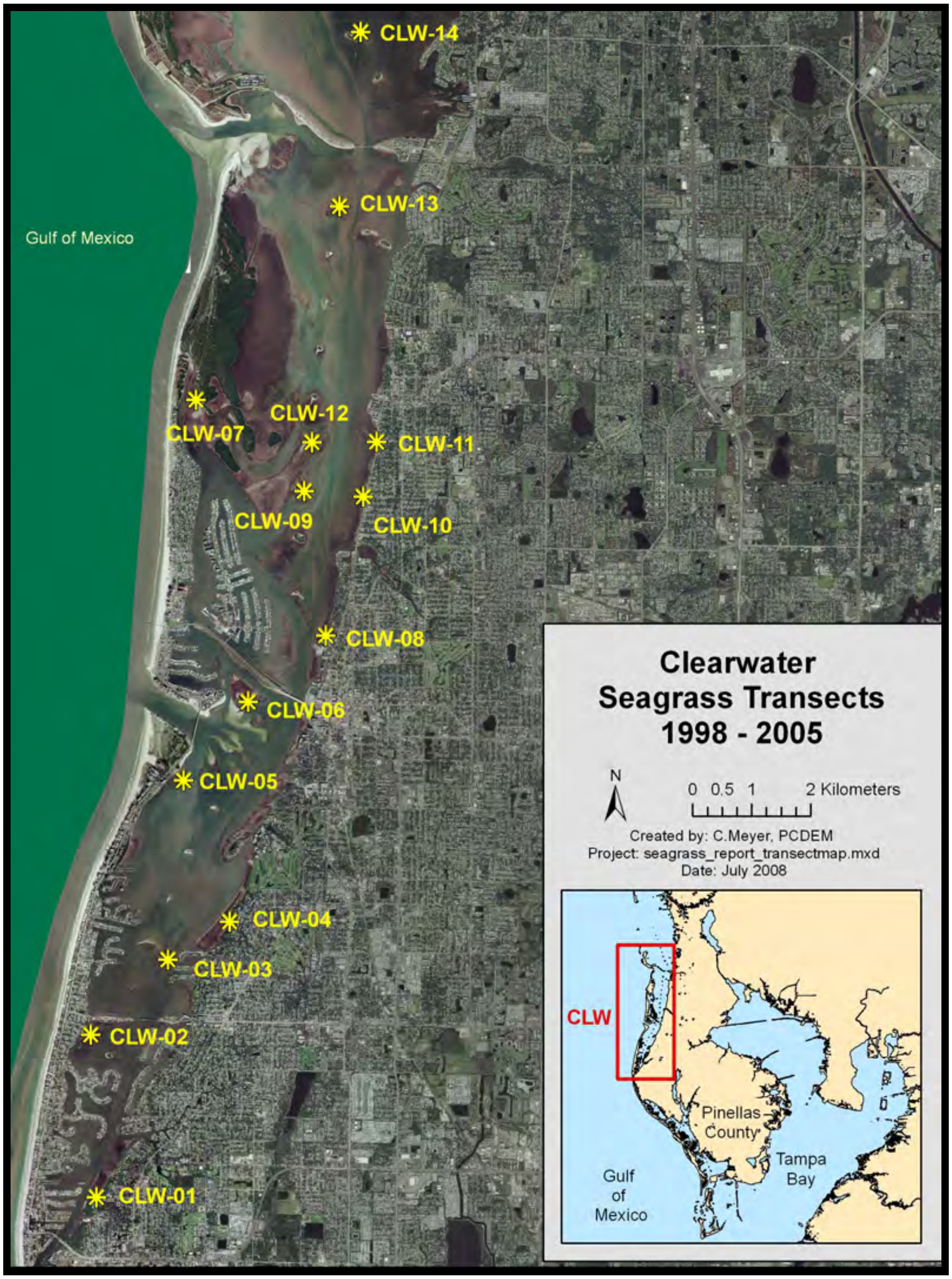


Figure 8. Clearwater fixed transect locations 1998-2005.

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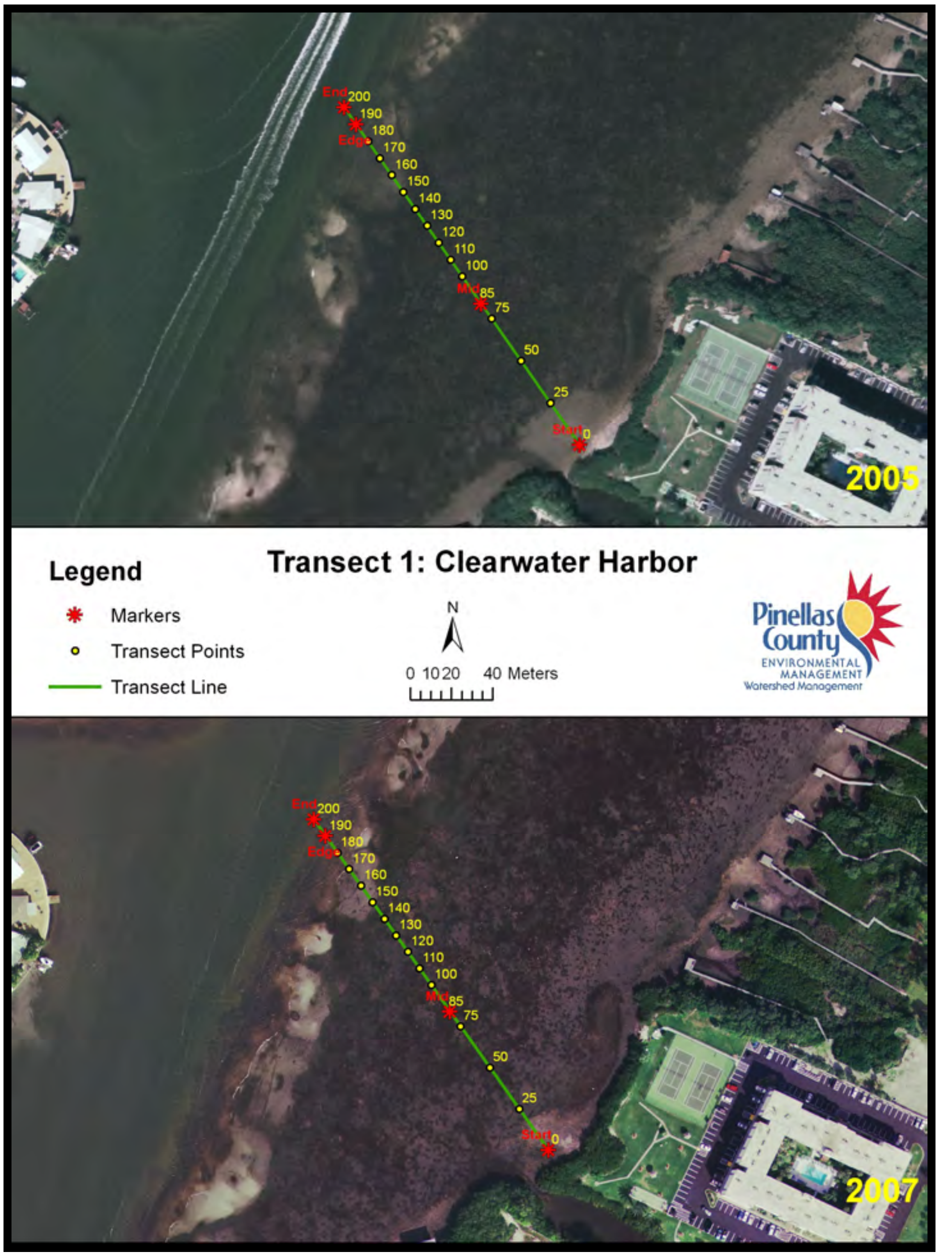
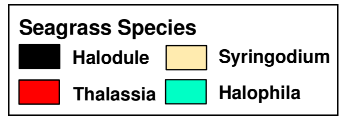
3.2.2.1 CLW-01

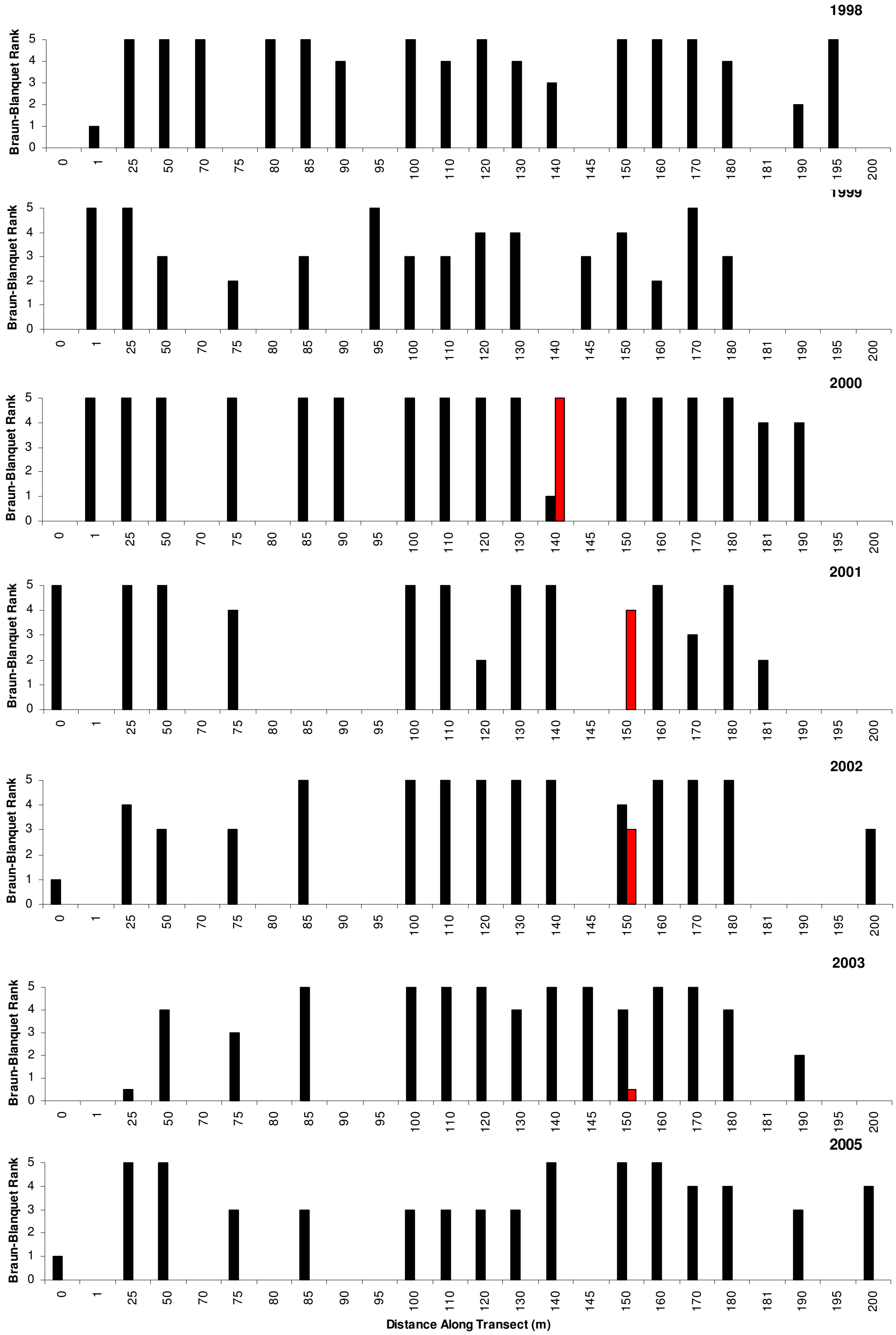
CLW-01 is located north of the Walsingham Causeway Bridge on the east side of the Intracoastal Waterway (ICW). The transect extends 200m from the shoreline towards the boat channel. The depth ranged from 30cm-110cm. The sediment composition was sandy mud. The prominent seagrass was *Halodule* with occasional *Thalassia*. The condition of the seagrass was good.

CLW-01 remained stable throughout the monitoring program. The data indicated that the edge of bed fluctuated from 180m-200m. The epibiont density varied from light to heavy with assemblages consisting of attached algae, polycheates, barnacles, and tunicates. The canopy height ranged from 5cm-30cm with an increasing trend from 1998 to 2003. The shoot density ranged from 50-2500 shoots (per m^2).

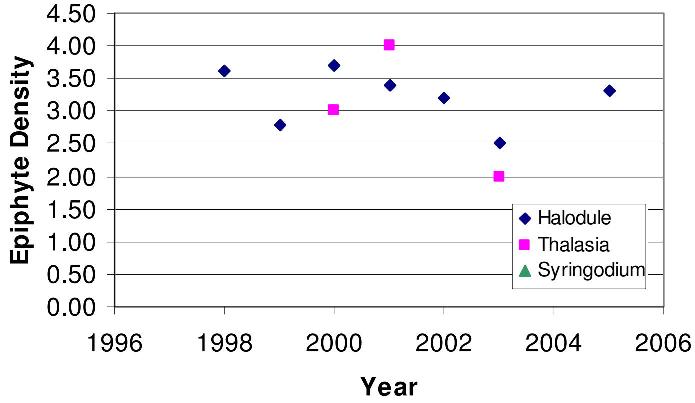




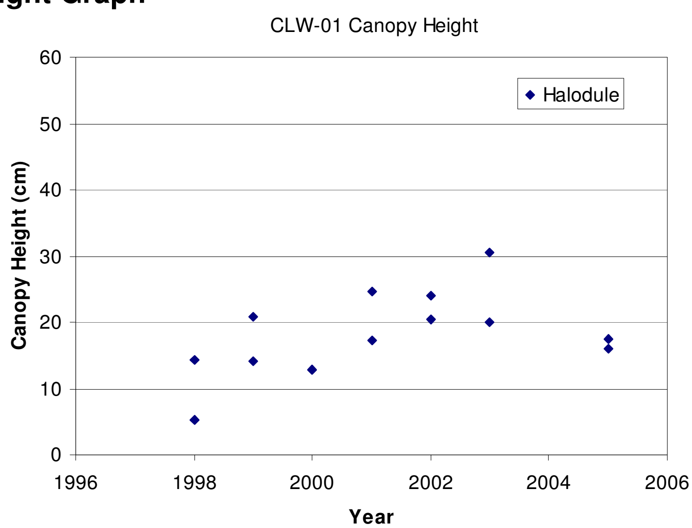
CLW-01 Transect Graphs



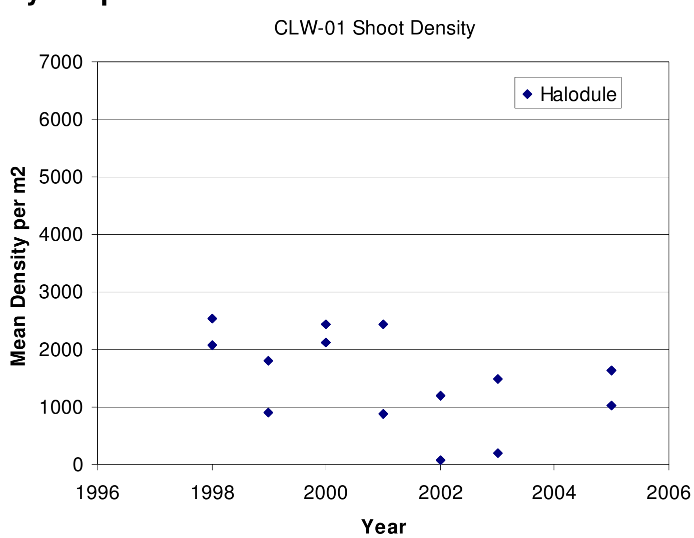
CLW-01 Epibiont Density Graph



CLW-01 Canopy Height Graph



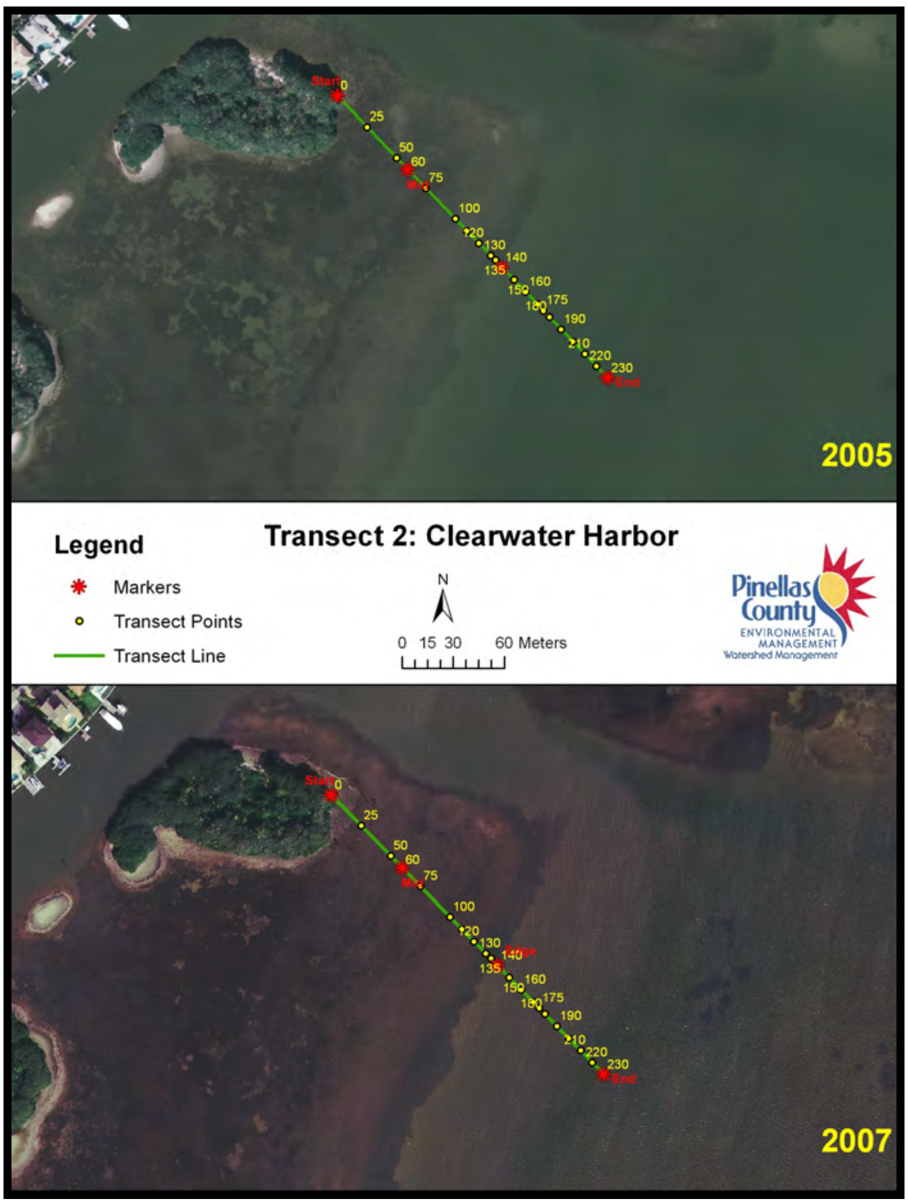
CLW-01 Shoot Density Graph



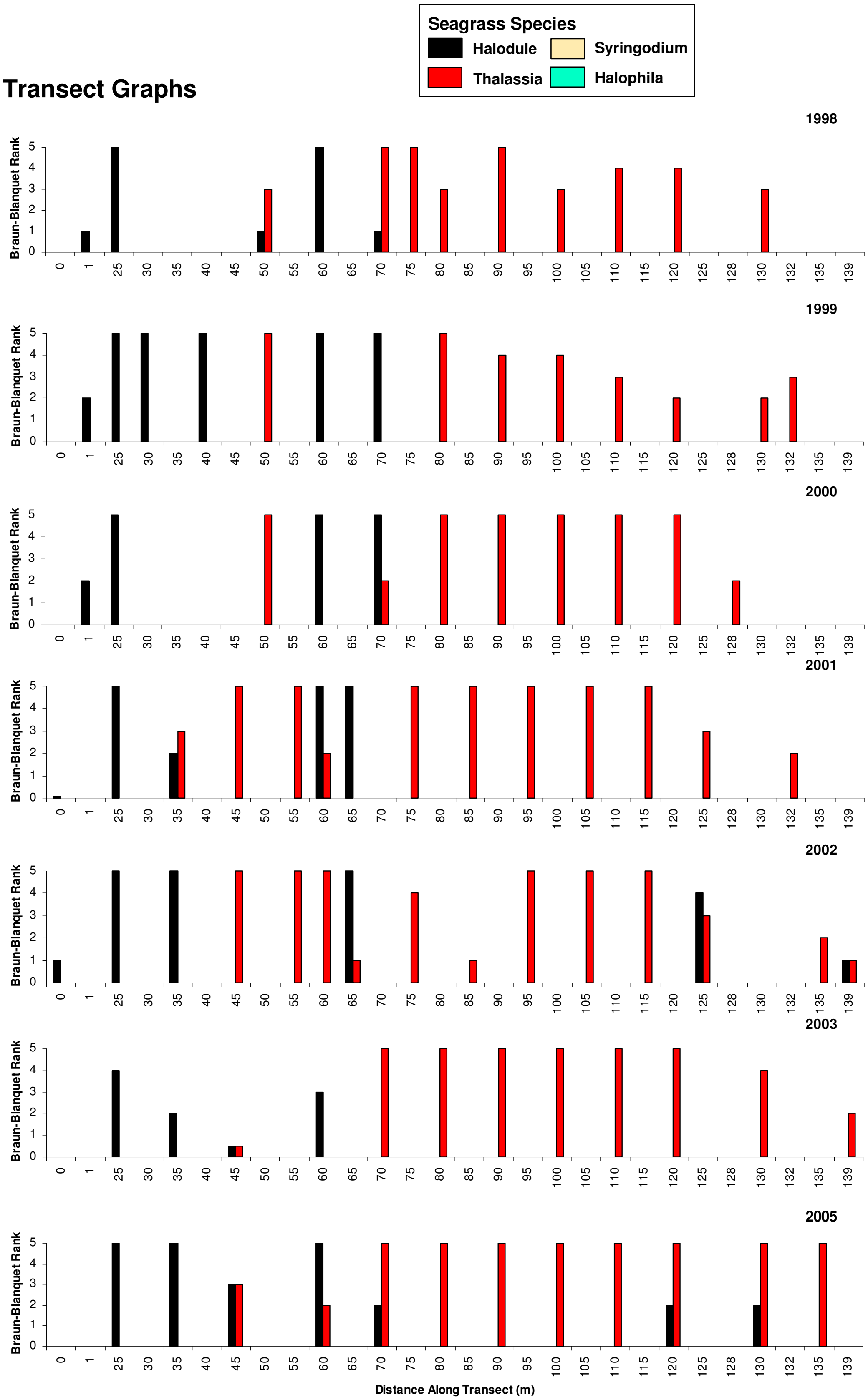
3.2.2.2 CLW-02

CLW-02 is located south of the Belleair Causeway. The transect extends southeast 230m from a mangrove island towards the boat channel. The depth ranged from 40cm-110cm. The sediment composition varied from sand (0m-25m) to mud (25m-100m) and back to sand (100m-230m). The prominent seagrass was *Thalassia* with *Halodule* nearshore. The condition of the seagrass was good.

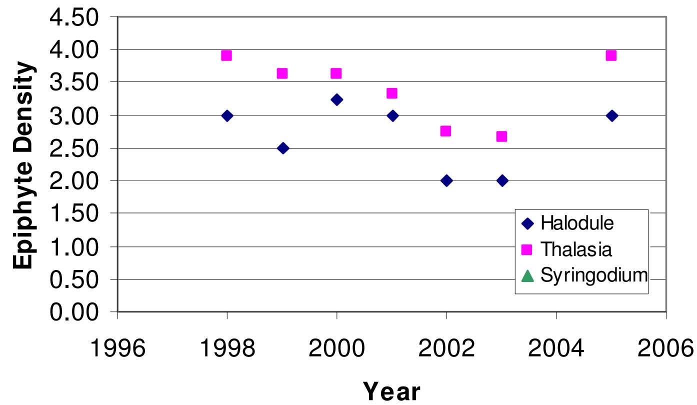
CLW-02 remained stable throughout the monitoring program. The data indicated that the edge of bed varied from 125m-139m. The epibiont density varied from heavy to light with a decreasing trend from 1998-2003. The epibiont assemblages consisted of attached algae, polycheates, and barnacles. The canopy height ranged form 18cm-32cm. The shoot density ranged from 25-600 shoots (per m^2) with shoot counts over 1200 shoots (per m^2) in 2001 and 2003.



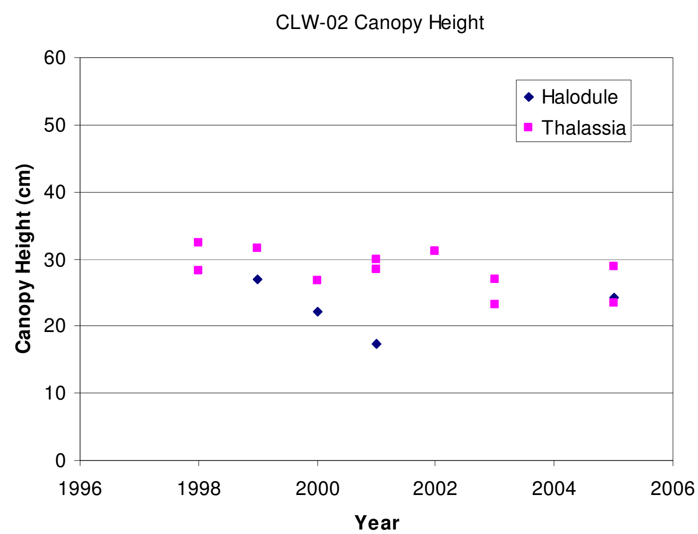
CLW-02 Transect Graphs



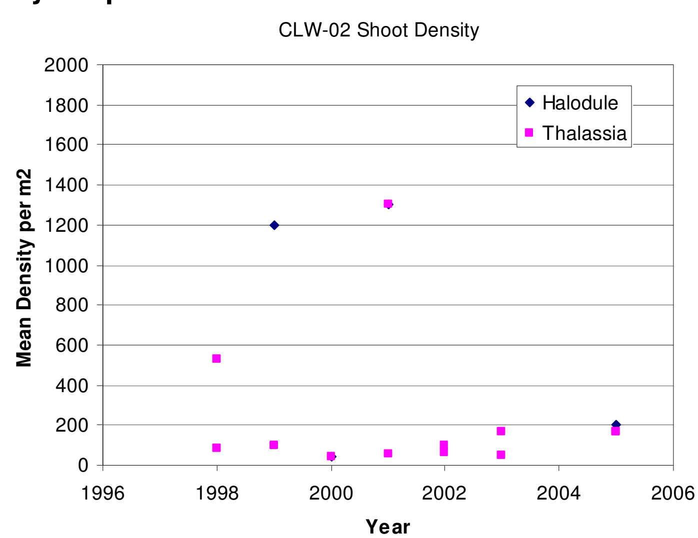
CLW-02 Epibiont Density Graph



CLW-02 Canopy Height Graph



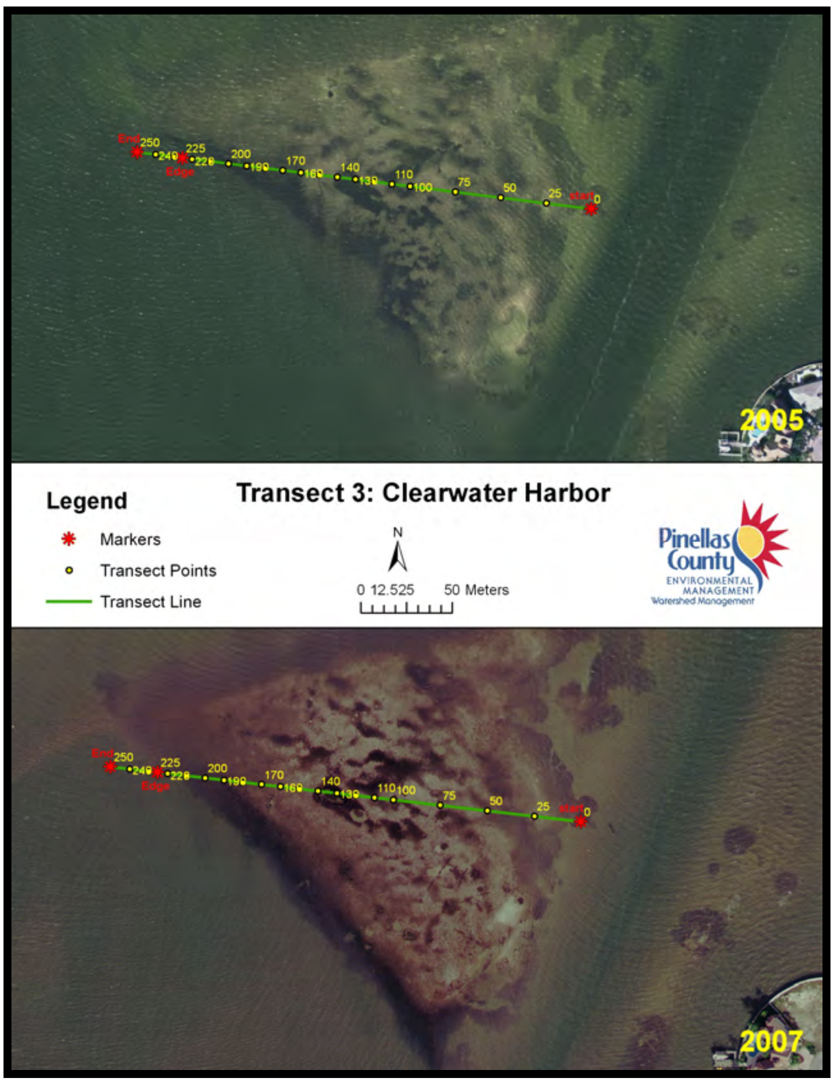
CLW-02 Shoot Density Graph



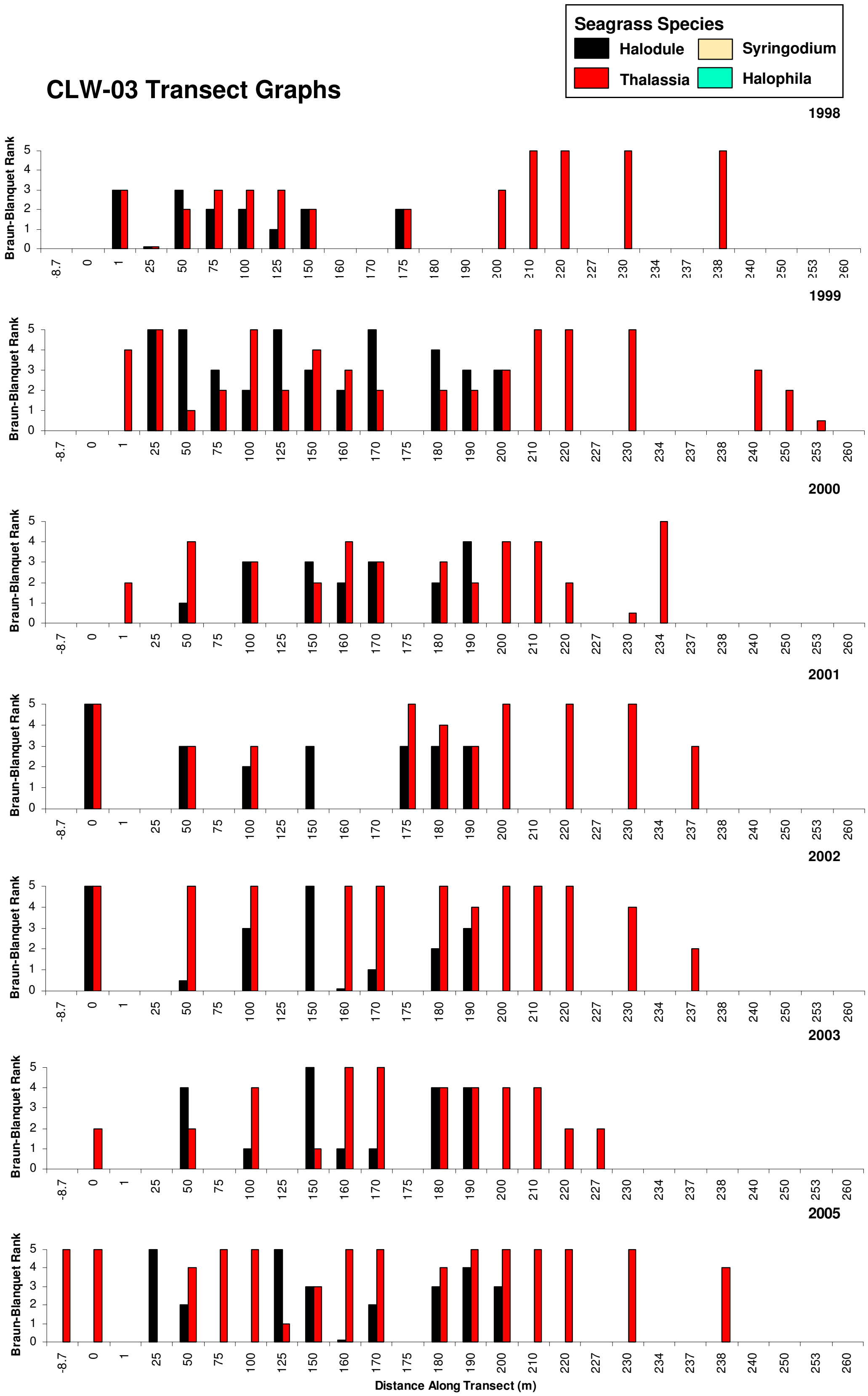
3.2.2.3 CLW-03

CLW-03 is located north of the Belleair Causeway Bridge. The transect extends west 260m from the boat channel. The depth ranged from 20cm-140cm. The sediment composition was sand with a patch of sandy mud near the middle of the transect. The seagrass consisted of *Thalassia* and *Halodule*. The condition of the seagrass fluctuated from good/fair in 1999 to poor/fair in 2000-2001, to good in 2002-2003, and back to poor/fair in 2005.

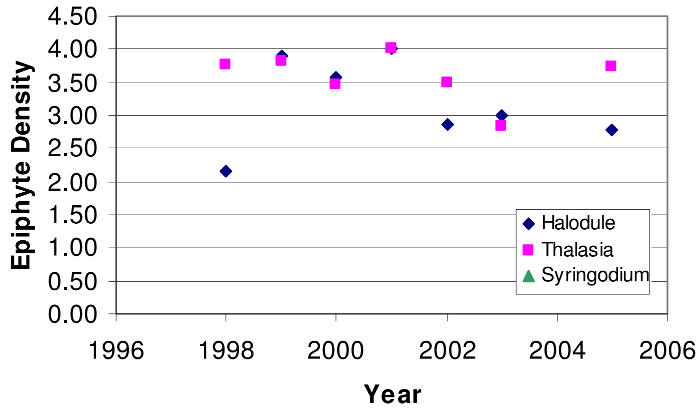
CLW-03 remained stable throughout the monitoring program. The Thalassia was consistent along the transect and the *Halodule* decreased in occurrence. The data indicated that the edge of bed varied from 227m-238m. In 1999 the edge of bed increased to 253m. The epibiont density was moderate to heavy with assemblages consisting of attached algae, polycheates, barnacles, and bryozoans. In 1998, the epibiont density on the *Halodule* was light. The canopy height ranged from 20cm-40cm with the *Halodule* typically shorter than the *Thalassia*. The shoot density ranged from 25-1850 shoots (per m^2). The Halodule shoot density increased from 1998-2005.



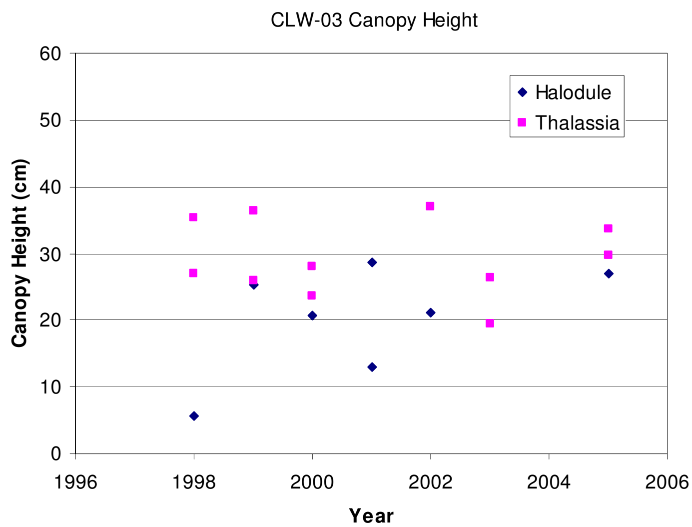
CLW-03 Transect Graphs



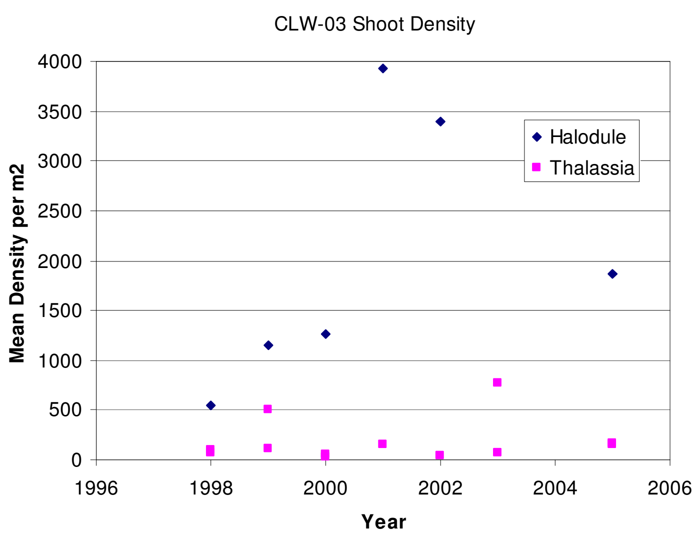
CLW-03 Epibiont Density Graph



CLW-03 Canopy Height Graph



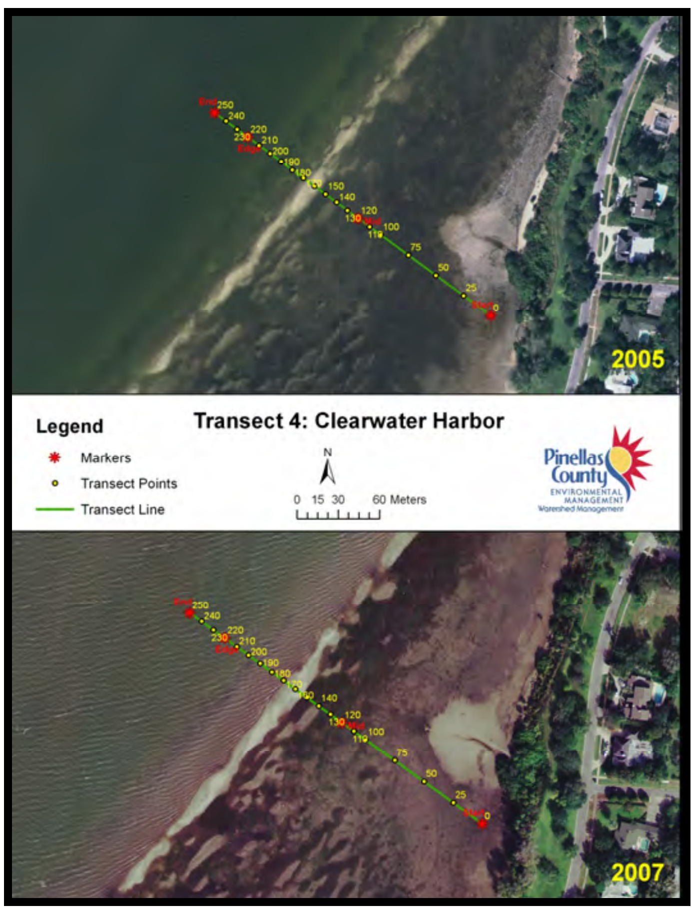
CLW-03 Shoot Density Graph

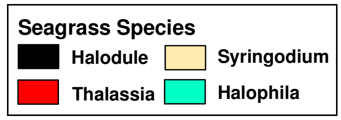


3.2.2.4 CLW-04

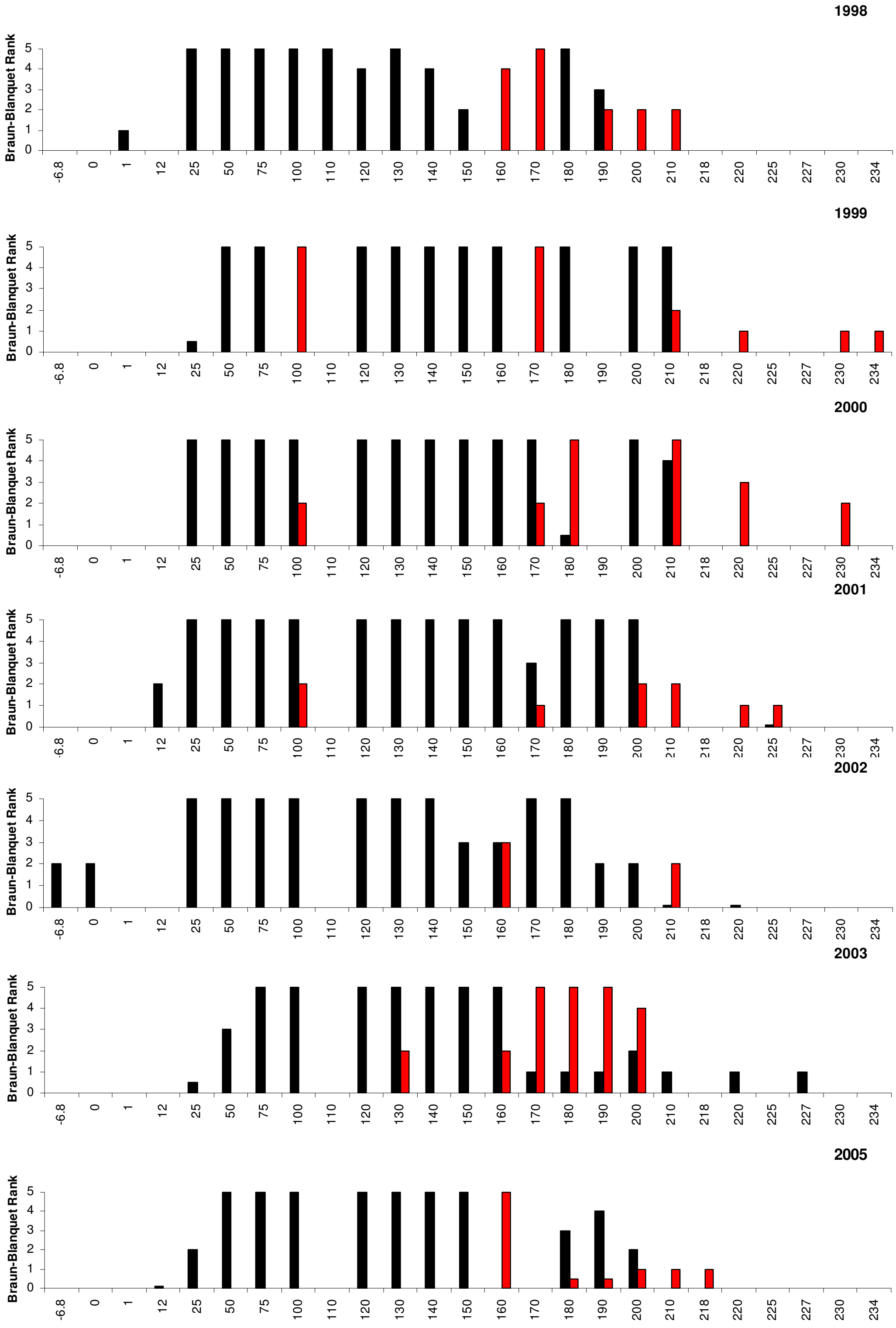
CLW-04 is located north of the Belleair Causeway on the east side of the ICW. The transect extends 250m from the shore towards the boat channel. The depth ranged from 15cm-140cm. The sediment composition changed throughout the monitoring program. In 1998-2000, the sediment composition was sandy mud from 0m-140m and then changed to sand from 150m-250m. In 2001, the nearshore area was mud and sandy mud, and then transitioned to sand at 180m. In 2002-2005, the sediment composition was mud from 0m-180m and sand from 190m-250m. The field staff noted that the mud was very thick and may have accumulated from the outfall of Rattlesnake Creek. The prominent seagrass was *Halodule* with *Thalassia* from 160m-235m. The condition of the seagrass varied from poor to good and seemed to be correlated with the distance from shore, respectively.

The seagrass abundance along the transect, CLW-04, appeared to decrease slightly throughout the monitoring program. The data indicated that the edge of bed varies from 210m-235m. The edge of bed decreased from 235m in 1999 to 218m in 2005 with a marked reduction of *Thalassia*. The abundance of *Halodule* also decreased from 1999-2005 mainly between 150m-200m. The epibiont density varied from light to heavy coverage with a decreasing trend from 1999-2005. The epibiont assemblages consisted of attached algae and polycheates. The canopy height ranged from 10cm-35cm. The shoot density for *Thalassia* ranged from 20-200 shoots (per m^2). The shoot density for *Halodule* ranged from 20-5200 shoots (per m^2). The shoot density for *Halodule* decreased abruptly from 5200 shoots (per m^2) in 2001 to 1000 shoots (per m^2) in 2002 and 2003. In 2004, the shoot density for *Halodule* increased to 2000 shoots (per m^2).

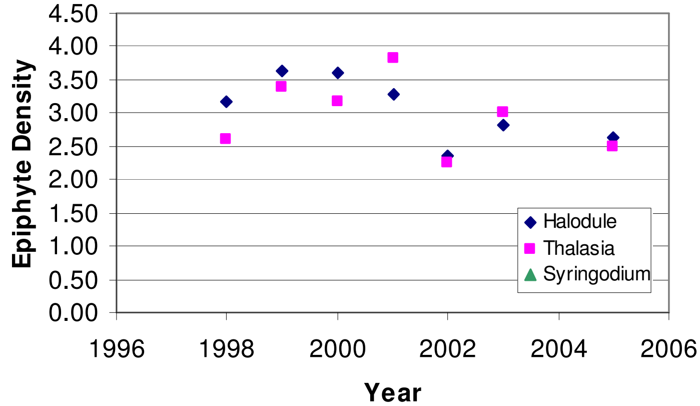




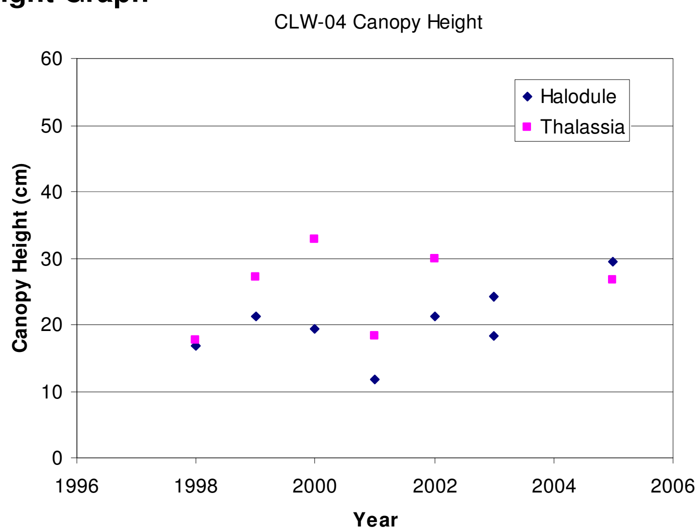
CLW-04 Transect Graphs



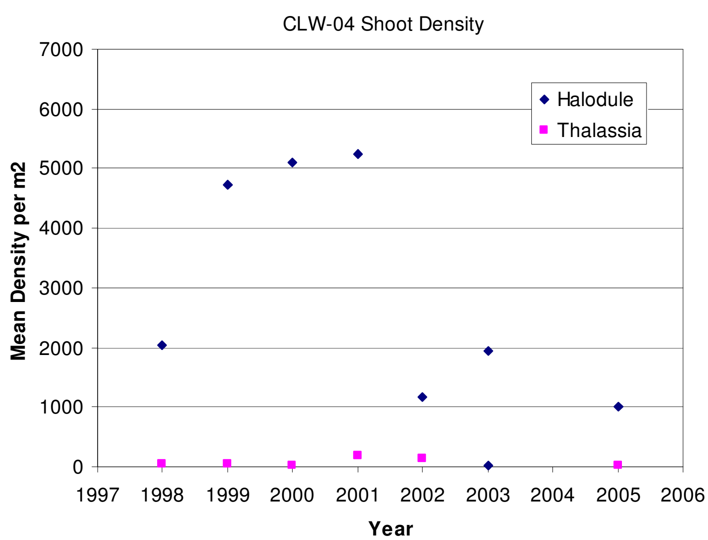
CLW-04 Epibiont Density Graph



CLW-04 Canopy Height Graph



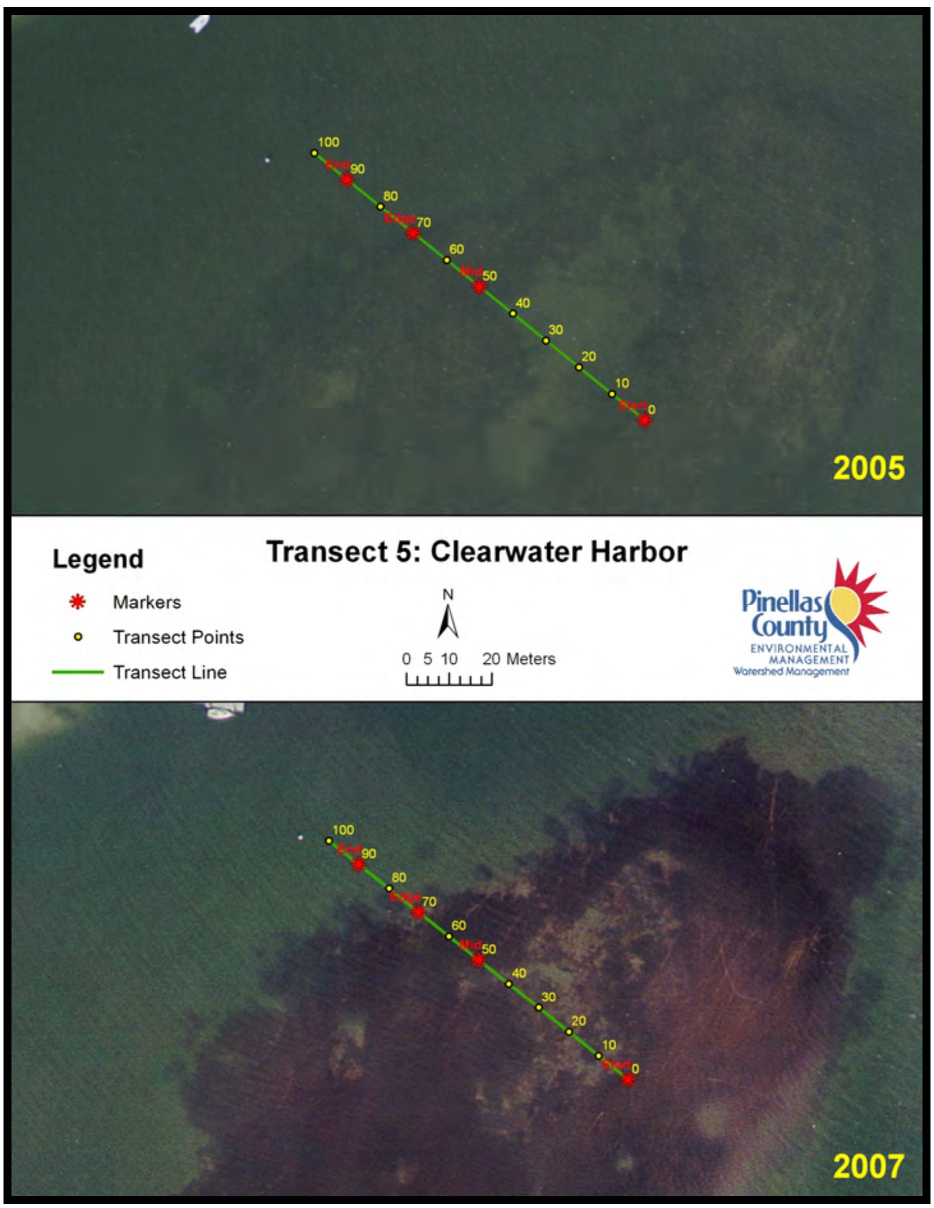
CLW-04 Shoot Density Graph



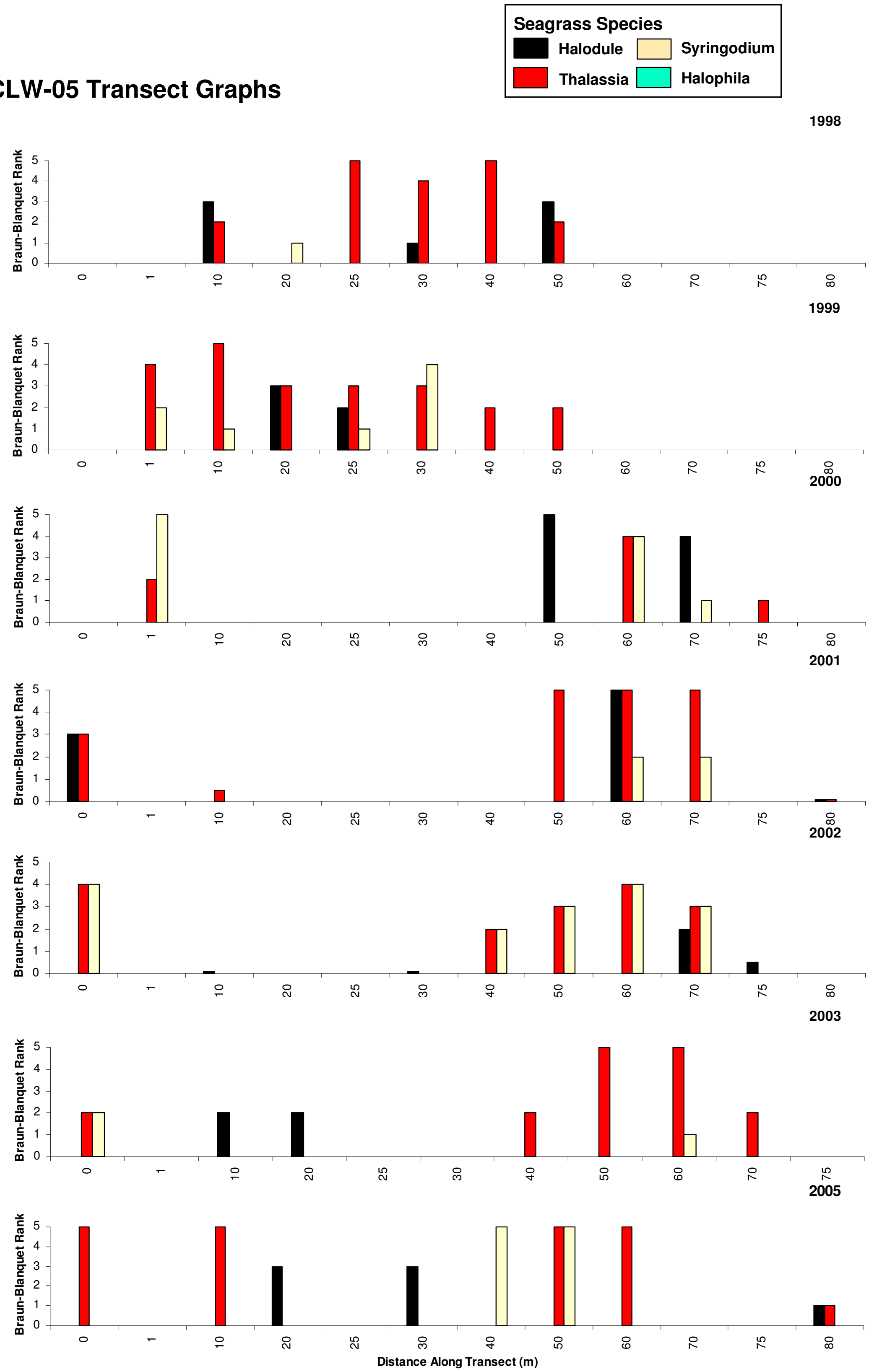
3.2.2.5 CLW-05

CLW-05 is located near the north end of Sand Key. The transect extends 90m from the middle of the seagrass bed towards the boat channel. The area experiences strong currents and heavy boat traffic. The depth ranged from 45cm-200cm. The sediment composition was sand with a few occurrences of sandy mud. The seagrass consisted of *Halodule, Syringodium*, and *Thalassia*. The condition of the seagrass was good.

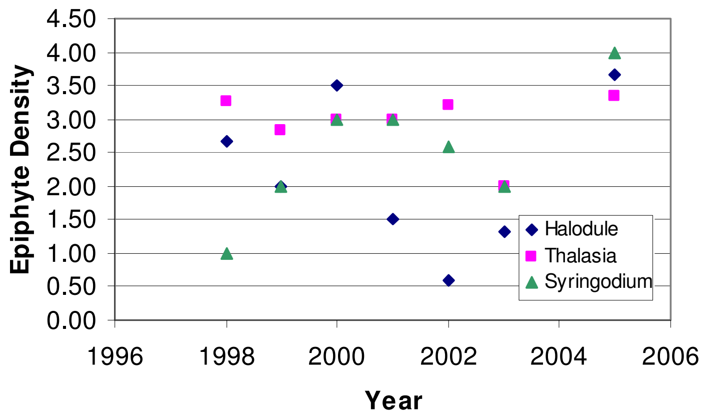
CLW-05 varied throughout the monitoring program. In 2000-2002, staff found very sparse seagrass from 10m-40m. The data indicated that the edge of bed varied from 50m-80m. The epibiont density ranged from clean to heavy with assemblages consisting of attached algae, polycheates, and bryozoans. The canopy height ranged from 15cm-45cm. The shoot density ranged from 50-1200 shoots (per m^2).



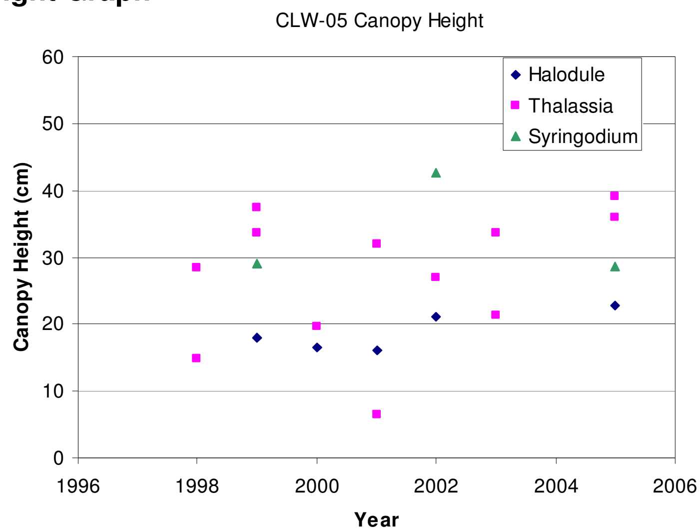
CLW-05 Transect Graphs



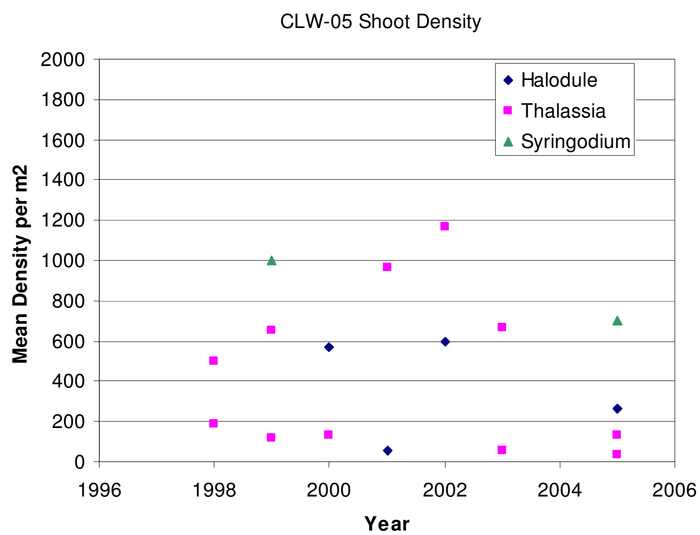
CLW-05 Epibiont Density Graph



CLW-05 Canopy Height Graph



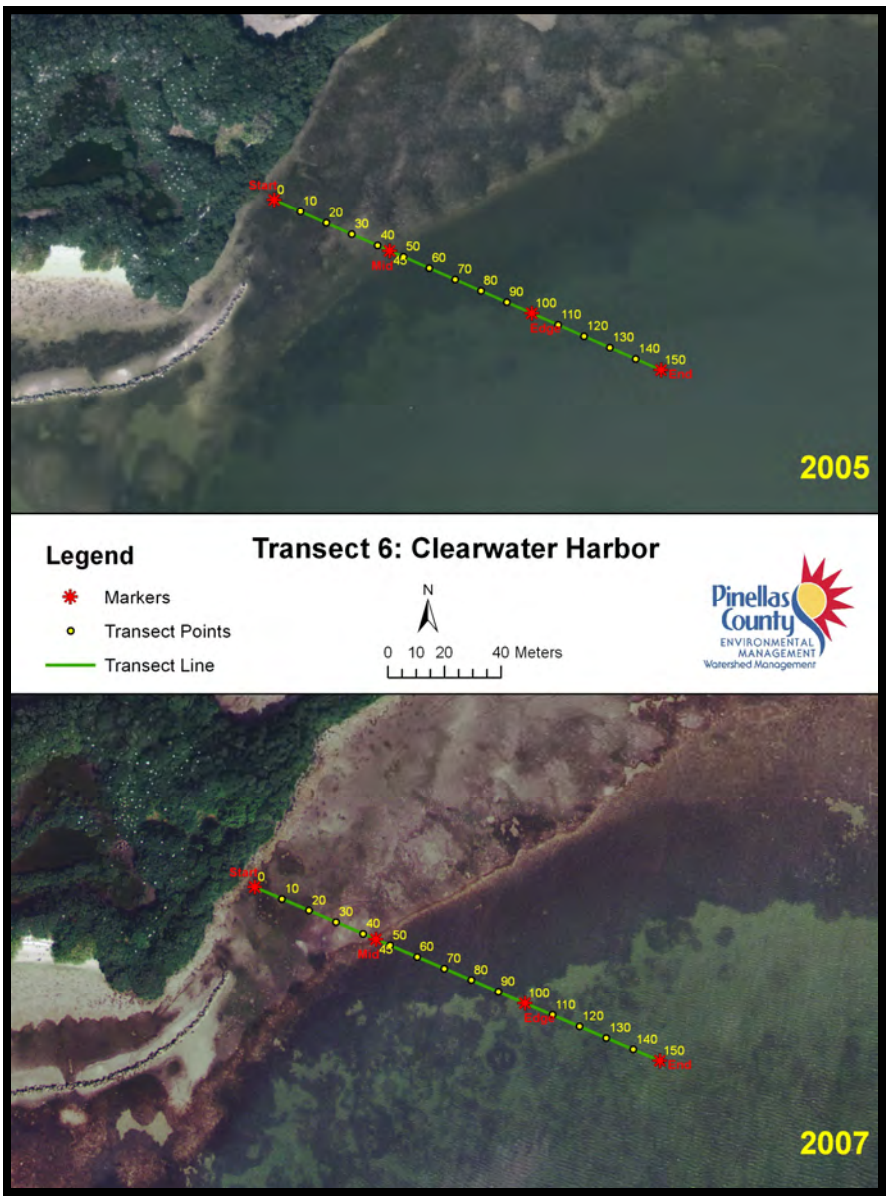
CLW-05 Shoot Density Graph



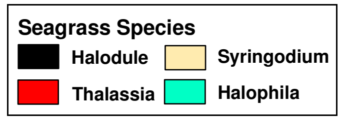
3.2.2.6 CLW-06

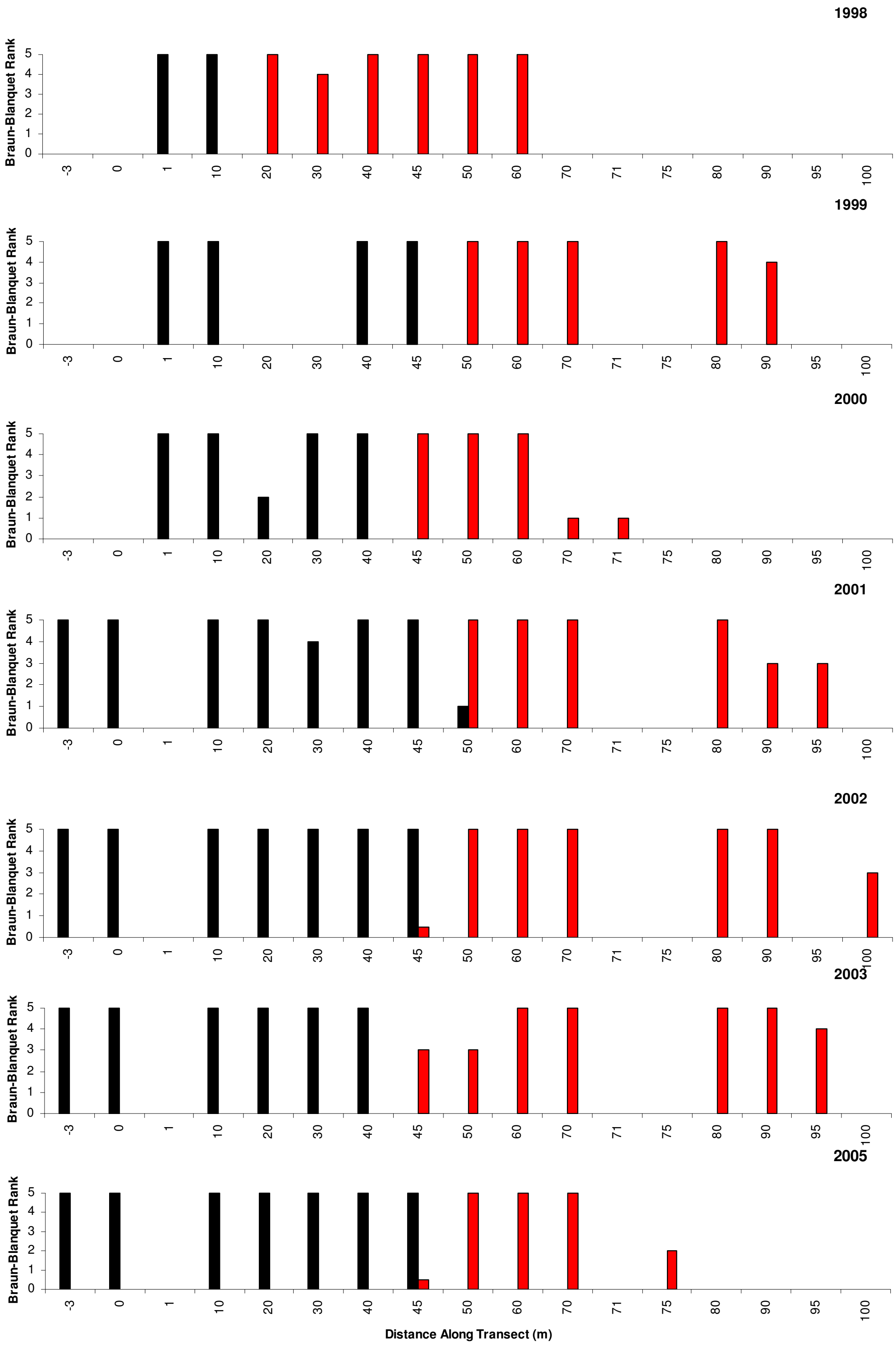
CLW-06 is located south of the Clearwater Memorial Bridge. The transect extends 100m from the mangrove spoil island. The area experiences strong currents and heavy boat traffic due to its proximity to Clearwater Pass. The depth ranged from 5cm-150cm. The sediment composition was sand and sandy mud. The seagrass consisted of *Halodule* from 0m-45m and *Thalassia* from 45m-100m. The condition of the seagrass was good.

CLW-06 remained stable throughout the monitoring program. The data indicated that the edge of bed varied from 60m-100m; however, the orientation or placement of the transect may have been adjusted in 1999. The epibiont density was moderate to heavy with the assemblages consisting of attached algae and polycheates. The canopy height ranged from 15cm-45cm. The shoot density ranged from 100-1000 shoots (per m^2) with Halodule densities of 2000-3000 shoots (per m^2) in 1999 and 2001.

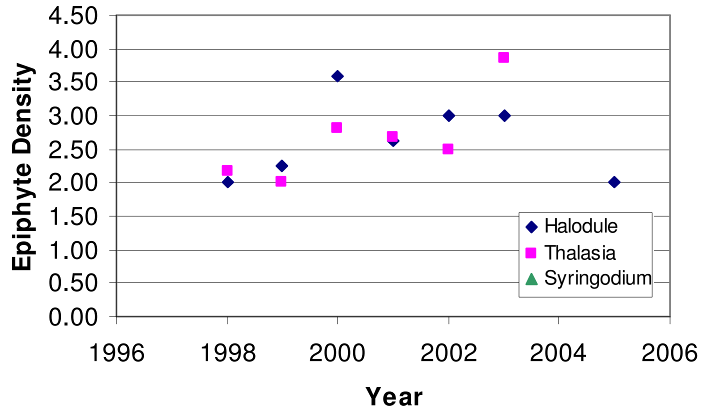


CLW-06 Transect Graphs

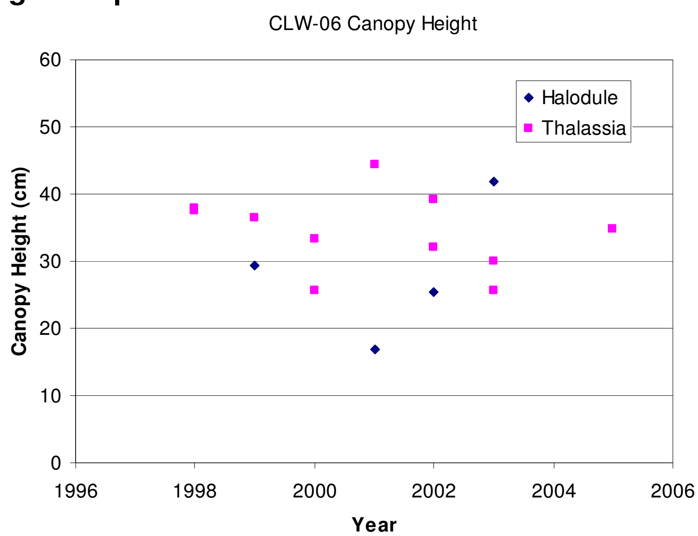




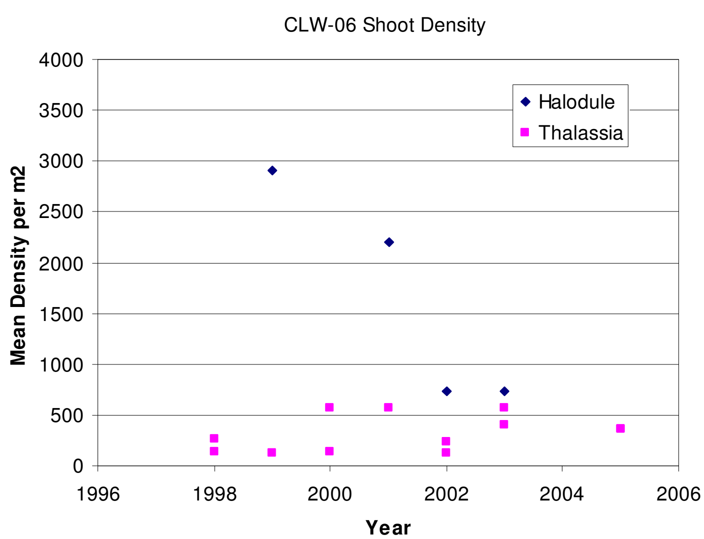
CLW-06 Epibiont Density Graph



CLW-06 Canopy Height Graph



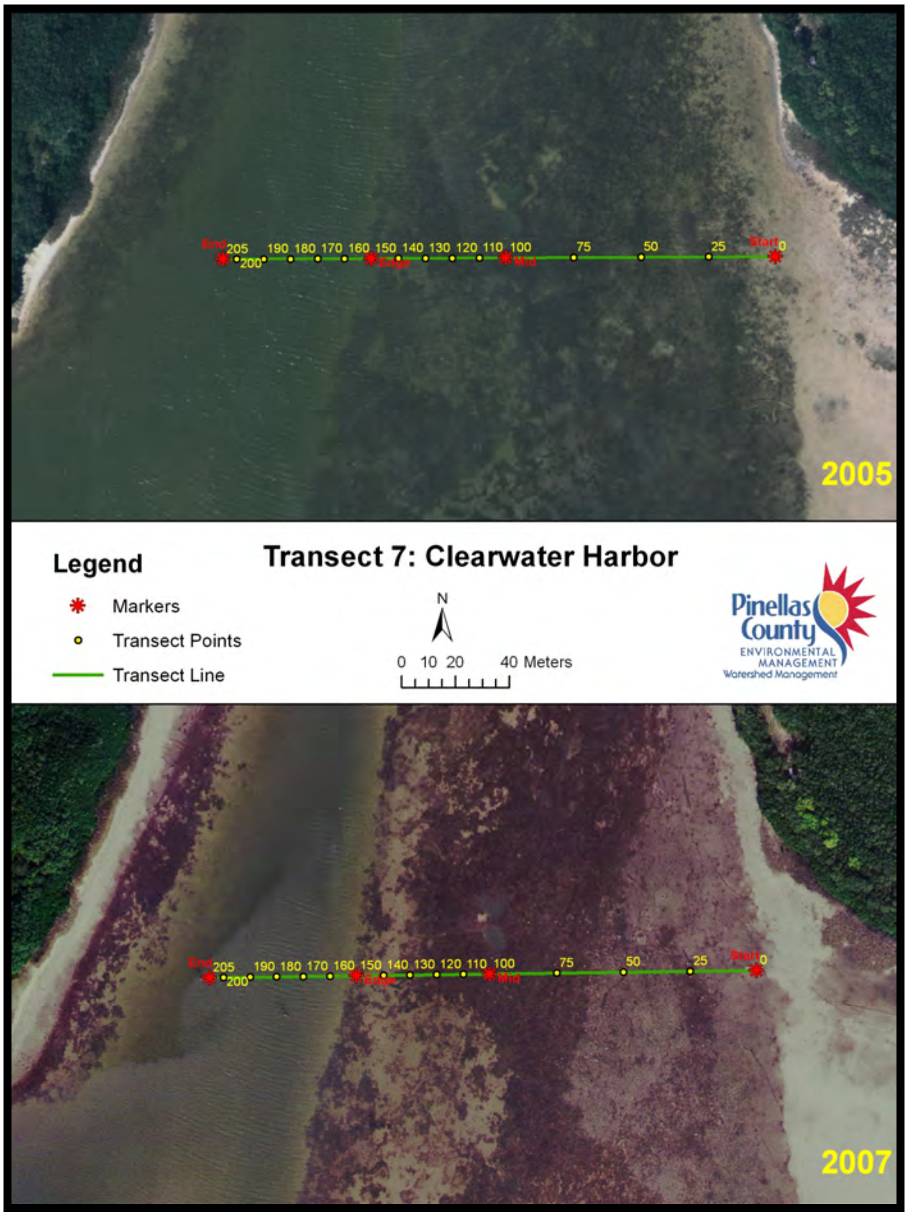
CLW-06 Shoot Density Graph



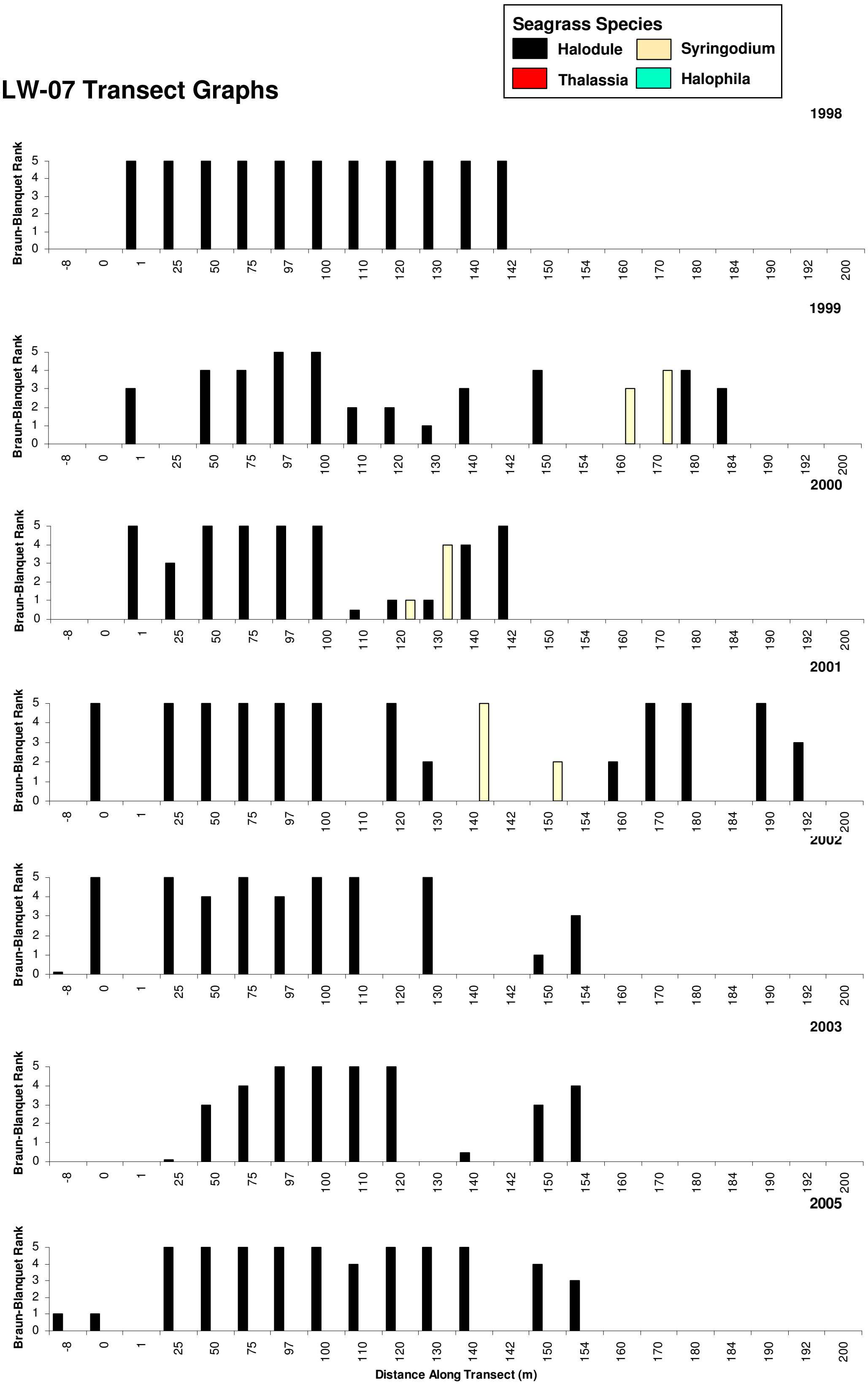
3.2.2.7 CLW-07

CLW-07 is located between Caladesi Island and the northern end of Clearwater Beach. The transect extends west 200m from the mangrove shore towards the boat channel. The depth ranged from 40cm-170cm. The sediment composition was sandy mud. The prominent seagrass was *Halodule* with occasional *Syringodium* in 1999-2001. The condition of the seagrass was consistently good.

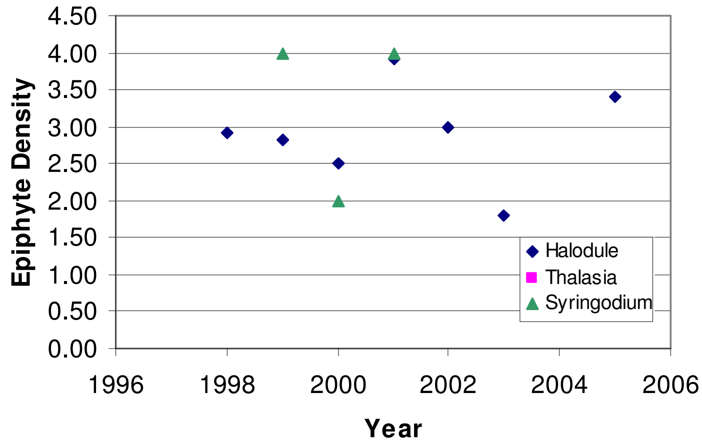
CLW-07 remained stable throughout the monitoring program. The data indicated that the edge of bed varied from 140m-192m. The epibiont density was light to heavy with assemblages consisting of attached algae, polycheates, bryozoans, and barnacles. The canopy height ranged from 15cm-35cm. The shoot density ranged from 50-2500 shoots (per m^2).



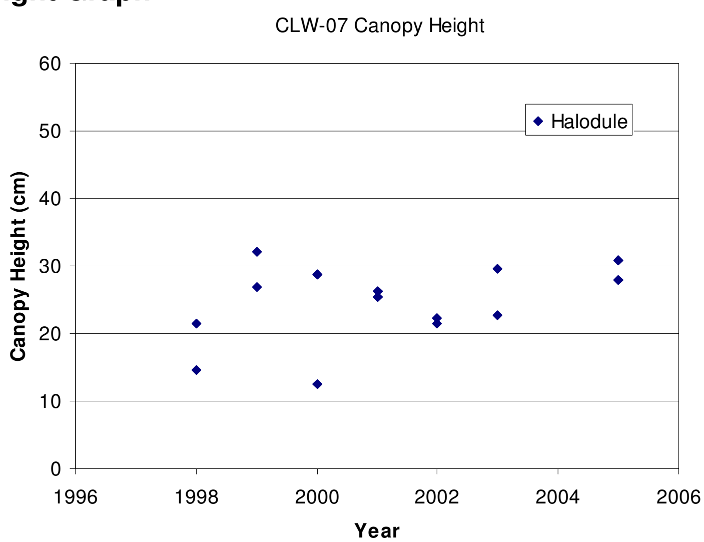
CLW-07 Transect Graphs



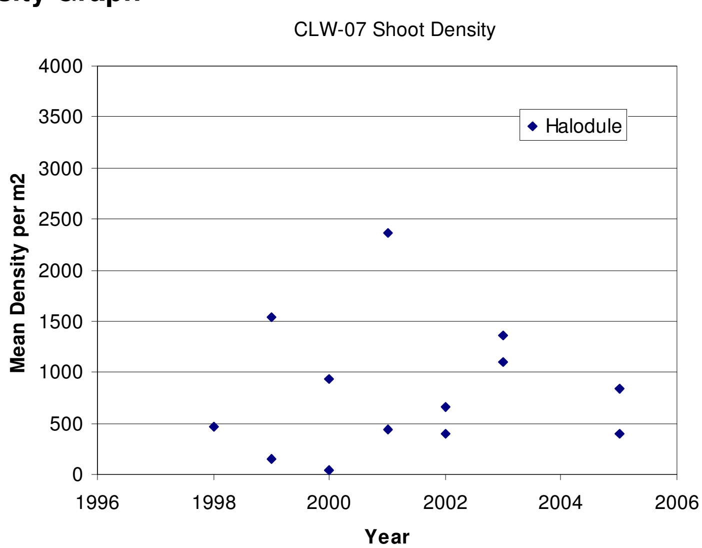
CLW-07 Epibiont Density Graph



CLW-07 Canopy Height Graph



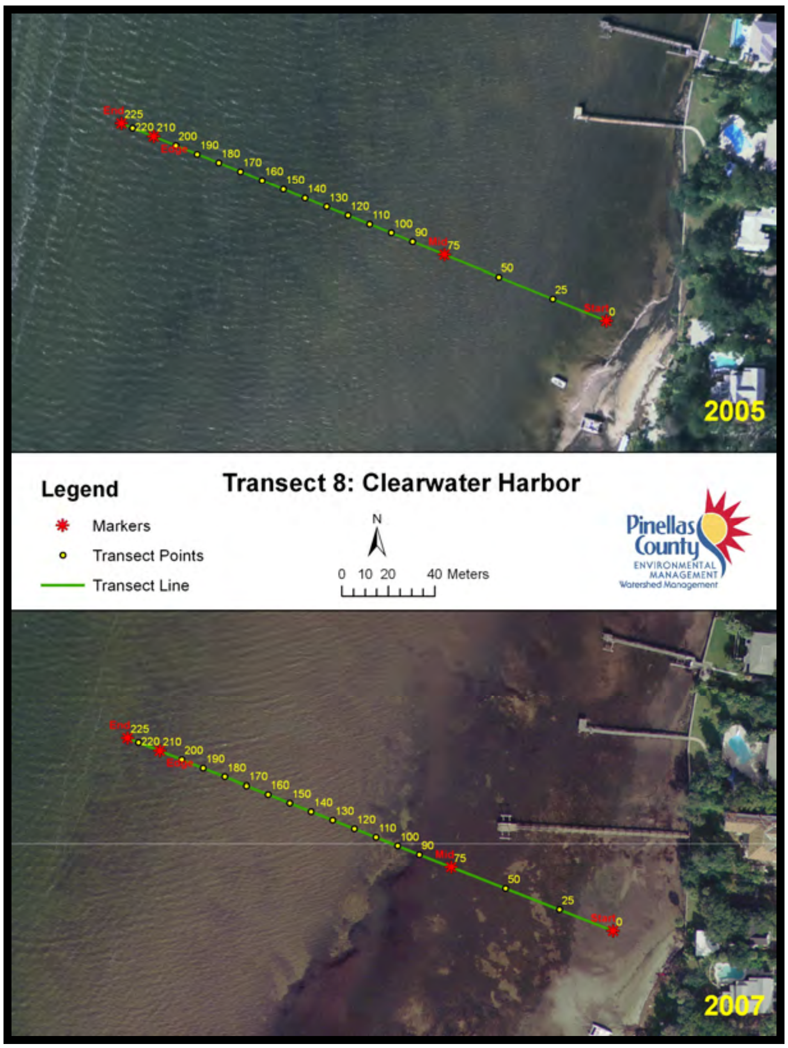
CLW-07 Shoot Density Graph



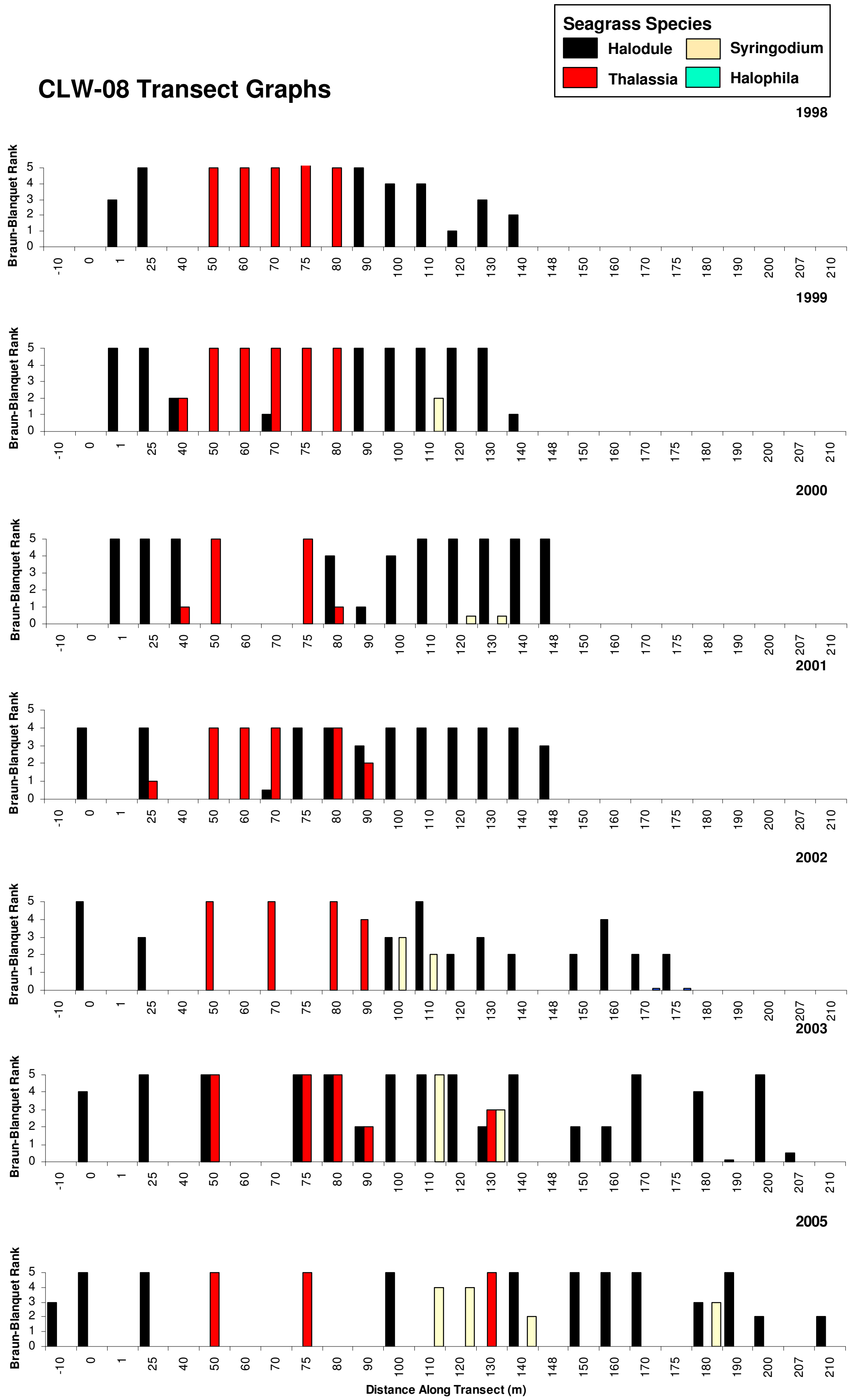
3.2.2.8 CLW-08

CLW-08 is located north of the Clearwater Memorial Bridge on the east shore of the ICW. The transect extends west 225m from the shore towards the boat channel. The depth ranged from 45cm-150m. The sediment composition was mud from 0m-25m then sandy mud from 25m-225m. The seagrass species composition was a mixture of *Halodule* and *Thalassia* with occasional *Syringodium* and sparse *Halophila*. The condition of the seagrass was good.

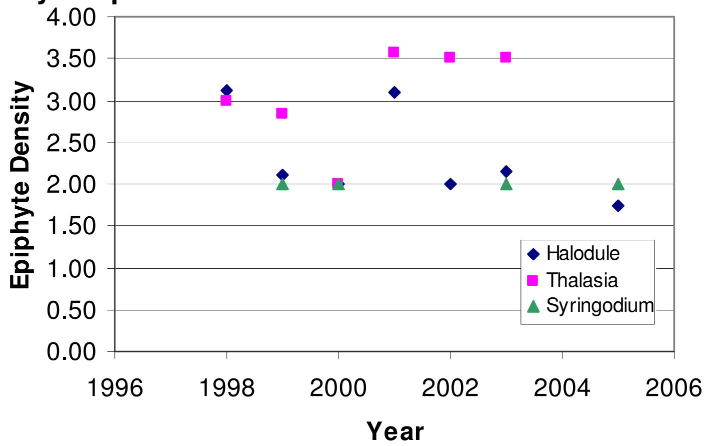
The length of transect CLW-08 increased throughout the monitoring program. The data indicated that the edge of bed increased from 140m to 210m. The Thalassia extended from 50m-80m in 1998 and to 50m-130m in 2005. In 2002, the field staff recorded *Halophila* at 170m-175m; however, it fell outside within the meter square quadrat and did not appear on the transect graphs. The epibiont density varied from light to moderate with assemblages consisting of attached algae and polycheates. The epibionts appeared less dense on the *Syringodium* and *Halodule*. The canopy height ranged from 5cm-30cm for the *Halodule* and 30cm-50cm for the *Thalassia*. The shoot density ranged from 50-1600 shoots (per m^2). In 2000-2003, the *Thalassia* shoot density rapidly increased from 200 shoots (per m^2) to 1400 shoots (per m^2).



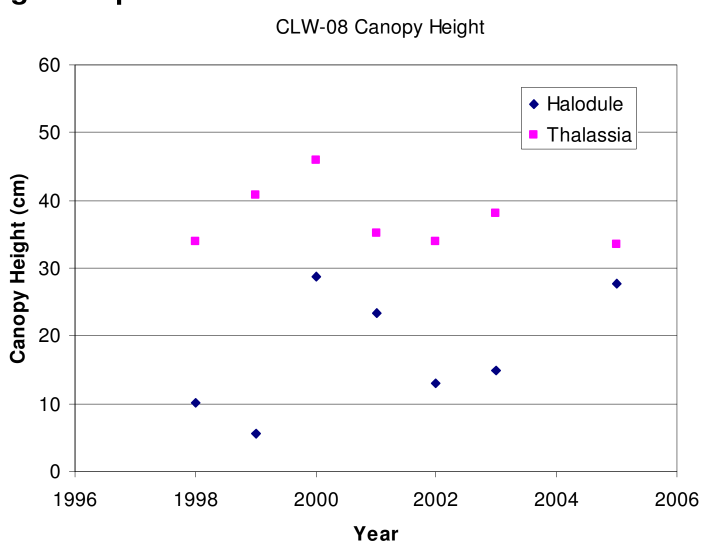
CLW-08 Transect Graphs



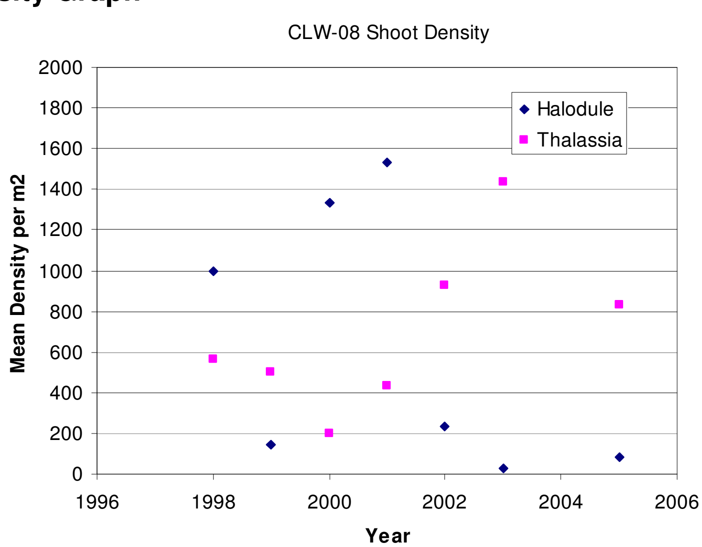
CLW-08 Epibiont Density Graph



CLW-08 Canopy Height Graph



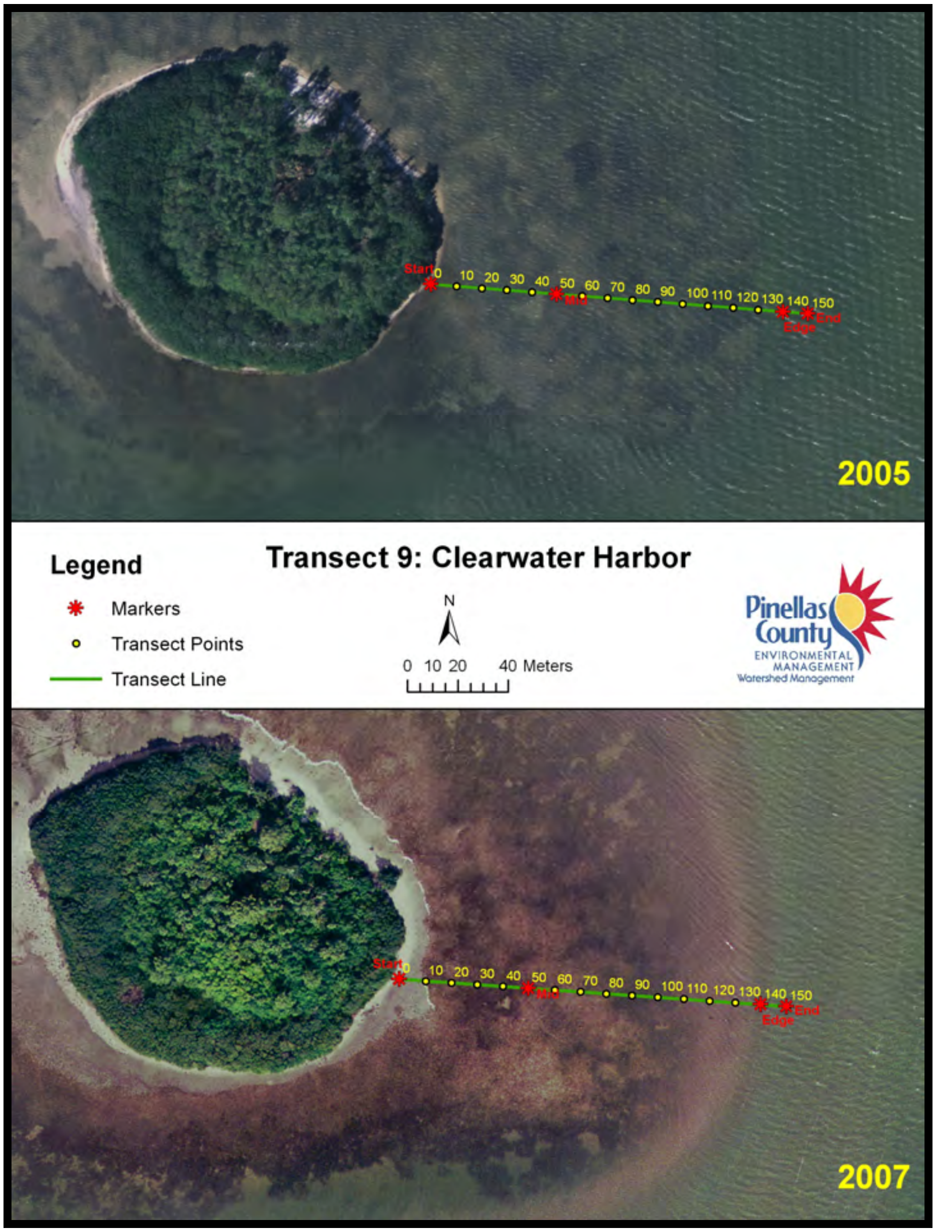
CLW-08 Shoot Density Graph



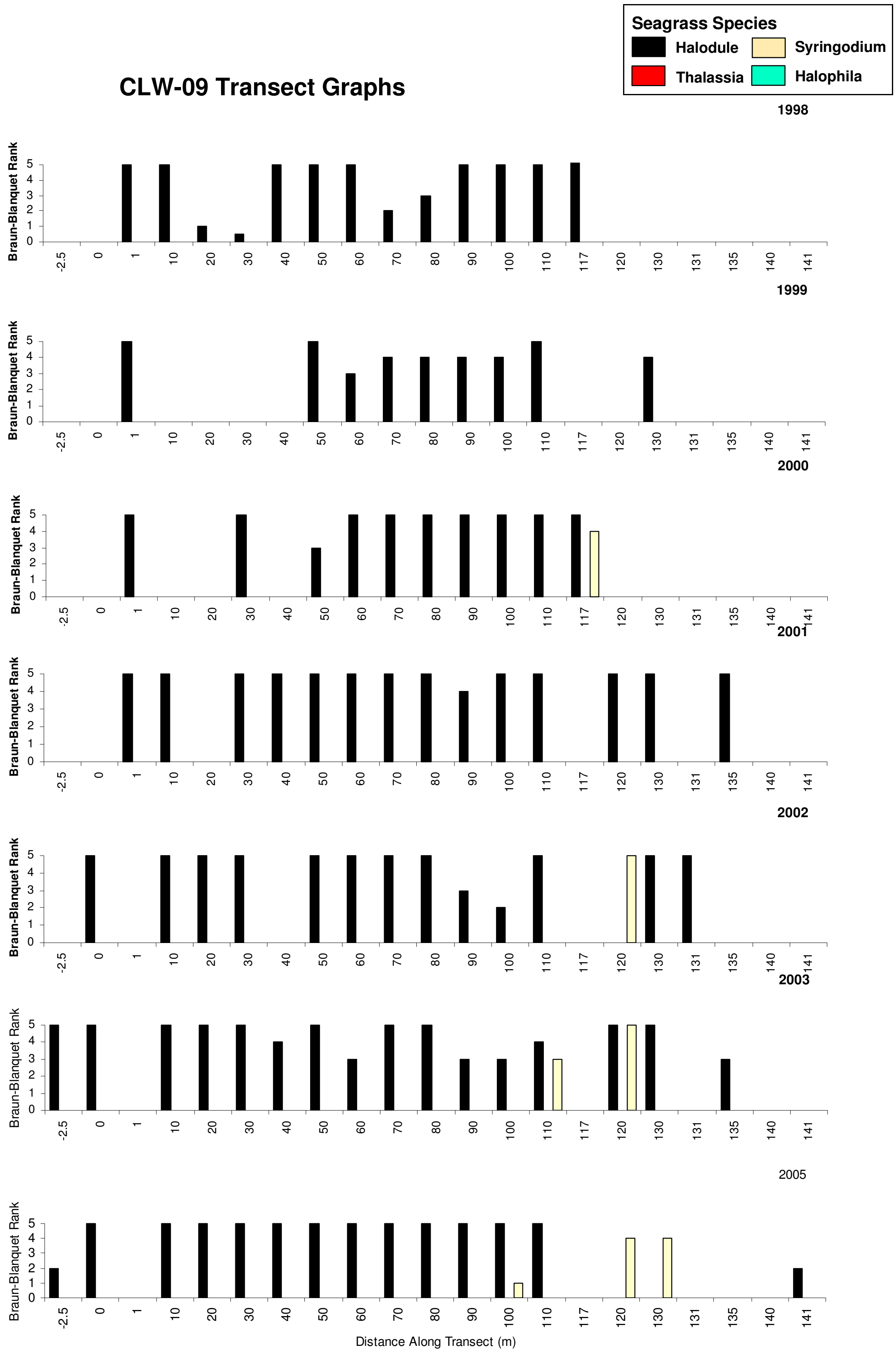
3.2.2.9 CLW-09

CLW-09 is located north of the Clearwater Memorial Bridge off the third spoil island. The transect extends east 150m from the mangrove island towards the boat channel. The depth ranged from 40cm-150cm. The sediment composition was sand and sandy mud. The prominent seagrass was *Halodule* with occasional *Syringodium*. The condition of the seagrass was fair-good.

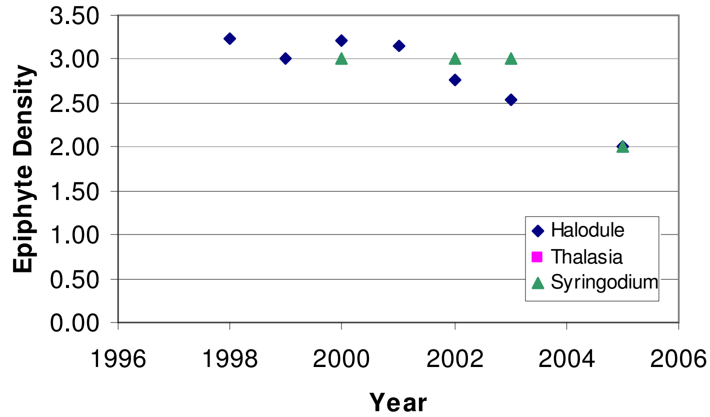
CLW-09 remained stable throughout the monitoring program. The data indicated that the edge of bed varies between 117m-141m. The epibiont density was moderate with assemblages consisting of attached algae, polycheates, and bryozoans. The canopy height ranged from 15cm-45cm. The canopy height of the *Halodule* increased from 1998-2003. The shoot density ranged from 100-2500 shoots (per m^2).



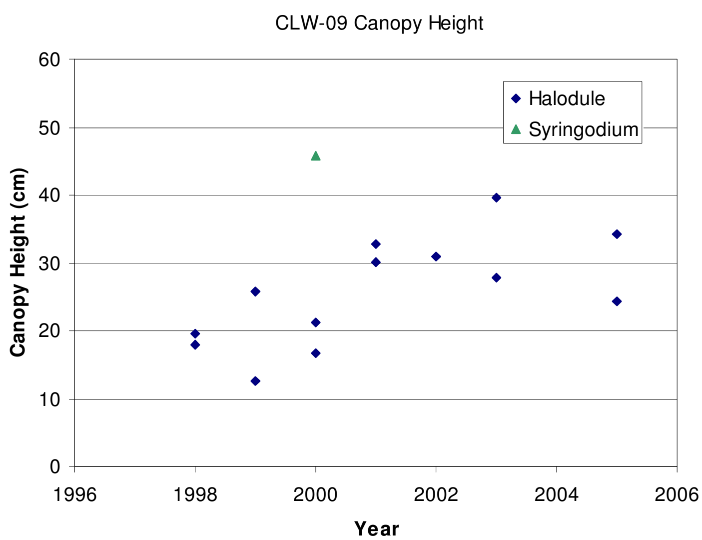
CLW-09 Transect Graphs



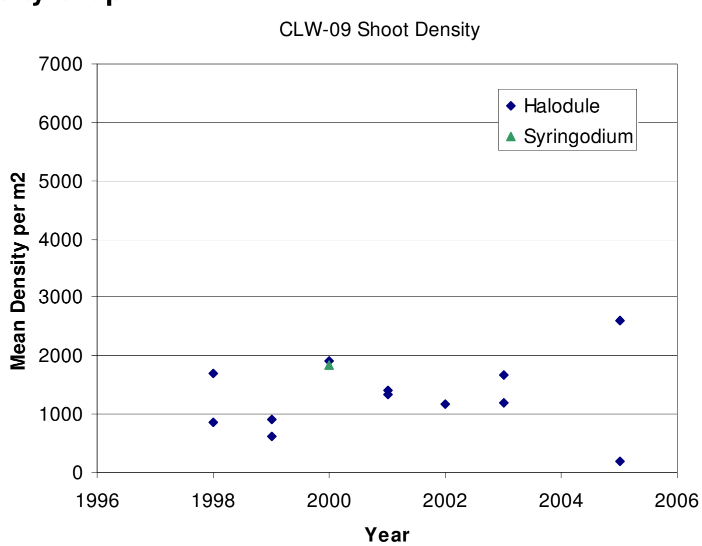
CLW-09 Epibiont Density Graph



CLW-09 Canopy Height Graph



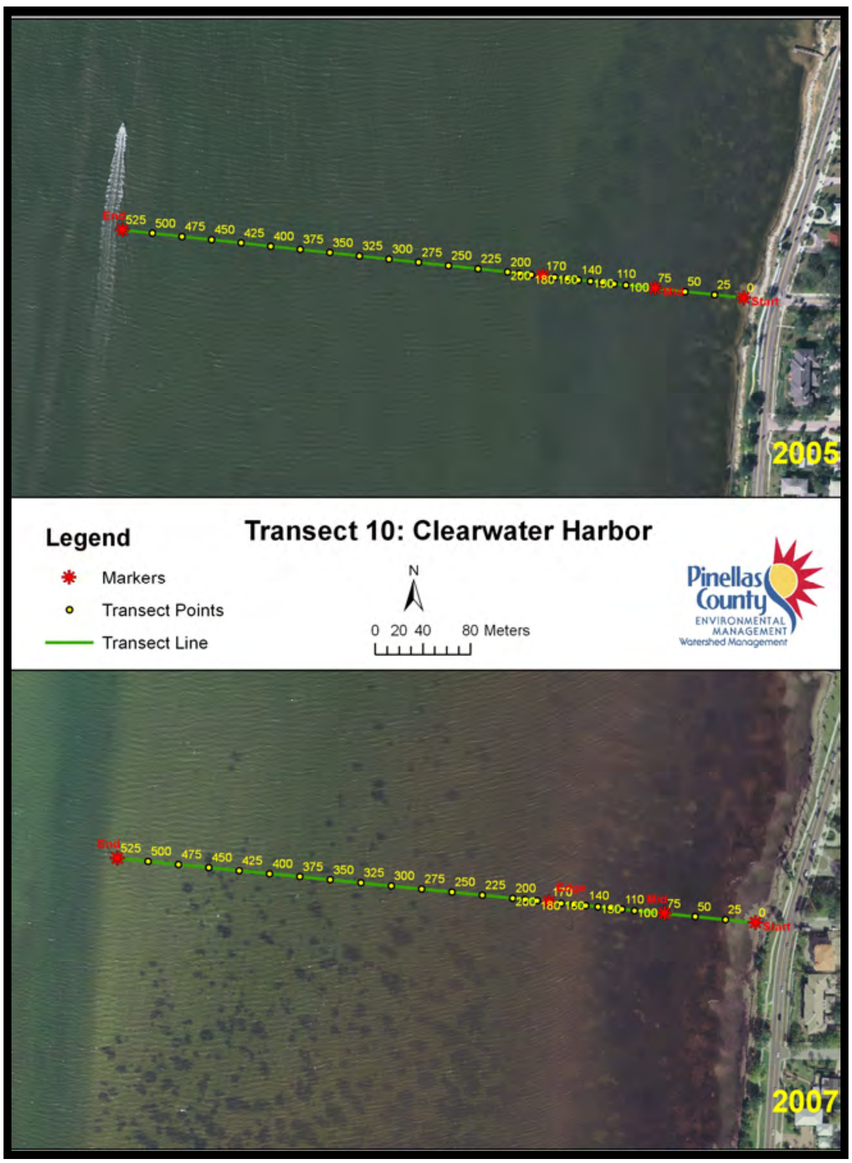
CLW-09 Shoot Density Graph



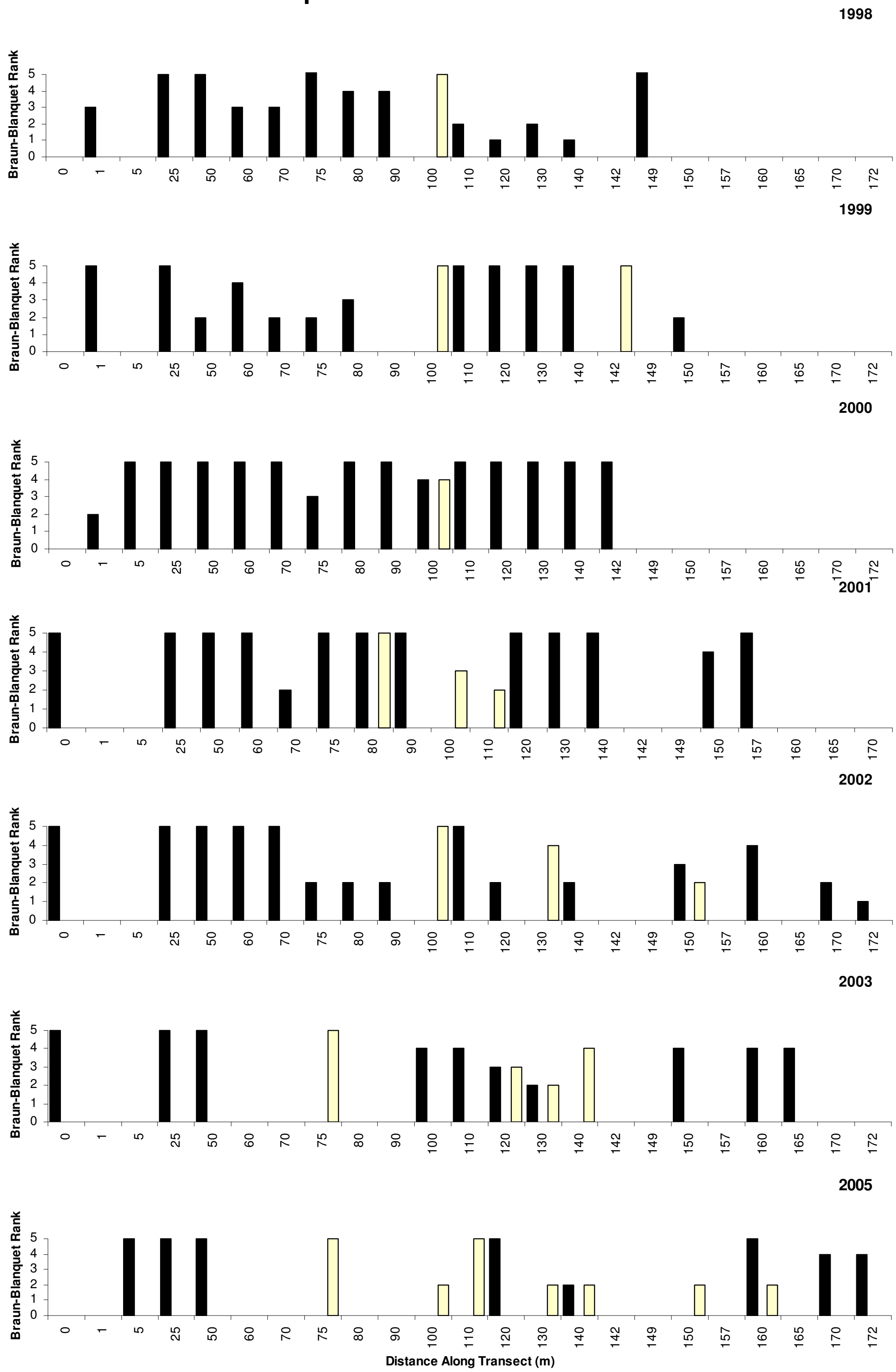
3.2.2.10 CLW-10

CLW-10 is located north of the Memorial Causeway Bridge on the east side of the ICW. The transect extends west 200m from the shore towards the boat channel. The depth ranged from 15cm-150cm. The sediment composition was sandy mud. The prominent seagrass was *Halodule* with increasing *Syringodium* throughout the monitoring program. The condition of the seagrass was good-very good.

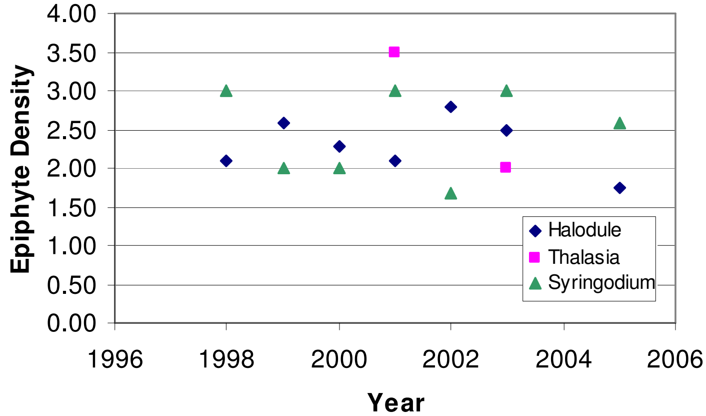
CLW-10 remained stable throughout the monitoring program with most variation occurring between 110m-200m. The seagrass species composition varied with the appearance of *Syringodium* from 75m-160m. The *Halodule* abundance decreased from 2000-2005. The data indicated that the edge of bed increased from 149m in 1998 to 172m in 2005. The epibiont density was light to moderate with assemblages consisting of attached algae, polycheates, bryozoans, and barnacles. The canopy height ranged from 20cm-40cm. The shoot density ranged from 250-1500 shoots (per m^2) with a gradual increasing trend throughout the monitoring program.



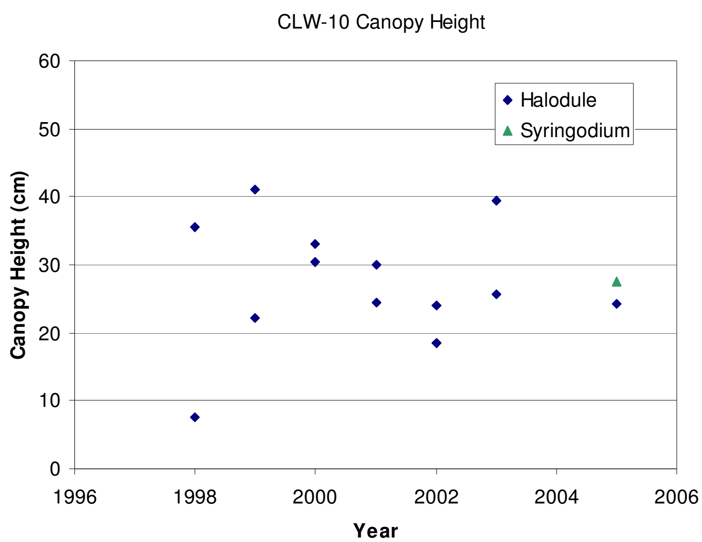
CLW-10 Transect Graphs



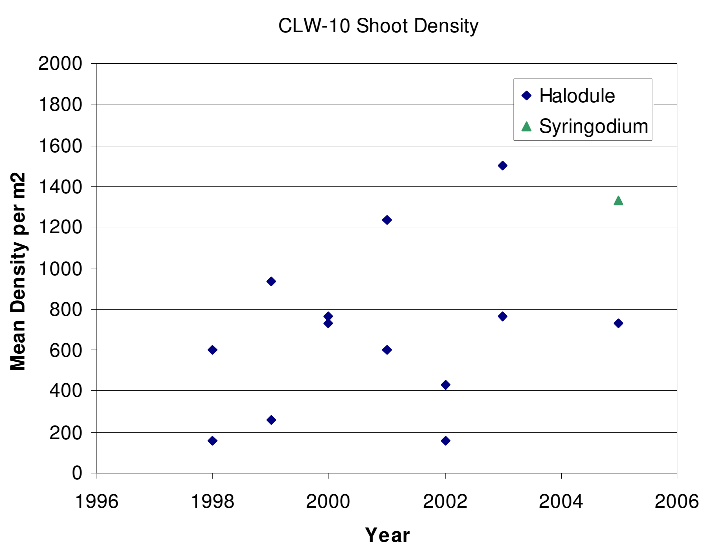
CLW-10 Epibiont Density Graph



CLW-10 Canopy Height Graph



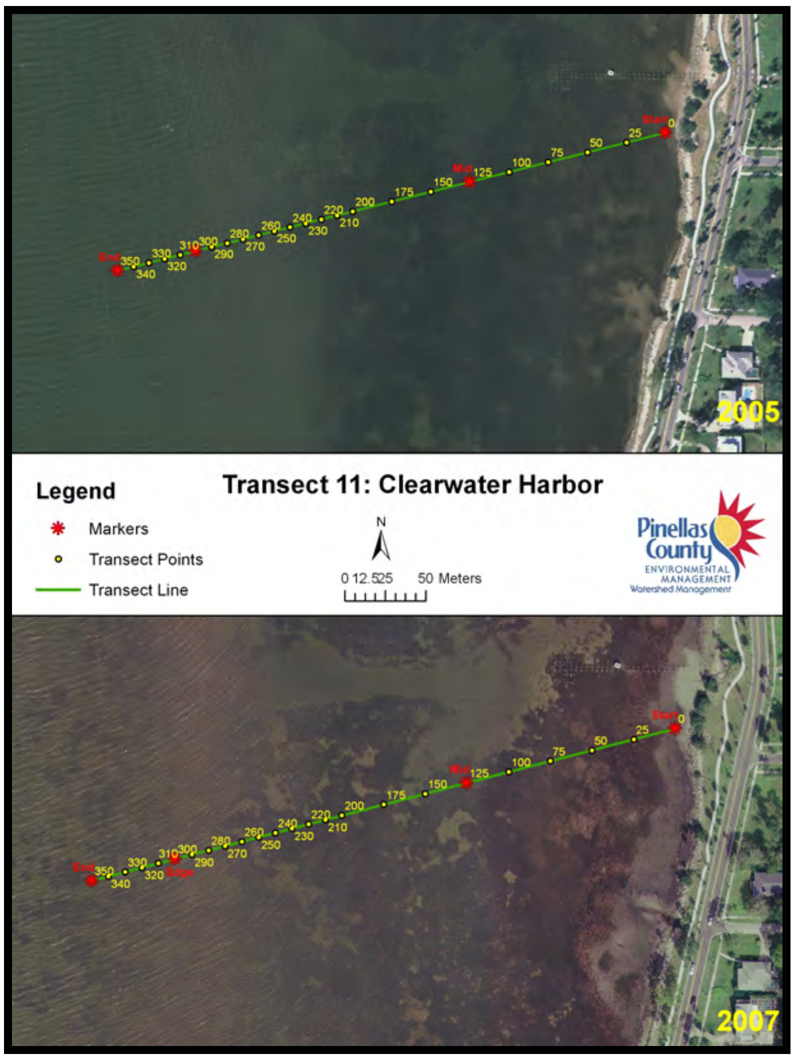
CLW-10 Shoot Density Graph

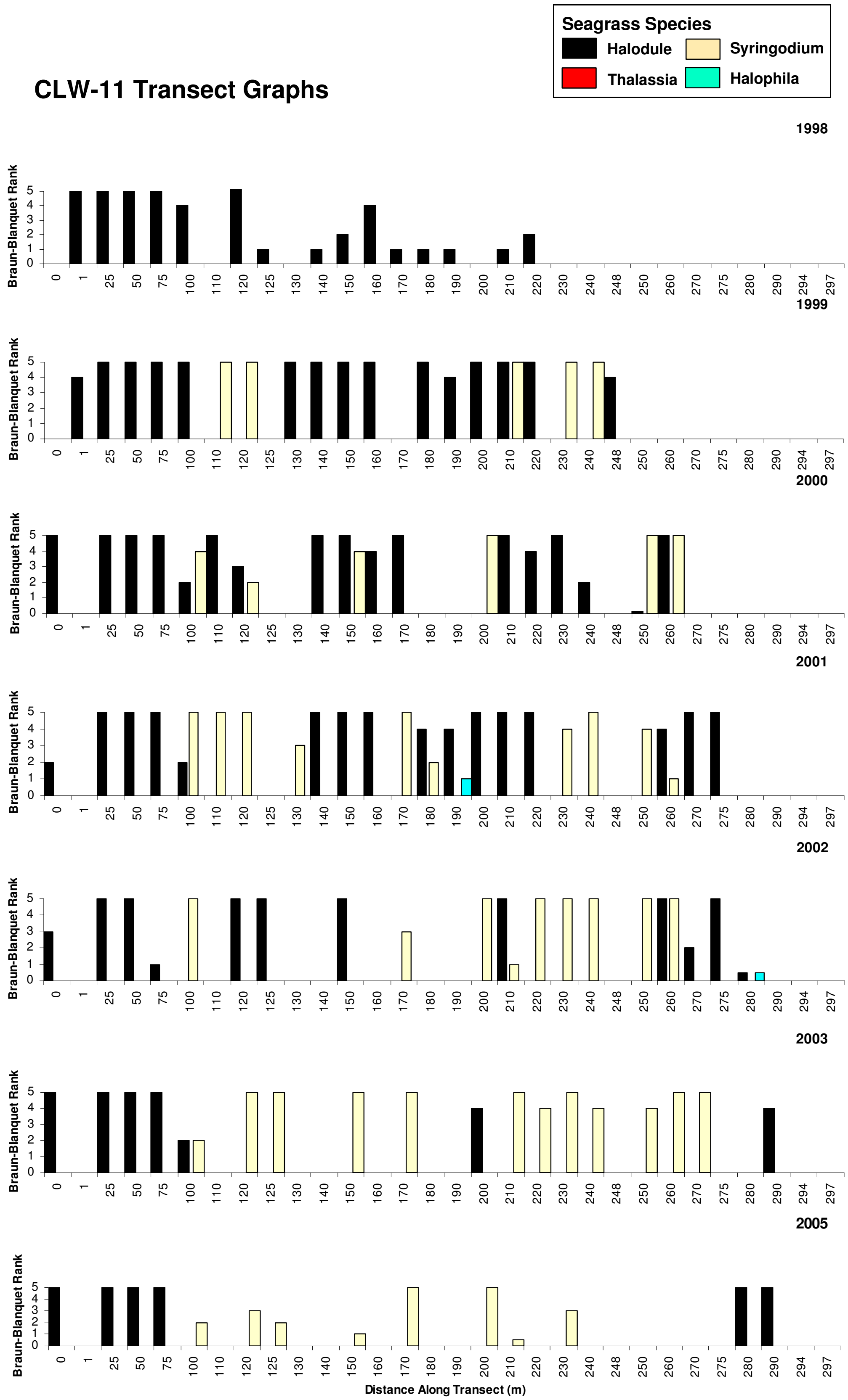


3.2.2.11 CLW-11

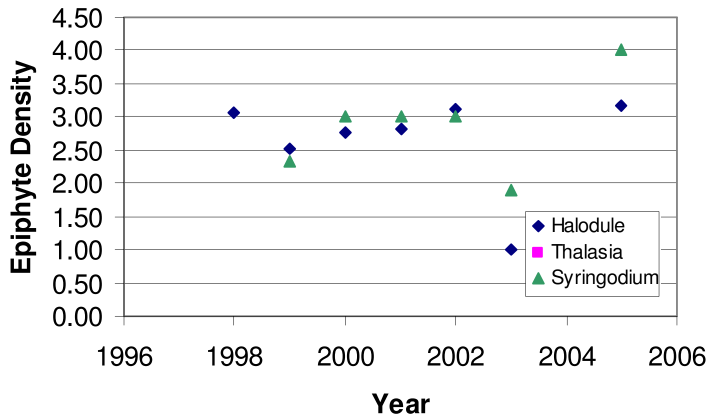
CLW-11 is located north of Clearwater Memorial Bridge on the east side of the ICW. The transect extends west 300m from the shore towards the boat channel. The depth ranged from 20cm-150cm. The sediment composition was sandy mud. The prominent seagrass in 1998-2000 was *Halodule*; however, by 2003 the prominent species was *Syringodium*. In 2002 and 2003 staff also found *Halophila*. The condition of the seagrass was good.

CLW-11 remained stable throughout the study; however, the species composition changed. The data indicated that the edge of bed increased from 220m-290m. The epibiont density varied from light to heavy with the heaviest density in 2005. The epibiont assemblages consisted of attached algae, polycheates, bryozoans, and barnacles. The canopy height ranged from 5cm-45cm with an increasing trend for Halodule from 1998-2003. The shoot density ranged from 100-1100 shoots (per m^2).

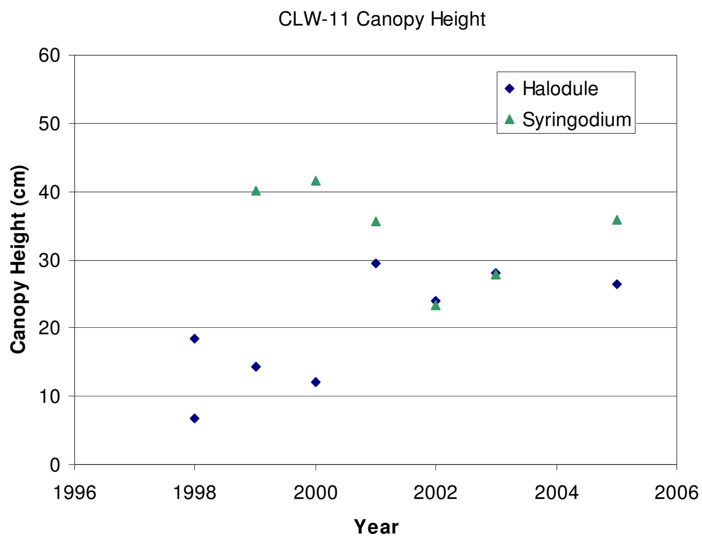



Seagrass Species
Halodule
Syringodium
Thalassia
Halophila
CLW-11 Transect Graphs
1998
1999
2000
2001
2002
2003
2005
Braun-Blanquet Rank
0 1 2 3 4 5
0 1 25 50 75 100 110 120 125 130 140 150 160 170 180 190 200 210 220 230 240 248 250 260 270 275 280 290 294 297
Distance Along Transect (m)

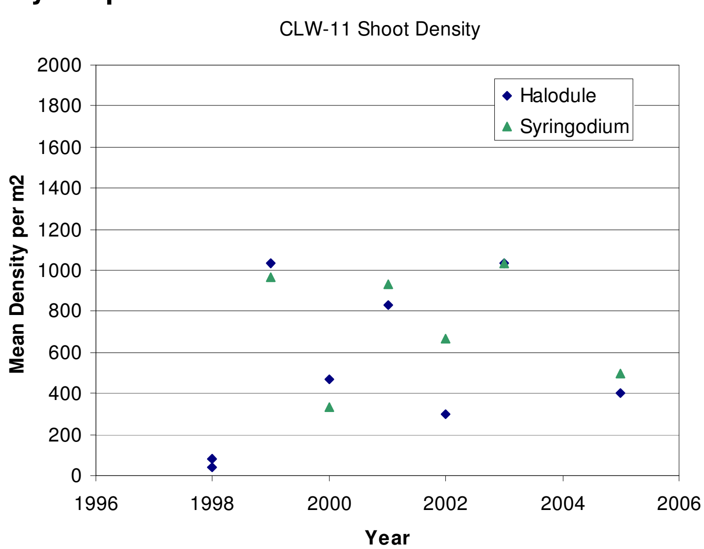
CLW-11 Epibiont Density Graph



CLW-11 Canopy Height Graph



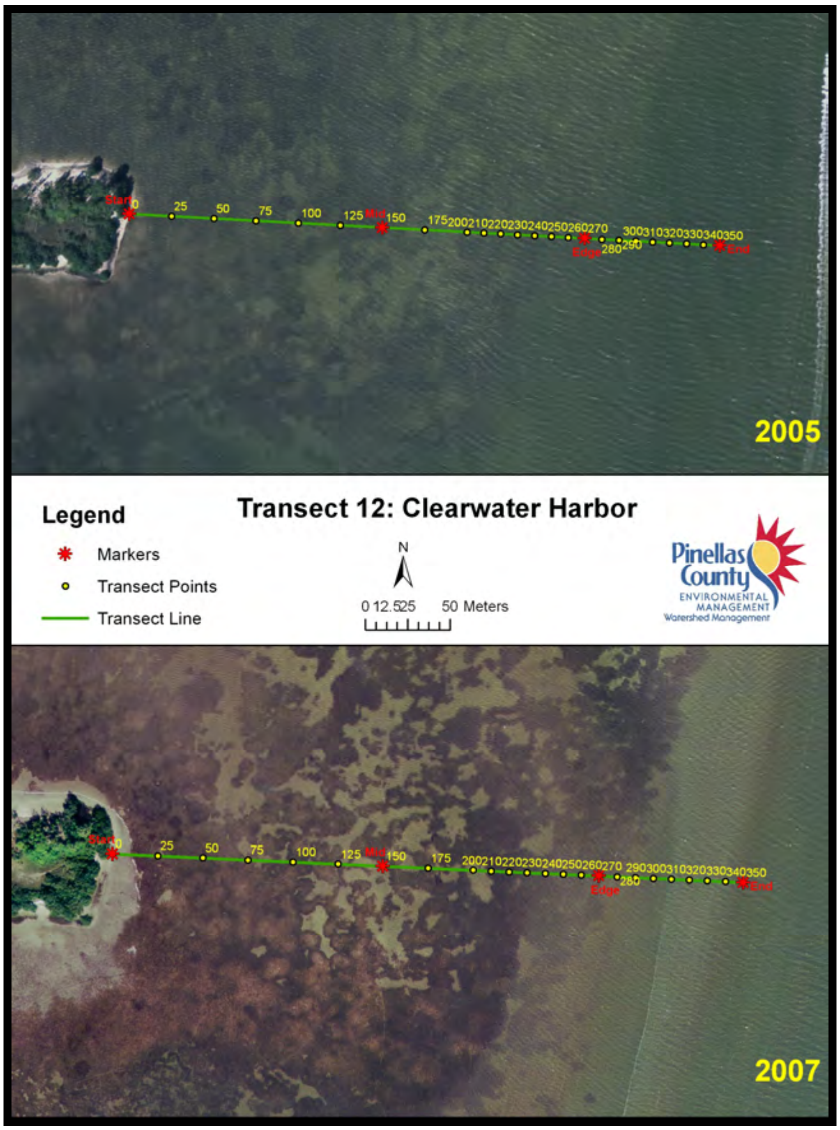
CLW-11 Shoot Density Graph



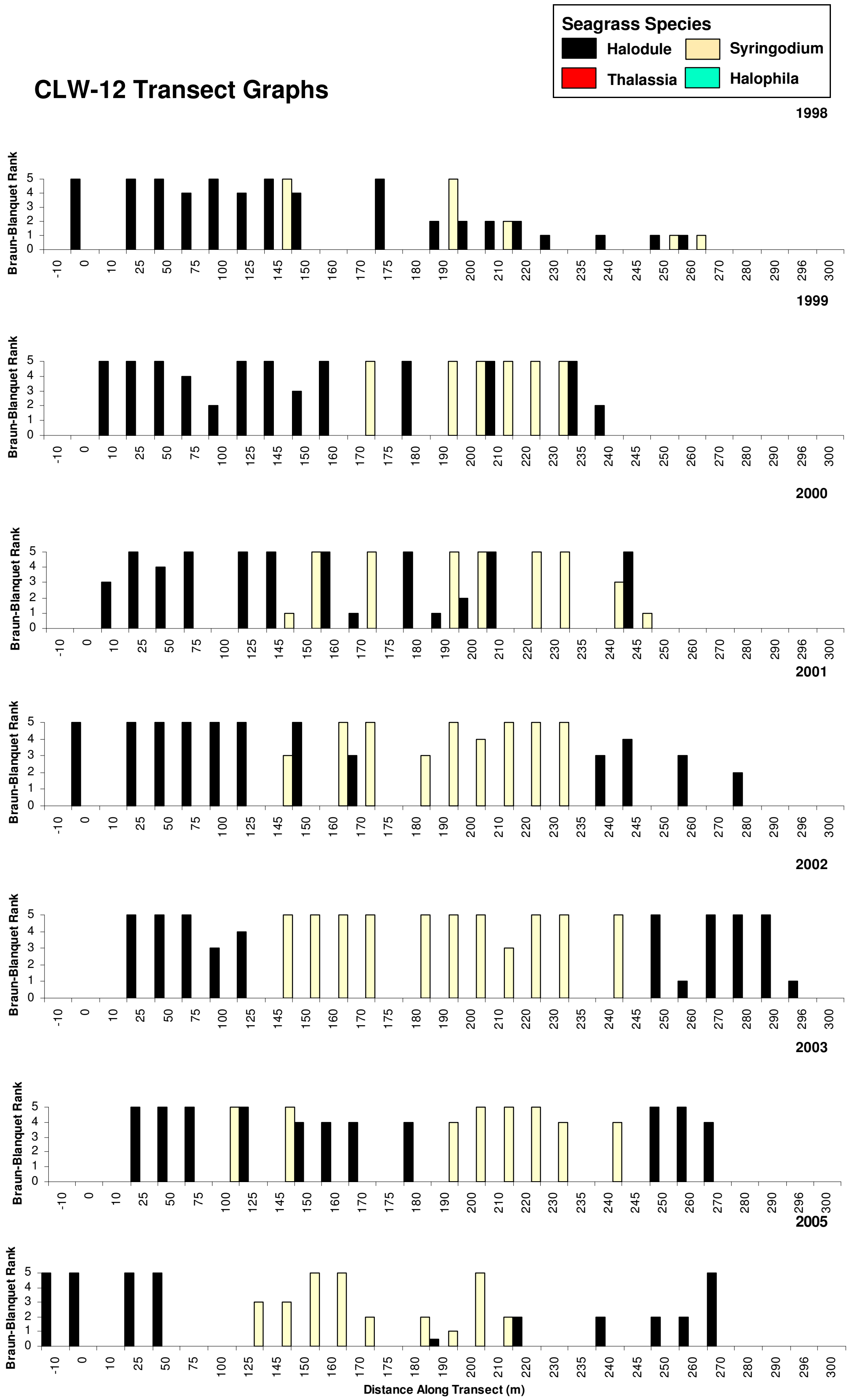
3.2.2.12 CLW-12

CLW-12 is located north of the Clearwater Memorial Bridge near the fourth spoil island. The transect extends east 300m from the spoil island towards the boat channel. The depth ranged from 30cm-160cm. The sediment composition was sandy mud. The prominent seagrass species were *Halodule* and *Syringodium*. The condition of the seagrass was fair-good.

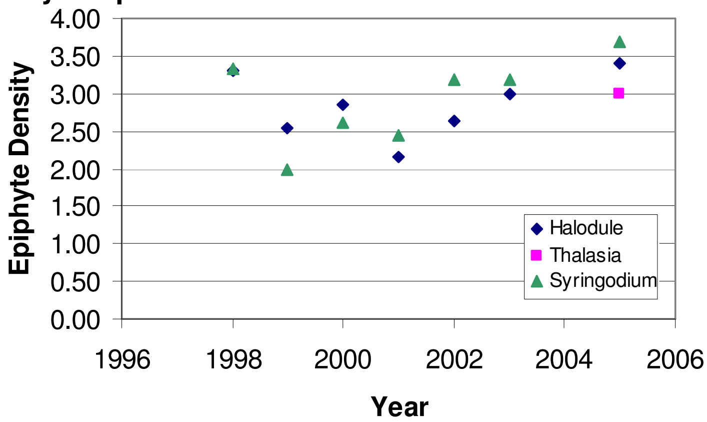
CLW-12 remained stable throughout the study; however, the species composition changed. The frequency of *Syringodium* increased in abundance along the transect. The data indicated that the edge of bed varied from 240m-296m. The epibiont density was light to heavy with increased density from 2001-2005. The epibiont assemblages consisted of attached algae, polycheates, bryozoans, and barnacles. The canopy height ranged from 10cm-45cm. The shoot density ranged from 50-1200 shoots (per m^2). In 2002 and 2003, the Syringodium shoot density was 5333 shoots (per m^2) and 3000 shoots (per m^2) respectively.



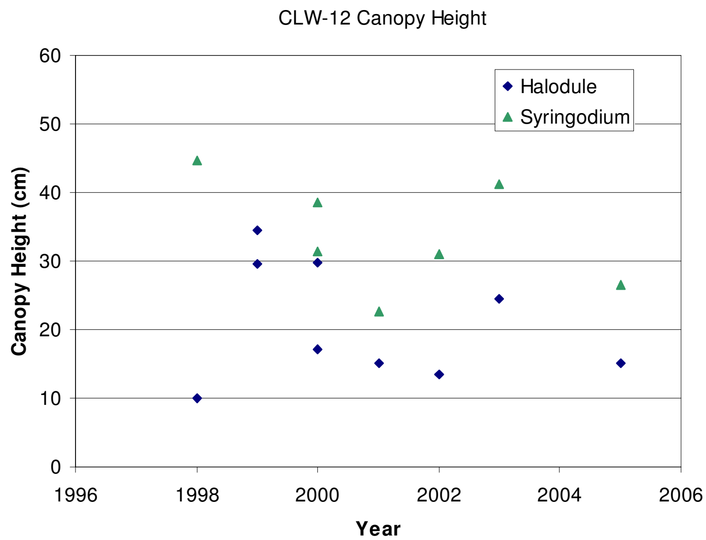
CLW-12 Transect Graphs



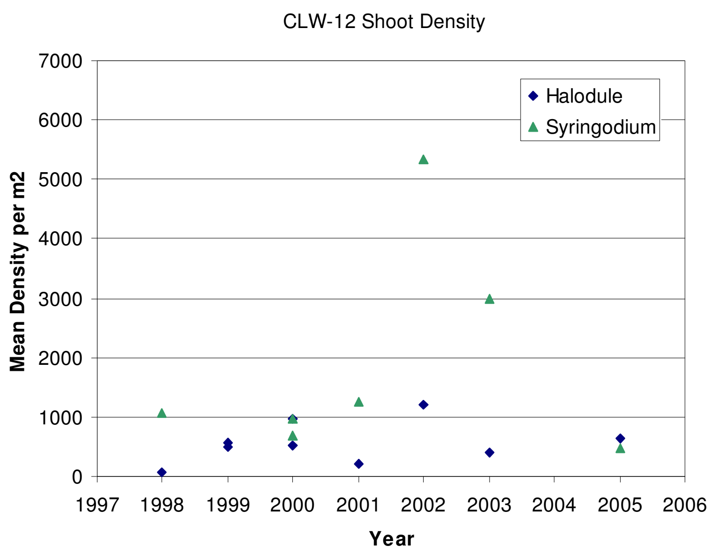
CLW-12 Epibiont Density Graph



CLW-12 Canopy Height Graph



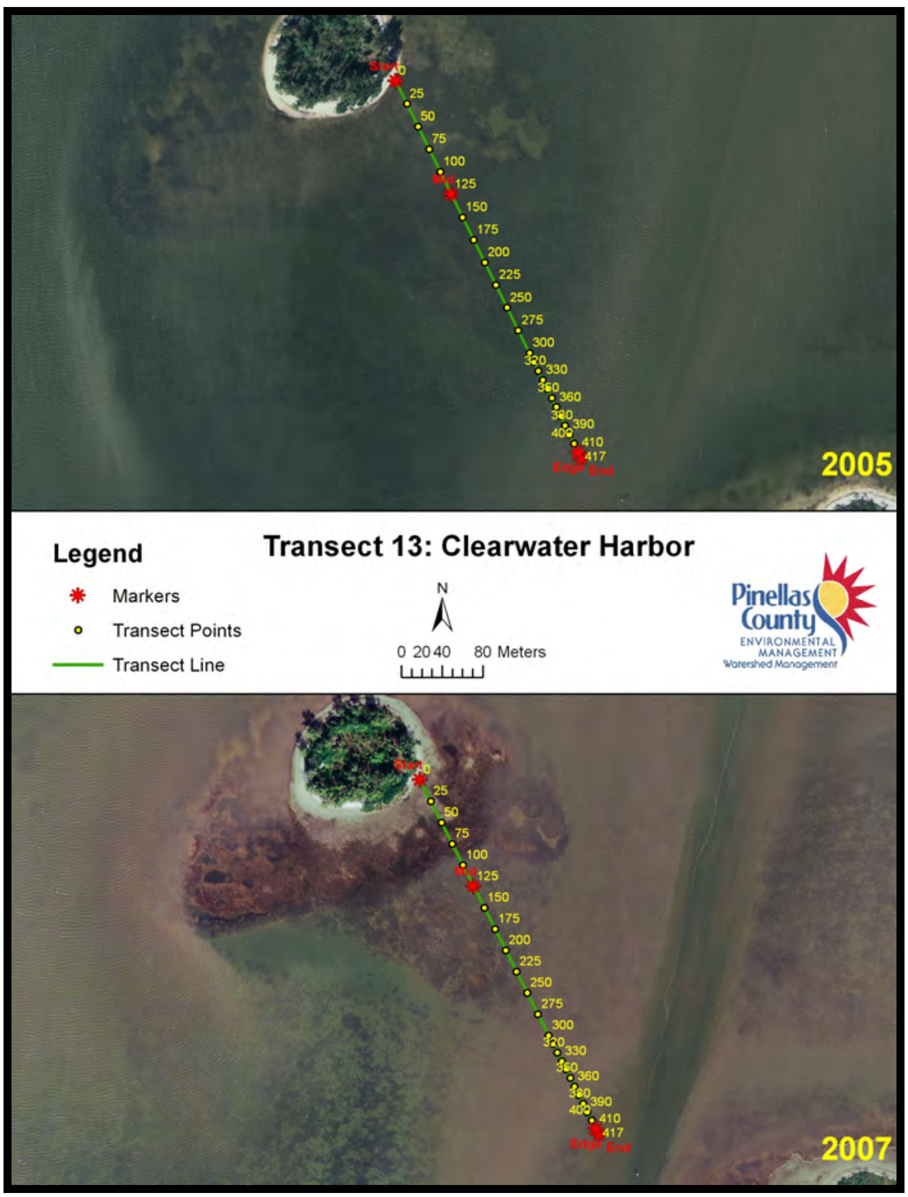
CLW-12 Shoot Density Graph

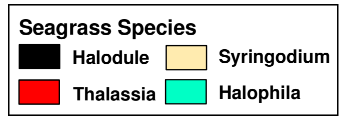


3.2.2.13 CLW-13

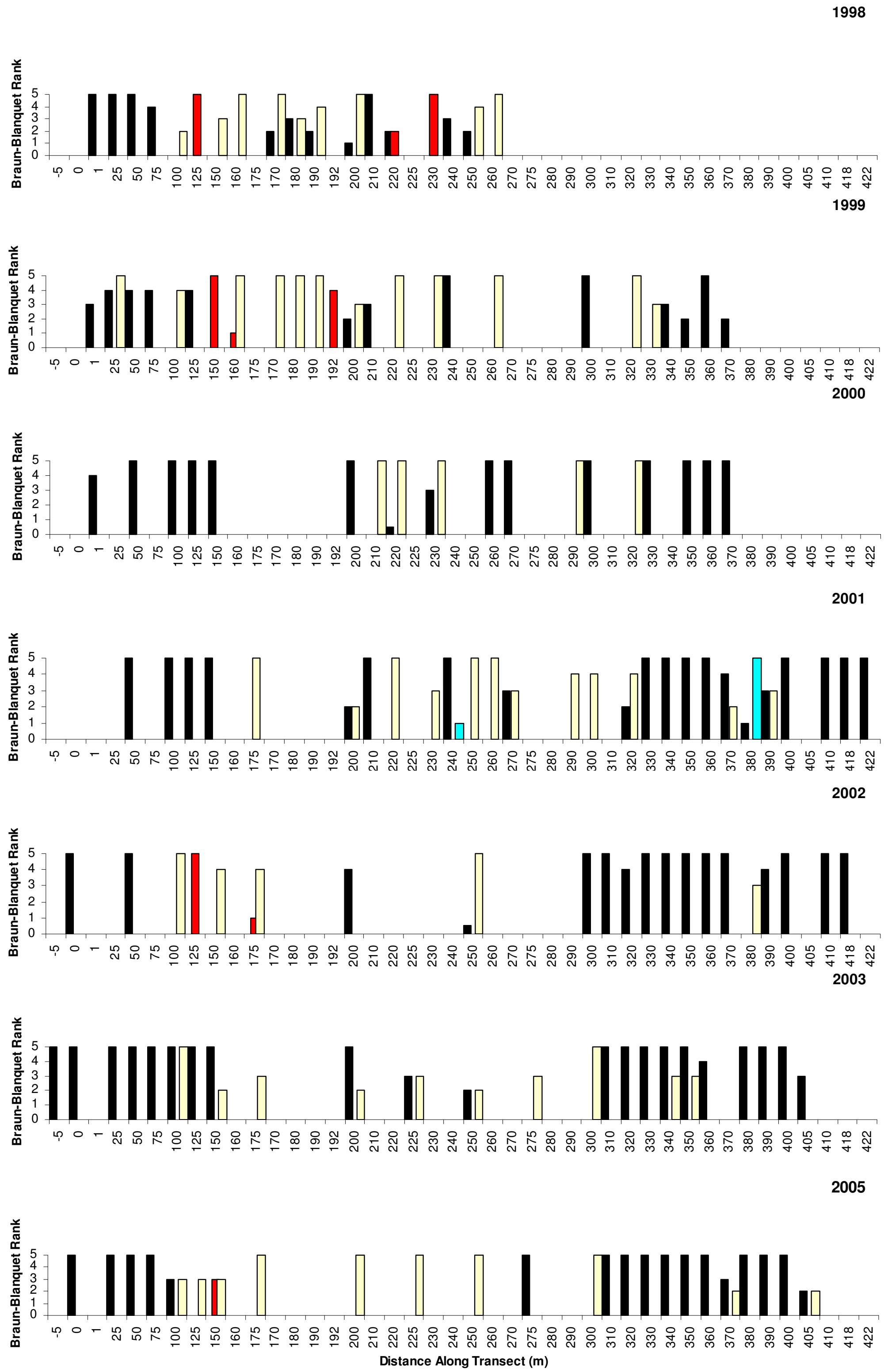
CLW-13 is located southwest of the Dunedin Causeway near the first spoil island. The transect extends southeast 450m from the spoil island towards the boat channel. The depth ranged 20cm-140cm. The sediment composition was sandy mud. The prominent seagrass was *Halodule* and *Syringodium* with occasional *Thalassia* and *Halophila*. The condition of the seagrass was fair-good.

CLW-13 remained stable throughout the monitoring program; however, the species composition changed. The data suggested that the frequency and abundance of *Syringodium* increased along the transect. The data indicated that the edge of bed varied from 270m-422m. The epibiont density varied from light to heavy with assemblages consisting of attached algae and polycheates. The canopy height ranged from 20cm-40cm. The shoot density ranged from 100-1500 shoots (per m^2) with the lowest density in 2005.

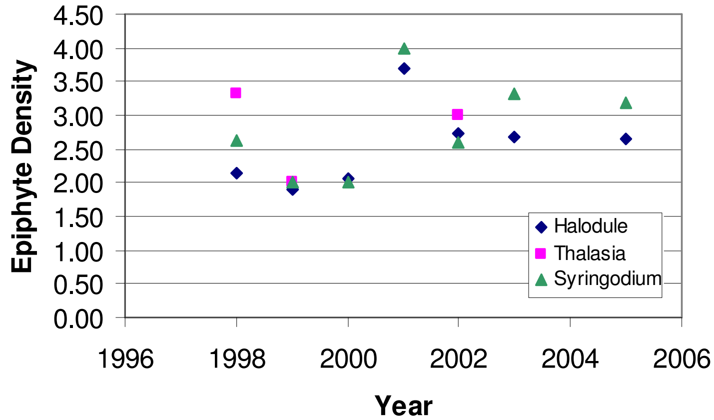




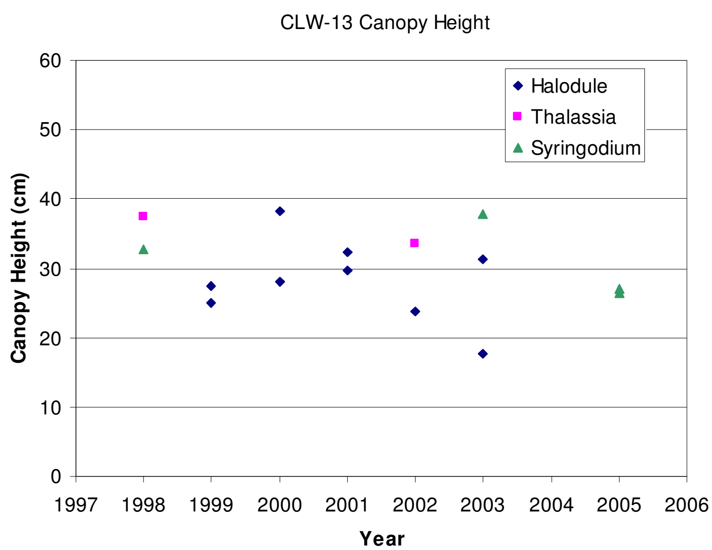
CLW-13 Transect Graphs



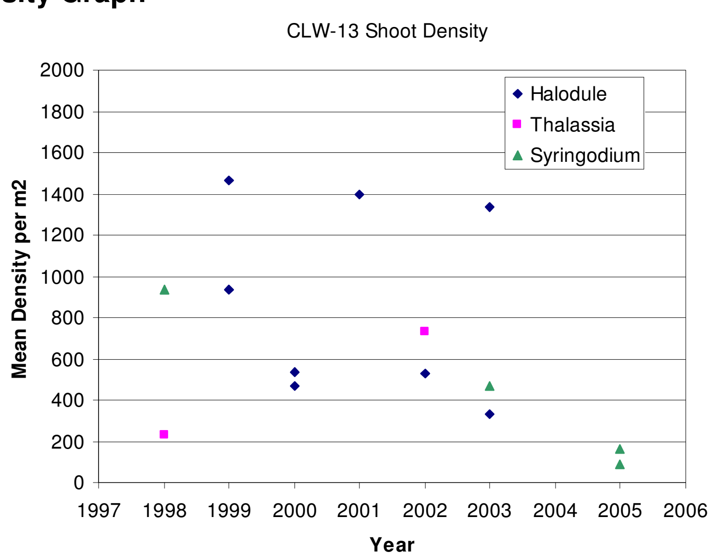
CLW-13 Epibiont Density Graph



CLW-13 Canopy Height Graph



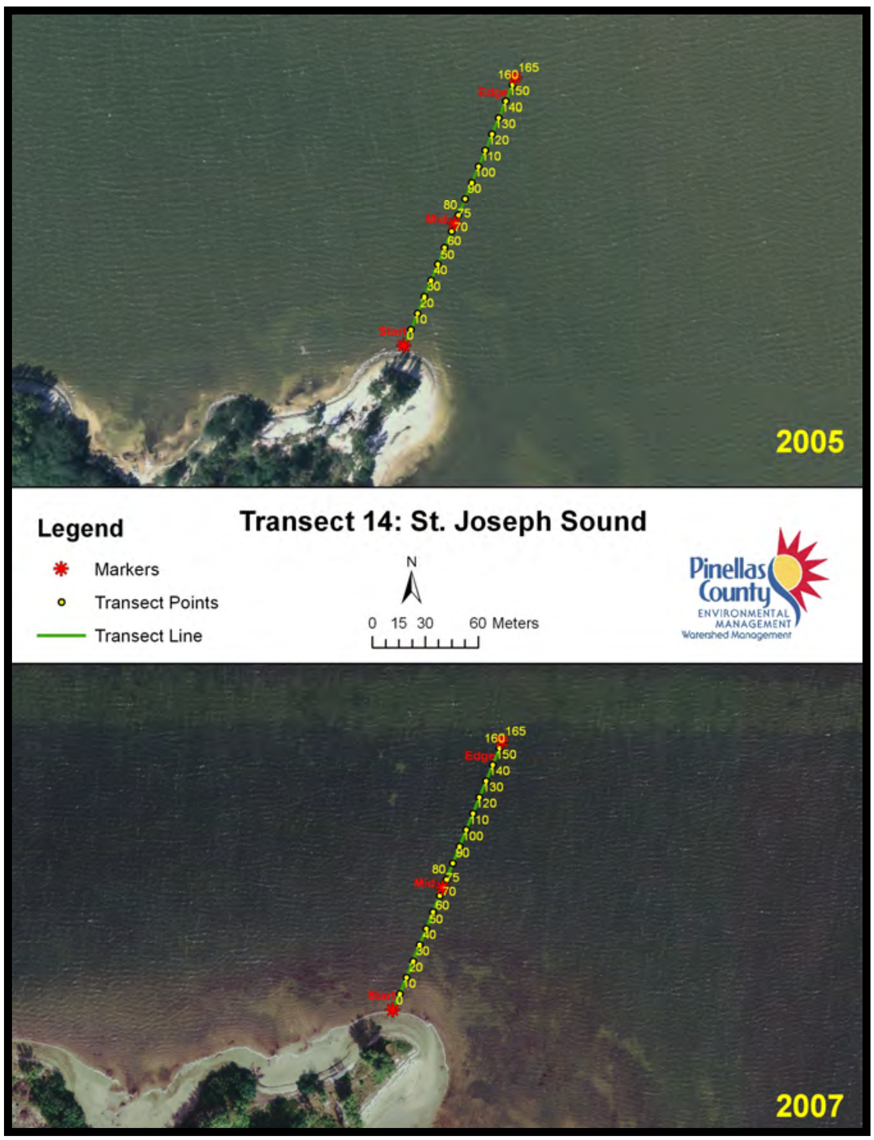
CLW-13 Shoot Density Graph



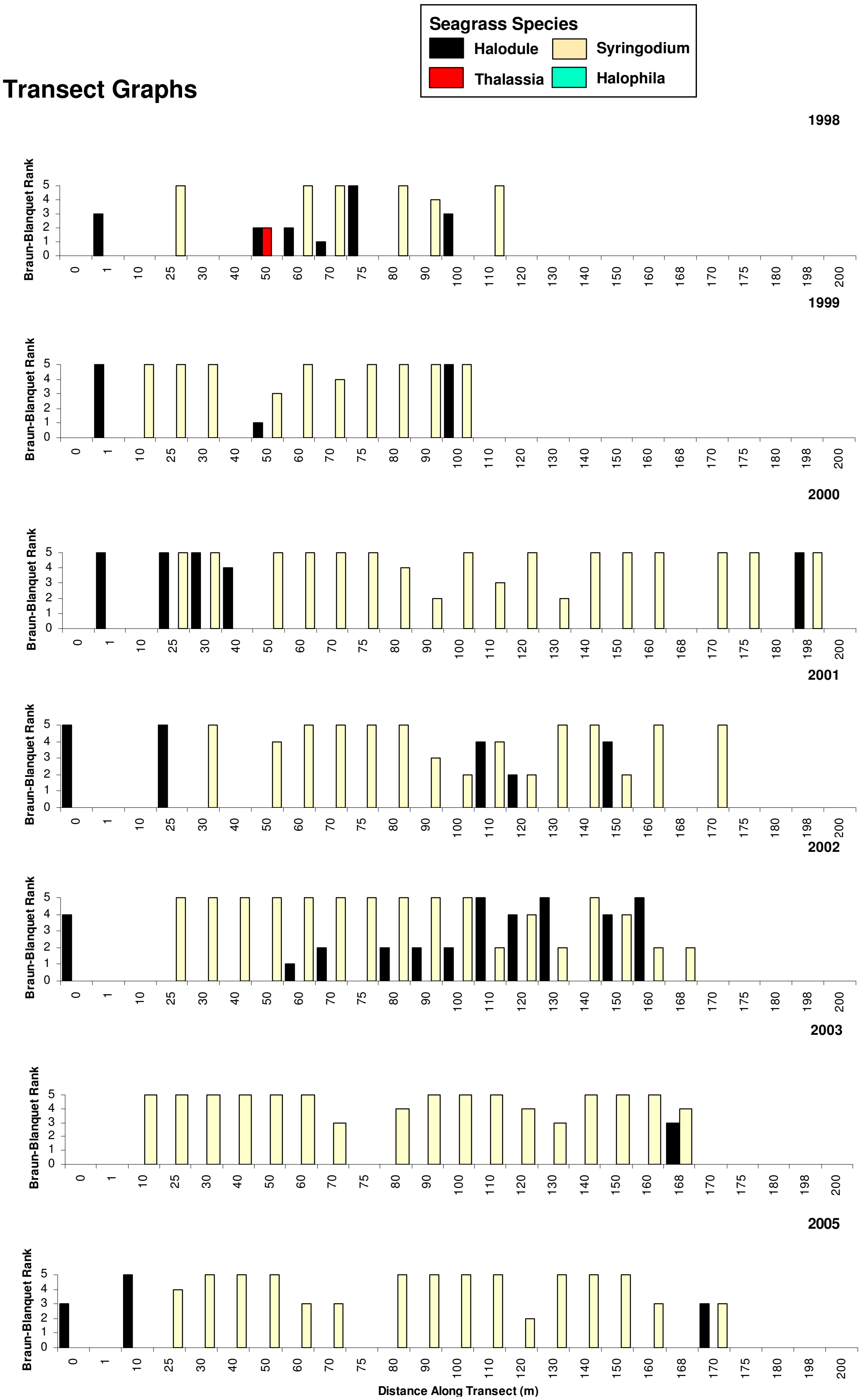
3.2.2.14 CLW14

CLW-14 is located north of the Dunedin Causeway near the second spoil island. The transect extends north 200m from the spoil island towards the boat channel. The depth ranged from 30cm-200cm. The sediment composition was sand and sandy mud. The prominent seagrass was *Syringodium* with some *Halodule*. The condition of the seagrass was good-very good in 1998-2003. In 2005, the condition was poor-fair.

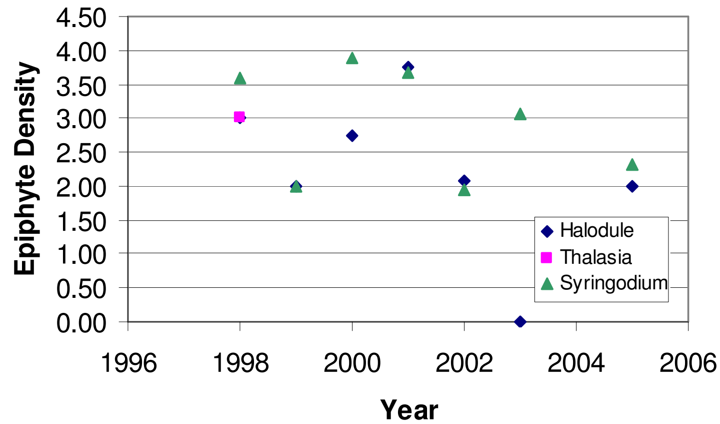
CLW-14 remained stable throughout the monitoring program. The transect may have been realigned in 2000 accounting for the variation in the length of the seagrass bed. The data indicated that the edge of bed varied from 110m-198m. The epibiont density varied from light to heavy with assemblages consisting of attached algae and polycheates from 1998-2003. In 2005, the epibionts consisted of attached algae, bryozoans, holothuroidians, and tunicates. The shift in epibionts may have correlated with the condition of the seagrass. The canopy height ranged from 25cm-50cm with the lowest height recorded in 2002. The shoot density ranged from 75-1400 shoots (per m^2).



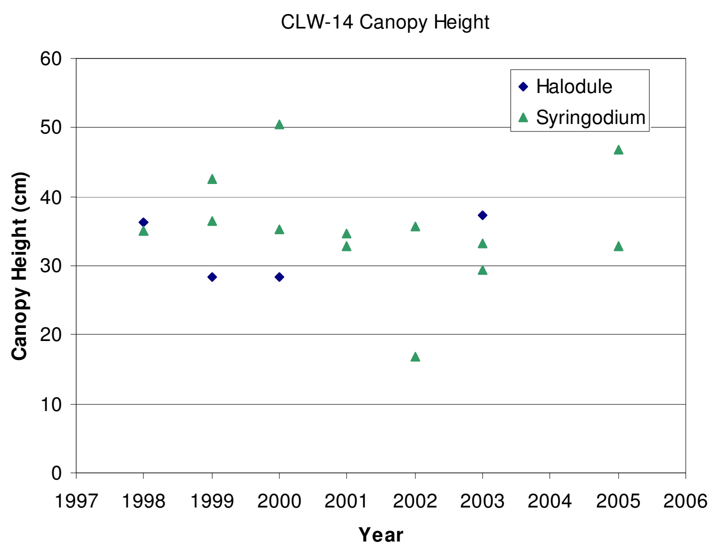
CLW-14 Transect Graphs



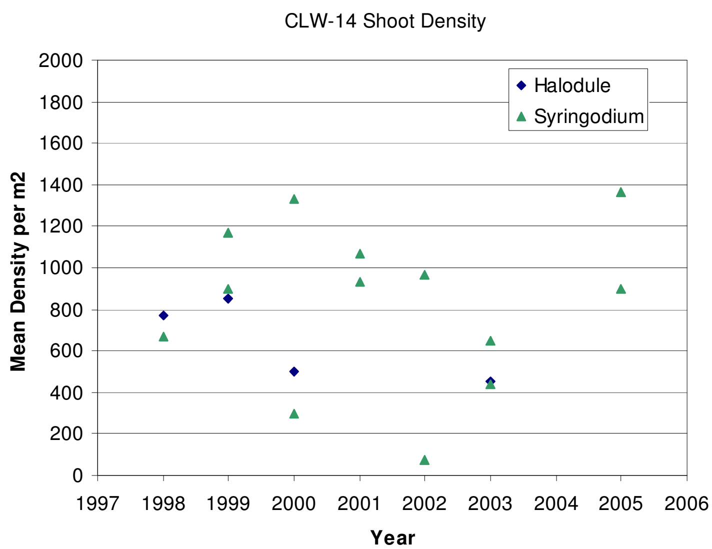
CLW-14 Epibiont Density Graph



CLW-14 Canopy Height Graph



CLW-14 Shoot Density Graph



3.3 Discussion: Fixed Transect Monitoring

The fixed transect monitoring program focused on temporal variation of the seagrass abundance, species composition, and condition. Throughout the thirteen year monitoring program, the data showed very few trends that would indicate a change in the seagrass resource. Some of the variation in the data may be attributed to natural variability as well as sampling inconsistencies.

Several factors contributed to the variation in the transect data. The logistics of monitoring fixed transects were challenging and resulted in sampling inconsistencies. The placement of the transects may have varied between years due to the inability to find the PVC marker stakes and bowing of the transect line from currents. In addition, variation may also be attributed to the observer. Different field crews conducted the study throughout the monitoring program. Even though all the staff attended a training session hosted by the City of Tampa, many of the data variables were subjective and/or qualitative in nature. The results were based solely on the data recorded within the meter square quadrat recorded incrementally along the transect. This allowed the possibility of other species and conditions to occur in the vicinity of the transect without being reflected in the data.

Weather patterns, storm events, and other natural and anthropogenic factors may affect the year-to-year results (Deitche and Meyer, 2003). A source of natural variability revolves around the placement of the transects near the boat channels. The migration of the boat channels results from the natural fluctuations in the tides and currents. This may cause changes to the edge of bed. Additionally, the exponential increase in boat traffic may be correlated with a higher frequency of propeller scar damage within the seagrass beds. Natural events also prompt variation in the seagrass resource. Four hurricane events in 2004 caused an increase in currents, tides, and turbidity in the area. These disturbances may be reflected in the lower seagrass abundances on some of the transects in 2004 and 2005.

In summary, the seagrass transects monitored by Pinellas County provided time-series information for the transect locations. The data indicated that the seagrass along the transects appeared to be in good health and with few exceptions remained stable throughout the monitoring program.

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4.0 Part II: Stratified Random Transect Monitoring

4.1 Methods: Stratified Random Transect Monitoring

The site selection for this program was based on a probabilistic stratified random sampling design. The area was divided into three strata Clearwater Harbor North (CLWN), Clearwater Harbor South (CLWS), and St. Joseph Sound (SJS) (Figure 9). The 2010 seagrass map from the aerial photointerpretation project was used as a boundary for the stratification of sites in the areas classified as continuous or patchy grassbeds. Fifteen percent of the sampling sites were allocated to the areas classified as "no grass". The sites were stratified into depth zones (0-0.5m, 0.51-1.2m, and 1.2-2.0m) based on mean low low water (MLLW). Fourteen of the transects aligned with the previous fixed transect monitoring sites. In 2006, Pinellas County monitored a total of 66 sites. In 2007, the sampling design was modified to reallocate the sampling sites on a seagrass acreage basis, approximately one transect per 250 acres of seagrass. The 1:250 ratio resulted in 40 sites in SJS, 17 sites in CLWN, and 10 sites in CLWS.

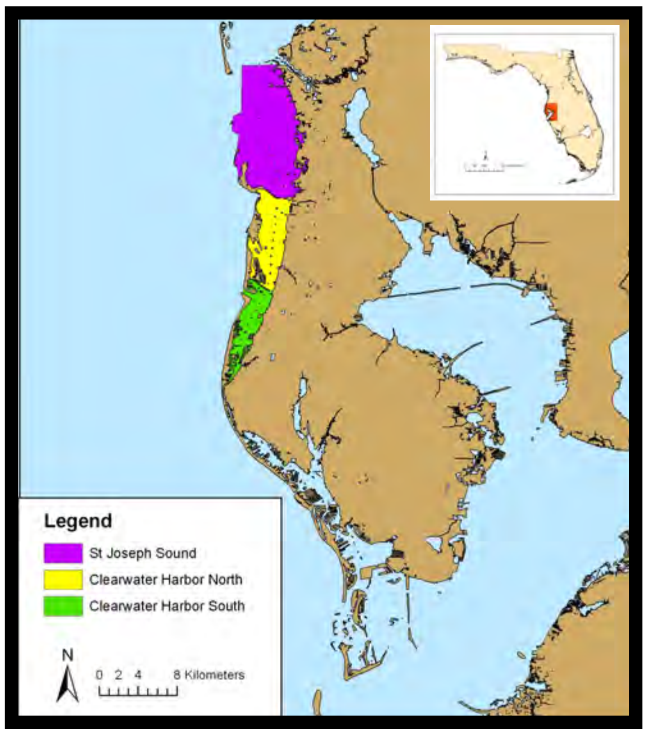

Figure 9. Map of seagrass strata.

Transect starting points were located using spatial coordinates from a Trimble® GPS unit. In most cases, the transects were oriented north to south, parallel to the shoreline, and perpendicular to the depth gradient. After deploying the 30 meter transect and dive flags, staff swam along the transect line with a quarter meter square frame. Starting at the zero meter mark, the seagrass condition was recorded at five meter intervals. Seagrass abundance was assessed by estimating the percent of coverage within the quadrat evaluating each species independently. At 0, 15, and 30 meter marks three shoot density counts and five blade length measurements were also collected for each seagrass species present. The density counts were made using the subdivisions of the quarter meter square frame which measure 10cmx10cm.

Other data collected included: water depth, sediment composition, seagrass appearance, and algae occurrence. Epibiont coverage was assessed using a numerical rating scale: 1= clean, 2= light coverage, 3= moderate, 4= heavy. Water quality parameters included transmissivity, Hydrolab®, and LICOR®. Transmissivity samples were collected using a 100ml Nalgene bottle. Transmissivity was measured at 660nm to determine relative water clarity. The Hydrolab® provided measurements of: depth, pH, temperature, salinity, conductivity, and dissolved oxygen. When conditions allow LICOR® readings were used to calculate water column photosynthetically active radiation (PAR) values for the transects.

The data analysis included the use of ESRI ArcMap and SAS software. The statistical analyses for the seagrass abundance and density applied the univariate, general linear model, and Tukey test procedures. The comparisons included significant differences among the variables of strata, depth zone, and the interaction of strata*depth zone. The univariate procedure was used to determine if the data was normally distributed. A general linear model was then used to determine if differences among the variables of comparison were significant. Finally, a Tukey test was used to determine whether the groups within the variables were significantly different from one another (e.g. SJS vs. CLWN, depth zone A vs. depth zone C, etc). The depth zones for each transect were determined by applying a tide correction to the recorded depth. Depth zones A, B, and C represented 0-0.6m, 0.6-1.2m, and >1.2m, respectively. The mean submerged aquatic vegetation coverage was calculated by transect from the recorded observations.

4.2 Part II- Results: Stratified Random Transect Monitoring

The sampling design allowed for the comparison among strata and depth zones for several parameters; however, the qualitative parameters were only presented with descriptive statistics due to the subjectivity of the data.

4.2.1 Mean Abundance

Submerged Aquatic Vegetation (SAV) covered most of the study area (Figure 10). SAV occurred at the highest mean abundance in SJS (62%) and CLWN (62%), while the least mean abundance in CLWS (55%). The highest mean abundances of SAV were found in CLWN zone A and the least in CLWN zone C. There were no significant differences among strata for mean abundance of SAV (p=0.35, alpha=0.05). There were however, significant differences among all depth zones. The mean abundance in depth zone A (75%) was significantly different than zones B (61%) (p= 0.0001, alpha= 0.05) and C (42%) (p= 0.0001, alpha= 0.05). The mean abundance for zone B was significantly different from the mean abundance for zone C (p= 0.0002, alpha= 0.05).

Halodule was geographically distributed across the study area (Figure 10). *Halodule* occurred at the highest mean abundances in CLWS (35%) and CLWN (33%) and least mean abundance in SJS (13%). The highest mean abundances were found in depth zone A (32%) and the lowest were found in zone C (13%). There was a significant difference in mean abundance of *Halodule* among strata (p=0.0001, alpha = 0.05). The mean abundance in SJS (13%) was significantly different than CLWS (35%) (p=0.0001 alpha = 0.05) and CLWN (33%) (p=0.0006, alpha = 0.05). The mean abundances in CLWS and CLWN were not significantly different from one another (p=0.68, alpha=0.05). A significant difference in mean abundance of *Halodule* among zones existed (p=0.0001, alpha = 0.05). The mean abundance of depth zone A (33%) was significantly different than depth zones B (18%) (p=0.0025, alpha=0.05) and C (13%) (p=0.0001, alpha=0.05). The mean abundances of depth zones B and C were not significantly different (p=0.22, alpha=0.05).

Thalassia was geographically distributed throughout the study area (Figure 10). The highest mean abundance of *Thalassia* occurred in SJS (22%) and the lowest mean abundances occurred in CLWS (18%) and CLWN (17%). There was no significant difference in mean abundance among strata (p=0.41, alpha=0.05). There was a significant difference in mean abundance among depth zones (p=0.0001, alpha=0.05). The mean abundance in depth zone A (33%) was significantly different from zone B (16%) (p=0.008, alpha= 0.05) and zone C (6%) (p= 0.02, alpha=0.05). The mean abundance of depth zone B was significantly different from depth zone C (p= 0.03, alpha=0.05).

Syringodium was observed in the mainly in the northern portions of the study area (Figure 10). *Syringodium* occurred at the highest mean abundance in SJS (27%) and lowest in CLWS (3%) The highest mean abundances of *Syringodium* occurred depth zones B (26%) and C (22%), while the lowest occurred in depth zone A (10%). There was a significant difference in mean abundance among strata (p= 0.0001, alpha = 0.05) and depth zones (p= 0.002, alpha = 0.05). The mean abundance in SJS (27%) was significantly different than CLWN (11%) (p=0.0001, alpha =0.05) and CLWS (3%) (p=0.0001, alpha=0.05). The mean abundances in CLWN and CLWS were not significantly different. A significant difference in mean abundance of *Syringodium* among zones existed (p=0.0001, alpha = 0.05). The mean abundance in depth zone A (10%) was significantly different than zone B (26%) (p=0.0201, alpha=0.05). No significant differences were found among depth zones B and C (p=0.14, alpha=0.05) and depth zones A and C (p=0.49, alpha=0.05).

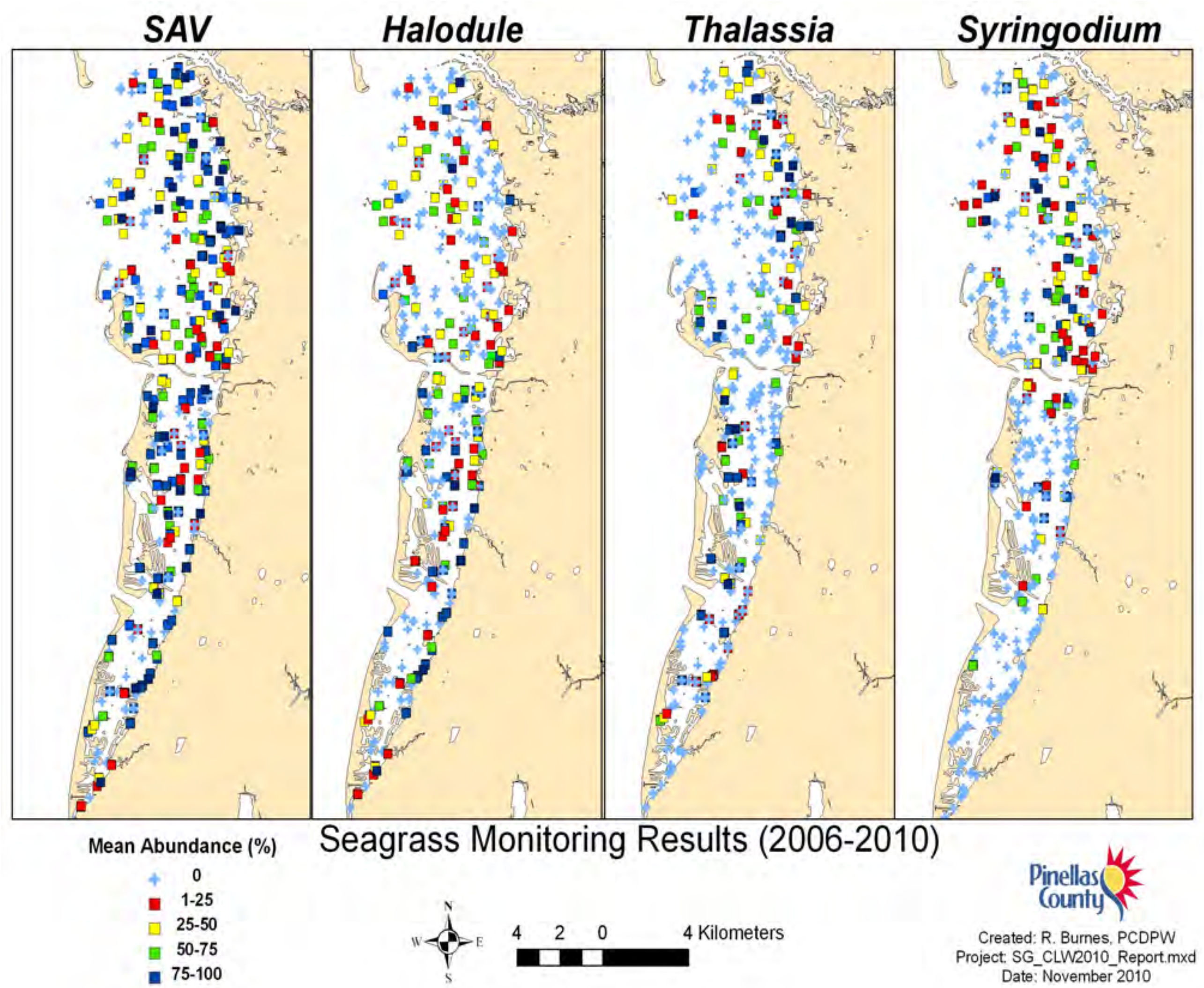

Figure 10. Spatial representation of the SAV species mean abundance per transect.

Several marine algae species occurred in the study area (Figure 11). The marine algae consisted of drift algae, rhizophytic algae, and *Caluerpa prolifera*. The drift algae were recorded throughout the study area (Figure 11). The highest mean abundance of drift algae occurred in SJS and near shore in CLWN. The rhizophytic algae constituents (Figure 11) were most abundant in SJS in depth zones A and B (Figure 11). *Caluerpa prolifera* was analyzed separate from the rhizophytic algae due to local concerns regarding this species. *C. prolifera* was most abundant in SJS in depth zones A and B (Figure 11). In addition to the marine algae, staff recorded the presence of bay scallops (*Argopecten irradians*) along the transects (Figure 11). The scallops were most abundant in SJS and CLWN and commonly noted in areas with rhizophytic algae.

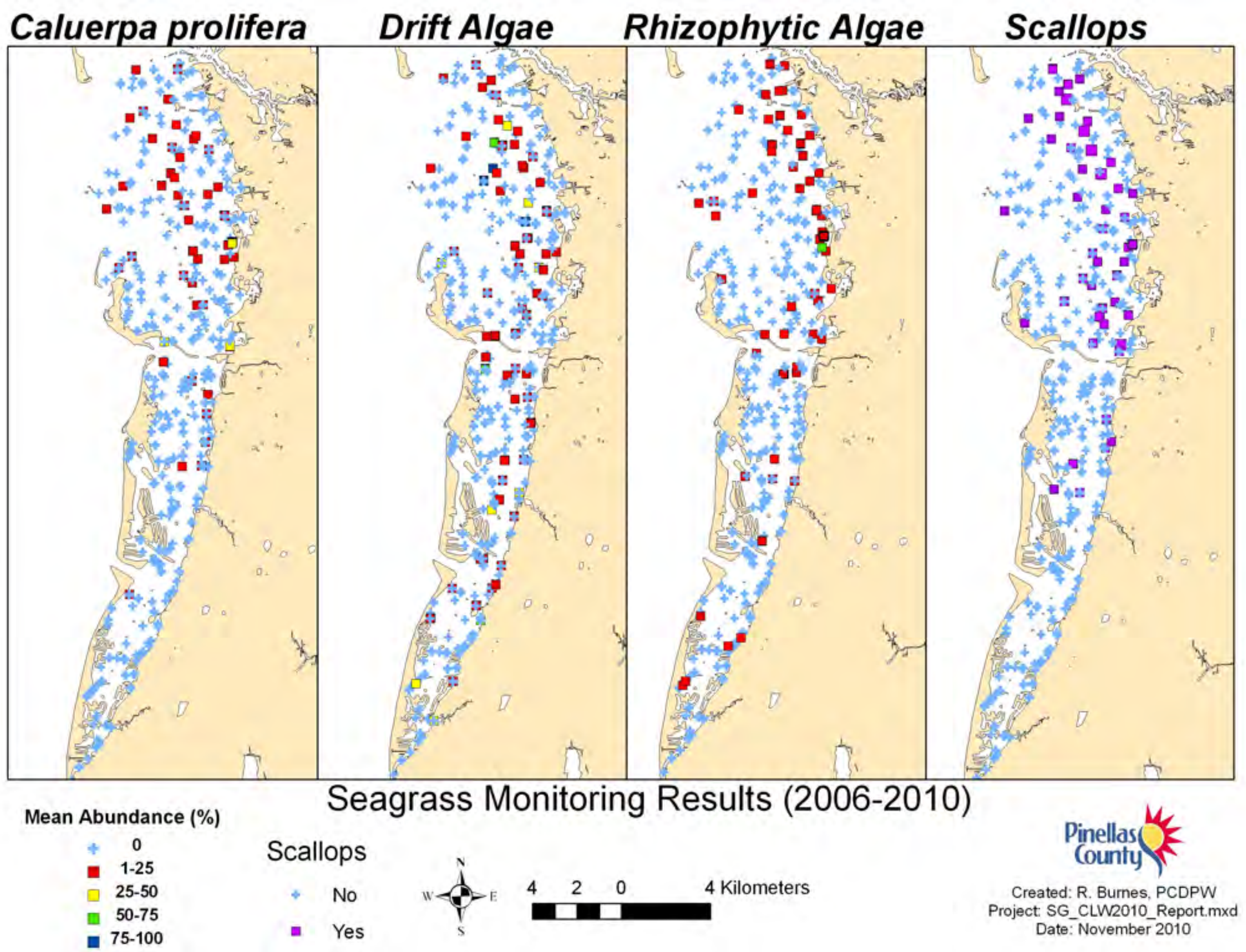

Figure 11. Mean abundance of marine algae and the presence of scallops per transect.

4.2.2 Shoot Density

The shoot density varied between the seagrass species. The seagrass shoot density did not vary greatly between the sampling events. *Halodule* had the highest shoot density and the greatest variability (Figure 12). The combined mean was 1323 shoots per m^2 (SD= 1206). The highest shoot density was in CLWS zone A. *Thalassia* had the lowest combined mean shoot density and smallest variability, 528 shoots per m^2 (SD= 400). The highest shoot density occurred in SJS in depth zone A. *Syringodium* had the highest shoot density in strata SJS and in depth zones A and B. Overall, the shoot densities for each species were not significantly different between years.

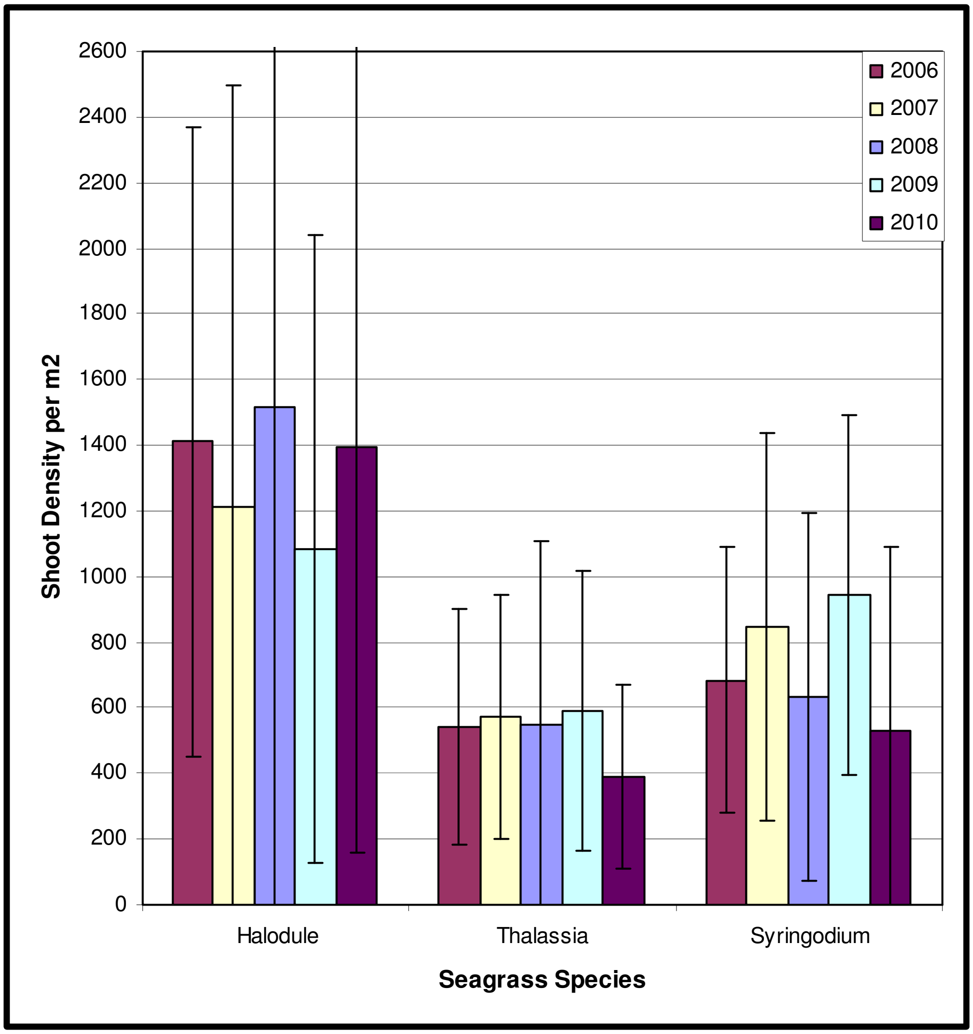

Figure 12. Mean shoot density (shoots per m2) by species and year.

4.2.3 Blade Length

The mean blade lengths varied by species and by year. The blade lengths tended to be longer in 2009 and 2006 for all the species (Figure 13). Due to the distribution of the data, the general linear model was not calculated for the mean blade length.

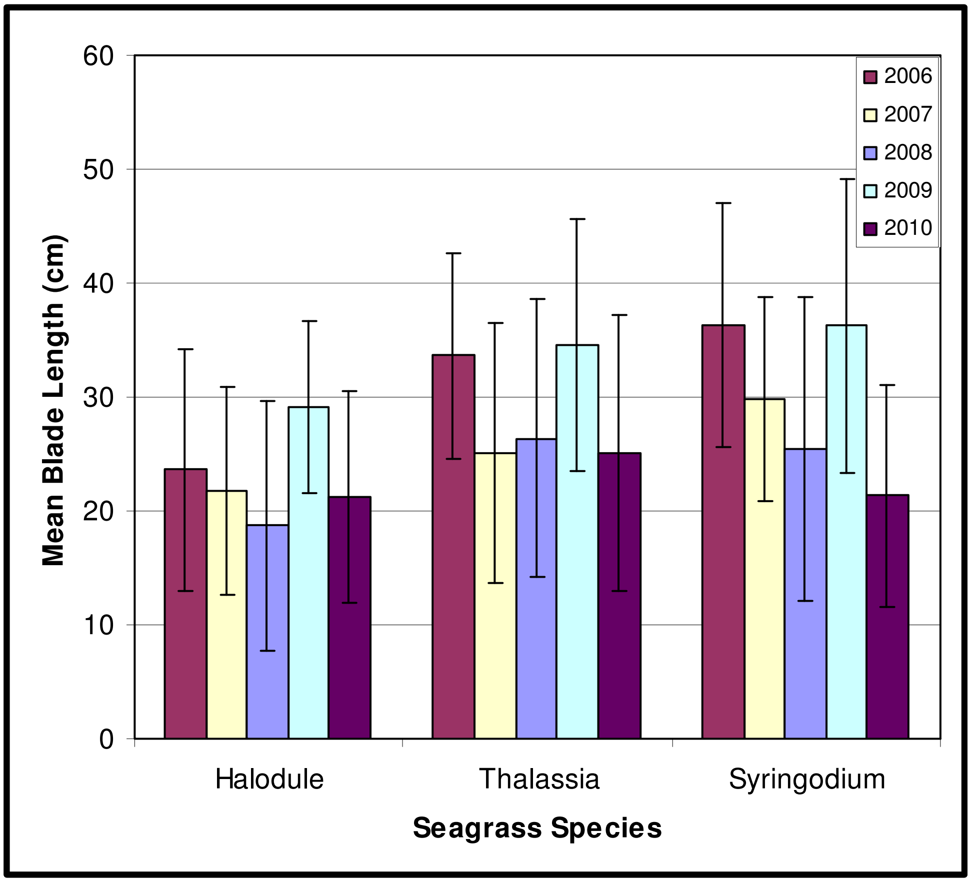

Figure 13. Mean blade length for seagrass species.

4.2.4 Health and Epibionts

The qualitative assessments of the health and epibiont fouling on the seagrass assisted in the determination of the seagrass resource condition. Excessive epiphytic coverage on seagrass has been shown to have a detrimental effect on seagrass growth (Irlandi et. al., 2004) by decreasing light availability (Brush and Nixon, 2002 and altering surface gas exchange of the grass (Sand-Jensen, 1977). Due to the subjective nature of these qualitative parameters, only the descriptive statistics are presented.

The health of the seagrass ranged from very poor to very good. The majority of the resource was classified as fair to good throughout the study area (Figure 14). There were a few occurrences of poor health.

The epibiont fouling also contributed to the condition of the seagrass. The epibiont fouling ranged from clean to heavy (Figure 14) with the majority of the observations from light to moderate. The epibiont fouling varied between seagrass species. Epibiont fouling on *Halodule* was greatest in CLWN and CLWS and zones A and B, and least in SJS and zone C. Epibiont fouling on *Thalassia* showed the most variation between depth zones. The epibiont density on *Thalassia* was highest in depth zone A and CLWS and lowest in SJS zone C. Epibiont fouling on *Syringodium* varied by strata and depth zone. The epibiont density was greatest in SJS and in depth zone B. Epibiont assemblages consisted of attached algae, barnacles, polycheates, bryozoans, holothuroidians, and hydroids. In 2006, staff recorded eggs deposited on the *Syringodium* and *Thalassia* blades in strata SJS.

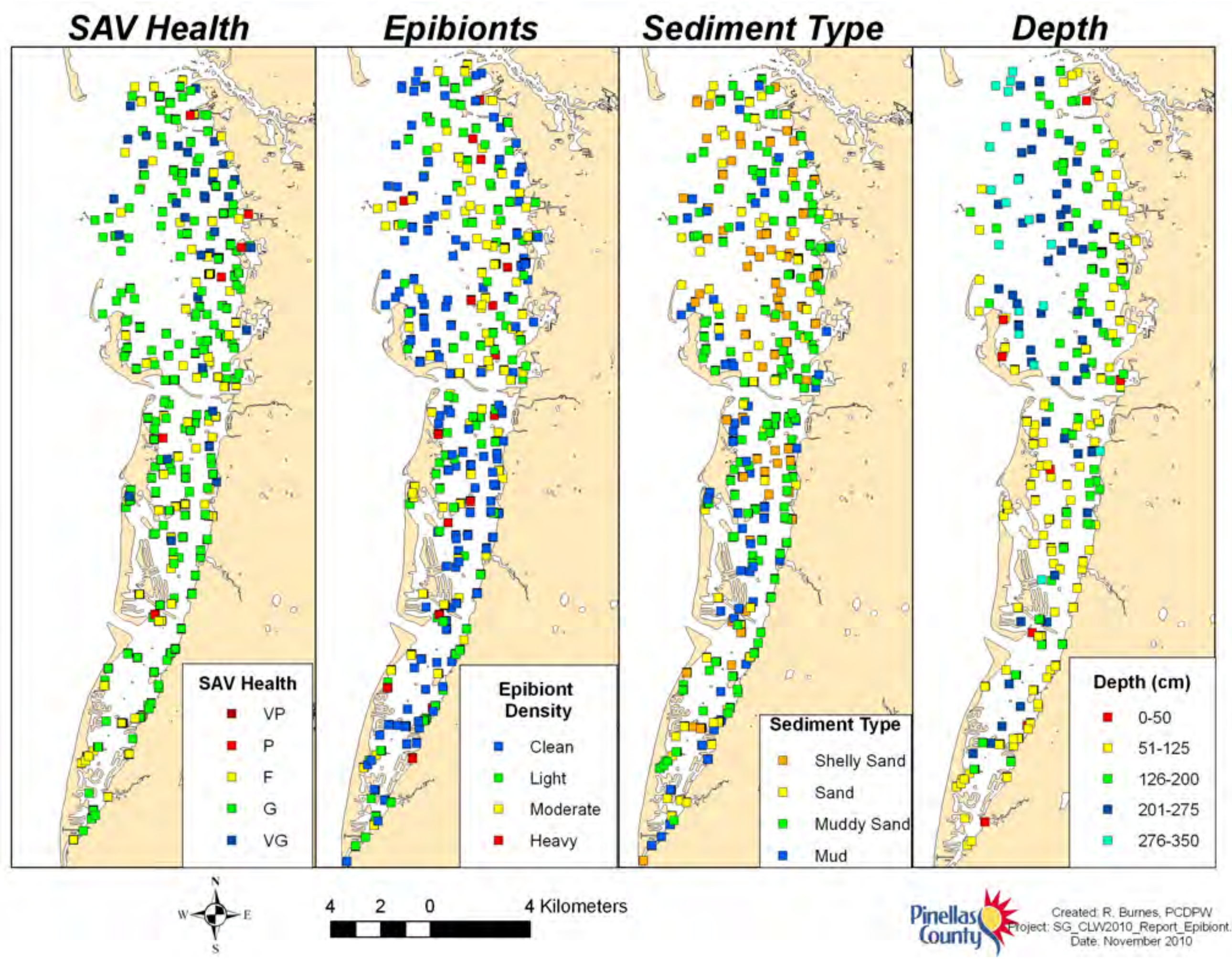

Figure 14. Spatial representation of SAV health, epibiont density, sediment type, and depth for the seagrass transects from 2006-2010.

4.2.5 Sediment Type and Depth

The sediment type and depth of the transect may be correlated to the habitat suitability for SAV. The sediment type recorded for the transects varied throughout the study area (Figure 14). The sediment type of mud commonly occurred in shallow nearshore areas. The majority of SJS sediment consisted of sand and shelly sand. Due to the lack of bathymetry data in the study area, the water depth was collected with each transect (Figure 14). The tidal fluctuation in the study area varied by +/- 1.0 meter during sampling events. The increased depths required staff to utilize SCUBA for data collection.

4.2.6 Water Quality

Water quality data was collected at each seagrass transect during monitoring (Figure 15). The mean dissolved oxygen was highest in SJS (6.41 mg/L) and CLWS (6.44 mg/L). The mean salinity was lowest in SJS (32.55 ppt). The mean pH was highest in SJS (8.31) and lowest in CLWS (8.04). The mean transmissivity, measured at 660nm, was highest in SJS (93.17 %) and lowest in CLWS (72.85 %). Overall, the water quality collected on the day of seagrass monitoring only provided a brief snapshot and should not be used solely to correlate with seagrass condition.

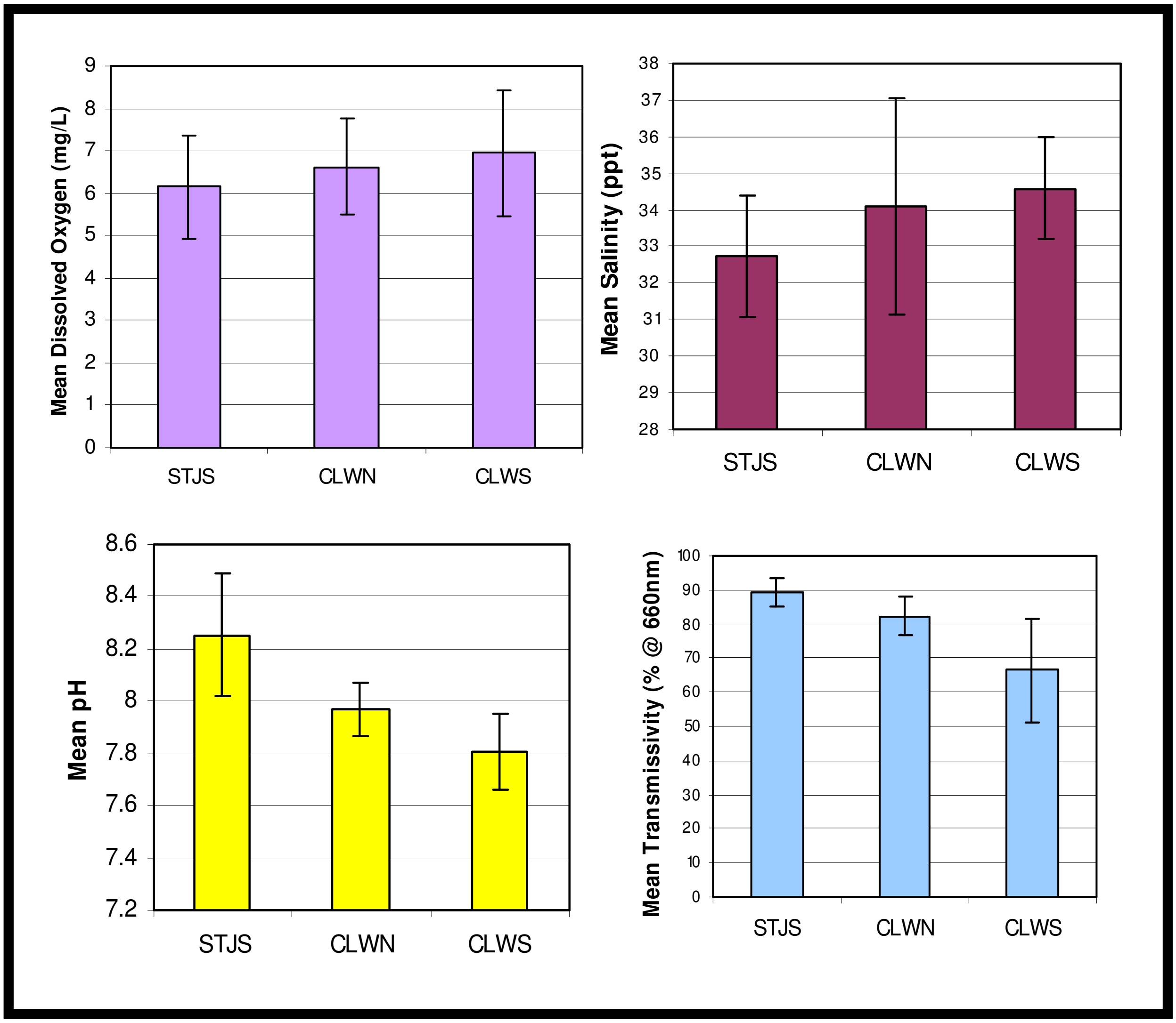

Figure 15. Mean water quality data collected during seagrass monitoring from 2006-2010.

4.3 Part II- Discussion: Stratified Random Transect Monitoring

Overall, the data from this study indicated that the seagrass resource in CLWN, CLWS, and SJS were stable and in relatively good condition. The abundance and density of seagrass showed little variation. The seagrass species spatial distribution indicated a possible ecotone through the study area consisting of variation by strata and depth zone.

There was no significant difference observed in overall SAV abundance between strata, but overall SAV abundance was significantly greater in the shallowest depth zone (A) than in the deepest (C). When SAV abundance is analyzed at the species level for the three most common seagrasses in the area several spatial trends emerged. *Halodule* abundance was significantly lower in SJS than in CLWN and CLWS and was in significantly greater abundance in the shallowest depth zone (A) than in the deepest depth zone (C). *Thalassia* abundance did not differ significantly between strata, but was significantly greater in the shallowest depth zone (A) than the deepest depth zone (C). *Syringodium* was significantly more abundant in SJS than in CLWN and CLWS and significantly more abundant in the deeper depth zones (B and C) than in the shallowest depth zone (A). The species depth trends that emerged are not unexpected as *Halodule* and *Thalassia* are typically found in shallower habitat and can handle conditions that may leave them exposed during low tides, while *Syringodium* occurs in deeper areas. The habitat preferences of the three major seagrass species in the study help to explain the spatial trend in terms of strata. CLWN and CLWS segments are generally shallower and the majority of the seagrass areas in these strata occurs in the intertidal and shallows of the subtidal zones. This type of habitat is preferred by *Halodule* and *Thalassia*. In SJS a majority of the seagrass habitat resides in the subtidal zone in deeper water that is the preferred habitat of *Syringodium*. Therefore we feel that the morphology of the strata is the key component that dictates seagrass assemblage.

Variability in the data may have contributed to a number of issues. Natural variation may include the influence of weather patterns, storm events, and other factors that may have affected year-to-year results from the transect monitoring. Another factor may be natural events that affected long-term water quality but were not reflected in data taken on the day of sampling (Deitche and Meyer, 2003). The density by year variation may be related to the expansion of the sampling design to include deeper areas that may consist of more “patchy” beds.

The sampling design for this seagrass study diverged from the traditional methods. The goal of the design was to increase the geographic extent and statistical defensibility of the seagrass monitoring program.

The increased geographic extent of the program provided an opportunity to characterize a greater portion of the resource. Prior to this study, the abundance and extent of the rhizophytic algae in SJS and CLWN was unknown. Additionally, the extent of the edge of bed in SJS toward the Gulf of Mexico was assumed to be limited to the two meter contour similar to the Tampa Bay ecosystem. Findings from this study indicated that the seagrass resource extends in to water depth of 3m-4m. This extent has not been represented in the previous monitoring or remote sensing studies for the area. Interesting spatial trends arose during the analyses including an apparent ecotone for the distribution of *Syringodium* which rarely occurred in CLWS and increased in frequency heading north through the study area into CLWN and SJS

Using a stratified random sampling design allowed for the calculation of statistics to compare the seagrass by variables such as year, strata, depth zone, and species. Although the power of the design to detect change in the resource has not yet been assessed, the information from the study has far surpassed the data provided from the previous fixed transect monitoring program for the study area.

When combined, the field survey data from this study, the ancillary data from water quality and remote sensing studies provide a comprehensive evaluation of the resource. The results of this study were used to help verify the results of the 2010 aerial photo-interpretation mapping study conducted by SWFWMD (Figure 16). Due to the limitation of the aerial photography to penetrate the water column, seagrass beds growing at depths greater than 2m may not be visible for mapping. Current studies investigating the mapping of seagrass from remote sensing multispectral satellite imagery may provide increased depth penetration to further assess the extent of the seagrass resource (Meyer, 2008).

The water quality data collected at the time of seagrass monitoring is not adequate to assess the spatial and temporal trends of water quality or the response of the seagrass condition. The integration of ancillary data from the Pinellas County Ambient Water Quality Monitoring Program (WQMP) enhances the knowledge of the water quality in the study area (Figure 19). In addition to water quality parameters, staff collected environmental habitat information such as sediment type and seagrass presence/absence for each sampling site (Levy et al, 2010). The data from the WQMP also provided additional spatial seagrass data (Figure 17). During the five years of the stratified random seagrass monitoring program, 326-30m transects and 168 WQMP sites were evaluated. This exceeds the data collected from the previously sampled (1998-2006) 14 fixed transect locations. This provides a robust independent dataset for the validation and ground-truthing of maps delineated from remote sensing data.

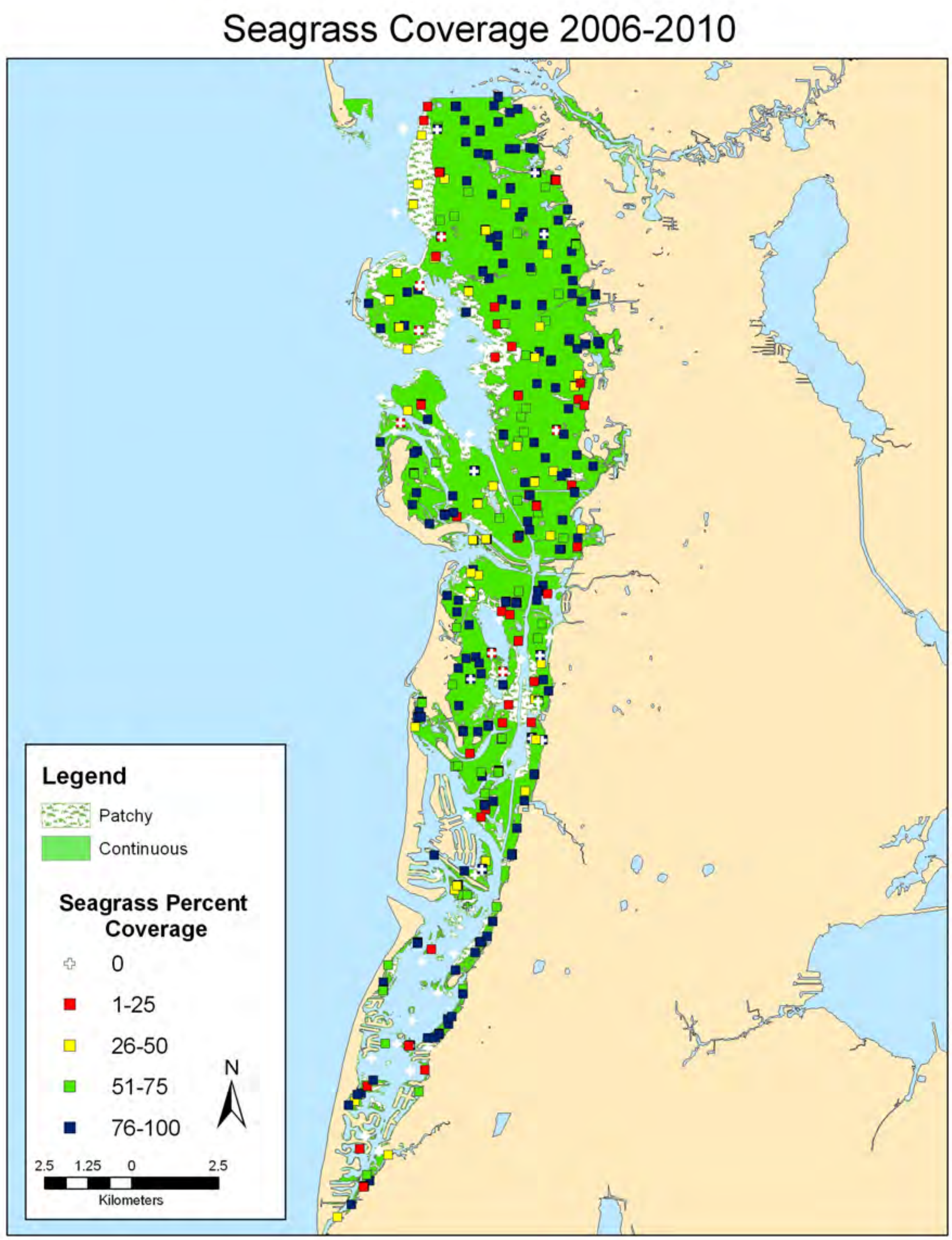

Figure 16. Combination of field survey data and SAV map from the aerial photointerpretation study (Kaufman, 2011).

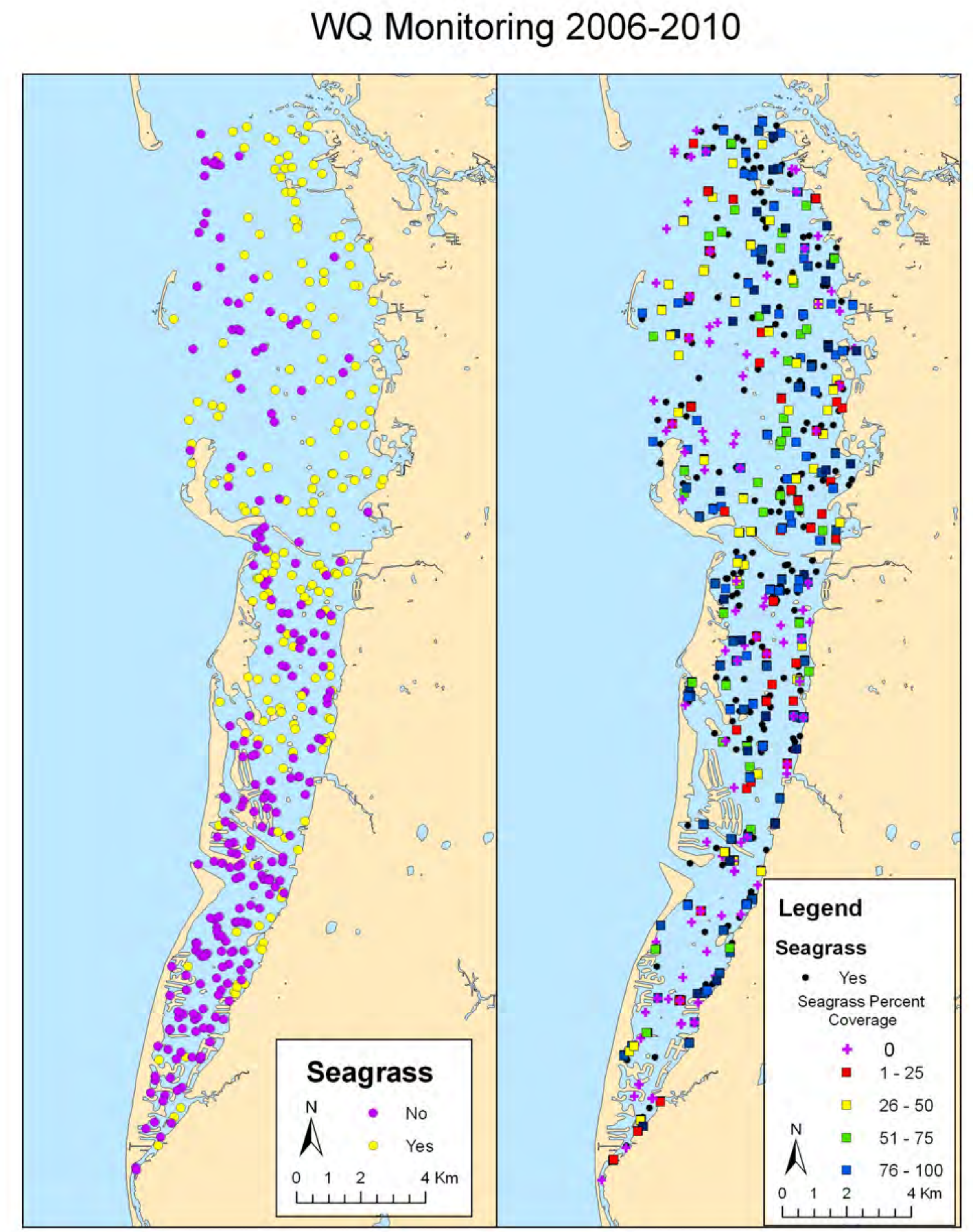

Figure 17. The presence/absence of seagrass was collected by the WQMP from 2006-2009 (left). The WQMP data was combined with the seagrass monitoring data (right).

5.0 Conclusion and Summary

In summary, the seagrass monitoring activities conducted by Pinellas County Watershed Management Section suggest that the seagrass resource in Boca Ciega Bay and Clearwater Harbor/St. Joseph Sound is currently in good health and shows no trends indicating degradation. The species found during monitoring included *Halodule wrightii, Thalassia testudinum, Syringodium filiforme,* and *Halophila engelmanni.* Although the seagrass resource is currently stable, many natural and anthropogenic factors may threaten the persistence of the resource. Natural concerns include weather events such as hurricanes, sea level rise, and climate change. Anthropogenic factors include damage from increased boat traffic and propeller scarring, dredging activities, and degradation of water quality from stormwater runoff. Throughout the monitoring program, boat prop scars have been recorded frequently along the transects and seem to be increasing in frequency. During the imagery acquisition in 2007, two boats caused an 800 m propeller scar in the seagrass bed adjacent to BCB-01 (Figure 18). Education and enforcement is required to reduce the damage to the seagrass resource.

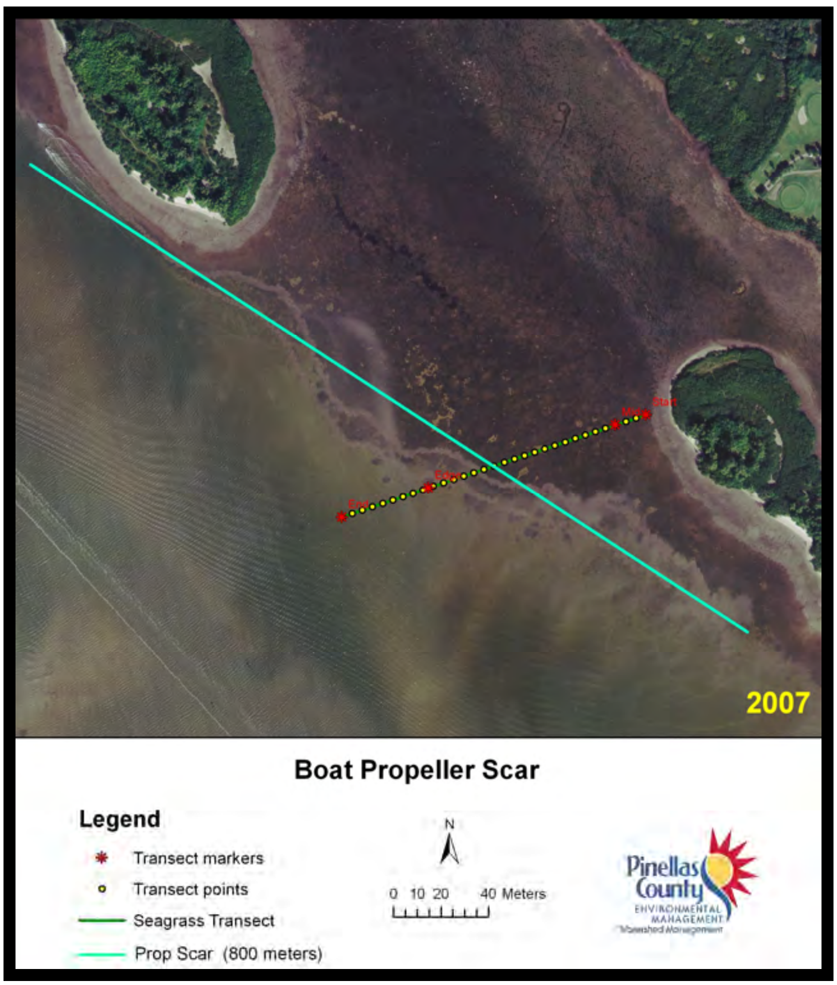

Figure 18. Creation of a boat propeller scar through the seagrass monitoring transect.

Both the fixed transect and stratified random transect sampling designs provided valuable information about the seagrass resource including information on the species composition, health, and condition of the seagrass. However, the most notable difference between the sampling programs was in the geographic extent and scale of the information. The fixed transect program provided time-series fine scale data along the transect. The nature of the fixed transect design severely limited the ability to extrapolate the data and conclusions to the rest of the seagrass resource. The data proved difficult to examine with statistically viable trend analyses. Additionally, the number of fixed transects to monitor the geographic extent of the resource would be cost prohibitive to most resource management agencies. The stable nature of the Pinellas County seagrass resource in SJS, CLWN, and CLWS allowed for the development of a new sampling design. The stratified random transect sampling design improved the geographic extent of the monitoring program and increases the ability to calculate viable statistical trend analyses. The design maintained the fine scale data collection for species composition, biomass, and density estimates; however, it lost the specific time-series data. This design encouraged the use of data from complementary monitoring programs, such as the WQMP, to further analyze the correlation between physical and biological variables. Ideally a hybrid design approach may have provided a good balance between the time-series, fine scale, geographic extent, and statistical defensibility and power for the evaluation of the seagrass resource.

Future studies to better assess the seagrass resource in Pinellas County should include examining the correlation between seagrass and water quality, and interpretation of remote sensing data. The County conducts a water quality monitoring program which provides spatial and temporal water quality information for the study area (Levy et al, 2010). The design focuses on the ability to detect trends in the water quality parameters and allows for spatial interpolation analyses. Parameters such as dissolved oxygen, chlorophyll-a concentration, and transmissivity are thought to be correlated with the condition and response trends of seagrass resources. The spatial analysis of these parameters reveals seasonal trends which may contribute to the seagrass trends. While chlorophyll-a concentrations are generally low during the dry season, the concentrations increase during the wet season in the southern portion of the study area (Figure 19). The spatial and temporal assessment of the water quality may allow the development of a model relating seagrass and water quality (Meyer 2008). Fourqurean (2003) used water quality data to develop a response model to predict the change in seagrass distribution. This would be a valuable tool to manage the seagrass resource. Another tool to assess the seagrass resource applies the interpretation of remote sensing satellite imagery to produce coarse scale maps of the resource (Meyer, 2008). Detailed habitat maps aid in the assessment and monitoring of changes within the seagrass meadows. The ability to integrate field monitoring data with remote sensing methods may be a cost-effective method to develop a comprehensive spatial change assessment of the seagrass resource.

It is the recommendation of the Pinellas County Watershed Management staff to continue the SJS and CLH stratified random transect monitoring activities. The SJS and CLH monitoring activities provide important information regarding geographic extent of the seagrass meadows as well as species, density, length, and epiphyte data that are important components for understanding overall health and community structure. While the resource is stable now it is important to continue monitoring efforts because of the complex interactions of anthropogenic and natural conditions on seagrass meadows. The SJS and CLH monitoring activities, when combined with other remote sensing activities provide a comprehensive view of the seagrass resource in the research areas. It is suggested, however, that the current sampling format be modified to most effectively and efficiently monitor the areas while taking into account reductions in staff time allocation to complete the monitoring effort.

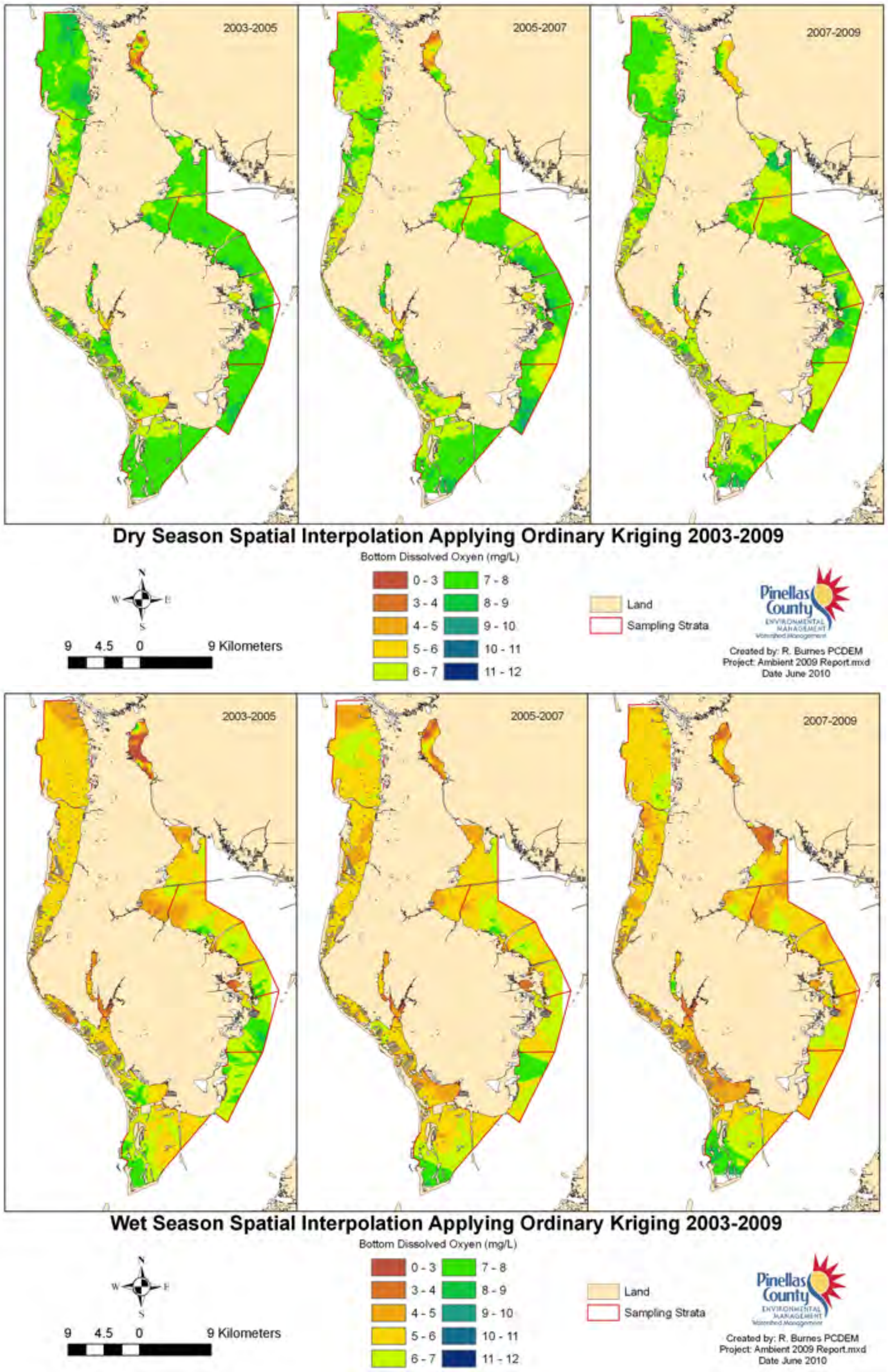

Figure 19. Seasonal Spatial Interpolation of the ambient water quality data for Bottom Dissolved Oxygen from 2003-2009 for the wet season (May-September) and the dry season (October-April) reproduced from Levy et al (2010).

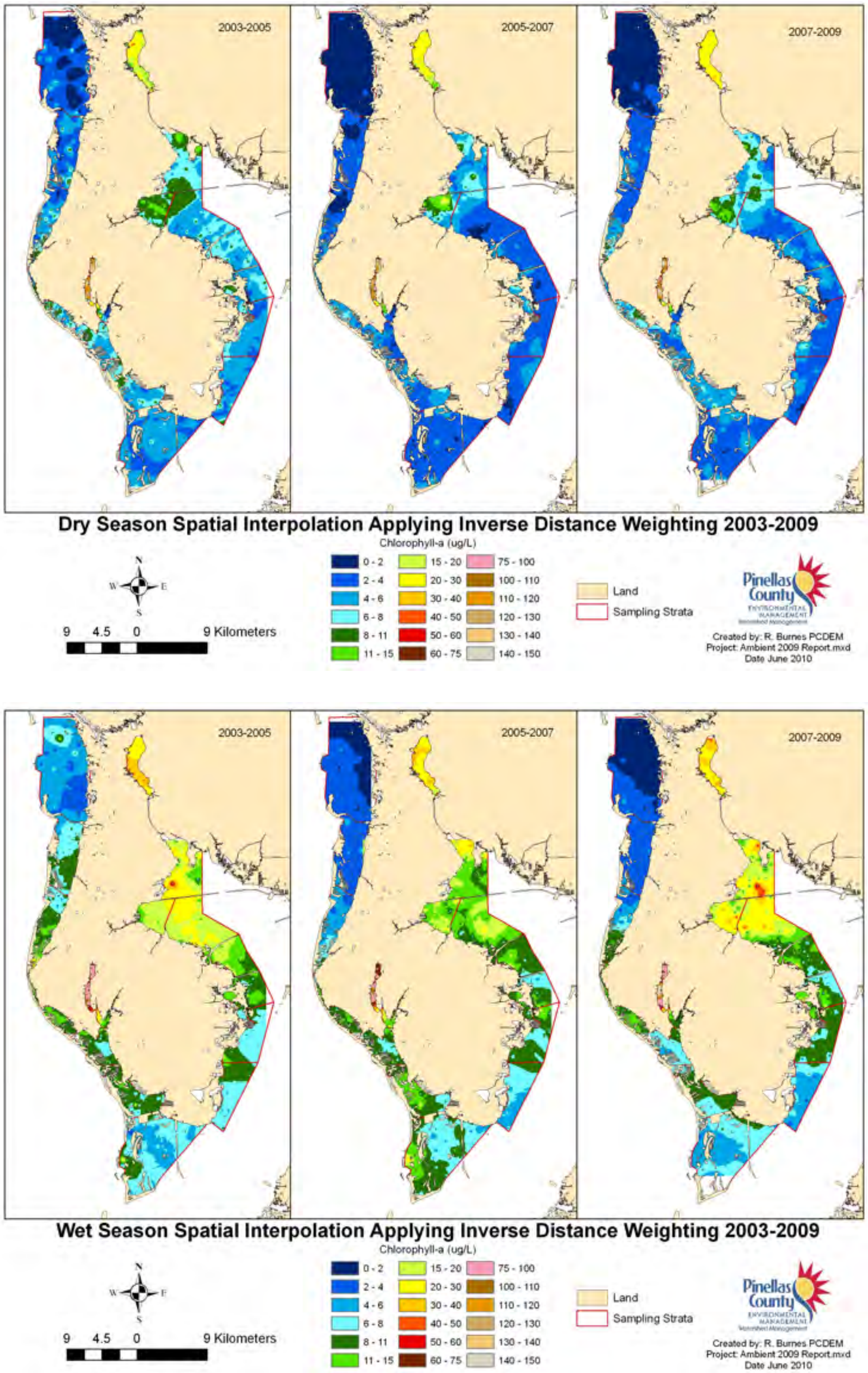

Figure 20. Seasonal Spatial Interpolation of the ambient water quality data for Chlorophyll-a from 2003-2009 for the wet season (May-September) and the dry season (October-April) reproduced from Levy et al (2010).

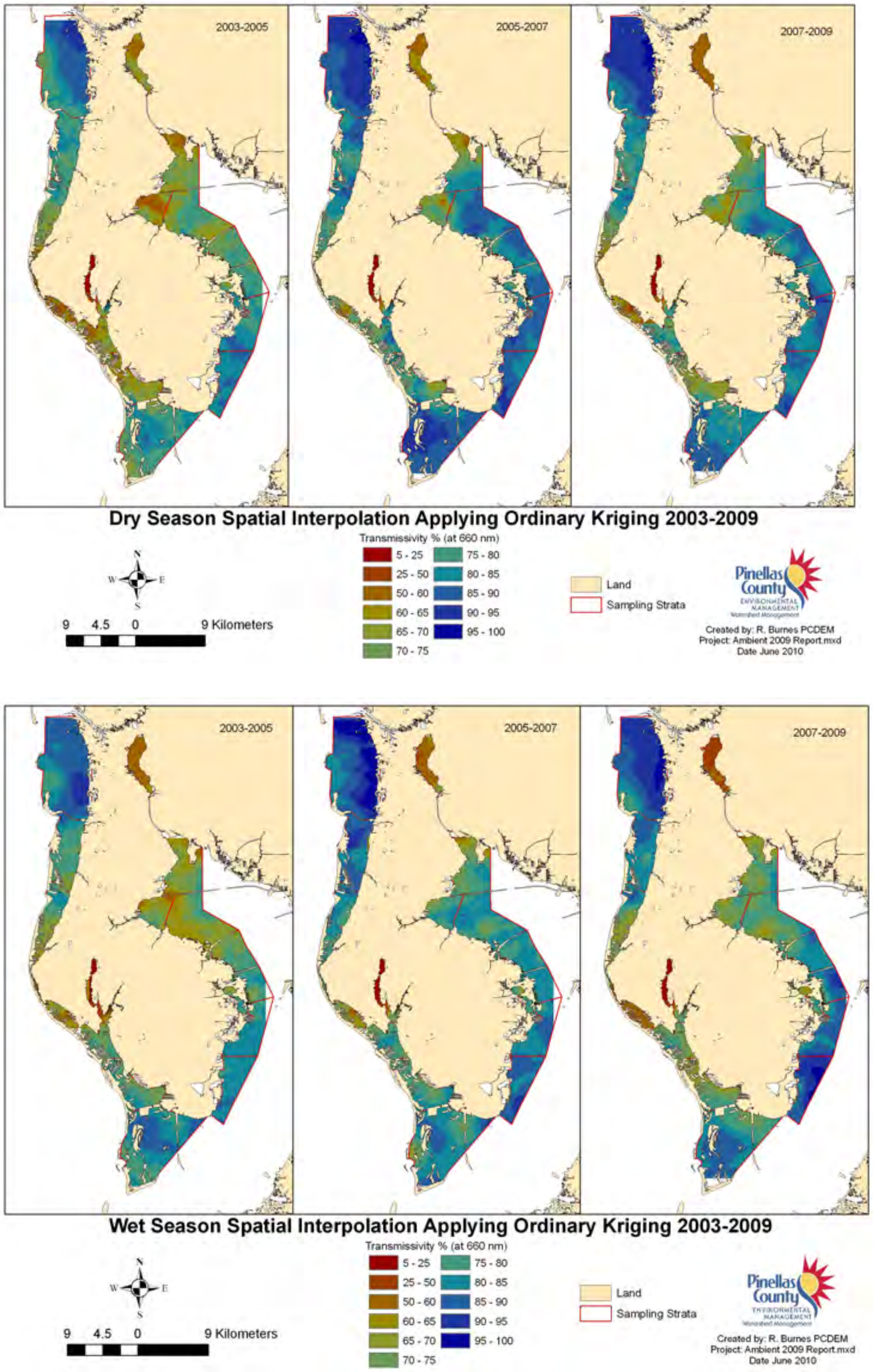

Figure 21. Seasonal Spatial Interpolation of the ambient water quality data for Transmissivity from 2003-2009 for the wet season (May-September) and the dry season (October-April) reproduced from Levy et al (2010).

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