The Ecological Impact and Geographic Extent of Freshwater Releases from Lake Okeechobee into the Caloosahatchee River/Estuary

Deliverable 5, Final Report

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Executive Summary

The optical and chemical properties of water from Lake Okeechobee and their contributions to the coastal waters were evaluated under periods of continuous Lake Okeechobee discharges, pulsed Lake Okeechobee discharges, pulsed basin discharges and continuous basin discharges. The purpose of these investigations was to determine the water quality tolerance ranges for Submerged Aquatic Vegetation (SAV) and whether the source of freshwater discharge makes a difference to SAV ecological success. Light attenuation coefficients (Kd) were above published limits for sustaining seagrass populations during continuous Lake Okeechobee discharges and continuous basin discharges. Light attenuation coefficients in the *Vallisneria americana* regions near Beautiful island were exceeded those required for sustaining seagrasses during all periods and may provide an explanation for the slow recovery of SAV in this region. Lake Okeechobee discharges carried high loads of suspended particles, which scattered light and increased Kd. The effect of Lake Okeechobee discharges on K_{Blue} (433-453 nm) was evident when both TSS loads and K_{Blue} were correlated to 4-day averaged discharge volumes. There was a short-term response of seagrasses to freshwater discharges (both Lake Okeechobee and Basin) as evidenced in significantly slower growth rates near the mouth of the Caloosahatchee compared to Pine Island Sound. Density depth distributions of SAV were obtained by measuring spectrally-resolved Kd in San Carlos Bay and employing a predictive model based on SAV physiology. According to the model, measured Kd supported low density seagrasses at depths greater than 1 m. The model predictions were very close to actual depth distributions and can be used to determine how to improve SAV habitats. Based on the model, there would be improved SAV

densities at depths greater than 1 m if light attenuation targets were set for San Carlos Bay at 0.7. While most of the increases in Kd during periods of Lake Okeechobee discharges were caused by high TSS loads, increases in Kd during periods of basin discharges were caused by colored dissolved organic matter (tannins; cDOM). Water in the main stem of the Caloosahatchee River/Estuary had distinctive fluorescence emission spectra with upstream samples having greater blue light absorption features and distinct emission features. The ratio of emission peaks plus the chemical fingerprints of water samples provides the ability to assess whether the source of water is important to SAV ecological success. Chemical composition of water samples from Beautiful Island and San Carlos Bay shared 50% of the chemical composition, while 50% of the chemistries in Gulf of Mexico samples were unique. A complete analysis of the collected data was not possible within the limited duration of the contracted work, however, several significant new findings with regard to the source of freshwater discharges and SAV success were elucidated.

Statement of Problem

While many agree that there are few alternatives in the short-term, the current water management plan is impacting the water quality and critical resources like SAV and associated fauna in the Caloosahatchee River and associated estuary. Restoration of historical water flow conditions is the intended outcome of CERP project implementation that will dramatically alter the current quantity and sources of water in the river and estuary. Collectively these plans raise several key overarching questions regarding the management of water and water quality in South Florida.

- What are the impacts of Lake Okeechobee releases on water quality in the Caloosahatchee River and estuary?
- How will CERP implementation be manifested in water quality parameters in the Caloosahatchee River and estuary?
- What are the impacts of anthropogenic versus natural factors influencing water quality in the Caloosahatchee River and estuary?

Work Summary

The contract focused on the first stated question above to answer a specific set of questions (provided below) related to impacts from Lake Okeechobee discharges utilizing new approaches and technologies for water quality assessment and ecological response. It is not possible to examine lake discharges exclusively without considering basin inputs in the Caloosahatchee River/Estuary system. Therefore, we addressed linkages between water quality parameters (optical, chemical and physical properties) and Submerged Aquatic Vegetation (SAV) ecological success, and exploited the understanding and insights gained to improve water management practices for the protection and preservation of critical SAV habitat.

The specific questions addressed included:

- What are the effects on water clarity related to SAV light and growth requirements?
- What are the short- and long-term impacts of Lake Okeechobee releases on SAV along the salinity gradient of the estuary?
- What are the sources of the responsible constituents (i.e., Lake Okeechobee, watershed runoff) and what portion did each contribute to light attenuation and other water quality parameters that impact SAV?
- Does the water source a difference to SAV ecological success?
- What is the critical level of light attenuation and exposure time that dictates SAV decline within two SAV regions/beds in the Iona Cove region, San Carlos Bay, Matlacha Pass, and Lower Charlotte Harbor?
- What are the spatial (geographical extent) and duration impacts of Lake Okeechobee releases on SAV in relation to discharge volumes and periodicity?
- What are the critical linkages between in-water optical properties, a feature of water quality, and water column chemistry and how do these linkages control and/or predict SVA success?

Work Findings and Results

Below responses to each of the questions above were addressed in terms of the findings from the study. Below each question is bulleted the major findings and/or conclusions obtained from the research product.

(1) *What are the impacts on water clarity related to SAV?*

- Total light attenuation (K_{PAR} and K_{BLUE}) in the system exceeded (3 to 6 times) those required for SAV growth during periods of sustained high level (> 2,000 cfs) Lake Okeechobee releases
- Pulsed releases < 2,000 cfs dramatically improved the light environment for SAV in San Carlos Bay, but there was little change near Beautiful Island.
- The Caloosahatchee River system has very high levels of blue light attenuation from both particle scattering and blue light absorbing DOM, a unique property in estuaries
- Light attenuation (K_{PAR}) approach ranges that would support SAV growth, however, K_{Blue} remained unusually high
- Blue light attenuation (K_{Blue}) is a critical water column feature in SW Florida and a critical component of water quality management

The light attenuation (K_{PAR} and K_{BLUE}) contour maps show water with high light attenuation was found through-out the River down-stream from the Lake, and closer to the mouth of the Caloosahatchee and the source of Lake releases (Figure 1a, 1b, 1c, and 1d). January through May 2006 was one of the driest periods on record for the region, therefore, the input of freshwater into the system was exclusively from Lake Okeechobee releases during this period (Figure 1a, 1b). We obtained in-water attenuation coefficients (K_{PAR}), which is a measure of the total light available in the water column (overestimates

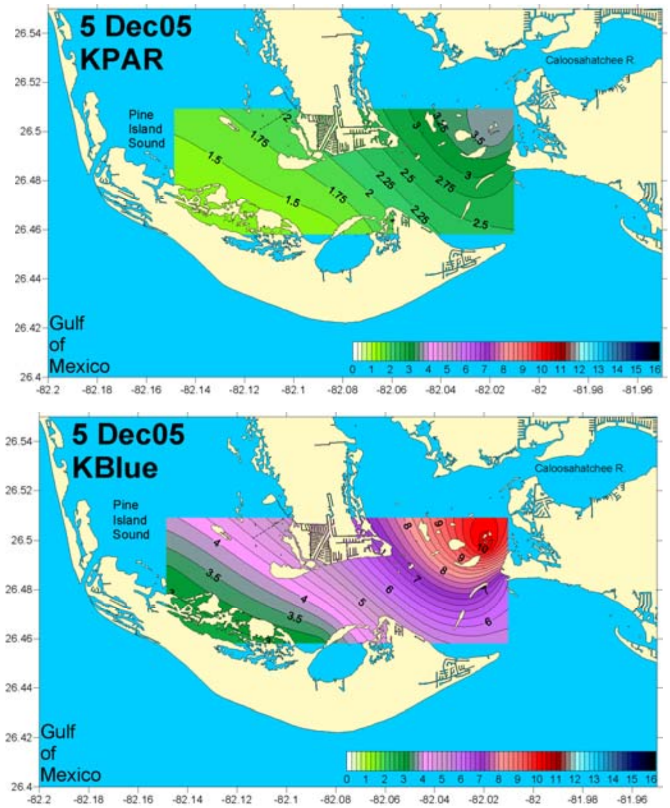

Figure 1a. *Lake continuous*, In water light attenuation coefficients (K) for Photosynthetically Active Radiation (PAR, 400-700 nm) and blue light (433-453 nm).

light available to support SAV growth) and spectrally resolved $K_{Blue,}$ which provided a direct measure of light available to support the growth and photosynthesis of seagrass species. Light attenuation coefficients measured in Lake Okeechobee were high (3.4 to 4.4), as expected.

Under continuous lake discharges above 2,000 cfs, water quality conditions were poor in the San Carlos Bay region (Figure 1a). Light attenuation coefficients in the Photosynthetically Active Region (PAR) ranged from 1.7 to 3.2 in areas with extensive seagrass habitats; these values are 3 to 6 times higher than those that would support optimal seagrass growth. However, under pulsed discharges of less than 2,000 cfs, conditions improved significantly in San Carlos Bay to K_{PAR} values between 0.75 and

0.80 (Figure 1b). However, water column light attenuation conditions in the *V. americana* regions adjacent to Fort Myers were very poor (K_{PAR} 3-4).

There were large differences in light attenuation coefficients when measured as the total visible spectrum (PAR = 400-700 nm) and only for the blue portion of the visible spectrum (433-453nm); the latter is the only light available to support seagrass growth. The importance of measuring the quality of light in the management of seagrass resources is discussed in more detail in response to Question 2, however, the relatively high blue light attenuation in the Caloosahatchee River system is a unique to Southwest Florida and to our knowledge higher than anywhere in the continental United States.

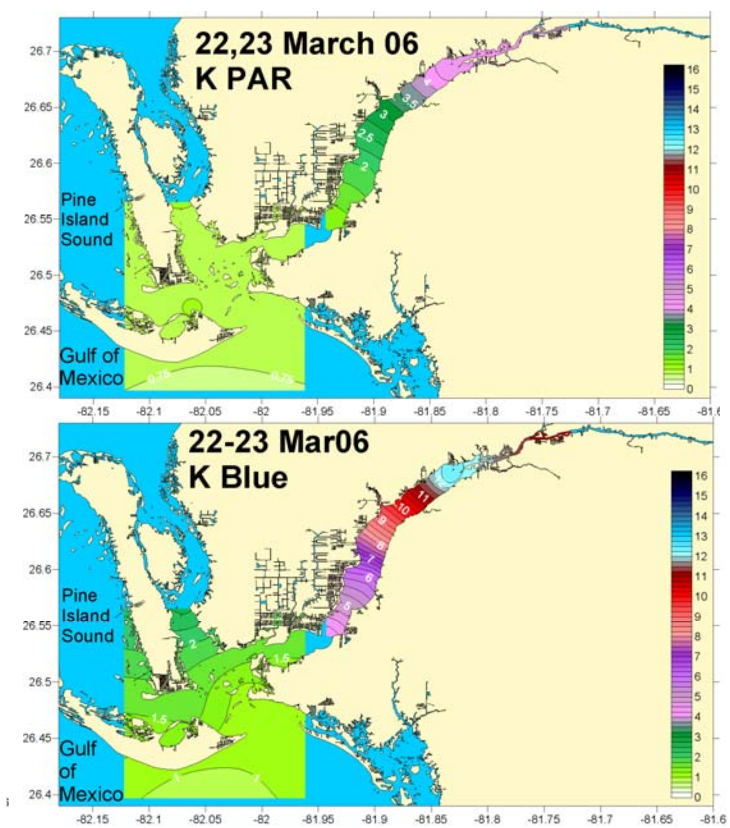

Figure 1b. *Lake pulsed*, In water light attenuation coefficients (K) for Photosynthetically Active Radiation (PAR, 400-700 nm) and blue light (433-453 nm) .

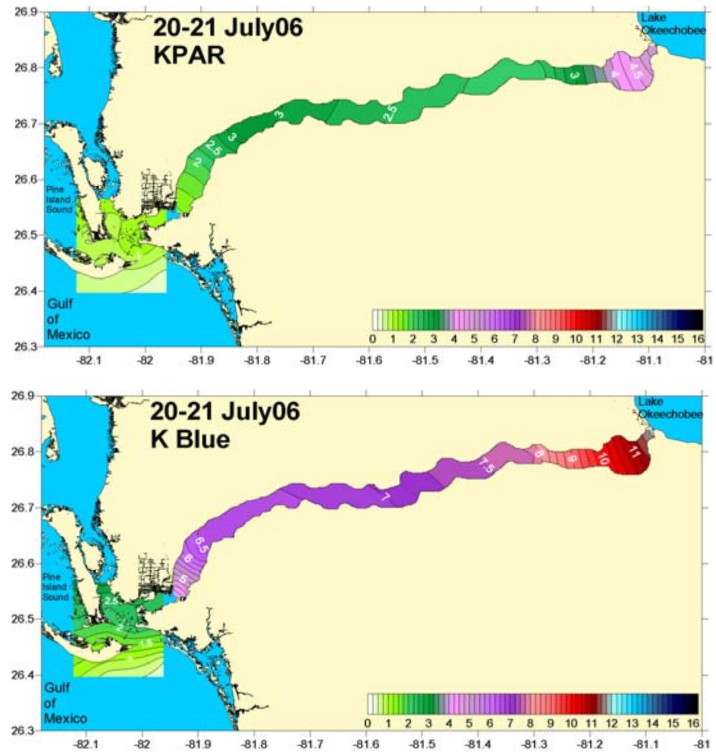

Figure 1c. *Basin pulsed*, In water light attenuation coefficients (K) for Photosynthetically Active Radiation (PAR, 400-700 nm) and blue light (433-453 nm).

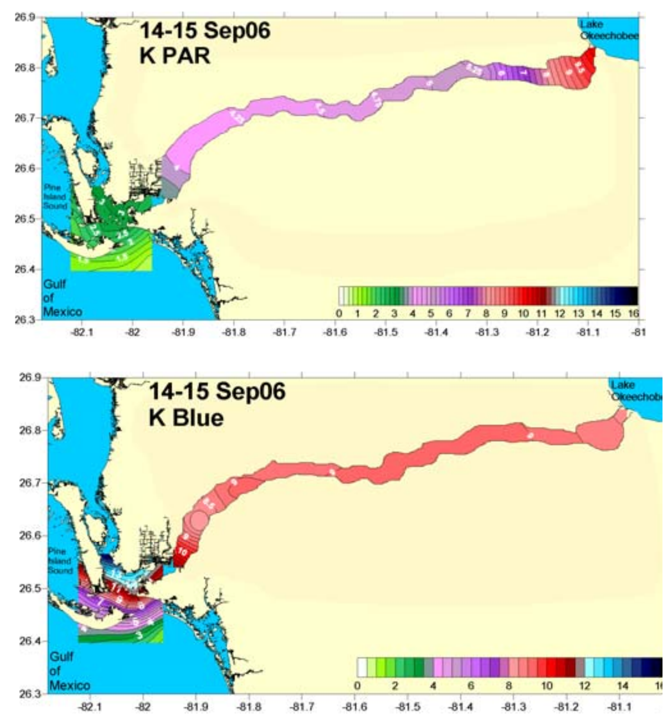

Figure 1d. *Basin continuous*, In water light attenuation coefficients (K) for Photosynthetically Active Radiation (PAR, 400-700 nm) and blue light (433-453 nm) .

It is clear that information about blue light attenuation in SW Florida waters will vastly improve predictions of seagrass ecological success and allow for improve water management practices. As an example of why the quality of light is important in the Caloosahatchee estuary, a correlation between lake releases and light attenuation in PAR (400-700 nm) and blue light were compared in Figure 2. K_{PAR} and K_{Blue} were correlated to the four-day averaged flow rates from S-79 (Fig. 2). Blue light attenuation had significantly greater r-squared values than PAR attenuation. Therefore, lake releases are disproportionately attenuating light available to seagrasses compared with light available to other primary producers, particularly phytoplankton and macrophytic algae. This may help explain high macroalgal biomass measured in the San Carlos Bay region (Bartleson, personal communication) because macroalgae are able to use a broader spectral range of light for photosynthesis (particularly the green portions of the spectrum) than SAV and are not light limited under conditions that light-limit seagrasses. One of the manifestations of the light limitation of seagrasses in this system is the dramatic reduction in blade width in areas with high K_{PAR} values (data not shown).

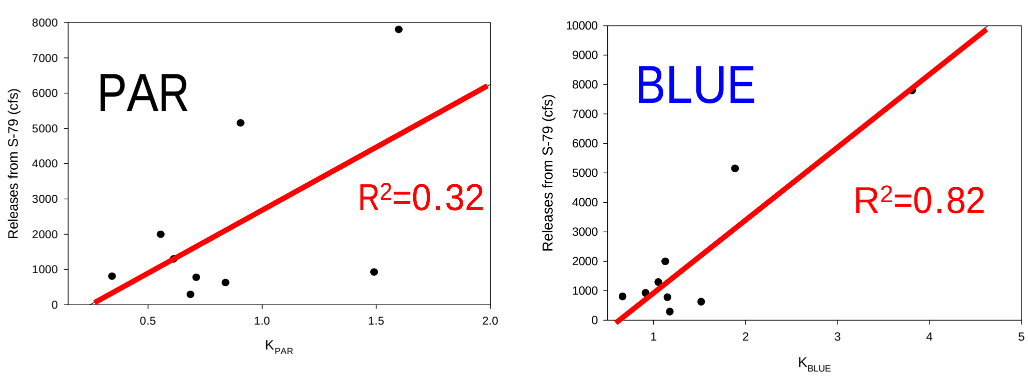

Figure 2. Correlation of discharge volume (4 day average) versus light attenuation.

During the dry period from January through May 2006, there were greater impacts from Lake Okeechobee discharges on blue light attenuation than on PAR attenuation. This can be explained in part by the preferential scattering of blue light by total suspended solids derived from Lake Okeechobee and by preferential blue light absorption by DOM as discussed above. Evidence for the scattering explanation comes from the significant correlation between total suspended solids and 4 day averaged flow from S-79 during the dry period. The total suspended solid loads in Lake Okeechobee were 5-6 times greater than in the coastal waters, suggesting a dilution of total suspended solids with the clear coastal waters (Fig. 3). During the same time period, there were no significant correlations between chl a concentrations and cDOM concentrations and flow. The feature of blue light scattering by total suspended solids described above has been described for many coastal and estuarine waters (Kirk – *Light in Aquatic Systems*). The TSS load from any given location is a useful indicator of the amount and impact of Lake-specific discharges on the downstream resources.

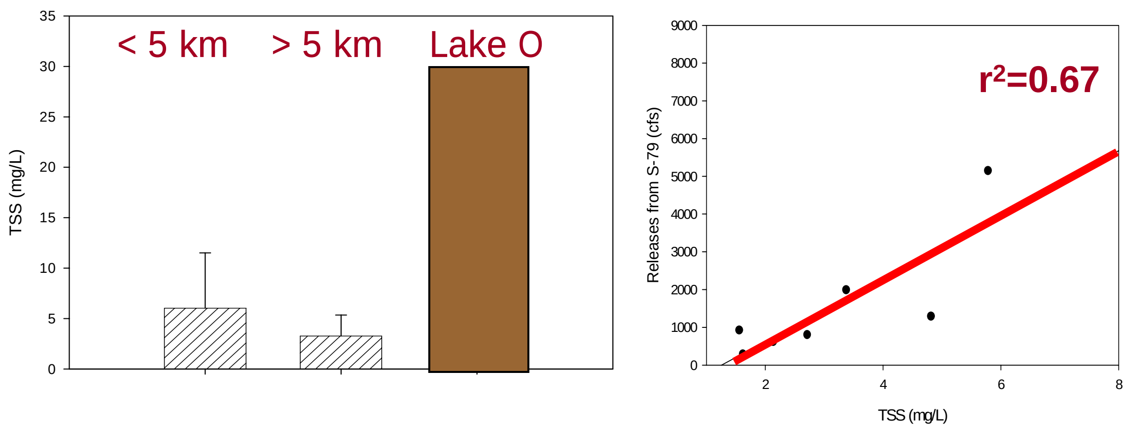

Figure 3. a.Total suspended solid loads in Lake Okeechobee and the distribution of TSS into the coastal waters. b. Correlation between discharge volume (4 day average) versus TSS loads during a period of Lake discharges and no basin discharges.

During the seasonal wet period from June through August, light attenuation was within ranges that would support SAV growth in San Carlos Bay and in the *V. americana* region adjacent to Fort Myers. However, there remained disproportionately high blue light attenuation during this period (Figure 1c). Light attenuation was highest during sustained high volume basin discharges that occurred in September 2006 (Figure 1d) following Tropical Storm Ernesto.

(2) *What are the short- and long-term impacts on the SAV along the salinity gradient of the estuary?*

- Long term seagrass abundance and distribution studies were supplemented to include monthly monitoring in San Carlos Bay
- Short-term impacts of seagrass growth in response to freshwater discharges, both Lake Okeechobee and basin, were realized in reduced growth, reduction in shoot density, and reduction in blade width
- The SAV growth impacts were greatest in response to the high level Lake Okeechobee discharges and high volume basin discharges associated with Tropical Storm Ernesto
- In vivo leaf analyses provides a rapid mean to assess light stress in SAV, as reflected in Chl *a*:Chl b ratios and Chl:carotenoid ratios

Long term impacts are currently being measured, in part by funding from this study and ongoing studies funded by SFWMD to monitor seagrasses in the River and in San Carlos Bay. In addition, long-term impacts are being measured by alternate year

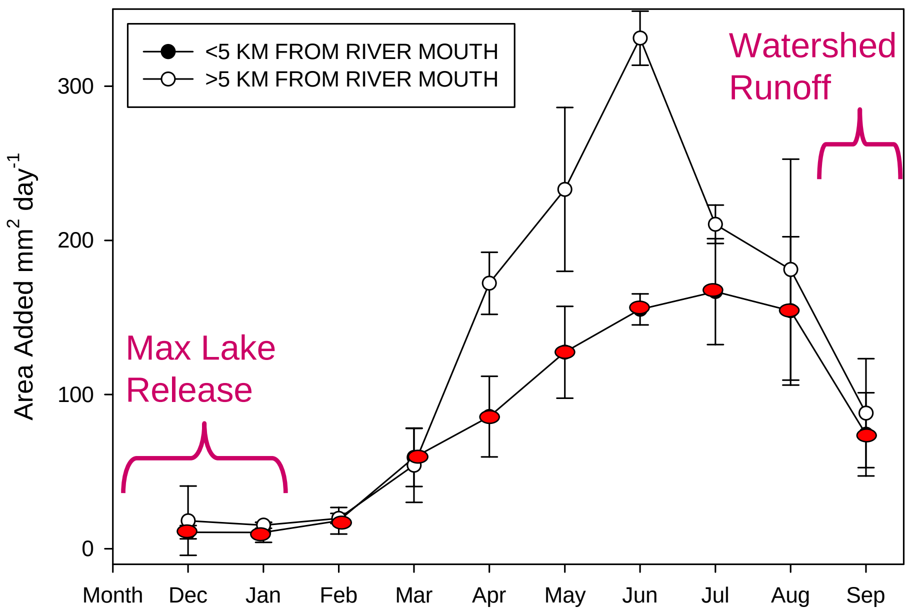

Figure 4. Seagrass growth rates in San Carlos Bay. River mouth is designated as Intercoastal Waterway # 101.

aerial monitoring of the extent of seagrass beds in the estuarine system being conducted by SFWMD.

Short-term impacts were directly addressed in this study by determining the specific in-water light regimes and the immediate SAV response to changes in the light fields in the Iona Cove and San Carlos Bay filed sites. Growth performance of *Thalassia testudinum* was monitored from Dec 05 through Sep 06. Data were analyzed by the distance from Intracoastal Waterway marker # 101; there were 4 sites < 5 km from marker 101 and 3 sites > 5 km from marker 101. Growth was significantly impacted by periods of high Lake Okeechobee discharges and the subsequent pulse released discharges (Fig. 4). Plants at sites < 5 km from ICW 101 had significantly narrower blade widths, an indication of light limitation. Light attenuation data for this period

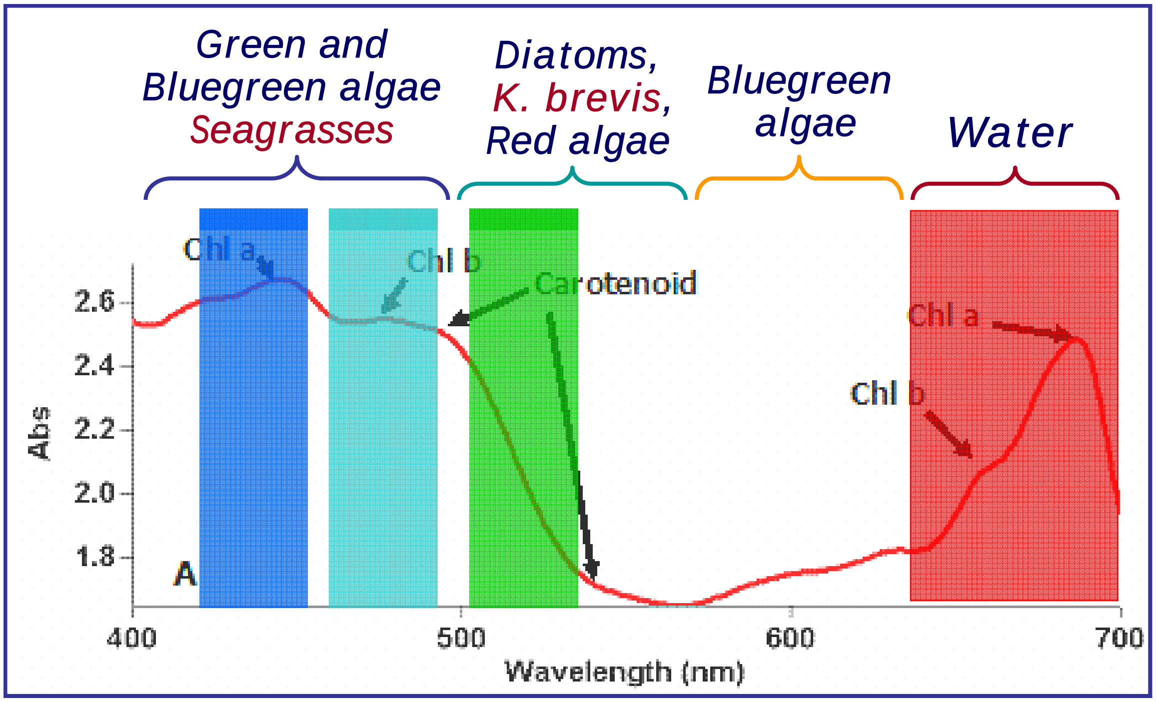

Figure 5. In vivo absorption of *Thalassia testudinum* leaf collected in San Carlos Bay. Boxes denote bands of color and the position relative to the absorption characteristics of seagrasses. Text denotes the capabilities of other primary producers to use parts of the photosynthetically available spectrum.

suggested that conditions were acceptable for SAV in the estuary during the period of maximum growth (March 05 to June 05), but the growth rates near the mouth of the estuary were 0.5 X slower than plants > 5 km from the mouth. This suggests that the impacts of high volume Lake Okeechobee discharges on SAV growth were realized after water quality conditions had improved.

Pigmentation of photoautotrophic marine organisms must respond quickly to changes in the amount of light available in order to acclimate to light fields that change on short time scales. Photosynthetic pigments in seagrass leaves were characterized by applying a 4^{th} derivative analysis to *in vivo* absorption spectra of whole leaves. As expected, *Thalassia testudinum* leaves preferentially absorbed light from 400 – 525 nm and 650 – 700 nm (Fig. 6). Given that red light is attenuated immediately by water, only blue light is available for photosynthesis in SAV. There is strong *in vivo* absorption of *T. testudinum* leaves in the range 500-525 nm due to carotenoids, but these pigments do not contribute to photosynthesis but do serve as photoprotectants for the photosynthetic machinery and DNA.

Losses of seagrasses in coastal estuaries have heightened the need for rapid metrics of physiological stress, particularly light limitation. Preliminary analysis indicated that the *in vivo* Chl *a*:Chl *b* ratios increased significantly in response to high light attenuation in the water column associated with high volume freshwater discharges. Across the same spatial gradient, Chl *a*: carotenoid ratios decreased. These observations indicate a decrease in photoprotection and an increase in chlorophyll b production in response to light limitation. These observations are fully consistent with earlier studies on light stress in seagrasses.

(3) *What are the sources of the responsible constituents and what portion does each contribute to light attenuation (i.e., Lake Okeechobee, watershed runoff, wastewater discharge, and marine/tidal inflow)?*

- Total suspended solids (TSS) and colored dissolved organic matter (cDOM) levels decrease the further away from Lake Okeechobee source in the River/estuary system during sustained Lake releaase; this gradient was not observed during pulsed releases
- Decreases in TSS in the coastal water may be contributed by dilution, sedimentation and/or advective transport

- During pulsed Lake Okeechobee discharges, no significant reduction in cDOM was observed
- Both cDOM and TSS loading contributed to blue light attenuation in the system
- It is possible to differentiate between Basin and Lake discharges in terms of those water quality parameters which scatter or absorb light used by SAV.

To predict the SAV responses to several water management scenarios, observations of the properties that effect light attenuation are summarized in Table 1. The three measured parameters are known to influence light attenuation in the water column (Kirk); total suspended solids (TSS), colored dissolved organic matter (*gelpstoffs*, yellow substances, or cDOM), and chlorophyll a concentrations. As mentioned previously, the TSS was the dominant component affecting light attenuation in the coastal waters. It is uncertain whether TSS loads are diluted or whether the decrease TSS at greater distances from the source (Lake Okeechobee) represents sinking and deposition of TSS to the bottom. There was no evidence of increased algal blooms (chl a) associated with the continuous discharge. There was a decrease in cDOM absorption at greater distances from the source (Lake Okeechobee) suggesting that cDOM in addition to TSS loads were contributing to light attenuation in the coastal waters are derived from Lake water releases.

During periods of pulsed discharges from Lake Okeechobee, lower levels of TSS load were observed at greater distances from the source. However, there was not a significant decrease in cDOM absorption along the same gradient. There was also no

Table 1. Absorptive constituents of water under four different water discharge periods. Lake continuous was the period from December 05 to January 06; lake pulsed was the period from February 06 to May 06; basin pulsed was the period between June 06 and August 06; basin continuous was in September 06. Abbreviations are as follows: cDOM, colored dissolved organic matter (absorbance at 410 nm), TSS, total suspended solids (mg/L), Chl a, chlorophyll a (μg/L).

Location	cDOM	TSS	Chl a
	Lake continuous		
Lake Okeechobee	6.88	28.6	11.63
< 5 km	3.84	5.75	2.09
>5 km	2.19	3.96	2.49
	Lake pulsed		
Lake Okeechobee	6.88	28.6	11.63
< 5 km	2.19	6.06	1.46
>5 km	1.98	2.81	1.42
	Basin pulsed		
Lake Okeechobee	6.88	28.6	11.63
< 5 km	1.73	1.69	3.49
>5 km	1.86	1.95	4.56
	Basin continuous		
Lake Okeechobee	6.88	28.6	11.63
< 5 km	12.92	1.89	12.17
>5 km	7.85	1.69	13.56

evidence that algal blooms were associated with pulsed discharges, although the Chl a concentrations in Lake Okeechobee were high (11.63 μg/ml).

Interestingly, the gradient of TSS and cDOM observed under sustained Lake discharge periods was not evident during periods of pulsed basin discharges. This represents a fundamental difference between the sources (Lake vs. Basin) of the responsible constituents that contribute to light attenuation in the system. During pulsed Basin discharges, there were low TSS loads and low cDOM absorption values in the coastal waters. The concentration of chlorophyll a increased during this period, suggesting that basin inputs were contributing to increased concentrations of phytoplankton. It is not known whether these are due to the input of nutrients from the basin or because of the increased incident irradiation associated with lower TSS loads or warmer temperatures coincident with the onset of the pulsed basin period.

Finally, additional evidence of the ability to differentiate between sources was obtained from the observation of significantly higher cDOM absorption during a period of continuous high volume basin inputs after Tropical Storm Ernesto. The contribution of TSS was negligible; however the chlorophyll a concentrations were significantly higher than found any other sample from the coastal waters suggesting the presence of a small algae bloom in the coastal waters. The collapse and dissolution of algal blooms generate significant additional cDOM as well as POM. However, the contribution of an algal bloom to the cDOM in this system is not known and requires additional analysis and there are characteristic markers that could be obtained from DART-TOF-MS.

(4) *Does the source of water make a difference to SAV condition?*

- The optical properties of the water column and of colored dissolved organic matter provide important markers of watershed and Lake inputs
- Optical markers of bacterial production/recycling capacity are under development
- Basin and Lake Okeechobee sources have different impacts on blue light attenuation in the system

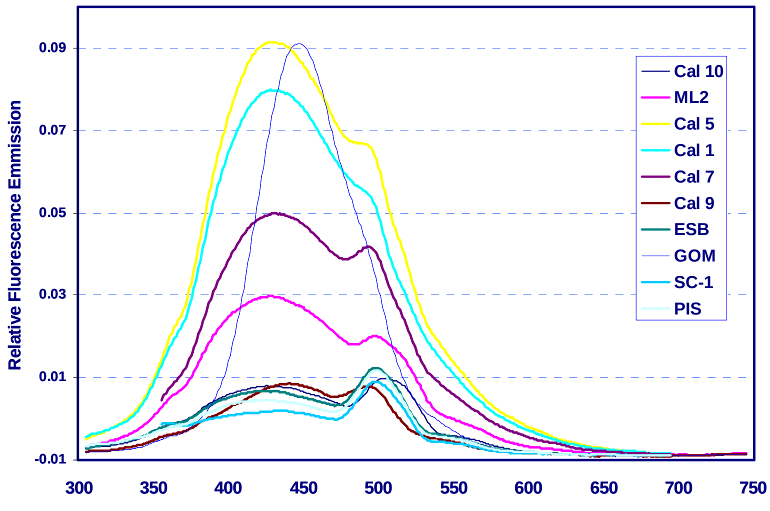

Figure 6. Fluorescence emission spectra of water samples from the main stem of the estuary collected in July 2006. Site names correspond to the map provided.

There were characteristic fluorescence emission characteristics from different watershed sources and at locations in the Caloosahatchee River/Estuary. Initial examinations of water samples suggested that a major component of the blue light absorbing materials derived from Lake Okeechobee and the basin are high in chemical species characteristic and present in high levels in bacteria (bacterial flavins). A significant ($r2 = 0.52$, $p<0.01$) correlation between the fluorescence emission ratios and the in-water blue light attenuation (K_{Blue}) was found to support this conclusion (not shown). Optical properties of DOM were analyzed from a variety of locations throughout the River/estuary system (Fig. 6). Significant blue-green emission (ca. 500 nm) was observed that we believe will prove to be a significant marker of bacterial production relating DOM and POM recycling and loading. Two dominant fluorescence emission bands were observed; one broad peak at ca. 430 nm and a shoulder or peak with maxima ranging between 500 and 530 nm. These two peaks were present in all of the DOM samples analyzed except water from the Gulf of Mexico collection site (e.g., 4 miles offshore) which showed only a single emission peak at 450 nm. The 430:500-530 nm ratios are greater than 1.0 in the freshwater reaches of the watershed and less than 1.0 in estuarine waters. Though the full explanation for this clear pattern is not known at this time, we believe that high levels of microbial processing of DOM polyphenolics and other organic matter is the most significant contributor to the greater than 1 ratios in the freshwater sites. The data reflected a large-scale gradient of chemical composition in the study area, whose inherent optical characteristics are useful indicators of water quality and the sources of watershed inputs. Inputs that appear to fuel microbial processes that may play a major role in algae bloom dynamics. Collectively, these results demonstrate that the source of water does make a difference to blue light attenuation and SAV success.

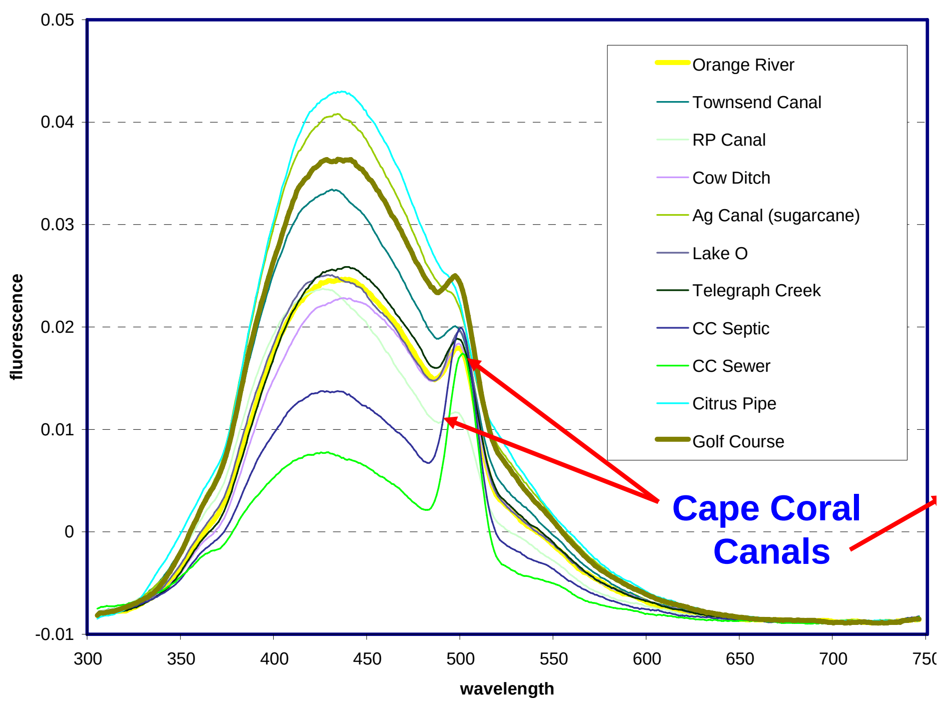

Figure 7. Fluorescence emission spectra of water samples from potential watershed sources.

To track the source of watershed inputs in the Caloosahatchee River/ Estuary system, several samples of potential watershed inputs were collected and similar fluorescence analyses as described above was performed on potential watershed inputs (Fig. 7). The samples included: a cow ditch, Cape Coral (CC) canals, citrus outfalls, and golf course runoff. Other canals and creeks which drain into the main stem of the Caloosahatchee River/Estuary system were also included. The 430:500-530 nm fluorescence emission ratios for these potential watershed inputs are summarized in Table 1. Notable in the data are the low ratios (e.g., < 1) obtained from water samples from the canal network in Cape Coral, while agricultural runoff sites (citrus, sugarcane) and a retention pond had the highest ratios (>1.7). There was separation of the fluorescence emission characteristics of the DOM of watershed inputs indicating that this parameter can be used to distinguish different watershed inputs and begin to quantity their respective contributions to the Caloosahatchee River/Estuary system. As determined previously, DOM abundance, chemical properties (see below) and optical features have significant impacts the light requirements to support healthy SAV. Therefore, management targets based on specific loading sources from the watershed can be used to sustain healthy SAV meadows. .

(5) *What is the critical level of attenuation and exposure time that are related to SAV decline and total defoliation at discrete depths within two general SAV regions/beds (V. americana near Beautiful Island and Halodule rightii/Thalassia testudinum in San Carlos Bay) in the Iona Cove region, and seagrasses in San Carlos Bay, Matlacha Pass, and Lower Charlotte Harbor)?*

- Use of the SAV model reveal that the light attenuation features at the River mouth and into the estuary during significant Lake releases will not support moderate SAV shoot densities and will limit the depth distribution to < 2.0 meters
- Ongoing analyses and modeling will yield estimates of the critical attenuation exposure time (H_{sat} and H_{sat} periodicity) for SAV in this system that can be used to improve water quantity/quality management in this system

An objective of this study was to develop time and release level/concentration response curves for the SAV systems in the Caloosahatchee River/Estuary system that will allow managers to eventually control discharges to levels that can avoid or minimize significant damage to the SAV arising from salinity, optical or chemical impacts. The efforts to address this question were more than merely a monitoring study, but included efforts to determine SAV responses to temporally and spatially resolved in-water conditions.

Preliminary model runs that utilize in-water PAR values to determine the shoot density and depth distribution of SAV revealed that light attenuation features at the mouth of the River and into the estuary during significant Lake releases will not support moderate SAV shoot densities and will limit the depth distribution to < 2.0 meters. Light attenuation properties of the water column in high-quality seagrass habitats at the mouth of the Caloosahatchee River/Estuary system were used to predict density-depth distributions of *Thalassia testudinum.* Three predictions of density-depth distributions of

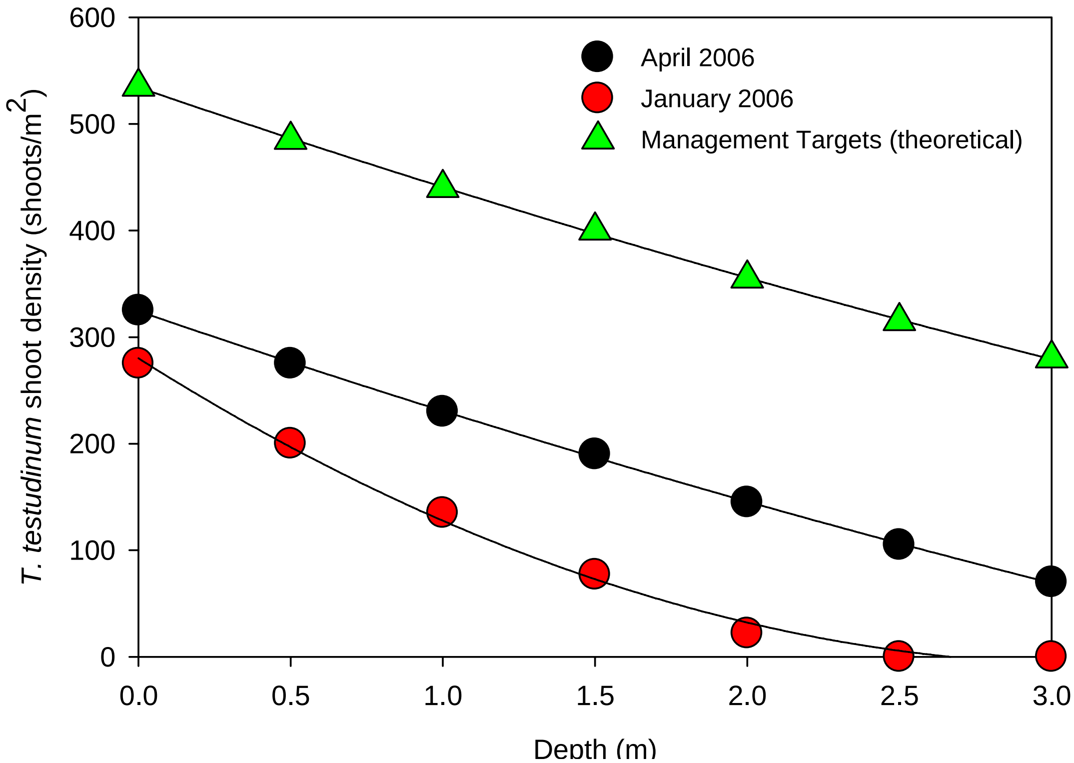

Figure 8. Density depth predictions based on model runs. The model uses in water, spectrally resolved light attenuation to predict shoot density at depth.

T. testudinum are shown in Figure 8. The depth distributions shown in Figure 8 are based on spectrally resolved Kd, but are reported as K_{PAR} for the sake of comparison to other available data. One prediction was based on high light attenuation (red symbols) associated with high Lake Okeechobee release volumes (January 2006), one was based on low light attenuation (black symbols) during Lake Okeechobee pulse releases (April 2006), and one was based on theoretical light attenuation targets set by resource managers (green symbols). It is clear that Lake Okeechobee releases during January 2006 and pulsed Lake Okeechobee releases had strong influences on light availability to support desirable seagrass shoot densities.

Downwelling irradiance data were also collected at high temporal resolution in two general SAV regions/beds (*V. americana* near Beautiful Island and *Halodule wrightii/Thalassia testudinum* in San Carlos Bay). The amount of incident light required to saturate photosynthesis (I_k) was used to determine the percentage of time each day when photosynthesis was saturated. The analysis of this dataset was not completed for inclusion in this report. Currently, the dataset is undergoing a correction for signal degradation due to fouling (Shapiro, personal communication). Continued funding from Lee County and SFWMD will be directed toward this analysis.

(6) *What are the spatial (geographical extent) and duration of impacts related to changes in discharge volumes and the portion contributed by Lake Okeechobee releases?*

- TOF-MS analyses revealed that Lake Okeechobee water, and other sources such as the Gulf of Mexico, have unique chemical compositions
- Site specific chemical fingerprints allow for the determination of the spatial extent of impacts due Lake Okeechobee discharge volumes and differentiate impacts from basin contributions

The portion of impacts attributable to Lake Okeechobee discharges can only be obtained if a parcel of water or the constituents of Lake Okeechobee can be tracked throughout the coastal ecosystem. Initial analyses based on TOF-MS analyses demonstrate that water from Lake Okeechobee, and other sources such as the Gulf of Mexico, have unique chemical compositions and by determination of the chemistries, one can determine the spatial extent of impacts related to discharge volumes (Fig. 9). Figure 9 shows water samples collected during a period of high-volume Lake discharges with no

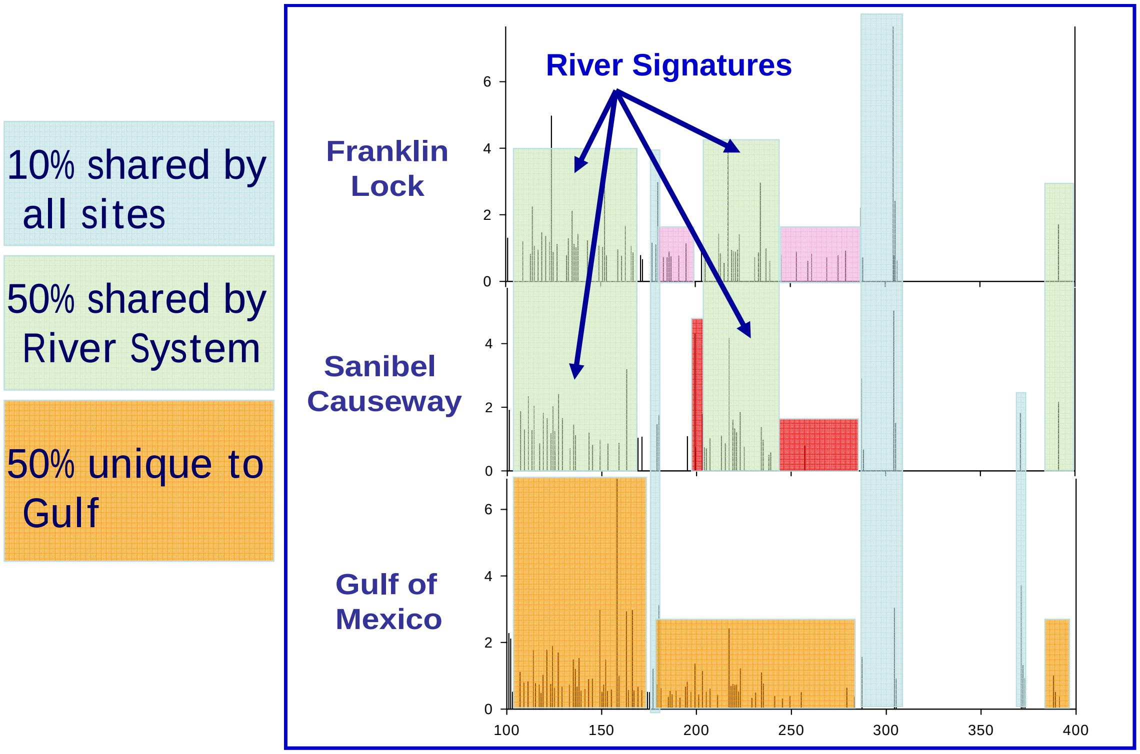

Figure 9. Percentage of shared chemical constituents in water samples from three locations collected in December 2005, a period of high volume Lake Okeechobee discharges.

Basin inputs (January 2006). We observed shared chemistries among all samples (10%), but more importantly, we observed unique chemistries to the Gulf of Mexico (50%) and to the water being discharged at Franklin Lock (50%). Further analyses indicated the chemistries found in Moorehaven (S-78) were also found in Matlacha Pass (Fig. 10). Further analysis of the multivariate dataset indicated that upstream samples were more similar to each other than estuary samples (Fig. 11). A strong seasonal signal was observed in the chemical composition of the Caloosahatchee River/Estuary. The wet season fingerprints were dramatically different from the dry season fingerprints

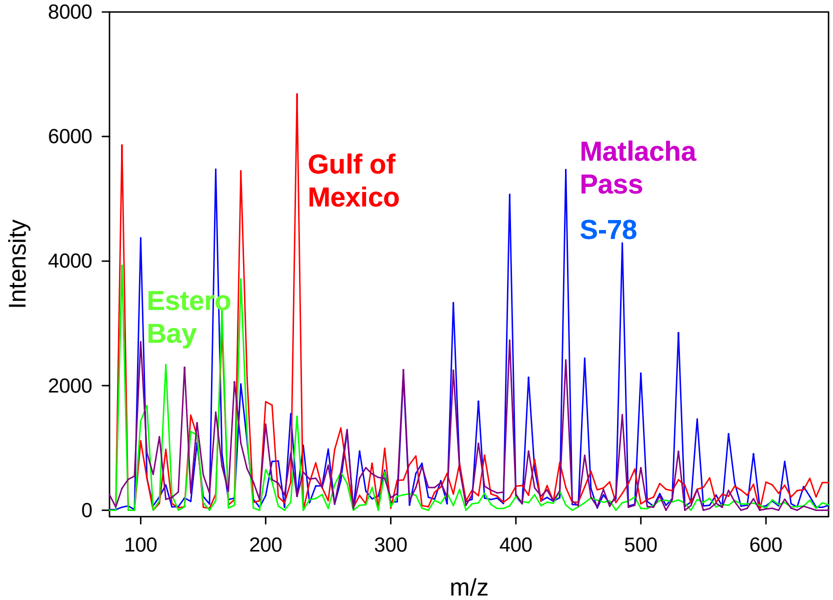

Figure 10. Chemical fingerprinting of water samples. Chemistries found in Moorehaven (S-78) were also found in Matlacha Pass. This allows for quantification of the impacts from Lake Okeechobee discharges on underlying seagrass resources.

indicating that Lake Okeechobee water releases have distinctly different impacts on the river/estuary system than wet season driven watershed inputs. Current efforts are focused on identifying regions of interest from the broad range of molecular masses in a water sample (Fig. 12). The identification of the chemical structure of these markers will provide an indication of whether the processes are primarily mediated by biological or other means. This is useful to managers who want to quantify the impacts to SAV resources caused by Lake Okeechobee discharges by identifying the source and proportion of water masses.

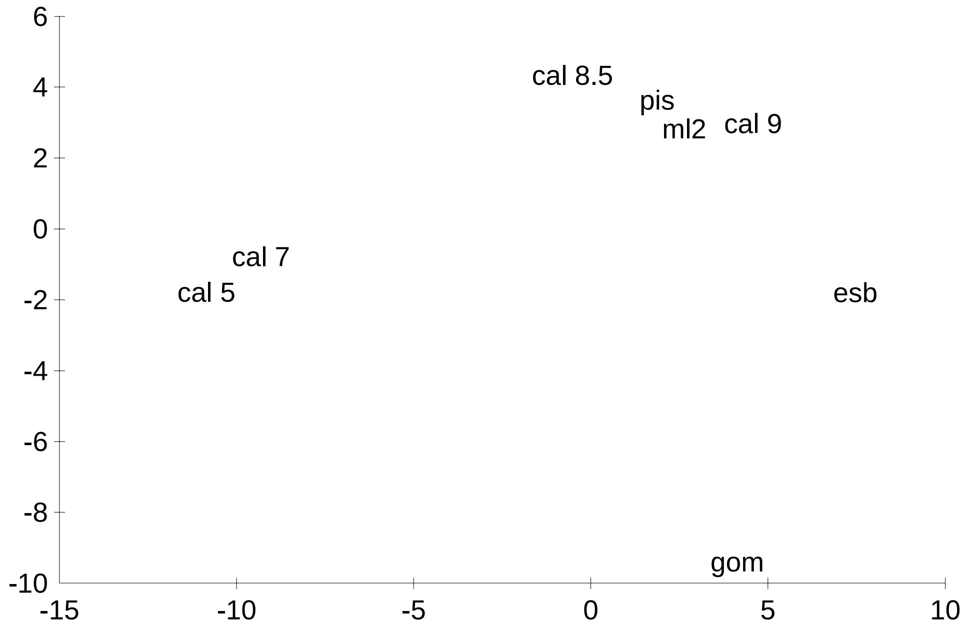

Figure 11. PCA of chemical constituents. Upstream (cal 5, cal 7) to downstream (cal 8.5, cal 9, pis, ml2, esb) pattern indicates more similar chemical constituents in upstream samples that are predictably diluted in the estuary. Locations for abbreviated site names can be found on the attached map.

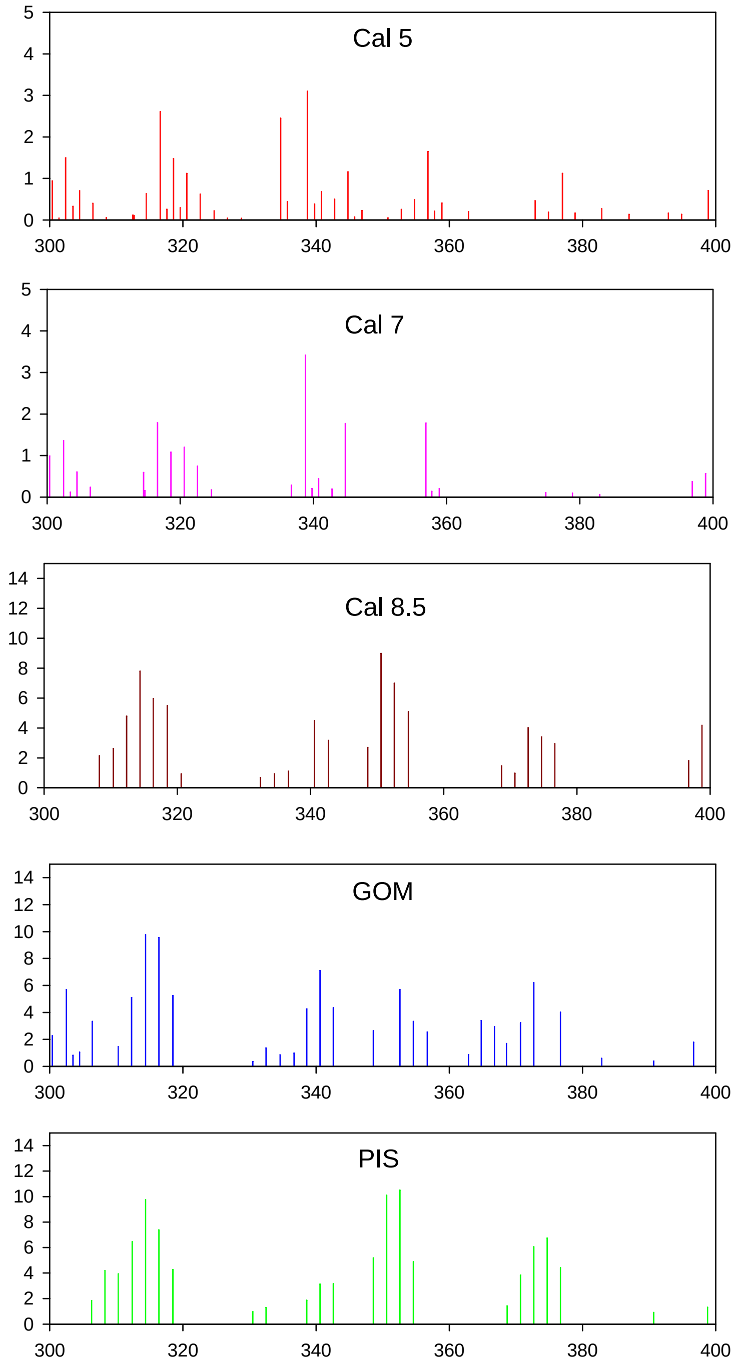

Figure 12. Mass spectra of water samples from the coastal ecosystem. Chemistries unique to a particulary location are being tracked from Lake Okeechobee through the coastal ecosystem.

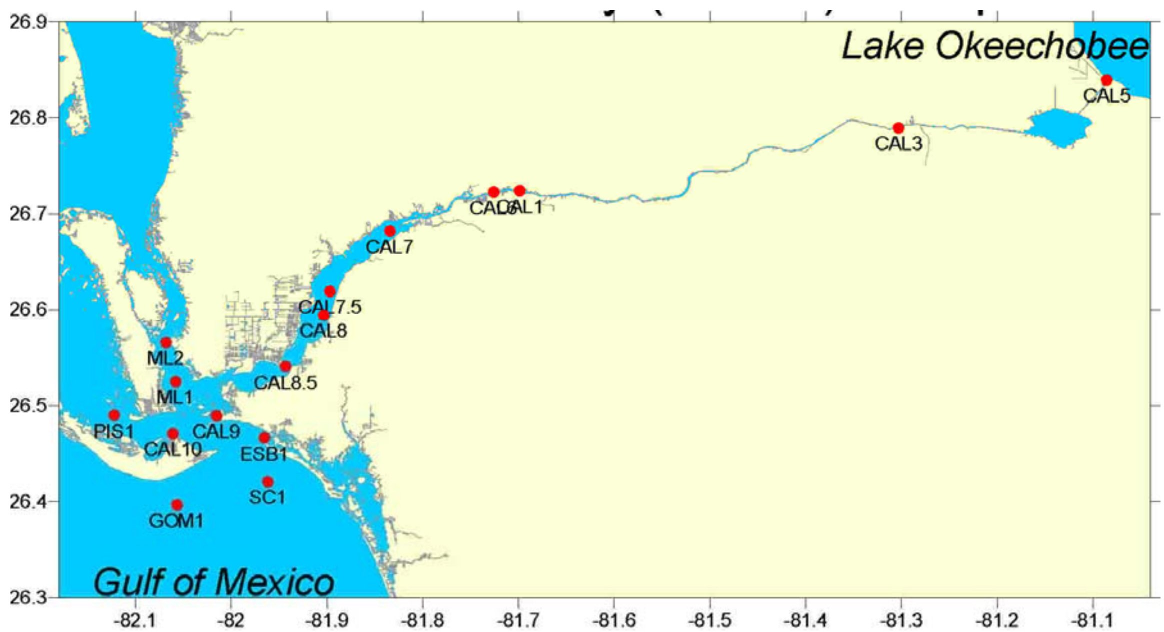

Figure 13. Map of monthly water collection sites and abbreviations.