**Southern Estuaries Hypothesis Cluster-Submerged Aquatic Vegetation**

**Abstract**

Seagrasses are the dominant biological communities in the coastal region to be affected by CERP and they provide the majority of the fisheries habitat in this system. The goal of the South Florida Fisheries Habitat Assessment Program (FHAP-SF) is to provide information for the spatial assessment and resolution of inter-annual variability in seagrass communities, and to establish a baseline to monitor responses of seagrass communities to water management alterations associated with CERP activities. FHAP-SF is documenting the status and trends of seagrass distribution, abundance, reproductive, and physiological status (ecoindicators), as well as providing process-oriented data such as photosynthetic quantum yields and epiphyte loads. Resource managers will be able to use these data to address ecosystem-response issues on a real-time basis and to weigh alternative restoration options.

Specific objectives of FHAP-SF are to: (1) develop a basic understanding of the relationships among water quality parameters (e.g. salinity, water clarity, nutrient levels) and seagrass species distribution and abundance in south Florida, (2) provide baseline data in in order to separate anthropogenically induced changes from natural system variation, and (3) assist in verifing model predictions on species and ecosystem-level responses to water quality changes associated with CERP. Results of the 2007 SSR suggest that the methods adopted can detect changes in SAV from pre-CERP conditions when there are sufficient reference data, and that the present trends are consistent with hypothesized causal relationships.

**Background Description**

Seagrasses (e.g., SAV) are characteristic of shallow coastal waters worldwide; however, few areas contain meadows as extensive as those found in the south Florida region (Fourqurean et al. 2002). SAV communities provide key ecological services, including organic carbon production, nutrient cycling, sediment stabilization, and enhanced biodiversity (Orth et al. 2006). These plants are not only a highly productive base of the food web, but are also a principal habitat for higher trophic levels. Because seagrasses live in close proximity to the land-sea interface, they are subject to physical disturbances and water quality changes associated with human population growth. As perennial plant species, seagrasses integrate net changes in water quality parameters (e.g. salinity, light availability, nutrient levels) which tend to exhibit rapid and wide fluctuations when measured directly. As such, seagrasses serve as biological sentinels of increasing anthropogenic influence in coastal ecosystems (Orth et al. 2006). To a large extent, seagrass abundance determines public perception regarding the health of the coastal waters of Florida (Goerte 1994, Boesch et al. 1995). Thus, the recent changes in the distribution and abundance of seagrasses within south Florida estuaries have been perceived as an especially significant change in the overall ecosystem health. For these reasons, seagrasses have been deemed one of the best indicators of change in the SE module (Fourqurean et al. 1992).

**Submerged Aquatic Vegetation Conceptual Ecological Model**

The hypotheses described below are derived from a heuristic conceptual model (***Figure 7-20***) of the factors that influence SAV community structure (e.g., water management, land use and episodic events), and the interaction of SAV with estuarine organisms and the physical environment. CERP implementation will alter the volume, timing, and spatial distribution of freshwater inflow into the SE. SAV field data and concomitant water quality information are being collected to establish baselines (i.e., reference conditions) against which the extent of system change will be measured once CERP is implemented. Analysis of this pre-CERP data is needed to determine the extent of ecosystem change that will be detectible (and how long that might take) once CERP is implemented. At an early stage, it will also reveal systematic problems in the monitoring or analysis and highlight areas where significant improvements can be made.

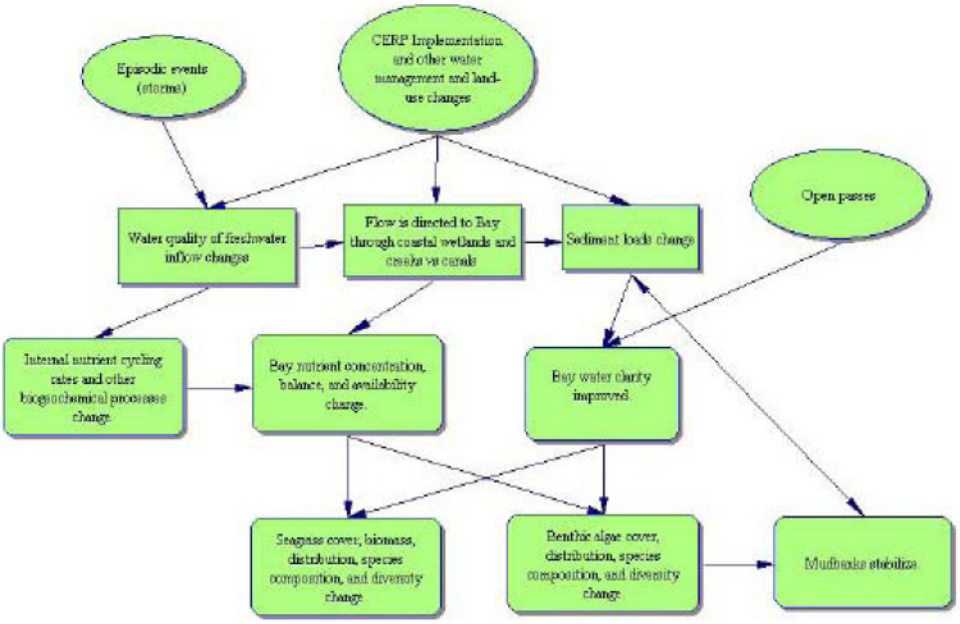



**Figure 7-20: SE Module SAV CEM**

Major CERP Relevant Hypotheses

• Hypothesis 1: Changes in both salinity and water quality resulting from CERP implementation are expected to result in changes in seagrass cover, biomass, distribution, species composition, and diversity though the combined and interrelated effects of light penetration, epiphyte load, nutrient availability, sediment depth, salinity, temperature, hypoxia/anoxia, sulfide toxicity, and disease.

• Hypothesis 2: Changes related to CERP implementation will include an expansion of areas with *Halodule wrightii* and *Ruppia maritima* cover and a reduction in areas of *Thalassia testudinum* monoculture along the northern third of Florida Bay. Based on

forecasted changes in hydrology, seagrass density and species composition in the southern two-thirds of Florida Bay and the eastern half of Biscayne Bay are not expected to change.

• Hypothesis 3: Changes in both salinity and water quality resulting from CERP implementation are expected to change benthic algal cover, biomass, distribution, species composition, and diversity though the combined and interrelated effects of light penetration, nutrient availability, salinity, temperature, and changes in seagrass density and species composition.

• Hypothesis 4: Significant changes in benthic algae and seagrass distribution can affect susceptibility of sediments to become resuspended and the stability of mudbanks as well as nutrient availability to other primary producers.

Interim Goals

Submerged aquatic vegetation distribution and abundance are central ecological indicators of ecosystem health in the south Florida region, and as such are PMs throughout the SE domain. However, based on the indicator selection criteria (i.e., predictability [including adequate existing monitoring data], ecosystem restoration effect, ease of recognition and understanding by the intended audience, and manageable total number of indicators), the IGs for SAV in the SE module are currently limited to several locations within Florida Bay. Water management has dramatically altered the natural freshwater flow patterns (quantity, timing, and distribution) to Florida Bay. These changes, including reduced volume of freshwater inflow, are thought to have affected SAV in the Florida Bay ecosystem (McIvor et al. 1994, Durako et al. 2003, Rudnick 2004). The IGs for Florida Bay seagrass are based on an estimate of ecosystem conditions prior to major human interventions. These conditions (i.e., Florida Bay ecosystem history) were determined from paleoecological research and historical accounts (Brewster-Wingaard et al., 2003; Zieman et al., 1999; Cronin et al., 2001).

It is likely that the Florida Bay of the 1970s and early 1980s, with lush *T. testudinum* and clear water, was probably a temporary and atypical condition. Additional ecosystem history research and increased SAV and water quality monitoring will help refine the IGs for SE SAV. Presently, seagrass meadows in northeastern Florida Bay consist primarily of sparse *T. testudinum* communities. Central and western Florida Bay are dominated by sparse *T. testudinum* to dense *T. testudinum* meadows, but *H. wrightii*, and to a lesser extent *Syringodium filiforme* are also common. The occurrence and relative abundance of these community types vary by basin. From an ecological perspective, restoration targets are established that envision a more diverse seagrass community with lower *T. testudinum* density and biomass than during that anomalous period. A diversity of seagrass habitat is expected to be beneficial to many upper trophic level species (Thayer et al. 1999). CERPimplementation should affect SAV in the north shore mangrove zone lakes and coastal embayments (closer to freshwater source) more than offshore areas in the Florida Bay ecosystem. However, central Florida Bay should also be a primary focus area. Spatially explicit SAV restoration targets for the Florida Bay ecosystem are discussed in detail in the Florida Bay and Florida Keys Feasibility Study Draft PMs

(USACE and SFWMD 1999) and to a lesser extent in the Florida Bay and Everglades Mangrove Estuaries CEMs (Rudnick et al. 2005, Davis et al. 2005).

**Methods and Analyses**

SAV species have been monitored at ten Florida Bay locations since 1995 by the Florida Bay Fisheries Habitat Assessment Program (FHAP-FB). As a component of MAP, the geographic scope of FHAP-FB was expanded in 2005 to a total of 22 locations extending from the Lostman's River to northern Biscayne Bay (***Figure 7-20***), and the program was renamed the FHAPSF. Monitoring stations are determined using a systematic randomsampling design. Each location is divided into approximately 30 tesselated hexagonal grid cells (***Figure 7-21***), and a single station position is randomly chosen from within each grid cell during each monitoring event. Sampling grids were generated using algorithms developed by the EPA's Environmental Monitoring and Assessment Program (EMAP).

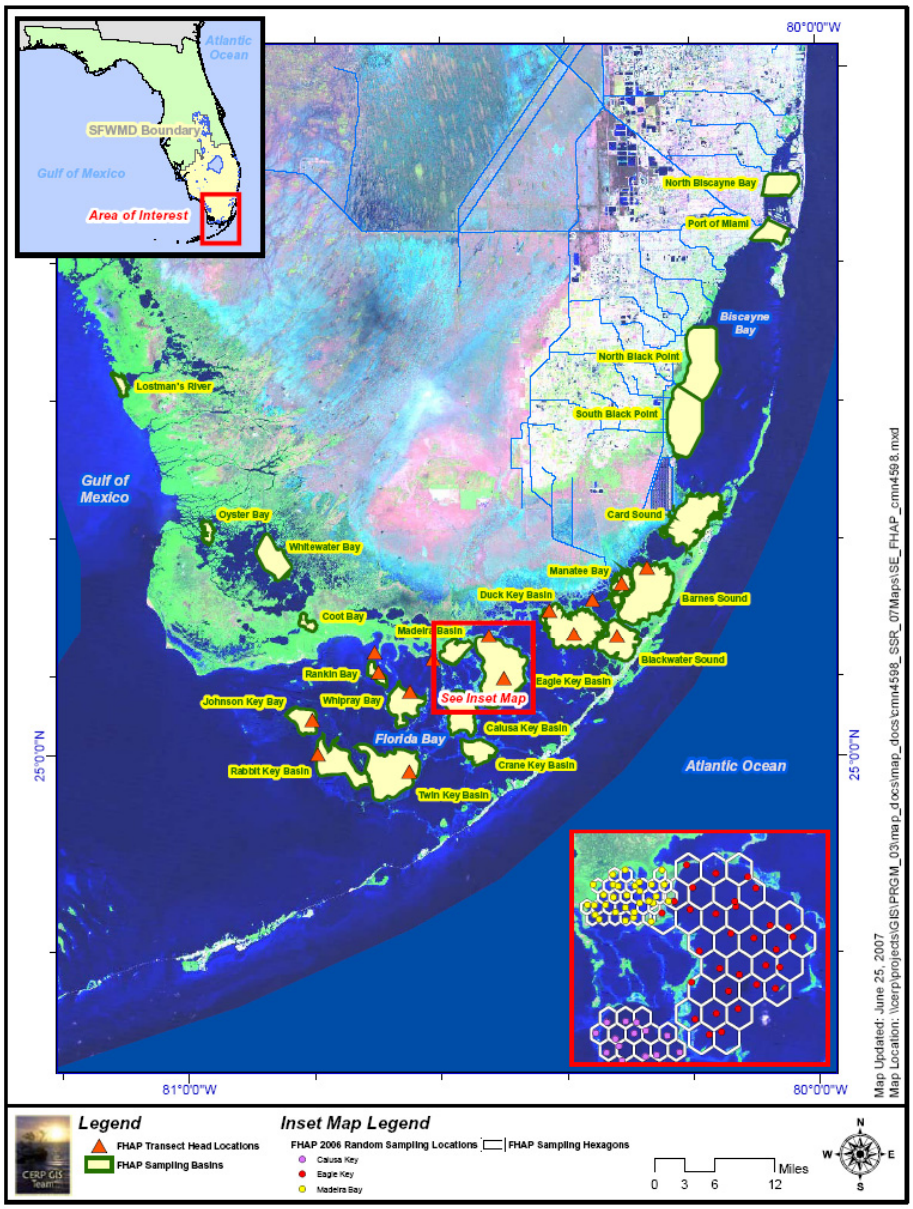



**Figure 7-21: Map Depicting the FHAP-SF Sampling Locations and Sampling Design (see Inset Map)**

Monitoring is conducted once per year at the end of the dry season (May-June). Salinity stress on seagrasses is typically highest at this time, and this is also the period when the dominant seagrass of the region, *T. testudinum* approaches its maximum leaf biomass, increasing the team's ability to detect changes in cover. Reproductive effort (flowering and fruit development) can also be assessed at this time. SAV community structure at each station is visually quantified using a modified Braun-Blanquet (BB) technique (Fourqurean et al. 2002). A series of 0.25 $m^2$ quadrats are placed on the bottom at each

sampling station. The number of individual BB quadrats examined in each location during each year is provided below in ***Table 7-6.***

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lostman's River* | - | - | - | - | - | - | - | - | - | - | 360 | 240 |
| *Oyster Bay* | - | - | - | - | - | - | - | - | - | - | 348 | 240 |
| *Whitewater Bay* | - | - | - | - | - | - | - | - | - | - | 372 | 232 |
| *Coot Bay* | - | - | - | - | - | - | - | - | - | - | 384 | 248 |
| *Johnson Key Basin* | 128 | 124 | 120 | 128 | 124 | 124 | 124 | 112 | 107 | 124 | 336 | 240 |
| *Rabbit Key Basin* | 136 | 132 | 108 | 112 | 108 | 120 | 112 | 124 | 107 | 108 | 371 | 248 |
| *Twin Key Basin* | 128 | 120 | 132 | 124 | 124 | 120 | 120 | 128 | 128 | 120 | 384 | 240 |
| *Rankin Lake* | 148 | 136 | 144 | 136 | 136 | 120 | 132 | 116 | 132 | 136 | 372 | 240 |
| *Whipray Basin* | 128 | 120 | 132 | 124 | 116 | 112 | 124 | 124 | 124 | 128 | 372 | 240 |
| *Madeira Bay* | 124 | 124 | 128 | 132 | 132 | 116 | 128 | 124 | 116 | 132 | 335 | 240 |
| *Calusa Key Basin* | 120 | 120 | 124 | 116 | 116 | 120 | 116 | 116 | 124 | 116 | 360 | 240 |
| *Crane Key Basin* | 140 | 132 | 136 | 136 | 136 | 132 | 136 | 140 | 128 | 136 | 408 | 232 |
| *Eagle Key Basin* | 136 | 144 | 148 | 128 | 128 | 136 | 128 | 132 | 144 | 124 | 396 | 248 |
| *Duck Key Basin* | - | - | - | - | - | - | - | - | - | - | 360 | 232 |
| *Blackwater Sound* | 132 | 120 | 128 | 136 | 136 | 120 | 136 | 128 | 124 | 136 | 392 | 232 |
| *Manatee Bay* | - | - | - | - | - | - | - | - | - | - | 360 | 240 |
| *Barnes Sound* | - | - | - | - | - | - | - | - | - | - | 360 | 240 |
| *Card Sound* | - | - | - | - | - | - | - | - | - | - | 348 | 232 |
| *South Black Point* | - | - | - | - | - | - | - | - | - | - | 348 | 232 |
| *North Black Point* | - | - | - | - | - | - | - | - | - | - | 360 | 232 |
| *Port of Miami* | - | - | - | - | - | - | - | - | - | - | 336 | 232 |
| *North Biscayne Bay* | - | - | - | - | - | - | - | - | - | - | 276 | 208 |

**Table 7-6: Number of Sampling Quadrats Surveyed in Each Basin for Each Year during the Spring Florida Bay Fisheries Habitat (FHAP) Monitoring Event**

Species occurring within the quadrats are assigned a cover/abundance value according to the following scale: 0 = absent; 0.1 = solitary with small cover; 0.5 = few with small cover, 1 = numerous but < 5% cover; 2 = any number with 5-25% cover; 3 = any number with 26-50% cover; 4 = any number with 51-75% cover; 5 = any number with 76-100% cover. The average BB score for each species is computed for the quadrats within a site to yield an average BB density estimate for each location. Epiphyte loads are also determined for each site. Most recently PAM fluorometry has been used to estimate quantum yield/photosynthetic efficiency. Concomitant with the SAV sampling, physical data are also collected including at least depth, temperature, salinity, pH, dissolved oxygen, and PAR.

Most Florida Bay seagrass reports to date have qualitatively compared maps of BB estimates per species among different years (e.g., Durako et al. 2002). While these maps are extremely informative, it is felt that a more quantitative procedure would also be required for CERP assessment purposes. However, the distribution of the BB data raised concerns because of the large number of zero observations in the quadrats surveyed, as well as many cases where even the positive values were distributed in a highly non-normal manner (***Figure 7-22***). A procedure known as the delta approach, which has been useful in other contexts where data are positively skewed and zero values predominate (Fletcher et al. 2005), was chosen for testing. The delta approach as applied here involves generating two data sets from the original: the first indicating the species presence (occurrence or frequency proportion of quadrats positive for the species in question), and the second abundance when present (concentration, mean BB abundance per quadrat, when present). The product of frequency and mean abundance values yields an index of

relative density. Such a statistic is considered more representative of the data than a mean density estimate calculated in the conventionalway, where the data set has a large number of zeros (Seber 1982). Separate analysis of the two components not only results in more robust estimation and understanding of the variance associated with each but typically reduces variability around the (composite) delta-mean value (Lo et al. 1992). Herein the term "delta-mean" will be used for the average deltadensity values calculated. Note that in the application using nontransformed data, the means calculated are identical to conventional means and only the variance changes. This approach was employed and proved successful in an analysis of spatio-temporal trends in shoreline fish species in southern Biscayne Bay (Serafy et al., 2007). It is also being employed in other MAP monitoring components such as the Juvenile Seatrout Monitoring for similar reasons (the large number of zero observations).

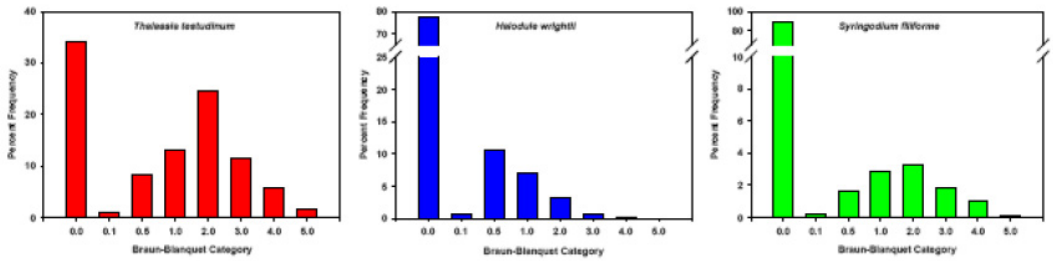



**Figure 7-22: Frequency Distribution of BB Estimates for Representative Seagrass Species**

Since all data collected thus far reflect pre-CERP conditions, the current assessment is simply the exercise of comparing the available baseline (pre-2006) data to the 2006 data with respectto the summary statistics discussed above. This exercise was confined to two Florida Bay locations, Johnson Key Basin and Blackwater Sound (***Figure 7-22***). These locations have substantially different environmental conditions (e.g., salinity patterns, sediment depth), and the seagrass in these areas have been monitored since 1995. For each of these basins, the 2006 values were compared to the means of the prior observations for that basin with respect to delta-mean and its constituent terms, frequency and concentration, and for predominant SAV taxa. A statistically significant difference occurred when the 2006 values fell outside the 95 percent confidence interval for the means of prior values (1995-2005). While not a power (or sensitivity) analysis in the formal sense, such an exercise is relatively free ofassumptions about the data and yields a quantitative appreciation for the underlying baseline data and its inherent variability (i.e., the context against which CERP induced changes will have to be discerned). In essence, a new tool to explore aspects of the data not usually considered is being added to the assessment toolbox, which will improve the SE module team's ability to detect CERP related changes beyond just comparing the spatial distributionof BB scores at different points in time.

Johnson Key Basin

**Brief History**–In 1987, extensive areas of *T. testudinum* began dying rapidly in central and western Florida Bay (including Johnson Key Basin). Factors that may have contributed tothe die-off were physiological stressors such as elevated water temperature and prolonged hypersalinity, excessive seagrass biomass leading to increased respiratory demands, hypoxia and sulfide toxity, and disease (Hall et al. 1999). Although *T. testudinum* mortality slowed substantially after several years, seagrass abundance in the central and western bay continued to decline due to an extended period of water column turbidity which began in 1991 and lasted until the late 1990s. Reduced water clarity was caused by resuspended sediments and phytoplankton blooms, most likely associated with the *T. testudinum* die-off (Durako et al. 2007). After water clarity improved, seagrass communities in Johnson Key Basin began to recover.

**Results of Analysis**–The 2006 Johnson Key Basin SAV community was composed of a variety of taxa, including substantial representation by *T. testudinum, H. wrightii* and S. *filiforme*, and occasional macroalgal species. With respect to *T. testudinum*, delta-density significantly differed in 2006 from the baseline condition (***Figure 7-23***), and did so with respect to both its components (frequency and concentration). In contrast, the 2006 *H. wrightii* delta-density was not significantly different from the baseline condition, although it declined substantially as a result of decreasing concentration with no change in occurrence.

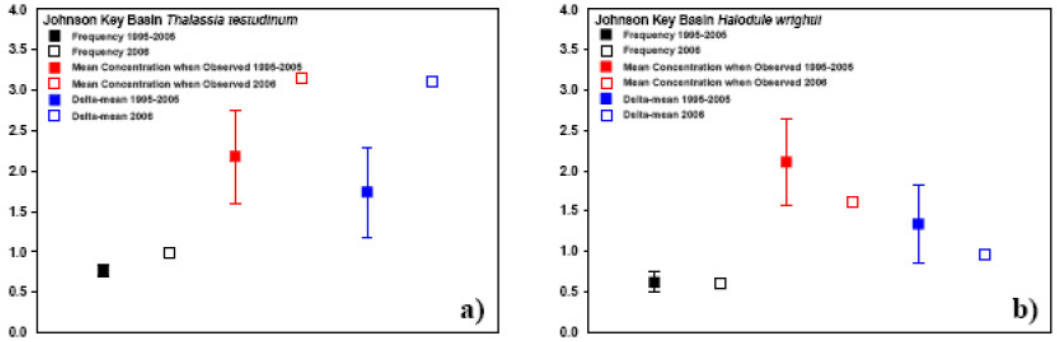



**Figure 7-23: Comparison of 2006 spring SAV observations with mean spring observations and 95% confidence intervals from 1995-2005 (n=11) in Johnson Key Basin for (a) Thalassia testudinum and (b) Halodule wrightii**
(open symbols indicate 2006 values)

An analysis of longer term trends (***Figure 7-24***) indicates that while *T. testudinum* has been increasing in both concentration and occurrence, the relative contribution of *H. wrightii* peaked approximately five years earlier in 2000.

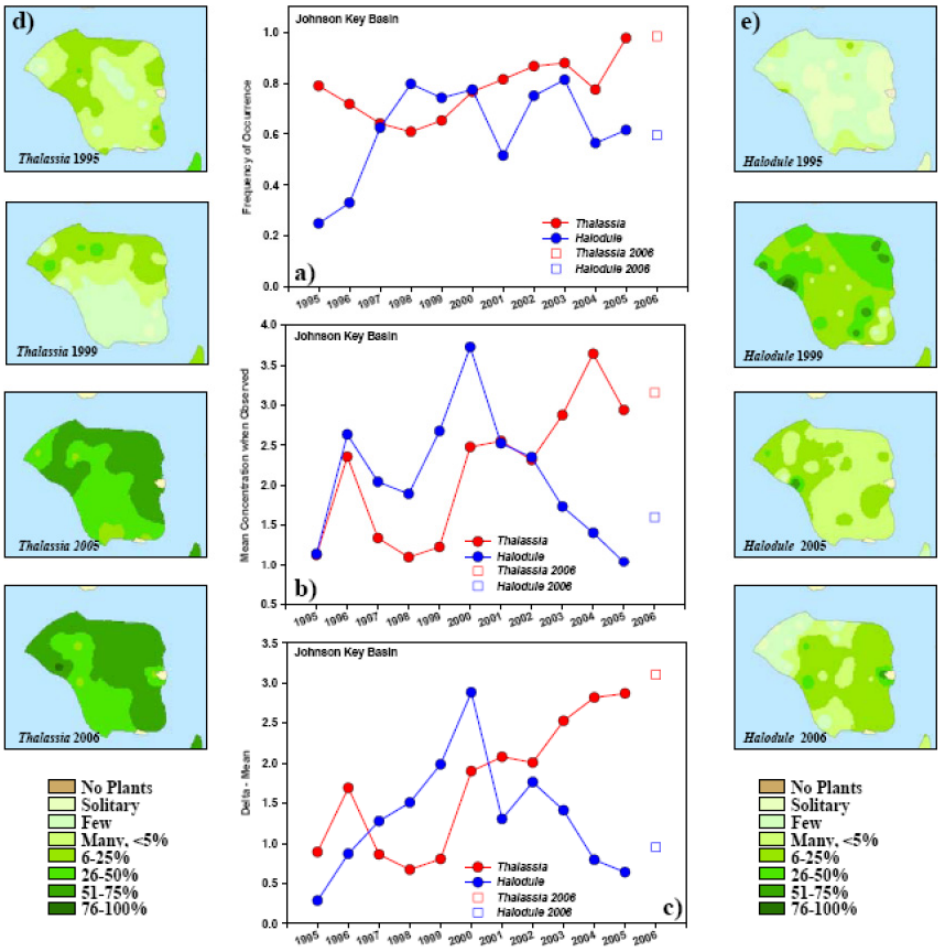
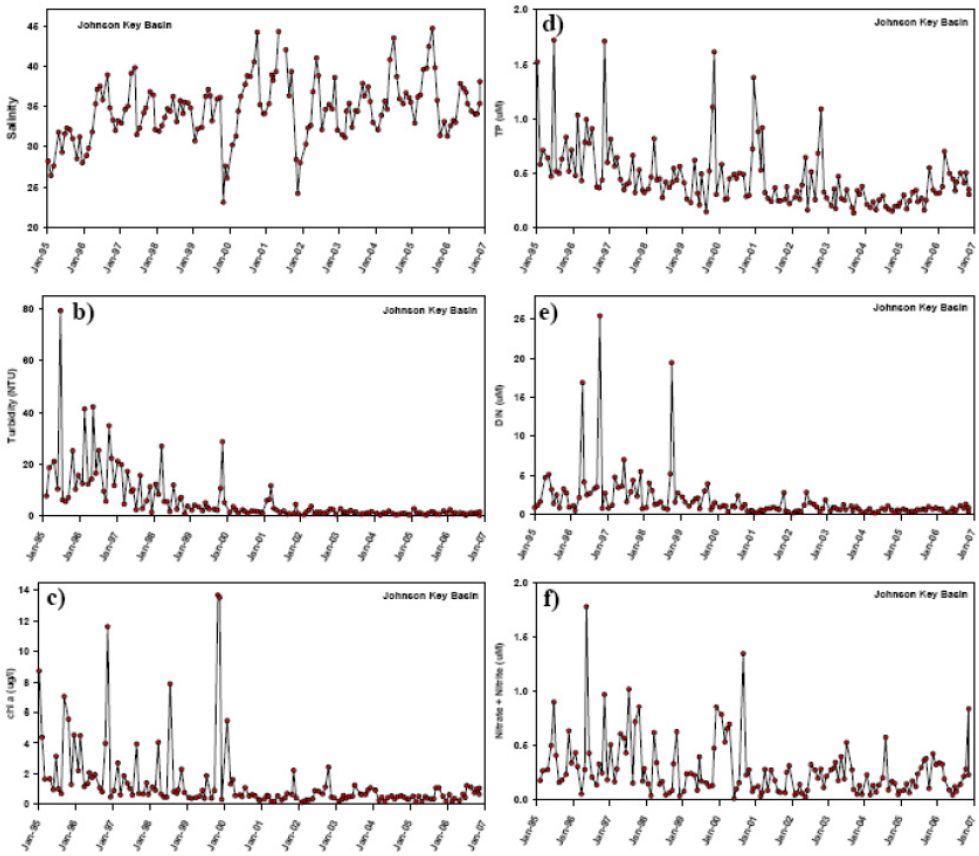



**Figure 7-24: (a) Frequency, (b) Concentration, and (c) Delta-density values for *Thalassia testudinum* and *Halodule wrightii* in Johnson Key Basin from spring 1995 to 2006 (open symbols indicate 2006 values). Contour plots illustrate the distribution and abundance of (d) *Thalassia* and (e) *Halodule* in 1995, 1999, 2005, and 2006 in Johnson Key Basin**

Comparing these temporal trends to Johnson Key Basin water quality (***Figure 7-25***), it was determined that the water quality trends are consistent with increasing light availability (lowered turbidity and water column chlorophyll *a*), increasing salinity, and decreasing water column nutrients (and one of the team's CERP hypotheses). The decreases in water column nutrients, turbidity, and chlorophyll *a* are also consistent with an overall increase in sediment stability, representing a positive feedback loop (another CERP hypothesis). In any case, there is little question that Johnson Key Basin is continuing to change as fish and invertebrate habitat in conjunction with water quality changes, and is doing so in a direction consistent with the SE module team's general hypotheses.



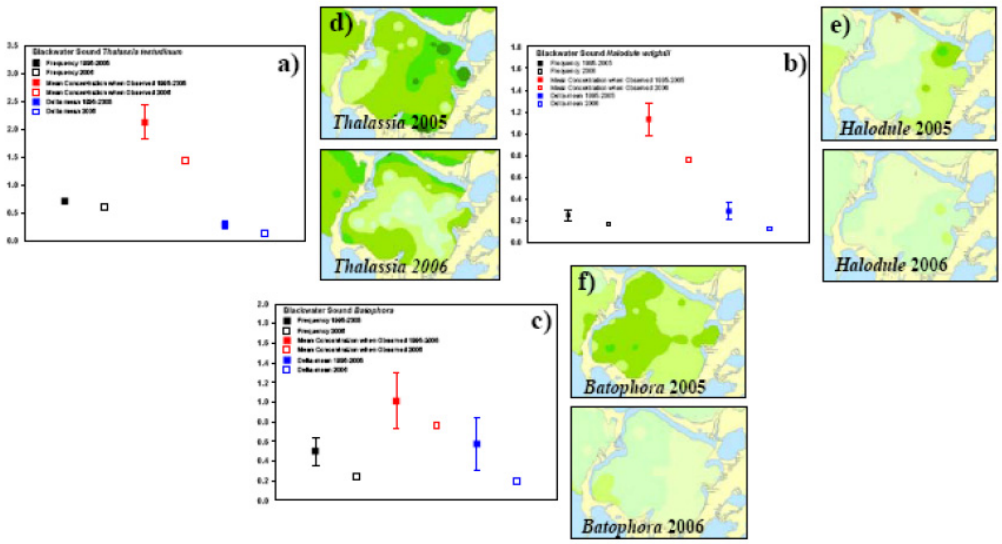

Data provided by the FIU SERC Water Quality Monitoring Network

Blackwater Sound

**Brief History-**A highly unusual algal bloom has persisted in northeastern Florida Bay and southern Biscayne Bay since fall 2005. Similar algal blooms have been observed in central and western Florida Bay, but never in eastern Florida Bay (Rudnick et al. 2006). Chlorophyll *a* concentrations (an indicator of the amount of algae in the water column) greatly exceeded values recorded during the previous fifteen years of water quality monitoring in this region (SFWMD/FIU Coastal Water Quality Monitoring Program). The algae bloom has been found to be mostly composed of blue-green algae, which are photosynthetic bacteria. Causes of the bloom are not certain, but may be related to at least two factors: 1) disturbance associated with road construction activity along U.S. Highway 1 between the Florida mainland and Key Largo (eighteen mile stretch); and 2) hurricane impacts from August through October 2005 (Hurricanes Katrina, Rita, Wilma). Highway construction has entailed the cutting and mulching of mangrove trees and soil tilling (mixing fresh mulch into the peat soil) and soil stabilization with injection of cement since May 2005. Hurricane disturbances included a large discharge of fresh water and P from the C-111 canal and the impact of high winds, waves, storm surge and abrupt salinity change on plants, soils, sediments, and ground water. The proximity of the blooms to both sides of U.S. Highway 1 (an area where blooms have not been previously

recorded) indicates the likelihood that the unique disturbance of road construction is involved as a cause of the bloom (see Rudnick et al. 2006 for complete summary).

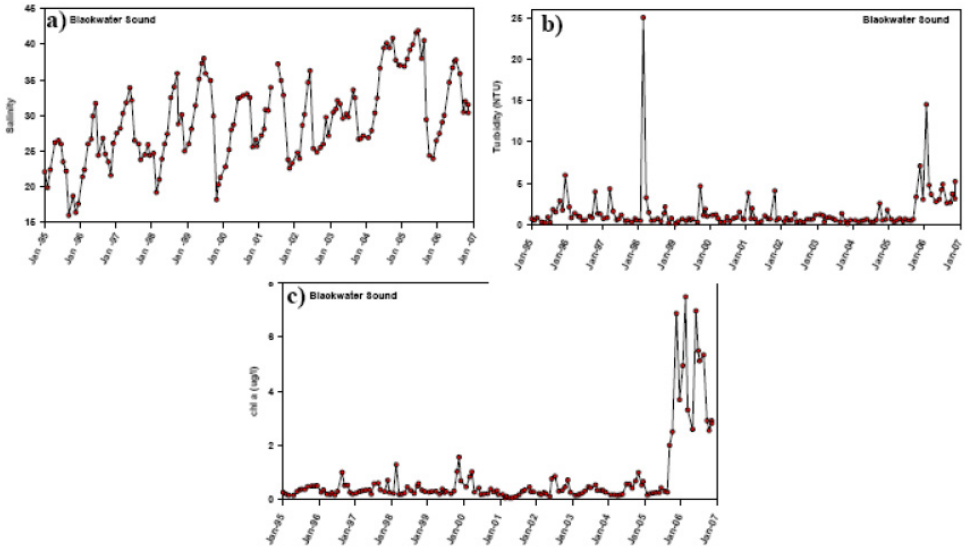
**Results of Analysis**-The 2006 Blackwater Sound SAV community was composed of sparse to moderate *T. testudinum*, sparse *H. wrightii*, and sparse *Syringodium* communities, and occasional macroalgal taxa (e.g., *Batophora*). Results of delta-mean analyses for *T. testudinum*, *H. wrightii*, and *Batophora* are illustrated in ***Figure 7-26***. Delta-density of all three taxa significantly differed in 2006 from the "baseline" condition, primarily as a result of significant declines in concentration.




(open symbols indicate 2006 values). Contour plots illustrate the distribution and abundance of d) *Thalassia*, e) *Halodule*, and f) *Batophora* in 2005 and 2006 in Blackwater Sound

**Figure 7-26: Comparison of 2006 spring SAV observations with mean spring observations and 95% confidence intervals from 1995-2005 (n=11) in Blackwater Sound for a) Thalassia testudinum, b) Halodule wrightii, and c) Batophora**

These declines are consistent with recent decreases light availability in Blackwater Sound due to substantial increases in both turbidity and chlorophyll *a* levels (***Figure 7-27***).




Data provided by the FIU SERC Water Quality Monitoring Network

**Figure 7-27: Time-Series Plots in Blackwater Sound for (a) Salinity, (b) Turbidity, and (c) Chlorophyll *a***

### 7.3.4 Discussion

Results of the 2007 SSR suggest that the methods adopted can detect changes in SAV from pre-CERP conditions when there is sufficient reference data, and that the present trends are consistent with hypothesized causal relationships. Partitioning the relative contribution of the causal factors will require judicious application of the mechanistic SAV model currently being developed for the SE module, as well as some sensitivity analyses. It will also require a considerable time series of data after CERP is implemented. Implicit is the quantitative understanding of the relationship between water management changes and both salinity and water quality. Developing these relationships throughout the SE module will almost certainly depend upon integrated water quality monitoring and modeling (including hydrodynamic and hydrologic). The present analysis suggests that it will require a decade or more of monitoring to obtain an adequate amount of data to detect and interpret ecosystem change related to CERP activities. Fortunately given the present implementation schedule, such a time series will be available if MAP monitoring is sustained as planned. There is a relatively close relationship between the SAV monitoring (and assessment) and the present IGs with respect to the SE but it is far from perfect. In fact the current MAP monitoring will not in itself be sufficient (unless modified and supplemented) to address some of the refined spatial goals discussed above. Explicit targeted transect sampling will be required, but a more troubling concern may be the need for modeling purposes to accurately assess biomass (rather than estimating it indirectly from regression relationships based on limited data). The SE module team has begun to address these concerns by establishing 15 permanent SAV monitoring transects in Florida Bay. These transects are co-located with long-term water quality monitoring stations of the FIU/SERC Coastal Water Quality Monitoring Network, and will be sampled twice each year. Cores for seagrass biomass will be collected in addition to BB cover estimates and seagrass shoot counts. Depending upon model sensitivity, additional

permanent transects may be required. It is probable that the IGs for SAV in the SE module will change in its next iteration. As a consequence, the MAP sampling will be updated in relatively short (two-four year) contract renewal intervals. The SE module team will have this opportunity, and will clearly need to take full advantage of the opportunity to, improve the match between the processes of model prediction and assessment.

Table 1. Basin-specific targets for Florida Bay seagrass status metrics nominally based on 10-year monitoring program record for each FATHOM basin. The zone within which each basin lies is indicated (NE=northeast, S= southern, W=western, C=central, TR=transition). Numbers in each cell represent the bound between "poor" and "fair" conditions left of the comma, and between "fair" and "good" conditions on the right. Zero and one are the lower and upper bounds for all ranges. Some targets were calculated based on shorter datasets.

| FATHOM Basin | Zone | Seagrass Extent (a) | Seagrass Density (b) | Species Dominance (c) | Target Species (d) |
|---|---|---|---|---|---|
| 5 | NE | 0.4, 0.6 | 0.1, 0.3 | 0.2, 0.5 | 0.1, 0.3 |
| 6 | NE | 0.4, 0.7 | 0.1, 0.2 | 0.2, 0.5 | 0.1, 0.3 |
| 7 | TR | 0.4, 0.7 | 0.1, 0.4 | 0.3, 0.7 | 0.1, 0.5 |
| 8 | NE | 0.5, 0.7 | 0.1, 0.3 | 0.2, 0.6 | 0.1, 0.3 |
| 9 | NE | 0.4, 0.6 | 0.1, 0.3 | 0.2, 0.7 | 0.1, 0.3 |
| 13 | TR | 0.4, 0.6 | 0.1, 0.4 | 0.3, 0.7 | 0.1, 0.5 |
| 14 | TR | 0.3, 0.6 | 0.1, 0.4 | 0.3, 0.5 | 0.1, 0.5 |
| 15 | NE | 0.4, 0.7 | 0.1, 0.3 | 0.2, 0.5 | 0.1, 0.3 |
| 21 | S | 0.6, 0.8 | 0.5, 0.7 | 0.1, 0.4 | 0.1, 0.4 |
| 22 | C | 0.6, 0.8 | 0.4, 0.6 | 0.2, 0.4 | 0.1, 0.4 |
| 24 | C | 0.6, 0.8 | 0.4, 0.6 | 0.2, 0.5 | 0.1, 0.4 |
| 32 | S | 0.6, 0.7 | 0.5, 0.7 | 0.1, 0.5 | 0.1, 0.4 |
| 34 | C | 0.6, 0.7 | 0.4, 0.6 | 0.2, 0.5 | 0.1, 0.4 |
| 37 | C | 0.6, 0.7 | 0.4, 0.6 | 0.2, 0.6 | 0.1, 0.4 |
| 38 | W | 0.6, 0.8 | 0.5, 0.8 | 0.2, 0.5 | 0.1, 0.3 |
| 47 | NE | 0.3, 0.5 | 0.1, 0.3 | 0.2, 0.6 | 0.1, 0.3 |

Table 2. Seagrass indicator metrics and ranges for zones.

| **Spatial Extent (a)** | **Northeast** | **Central** | **Western** | **Southern** | **Transition** |
|---|---|---|---|---|---|
| 🔴 | 0.0-0.4 | 0.0-0.6 | 0.0-0.6 | 0.0-0.6 | 0.0-0.4 |
| 🟡 | 0.4-0.6 | 0.6-0.8 | 0.6-0.8 | 0.6-0.8 | 0.4-0.6 |
| 🟢 | 0.6-1.0 | 0.8-1.0 | 0.8-1.0 | 0.8-1.0 | 0.6-1.0 |

| **Density (b)** | **Northeast** | **Central** | **Western** | **Southern** | **Transition** |
|---|---|---|---|---|---|
| 🔴 | 0.0-0.1 | 0.0-0.6 | 0.0-0.6 | 0.0-0.5 | 0.0-0.1 |
| 🟡 | 0.1-0.6 | 0.6-0.8 | 0.6-0.8 | 0.5-0.7 | 0.1-0.5 |
| 🟢 | 0.6-1.0 | 0.8-1.0 | 0.8-1.0 | 0.7-1.0 | 0.5-1.0 |

| **Species Dominance (c)** | **Northeast** | **Central** | **Western** | **Southern** | **Transition** |
|---|---|---|---|---|---|
| 🔴 | 0.0-0.2 | 0.0-0.2 | 0.0-0.2 | 0.0-0.1 | 0.0-0.1 |
| 🟡 | 0.2-0.5 | 0.2-0.5 | 0.2-0.5 | 0.1-0.4 | 0.1-0.6 |
| 🟢 | 0.5-1.0 | 0.5-1.0 | 0.5-1.0 | 0.5-1.0 | 0.6-1.0 |

| **Target Species (d)** | **Northeast** | **Central** | **Western** | **Southern** | **Transition** |
|---|---|---|---|---|---|
| 🔴 | 0.0-0.1 | 0.0-0.1 | 0.0-0.1 | 0.0-0.1 | 0.0-0.1 |
| 🟡 | 0.1-0.4 | 0.1-0.4 | 0.1-0.3 | 0.1-0.3 | 0.1-0.5 |
| 🟢 | 0.4-1.0 | 0.4-1.0 | 0.3-1.0 | 0.3-1.0 | 0.5-1.0 |

Table 3. Lookup table of decision gates for Abundance Axis A metrics for current status for Florida Bay, aggregating Extent and Density Indicator at zone scale (e.g. green + yellow = yellow).

| Case | Extent Metric (a) | Density Metric (b) | Abundance Axis A |
|---|---|---|---|
| 1 | 🟢 | 🟢 | 🟢 |
| 2 | 🟢 | 🟡 | 🟡 |
| 3 | 🟡 | 🟢 | 🟡 |
| 4 | 🟡 | 🟡 | 🟡 |
| 5 | 🟡 | 🔴 | 🔴 |
| 6 | 🟢 | 🔴 | 🔴 |
| 7 | 🔴 | 🟢 | 🔴 |
| 8 | 🔴 | 🟡 | 🔴 |
| 9 | 🔴 | 🔴 | 🔴 |

Table 4. Lookup table of decision gates for Species Axis B metrics for current status for Florida Bay, aggregating Dominance and Target Species Indicator at zone scale (e.g. green + yellow = green).

| Case | Dominance Metric (c) | Species Metric (d) | Species Axis B |
|---|---|---|---|
| 1 | 🟢 | 🟢 | 🟢 |
| 2 | 🟢 | 🟡 | 🟢 |
| 3 | 🟡 | 🟢 | 🟢 |
| 4 | 🟡 | 🟡 | 🟡 |
| 5 | 🟡 | 🔴 | 🟡 |
| 6 | 🟢 | 🔴 | 🟡 |
| 7 | 🔴 | 🟢 | 🟡 |
| 8 | 🔴 | 🟡 | 🟡 |
| 9 | 🔴 | 🔴 | 🔴 |

Table 5. Lookup table of decision gates for Carrying Capacity Axis C metrics for current status for Florida Bay, aggregating Abundance and Species Axes (A and B) at the zone scale (e.g. green + yellow = green).

| Case | Abundance Axis A | Species Axis B | Carrying Capacity Axis C |
|---|---|---|---|
| 1 | 🟢 | 🟢 | 🟢 |
| 2 | 🟢 | 🟡 | 🟢 |
| 3 | 🟡 | 🟢 | 🟢 |
| 4 | 🟡 | 🟡 | 🟡 |
| 5 | 🟡 | 🔴 | 🟡 |
| 6 | 🟢 | 🔴 | 🟡 |
| 7 | 🔴 | 🟢 | 🟡 |
| 8 | 🔴 | 🟡 | 🟡 |
| 9 | 🔴 | 🔴 | 🔴 |