

Seagrass Dynamics within the Estero Bay Aquatic Preserve Along Fixed Transects (2002-2009)



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Final Report

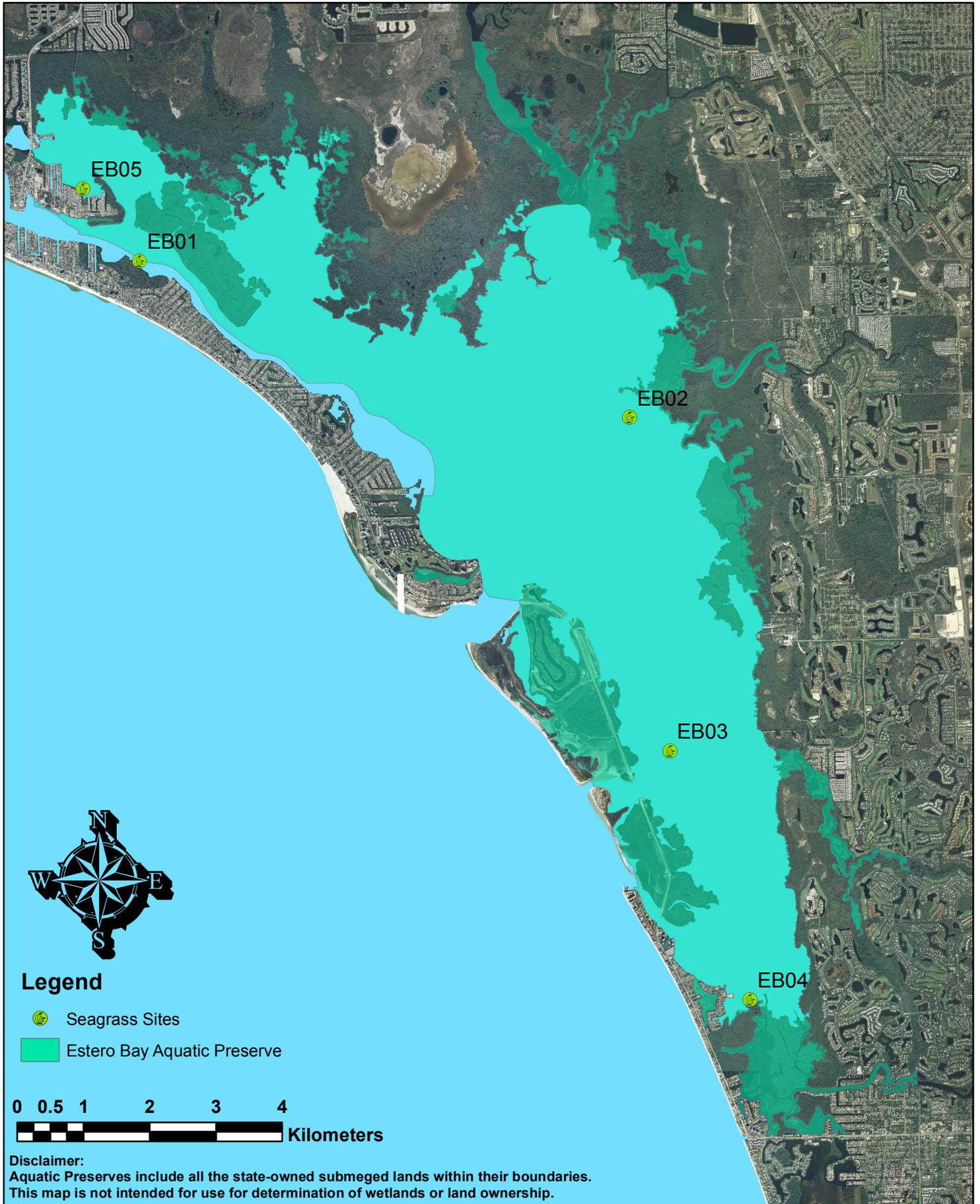
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Estero Bay Aquatic Preserve Seagrass Transect Monitoring Sites



Abstract:

*Since 2002, the Florida Department of Environmental Protection, Estero Bay Aquatic Preserve office in Fort Myers Beach has monitored seagrass meadows within the Estero Bay Aquatic Preserve along five fixed transects. The program is intended to establish current baseline conditions of seagrass meadows, track trends, and relate these data to water quality data. Analyses of data from 2002 through 2009 show that the abundance of both *Halodule wrightii* and *Thalassia testudinum* within the aquatic preserve as a whole are increasing; and that *H. wrightii* is the most frequently encountered species here. The average blade length for all species combined, and for *H. wrightii*, at site EB01 increased during this time. The same trend was found for site EB02. Site EB03 had significant increases in the abundance of *T. testudinum*. EB04 is the shortest and most stable of the five sites. And, EB05 had an increasing trend in the epiphyte densities upon *T. testudinum*. Continued monitoring is necessary in order to continue to track trends in the region, relate them to water quality, and aid in the management of submerged resources within the region.*

Introduction:

Seagrasses and other submersed aquatic vegetation provide many ecological services (e.g., Fourqurean et al, 1999; Hemminga and Duarte, 2000; Larkum et al, 2007). They serve as a nursery for many important shellfish and finfish; provide food for waterfowl, sea turtles, manatees, and other organisms; aid in nutrient cycling and sediment stabilization; and are considered as a major factor contributing to high levels of productivity in estuarine systems (e.g.: Kemp et al, 1984; Dennison et al, 1993; Madden and Kemp, 1996; Hemminga and Duarte, 2000; Orth et al, 2006; Bos et al, 2007; Larkum et al, 2007). In addition, seagrasses are considered by many to be an important indicator species of coastal and estuarine health (e.g.: Dennison et al, 1993). Many factors, both natural and anthropogenic, control the distribution, abundance and overall health and condition of seagrass meadows (e.g.: Kemp et al, 1983; Twilley et al, 1985; Dennison et al, 1993; Orth et al, 2006). Therefore, the Estero Bay Aquatic Preserve, with assistance from the Charlotte Harbor Aquatic Preserves and from volunteers, have been monitoring seagrasses along fixed transects in Estero Bay since 2002, in order to aid in resource management and protection (Stearns, 2007 and Brown et al, 2011).

The Charlotte Harbor watershed, located in southwest Florida, drains into the vast estuarine complex of Charlotte Harbor, which is one of the most pristine and socio-economically important ecosystems in the state. Located within this complex are many sub-estuaries, from Lemon Bay in the north to Estero Bay in the south, comprising nearly 250,000 acres of submerged habitat (e.g., Duffey et al, 2007; Leary, 2009; Leary 2010; Leary 2011c). Contained within the estuarine complex are six aquatic preserves: Lemon Bay, Gasparilla Sound-Charlotte Harbor, Cape Haze, Pine Island Sound, Matlacha Pass, and Estero Bay Aquatic Preserves. Aquatic preserves are areas of exceptional submerged resources that were set aside by the Florida legislature to be maintained in their essentially natural condition for future generations (Chapter 18-20, FAC). The aquatic preserves are managed by the Florida Department of Environmental Protection's Office of Coastal and Aquatic Managed Areas. The Estero Bay Aquatic Preserve is managed from the Estero Bay office located in Fort Myers Beach. This office administers the Seagrass Transect Monitoring Program for the Estero Bay portion of the Charlotte Harbor estuary complex. In addition, they assist in monitoring seagrass transects located in the other five local aquatic preserves and outside of the aquatic preserves'

boundaries, in Tidal Peace and Myakka Rivers and in San Carlos Bay, as well as a portion of Matlacha Pass that is not within the Matlacha Pass Aquatic Preserve (Stearns, 2007; Brown, 2011; and Leary, 2010).

Seagrass monitoring along fixed transects by the Estero Bay Aquatic Preserve began in 2002 using protocols established by the Southwest Florida Water Management District, Sceda Ecological, Inc. and Charlotte Harbor Aquatic Preserves. All sites have been monitored at least bi-annually, with the exception of 2002 in which sites were monitored only once. All sites, or transects, monitored by the Estero Bay Aquatic Preserve have remained in the same location over the years. There are six species of seagrass found within the Charlotte Harbor estuarine complex: *Halodule wrightii*, *Thalassia testudinum*, *Syringodium filiforme*, *Ruppia maritima*, *Halophila decipiens*, and *Halophila engelmannii*; and, although not always considered a seagrass by all, *Vallisneria americana* is included in our database because it is occasionally found in the low salinity regions of the tidal tributaries of Charlotte Harbor. This report explores seagrass dynamics within Estero Bay Aquatic Preserve only, and utilizes data collected for the Estero Bay Aquatic Preserve. Due to the manner in which seagrass densities were collected in the field, seagrass density (shoots per meter²) will not be included in this report. In addition, parameters that are influential to seagrass dynamics (i.e., light attenuation, salinity, rainfall, etc.) are not included in this report (e.g.: Leary, 2011c).

Methods:

Study Area:

Located in southwest Florida, the Estero Bay Aquatic Preserve is located within Lee County, and is adjacent to the cities of Fort Myers, Fort Myers Beach, and Bonita Springs. The aquatic preserve boundary follows the mean high waterline of the bay and the tributaries up-stream to section line boundaries, and south to the Collier County line. Although Estero Bay receives freshwater indirectly from the Caloosahatchee River, its main tributaries are: Hendry, Mullock and Spring Creeks, and the Estero and Imperial Rivers. Estero Bay is approximately 14 km long and 3 km wide. The aquatic preserve encompasses approximately 11,000 acres of submerged habitat and mangrove islands, of which approximately 2,500 acres are seagrass meadows. It is a shallow, micro-tidal, bar-built sub-estuary of the greater Charlotte Harbor estuarine system. The Estero Bay Aquatic Preserve was established in 1966, and was the first aquatic preserve established in the state.

Field Methods (adapted from Stearns, 2007 and Erickson, 2010):

At each site, a fixed linear transect was established from the shoreward edge of the seagrass meadow to the waterward edge, where possible. At regular intervals along each transect, detailed information such as seagrass species, abundance, and density were collected using a one square meter quadrat. Quadrat sampling points (stations) were marked with PVC stakes and many have established GPS coordinates used for reference (GPS coordinates were collected using differential GPS). Site-specific "repeated" quadrats were determined in 2007 to allow for greater long-term consistency in sampling locations and are monitored bi-annually. In addition to these regular intervals, data at the beginning and end of the grass bed were collected. Both end points vary annually and seasonally and can be difficult to determine particularly when

seagrass abundances are low. Flagging tape, PVC stakes, GPS coordinates, and fixed landmarks including navigation markers were utilized to reference site locations and assure repeatability. Sites were reached using shallow draft boats. Seagrass observations were made by snorkeling and/or SCUBA depending on water depth. The only time the ends of beds were not determined was when conditions were deemed to be too unfavorable and risky (i.e.: a storm was developing; currents were too strong; the meadow continued into an active channel; etc.).

Once near the site, reference points on shore were located using previous flagging tape, PVC stakes and/or known GPS coordinates. The shoreward extent of the transect was then found by measuring o the beginning of the seagrass meadow. The zero point of each transect was determined when the site was established in 2002 as the flagging point on shore. All measurements were made relative to the zero point. The only station which is denoted with a negative distance is EB03, which is located between two channels and does not have a true shoreward edge. From the zero point, a compass heading, point of reference (e.g., a landmark) and/or GPS coordinates were used to determine the waterward direction of travel along the transect. Each transect was then sampled at regular intervals (stations) specified in the site description using a tape measure to determine a known distance between points.

At each site, the date, observers, start and end times, general site comments, and weather conditions were recorded. At the beginning and end of monitoring each transect, tide levels (relative to the biological mean high water line) were recorded. Tide levels were measured as the height of the water (in feet) above or below the barnacle line on mangrove roots, adjacent navigation markers, or dock pilings. Local tide gauge information was used during data analyses to convert observed water depths to mean water (in meters).

At each station along the transect (except the beginning and end), the quadrat was centered on the PVC stake. Whereas, at the beginning and end of the grass bed, the quadrat was either placed forward of or behind the grass edge, respectively. This ensured that seagrass data were captured inside the seagrass meadow. Each station was denoted as being at the beginning, middle or end of the seagrass meadow, when possible. At each station, water depth (cm), sediment type, species types, abundances, blade lengths, and epiphyte loads were observed and recorded. Seagrass abundance was determined for each species (Species Abundance), as well as for the station as a whole (Total Abundance), using Braun-Blanquet areal coverage classes. The coverage classes are defined as follows: 0.1 = solitary; 0.5 = few; 1 = <5%; 2 = 5 - 25%; 3 = 26 - 50%; 4 = 51 - 75%; and 5 = 76 - 100% (e.g.: Fourqurean et al, 1999). Braun-Blanquet coverage was defined as: "The entire shoot system of all the individuals ... is thought of as projected on the ground and the area covered thereby is estimated... as areal percentage" (J. Braun-Blanquet, 1932), or as the percent of the quadrat that is obscured when viewed from above (Fourqurean et al, 1999) and all species are considered to be within the same layer, or stratum for Total Abundance. If present, abundance for other submerged aquatic vegetation (SAV, i.e., attached algal species) is recorded, but not included in Total Abundance. Drift algae information was also collected at each station when present. Drift algae were given their own abundance, and generally described. Drift algae abundance was not included as part of the station's Total Abundance. Five random blade lengths (cm) were recorded for each species. For *T. testudinum*, only blades with rounded, healthy, green tips were measured, when possible. Epiphytes were quantified as clean, light, moderate or heavy and briefly described (e.g., Avery and Johansson, 2001).

All Estero Bay Aquatic Preserve seagrass transects were monitored twice per year in the spring and summer, generally February through March (while the seagrasses are somewhat dormant) and August through September (during the height of the growing season). Total Abundance data were not collected until 2006.

Statistical Methods (from Leary, 2011a):

Statistics were selected based on three criteria. First, its power (β) which is a statistic's ability to detect differences amongst the data (i.e., the probability of rejecting the null when it is in fact false). Next, accuracy, which is a measure of the confidence interval (i.e., the smaller the confidence interval, the greater the accuracy). And robustness, which is how sensitive a particular statistic is to outliers. For all statistics, α (i.e., the probability of accepting the null when it is in fact true; the significance) was set at 0.05 (e.g., Wilcox, 2001).

A priori power analyses were run based on Cohen's D and adjusted to R^2 in order to determine the minimum number of results (samples) required for statistical analyses ($\alpha=0.05$; $\beta= 0.05$; and two tailed). It was determined that a minimum of 28 samples are required for regression analyses in order to detect a large effect size (i.e., something that is grossly visible to the naked eye when observed; $R^2\geq 0.49$). This criterion was ignored for Deep Edge, Beginning of Bed, End of Bed, and Bed Length, because they are collected only once at each site visit. This was also ignored for frequencies, since it was calculated as the percentage per year. Afterwards, *post hoc* power analyses were run to measure effect size (the strength of the relationship or the magnitude of difference; for example: regressions use R^2 to measure effect size, the larger the R^2 value, the greater the percentage of variability is explained and the greater the association). Exploratory statistics were then run. Multiple tests were then run in order to test the assumption of normality, including: Johnson's SU transformation for skew; Anscombe & Glynn's transformation for kurtosis; and Jarque & Bera LM test. Outliers were identified using Mahalanobis D^2 . The assumption of homoscedasticity was tested using Levene's test of homogeneity of variance.

From these statistics, assumptions of normality and homoscedasticity can be assessed in order to determine if and when data need to be screened or transformed. In addition, assumptions of linearity were examined using plots of observed versus predicted values and residuals versus predicted values. Assumptions of independence were assessed using autocorrelation function (ACF), combined with the Durbin-Watson d test. Where the assumptions were violated, three sets of methods were used to address this issue. Transforming the data was attempted first. Next, 20% trimming of the data was attempted. If neither of these worked, robust nonparametric regressions based on the Theil-Sen Estimator (Theil-Kendall regression) were used for detection of trends. However, if assumptions were met, linear regression was used.

Analyses were run for the Estero Bay Aquatic Preserve as a whole, by species, and by site, as well as frequencies by year. The ends of the seagrass beds were considered to be advancing if

they were progressing waterward; whereas the beginnings of beds were considered to be advancing if they were moving shoreward. Density data will not be included nor will total abundance data from prior to 2006, due to differences in sampling design. Lastly, due to the rarity of encounters with the two *Halophila* species, they will be combined as one (*Halophila spp.*) in the analyses. For detailed statistics and site specific results, see the appendices contained within Leary, 2011a.

Results:

Frequencies:

For the Estero Bay Aquatic Preserve as a whole and from 2006 to 2009, *H. wrightii* was the most abundant specie observed (73.09%) followed by *T. testudinum* (24.34%), *Halophila spp.* (1.90%), attached algae (*Caulerpa spp.*; 0.48%), and *S. filiforme* (0.20%). *R. maritima* and *V. americana* were not observed within the Estero Bay Aquatic Preserve during the study period along the transects.

Frequency as a Percentage of Abundance (2006-2009)						
Species	EB01	EB02	EB03	EB04	EB05	All Sites
<i>H. wrightii</i>	48.69%	100.00%	57.00%	100.00%	68.30%	73.09%
<i>S. filiforme</i>	2.99%	0.00%	0.00%	0.00%	0.00%	0.20%
<i>T. testudinum</i>	29.85%	0.00%	41.80%	0.00%	26.59%	24.34%
<i>Halophila spp.</i>	12.31%	0.00%	1.07%	0.00%	5.01%	1.90%
Attached Algae	6.16%	0.00%	0.13%	0.00%	0.10%	0.48%

Table 1. Average frequencies for all species, by site and for the Estero Bay Aquatic Preserve, for 2006 – 2009.

From 2006 to 2009, the frequency based on abundance for *H. wrightii*, *T. testudinum*, *Halophila spp.*, and Attached Algae decreased, however these were not significant ($p=0.067$, $p=0.509$, $p=0.123$, and $p=0.374$, respectively). Data for *S. filiforme* based upon abundance were insufficient for 2006 through 2009.

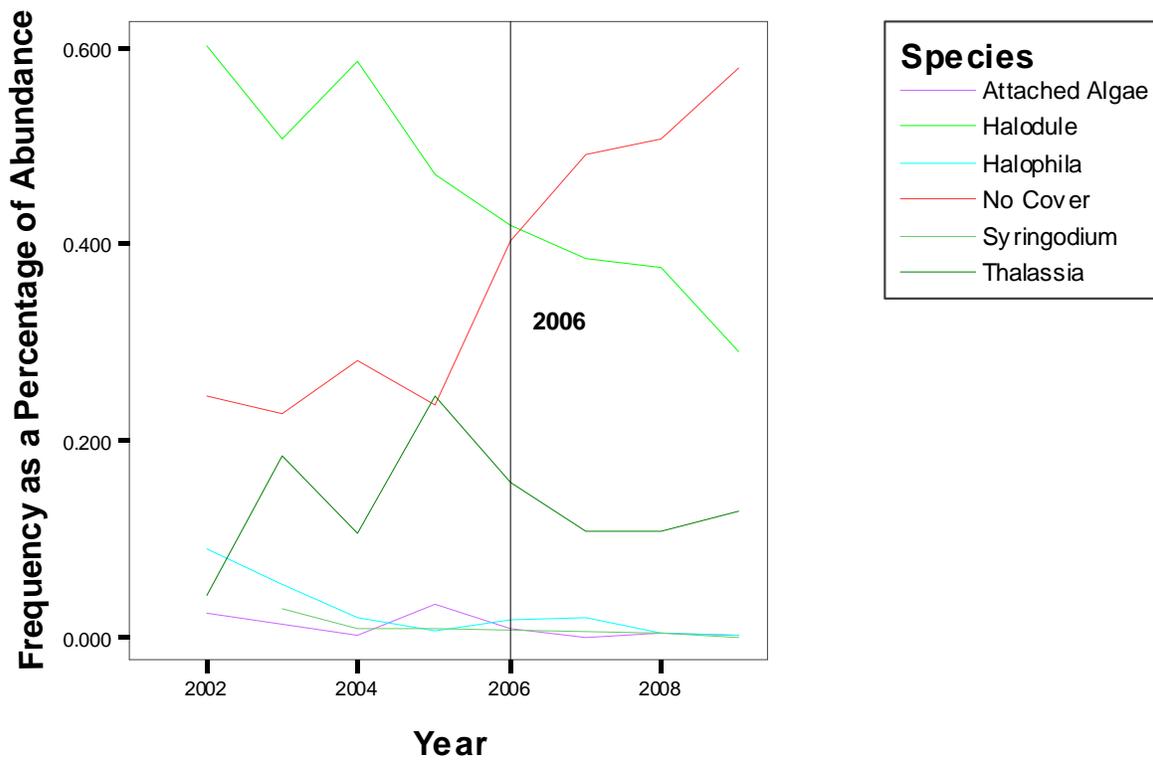


Figure 1. Frequencies for all species within each station for the Estero Bay Aquatic Preserve.

Abundances:

Data for Estero Bay Aquatic Preserve total abundance were found to be non-normal and heteroscedastic, numerous transformations and 20% trimming were attempted but could not resolve these issues; therefore Theil-Kendall regression was used. For the entire Estero Bay Aquatic Preserve, total abundance decreased, but was not significant ($p=0.063$; rate based on Braun-Blanquet coverage) for the time period of 2006 to 2009. During this time, *H. wrightii* decreased, but was not significant ($p=0.223$), whereas *T. testudinum* increased, but was not significant ($p=0.173$). There were insufficient data for the other species during the 2006 to 2009 time period. For the entire period of record (2002 – 2009), Theil-Kendall regression was used. During this time, the abundance of *H. wrightii* increased significantly ($p=0.048$), as did *T. testudinum* ($p<0.001$). There was no significant trend in *Halophila* spp. ($p=0.132$), and there were insufficient data for *S. filiforme* and attached algae. There were no other significant trends for Estero Bay Aquatic Preserve.

Average Total Abundance Cover Class (2006 - 2009)						
Year	EB01	EB02	EB03	EB04	EB05	All Sites
2006	5 - 25%	50 - 75%	50 - 75%	0 - 5%	5 - 25%	25 - 50%
2007	0 - 5%	25 - 50%	25 - 50%	5 - 25%	5 - 25%	5 - 25%
2008	0 - 5%	25 - 50%	25 - 50%	5 - 25%	5 - 25%	5 - 25%
2009	0 - 5%	5 - 25%	25 - 50%	5 - 25%	0 - 5%	5 - 25%
Total	0 - 5%	25 - 50%	25 - 50%	5 - 25%	5 - 25%	5 - 25%
Average Species Abundance Cover Class (2002 - 2009)						
Species	EB01	EB02	EB03	EB04	EB05	All Sites
<i>H. wrightii</i>	5 - 25%	5 - 25%	5 - 25%	0 - 5%	5 - 25%	5 - 25%
<i>S. filiforme</i>	0 - 5%	N/A	5 - 25%	N/A	0 - 5%	0 - 5%
<i>T. testudinum</i>	5 - 25%	N/A	5 - 25%	N/A	N/A	5 - 25%
<i>Halophila spp.</i>	0 - 5%	N/A	25 - 50%	N/A	0 - 5%	0 - 5%

Table 2. Average Braun-Blanquet coverage classes for sites by year, species, and the Estero Bay Aquatic Preserve.

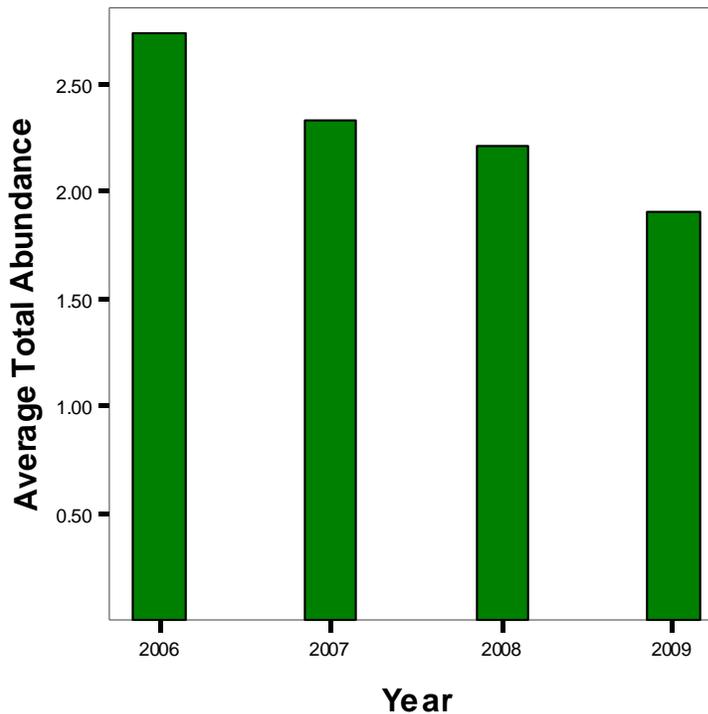


Figure 2. Average total abundance coverage class for all sites within the Estero Bay Aquatic Preserve.

Total abundance met all assumptions only at EB05, and decreased, but was not significant ($p=0.200$); data for the other sites were insufficient for 2006 - 2009. For the period of record (2002 - 2009), species abundances were square root transformed at EB01, EB04, and EB05; EB02

was Log transformed; and EB03 used the Theil-Kendall regression. During this period, *T. testudinum* increased significantly at EB03 ($p < 0.001$). There were no other site-specific trends in species abundances, or there were insufficient data.

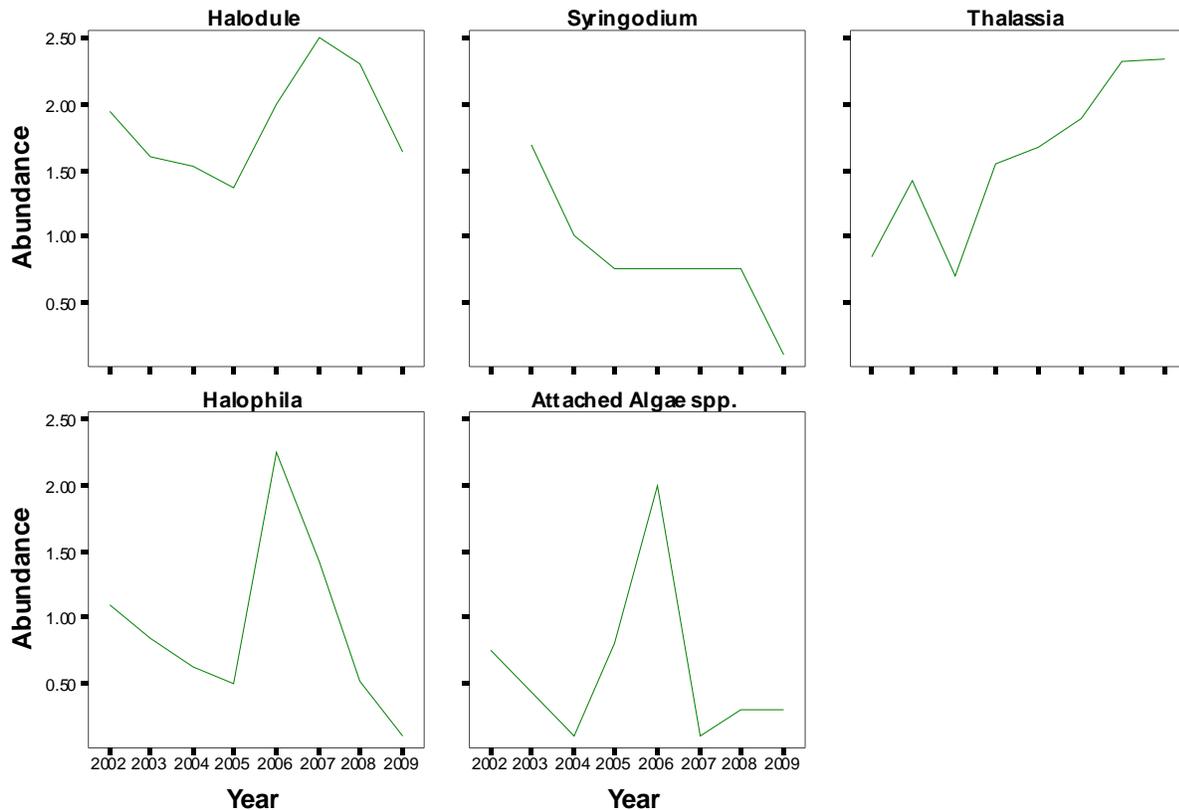


Figure 3. Average Abundances, by species and year, for all sites in the Estero Bay Aquatic Preserve.

Bed Dynamics:

The deep edges of seagrass beds within the entire Estero Bay Aquatic Preserve as a whole trended shallower within the study period, however this was not significant ($p = 0.146$). Deep edge measurements trended significantly shallower at EB02 ($R^2 = 0.506$; $F(1,13) = 13.317$; $p = 0.003$). At first glance, EB03 appeared to have no significant trend in the deep edge of bed, it was reanalyzed because there is no true shoreward edge of bed; i.e., it begins in one channel and continues to another channel. Therefore EB03 has two deep edges. At EB03 there was no significant trend in the deep edge identified as the end of bed (at the western edge of the transect), however the deep edge identified as the beginning of bed (the eastern edge of the transect) did advance significantly deeper ($p < 0.001$) at a rate of approximately 2.05 cm per year. Reanalysis of Estero Bay Aquatic Preserve as a whole, due to EB03, trended shallower, but still was not statistically significant ($p = 0.215$). There were no other significant trends for deep edge.

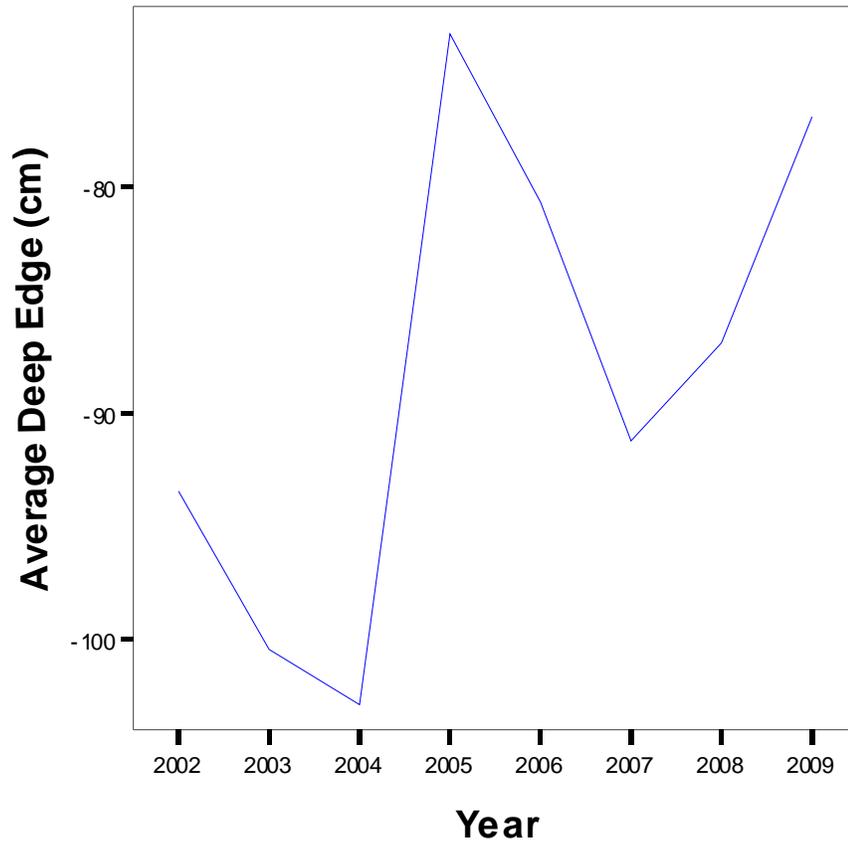


Figure 4. Average deep edge at the ends, by year, of bed for all sites within the Estero Bay Aquatic Preserve.

The locations of the beginning of the beds in Estero Bay were advancing ($p=0.100$; moving shoreward) for the region as a whole, but were not significant. The locations of the ends of beds increased, but were not significant ($p=0.515$) nor was there a significant increase in the overall bed lengths ($p=0.396$). However, the overall bed lengths increased significantly at individual sites: EB02 ($p<0.001$), EB03 ($p=0.036$), EB04 ($p<0.001$), and EB05 ($p=0.025$). The beginnings of the beds in EB02, EB03, EB04, and EB05 were advancing shoreward (waterward for EB03) significantly ($p=0.026$, $p<0.001$, $p<0.001$, and $p=0.025$, respectively). In addition, EB02 and EB04 ends of beds were advancing seaward ($p<0.001$ and $p=0.001$, respectively). There were no significant trends for EB01.

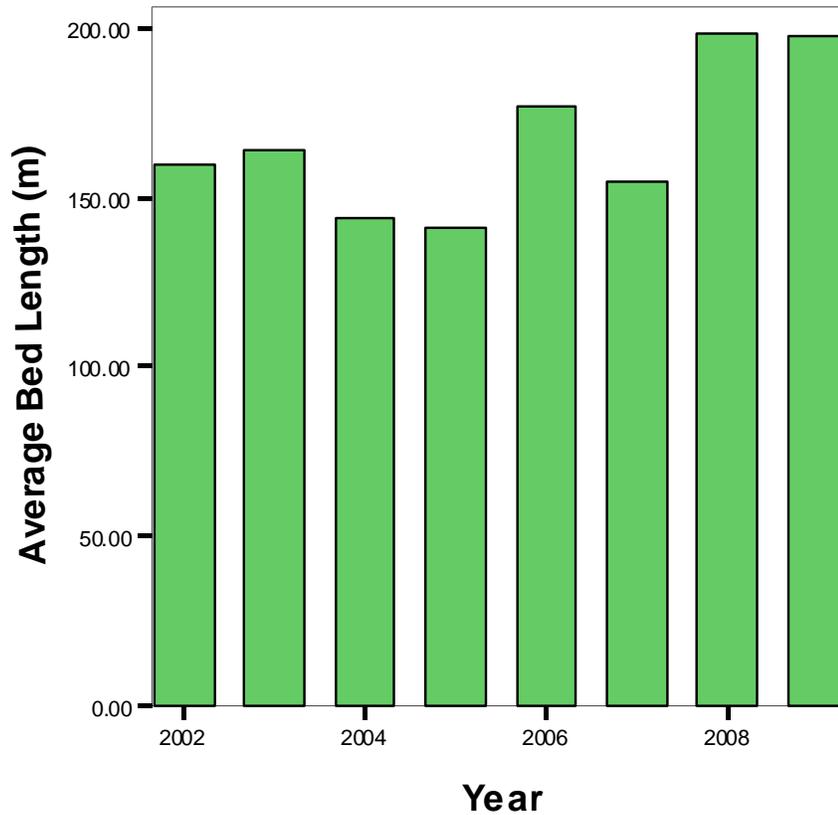


Figure 5. Average bed lengths, by year, for all sites in the Estero Bay Aquatic Preserve.

Blade Lengths:

Data for Estero Bay Aquatic Preserve average blade lengths were found to be non-normal and heteroscedastic, numerous transformations and 20% trimming were attempted but could not resolve these issues; therefore Theil-Kendall regression was used. The average blade length for all species combined and for the entire region increased significantly ($p=0.003$). The same was true for *H. wrightii* ($p=0.039$) and *T. testudinum* ($p=0.018$). There were no significant trends for *Halophila* spp. or *S. filiforme* ($p=0.357$ and $p=0.782$, respectively). Both EB01 and EB02 were Log transformed, and EB05 was square root transformed. Theil-Kendall regression was used for EB03 and EB04. All species combined increased significantly at EB01 and EB02 ($p=0.005$ and $p<0.001$, respectively). Both EB01 and EB02 had significant increases in blade lengths for *H. wrightii* ($p=0.003$ and $p<0.001$, respectively). There were no other significant trends for blade lengths.

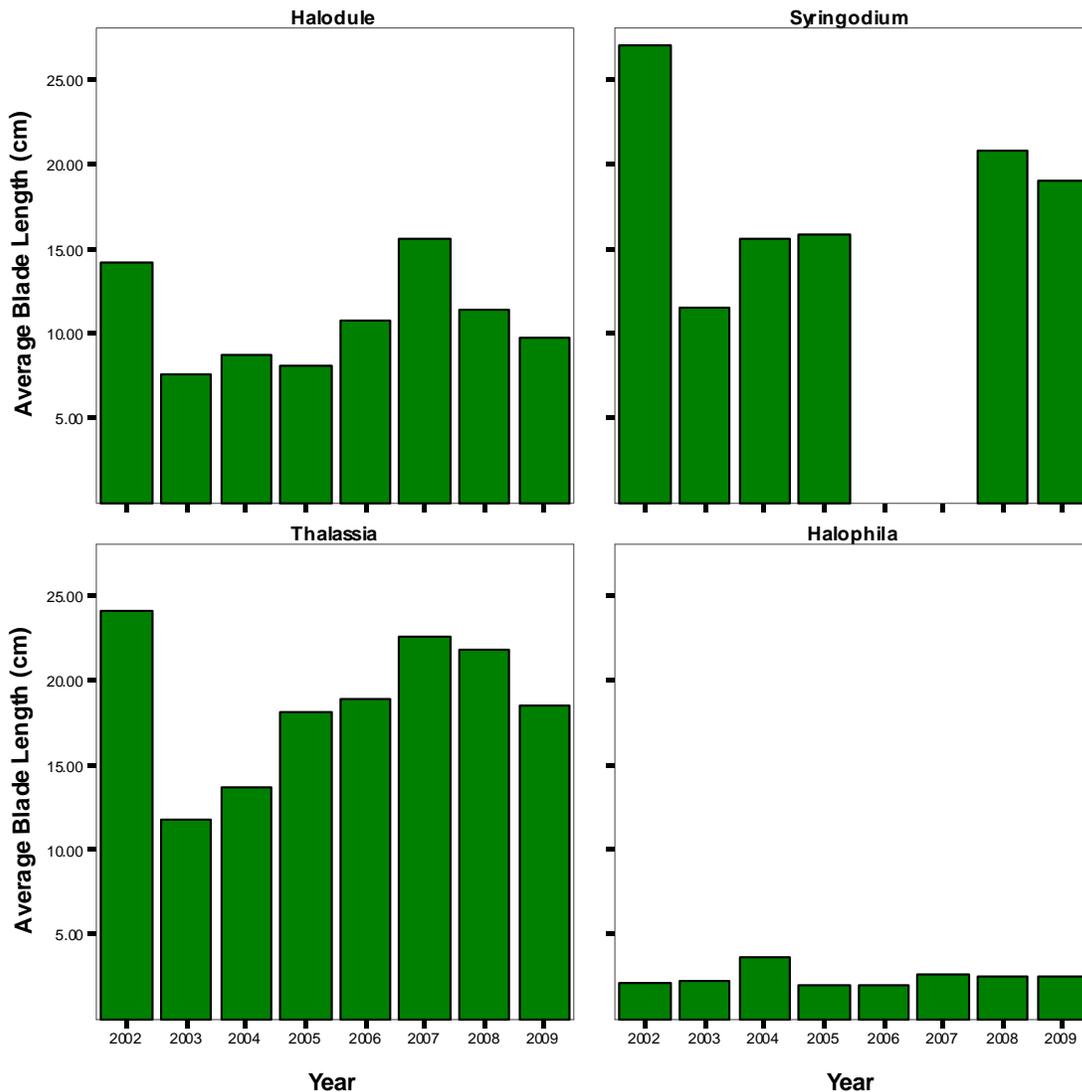


Figure 6. Average blade lengths, by species and year, for all sites within the Estero Bay Aquatic Preserve.

Epiphyte Density:

Data for Estero Bay Aquatic Preserve epiphyte densities were found to be non-normal and heteroscedastic, numerous transformations and 20% trimming were attempted but could not resolve these issues; therefore Theil-Kendall regression was used. For the entire region, irrespective of seagrass species, epiphyte densities increased, however this was not significant ($p=0.726$). *H. wrightii* showed insignificant increases in epiphyte densities for the region, as well ($p=0.367$), whereas epiphyte densities declined for *T. testudinum* and *Halophila* spp. ($p=0.899$ and $p=0.327$, respectively), but were not significant. There was insufficient data for *S. filiforme*. Theil-Kendall regression was used for EB03; all other sites met the required assumptions. Epiphyte densities overall increased significantly at EB02 ($p<0.001$), however *H. wrightii* is the

only species documented along this transect. At EB05 epiphyte densities increased significantly on *T. testudinum* ($p=0.015$). There were no other significant trends.

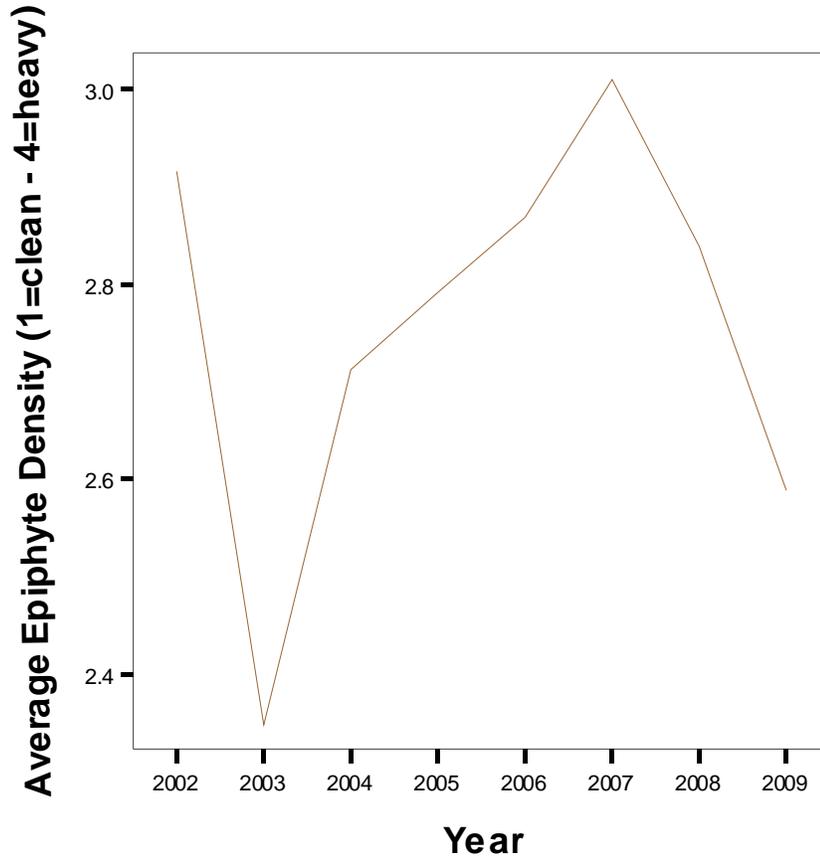


Figure 7. Average epiphyte densities, by year, for all species and sites within the Estero Bay Aquatic Preserve.

Discussion:

Estero Bay Aquatic Preserve:

Within the Estero Bay Aquatic Preserve, *H. wrightii* was the most frequently encountered seagrass species. This was to be expected, as it had been documented for the entire Charlotte Harbor estuary, similar surrounding estuaries (e.g., Sarasota Bay, Tampa Bay, etc.), and in previous findings for Estero Bay (e.g., Avery and Johansson, 2001; Corbett and Hale, 2006; Tomasko et al, 2011; Leary, 2011c). Although not significant, there was decline in total abundance, and should be further examined. The abundances of both *H. wrightii* and *T. testudinum* increased significantly for the aquatic preserve as a whole. The different trends in abundances are most likely due to differences in the sampling periods; species abundances are for 2002 through 2009, and total abundance was recorded from 2006 to 2009. In addition, the average blade length for all species combined increased significantly, as did the average blade length for both *H. wrightii* and *T. testudinum*. These trends, suggest that overall seagrass health within the Estero Bay Aquatic Preserve improved during the study period. However, it should

be noted that during 2004 and 2005 there were declines in seagrass abundances most likely due to increases in freshwater inputs from numerous tropical storms and hurricanes that hit the area, and increased rainfall (Brown et al, 2011).

EB01:

Located in the northwest portion of Estero Bay near Matanzas Pass, EB01 was the only site to observe all four species of seagrass listed along the transects within the Estero Bay Aquatic Preserve. Of the species encountered along EB01, *H. wrightii* was the most frequent, and it had the highest frequency of *Halophila* spp. and of attached algal species. It also should be noted that although *S. filiforme* was not recorded in 2006 and 2007, this simply means that it was not present within the sampling quadrats, but may have been along the transect, or in the surrounding area. Along with EB02, EB01 had significant increases in the average blade lengths of all species combined, and the average blade length for *H. wrightii* increased. This was the only site where both the beginning and end of bed was receding and the overall bed length was decreasing, however these were not significant. This site appears to be improving, but the reduction in bed length needs to be further investigated in order to insure that the decline does not become significant.

EB02:

Site EB02 is in the west-central portion of the Estero Bay Aquatic Preserve, and is located near the Estero River. Along this transect, *H. wrightii* was the most frequently observed species and the most abundant. However, this is only because it is the only species that has been observed at this site. During the study period, the abundance of *H. wrightii* increased significantly, but the total abundance decreased significantly. At first glance these results seem contradictory since *H. wrightii* was the only species observed, however this is simply because abundance data were collected for the entire period, whereas total abundance data were collected from 2006 on. Therefore, *H. wrightii* increased greatly at first, but declined from 2006 to 2009. EB02 was the only site in the Estero Bay Aquatic Preserve to have a significant decrease in the deep edge of seagrass growth. However, both the beginning and end of bed advanced significantly, and there was a significant increase in the overall bed length. This would suggest that the decrease in the deep edge is merely a result of undulations of the bottom contours; i.e., the bed was advancing waterward through a shallow ridge. The average blade length at this site increased significantly, as well. Epiphyte densities increased significantly here, and may be indicative of eutrophication (e.g., Twilley et al, 1985; Drake et al, 2003; Fourqurean and Rutten, 2003). Overall, EB02 was the most improved of the five sites; however the recent trend in total abundance and the increase in epiphyte loads should continue to be monitored in order to ensure that the meadow does not begin to decline.

EB03:

The only truly mid-water site (it does not begin at land), EB03 is located between two channels near Long Key, Big Hickory Island and New Pass in the southern third of the Estero Bay Aquatic Preserve. *H. wrightii* was the most frequently observed species at this site and had the greatest frequency of *T. testudinum* observed of all the sites within the Estero Bay Aquatic Preserve, and was the only site to have a significant increase in the abundance of *T. testudinum*.

There was a significant decrease in total abundance from 2006 to 2009, which suggests that the seagrass meadow may be declining in more recent years. The deep edge at the beginning of bed for this site had significantly increased during this time, whereas the deep edge at the end of bed had not. This is most likely due to the fact that there is an oyster reef at the end of bed where the meadow abruptly ends. The beginning of bed advanced significantly waterward, and the overall bed length increased significantly. This site is the longest (average length = 450.8 m) within the Estero Bay Aquatic Preserve, and appears to be in good condition; however the decline in total abundance should be further investigated.

EB04:

The southernmost site in the Estero Bay Aquatic Preserve, EB04 is located in Big Hickory Bay. Like EB02, the only specie present at this site is *H. wrightii*; this is also the only other site near the mouth of a river (the Imperial River). The other common characteristic EB04 shares with EB02 is that both the beginning and end of bed was advancing significantly, and the overall bed length increased significantly. On average, EB04 is the shortest of the five sites in the Estero Bay Aquatic Preserve (average length = 80.0 m). This site had the fewest significant trends, and appears to be the most stable within the Estero Bay Aquatic Preserve.

EB05:

Located in Hurricane Bay, EB05 is the northernmost of the five sites located in the Estero Bay Aquatic Preserve, and is the closest to a developed area (San Carlos Island). *H. wrightii* was the most frequently observed specie at this site. The beginning of bed advanced significantly and the overall bed length increased significantly. In addition, epiphyte densities increased on *T. testudinum* at this site. This site appears to be relatively stable.

Conclusions:

Overall, the seagrass meadows within the Estero Bay Aquatic Preserve appear to be stable or improving. At four of the five sites the beds were expanding; however this was not the case for the aquatic preserve as a whole. This may be due to the fact that EB03 (average length = 450.8 m) is so much larger than the other four sites which are more similar in size on average (EB01 = 94.4 m; EB02 = 83.3 m; EB04 = 80.0 m; and EB05 = 174.2 m), combined with the fact that EB01 is decreasing. The deep edge of seagrass growth extended deeper at the beginning of bed for EB03, but decreased at EB02; however this was not of great concern considering the beds expanded. There were no significant increases in total abundance, this may be due to the limited amount of time it has been collected and should be reanalyzed with a larger dataset over a greater period of time. However, the abundances of both *H. wrightii* and *T. testudinum* increased significantly for the aquatic preserve as a whole, as did *T. testudinum* at EB03. Average blade lengths increased significantly for all species combined within the Estero Bay Aquatic Preserve, as did the average blade lengths for *H. wrightii* and *T. testudinum*. In addition, the average blade length for all species combined increased at EB01, and both EB01 and EB02 had significant average blade length increases for *H. wrightii*. There was a significant increase in epiphyte densities at EB02, and EB05 had a significant increase on *T. testudinum*. These increasing trends in epiphyte densities need to be looked into more closely; as this can

harm the seagrasses due to shading. In addition, it needs to be ascertained if stable sites require improvements in order to maintain a healthy ecosystem.

These improvements to, and stabilization of, the seagrass meadows within the Estero Bay Aquatic Preserve are most likely due to multiple factors. The establishment of the aquatic preserve and Outstanding Florida Waters has most likely contributed to protecting the seagrass meadows, as well as other environmental legislation at the local, state and federal levels. Increased public awareness of the value of seagrasses has added to its protection and improvement. In particular, its use as a nursery by many commercially and recreationally valuable shellfish and finfish, as well as habitat, a food source for these fisheries. The amount, timing, and quality of freshwater being delivered to the region have likely played a part in the quantity and quality of the seagrasses within the Estero Bay Aquatic Preserve, as well. With continued protection and further research, the seagrass meadows of Estero Bay Aquatic Preserve can continue to enhance water quality, augment the esthetic value of the region, help sustain tourism, and support important fisheries for future generations.

References:

- Avery, W.M. and J.O.R. Johansson. 2001. Tampa Bay Interagency Seagrass Monitoring Program: Seagrass Species Distribution and Coverage Along Fixed Transects, 1997 – 2000. TBEP Publication.
- Bos, A.R., T.J. Bouma, G.L.J. de Kort, and M.M. van Katwijk. 2007. Ecosystem Engineering by Annual Intertidal Seagrass Beds: Sediment Accretion and Modification. *Estuarine, Coastal and Shelf Science*. 74: 344 - 348.
- Braun-Blanquet, J. 1932. *Plant Sociology: The Study of Plant Communities*. Fuller, G.D. and H.S. Conrad (Eds). 1st Edition, 5th Impression. Obtained from the World Wide Web 17 August, 2008. <http://www.archive.org/details/plantsociologist00brau>.
- Brown, M.A., R.E. Leary, N. Langenberg, M. McMurray and H. Stafford. 2011. Results of the Florida Department of Environmental Protection, Charlotte Harbor Aquatic Preserves' Seagrass Monitoring Program from 1999 - 2009. Submitted to Florida Scientist 01/31/2012, in review.
- Brown, M.A. 2011. Charlotte Harbor Aquatic Preserves' Eleven Year Results of the Seagrass Transect Monitoring Program (1999-2009). FDEP Publication.
- Corbett, C.A. and J.A. Hale. 2006. Development of Water Quality Targets for Charlotte Harbor, Florida Using Seagrass Light Requirements. Corbett, C.A., P.H. Doering and E. Estevez (Eds). *Florida Scientist*. 69(00S2): 36 - 50.
- Dennison, D.C., R.J. Orth, K.A. Moore, J.C. Stevenson, C. Carter, S. Kollar, P.W. Bergstrom, and R.A. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation: habitat requirements as barometers of Chesapeake Bay health. *Bioscience*. 43(2): 86 - 94.
- Drake, L.A., F.C. Dobbs, and R.C. Zimmerman. 2003. Effects of epiphyte load on optical

- properties and photosynthetic potential of the seagrass *T. testudinum* Banks ex König and *Zostera marina* L. *Limnology and Oceanography* 48(1, part 2): 456 – 463.
- Duffey, R., R.E. Leary and J.A. Ott. 2007. Charlotte Harbor & Estero Bay Aquatic Preserves Water Quality Status and Trends for 1998 – 2005. FDEP/CHAP Technical Report #2.
- Erickson, S. 2010. Estero Bay Aquatic Preserve Seagrass Monitoring Design. FDEP Publication.
- Florida Department of Environmental Protection, 1997. Chapter 18-20 of the Florida Administrative Code (44). Tallahassee, FL.
- Fourqurean, J.W. and L.M. Rutten. 2003. Competing Goals of Spatial and Temporal Resolution: Monitoring Seagrass Communities on the Regional Scale. Pp 257 – 288 in: Busch, D.E. and J.C. Trexler (Eds). *Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives*. Island Press, Washington, D.C. 447 pp.
- Fourqurean, J.W., M.J. Durako, M.O. Hall and L.N. Hefty. 1999. Seagrass Distribution in South Florida: A Multi-agency Coordinated Monitoring Program. In: J.M. Fourqurean, M.J. Durako and J.C. Zieman, Principal Investigators. *Seagrass Status and Trends Monitoring. Annual Report, Fiscal Year 1998. Volume 1*. FKNMS, USAEPA/WQPP.
- Hemminga, M.A. and C.M. Duarte. 2000. *Seagrass Ecology*. Cambridge University Press; Cambridge, United Kingdom.
- Kemp, W.M., W.R. Boynton, R.R. Twilley, J.C. Stevenson, and L.G. Ward. 2007. Influences of Submerged Vascular Plants on Ecological Processes in Upper Chesapeake Bay. Pp 367 – 394 in: Kennedy, V. (Ed.). *Estuaries as Filters*. Academic Press, New York.
- Larkum, A.W.D., R.J. Orth and C.M. Duarte (Eds). 2007. *Seagrasses: Biology, Ecology and Conservation*. Springer; Dordrecht, the Netherlands.
- Leary, R.E. 2009. Comparison of Water Quality Results from Fixed Station and Random Sampling Monitoring Programs in the Charlotte Harbor and Estero Bay Aquatic Preserves: 2001 – 2007. FDEP/CHAP Technical Report #3.
- Leary, R.E. 2010. State of the Southwest Florida Aquatic Preserves, Lemon Bay to Estero Bay: 40-year Status and Trends, 1970 – 2009. FDEP Publication.
- Leary, R.E. 2011a. Documentation of Screening for Outliers, Testing Statistical Assumptions, and Trends Showing Statistical Significance for Seagrass Transect Monitoring within the Estero Bay Aquatic Preserve (2002 – 2009). NOAA Award No. # NA10NOS4190178, FDEP Grant No. CM203, Submitted 28 July, 2011.
- Leary, R.E. 2011b. Documentation of Screening for Outliers, Testing Statistical Assumptions, and Trends Showing Statistical Significance for Seagrass Transect Monitoring within the Matlacha Pass Aquatic Preserve (1999 – 2009). NOAA Award No. # NA09NOS4190076, FDEP Grant No. CM030, Submitted 30 June, 2011.

- Leary, R.E. 2011c. Seagrass Dynamics within the Matlacha Pass Aquatic Preserve Along Fixed Transects (1999 – 2009). NOAA Award No. # NA09NOS4190076, FDEP Grant No. CM030, Submitted 30 September, 2011.
- Madden, C.J. and W.M. Kemp. 1996. Ecosystem Model of an Estuarine Submersed Plant Community: Calibration and Simulation of Eutrophication Responses. *Estuaries*. 19(2B): 457 - 474.
- Orth, R.J., T.M. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott, and S.L. Williams. 2006. A Global Crisis for Seagrass Ecosystems. *Bioscience*. 56(12): 987 - 996.
- Stearns, C. 2007. Standard Procedures for Seagrass Monitoring for the Charlotte Harbor Aquatic Preserves' Seagrass Transect Monitoring Program. FDEP Publication.
- Tomasko, D.A., E. Keenan, M. Alderson and J. Leverone. 2011. Sarasota Bay Seagrass Recovery: More of an Improvement Than Previously Thought? Presentation to the Tampa Bay Estuary Program. Taken from the World-Wide Web 9/29/2011. http://www.tbep.tech.org/attachments/085_Tomasko%20Seagrass%20Surveyresults%2008-31-10.pdf.
- Twilley, R.J., W.M. Kemp, K.W. Staver, J.C. Stevenson, and W.R. Boynton. 1985. Nutrient Enrichment of Estuarine Submersed Plant Communities. 1. Algal Growth and Effects on Production of Plants and Associated Communities. *Marine Ecology Progress Series*. 23: 179 - 191.
- Wilcox, Rand R. 2001. *Fundamentals of Modern Statistical Methods: Substantially Improving Power and Accuracy*. Springer-Verlag, New York, Inc. New York, New York.