LOXAHATCHEE RIVER MONTHLY SEAGRASS/ALGAE MONITORING

TASK 2: FINAL REPORT

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Respectfully Submitted by

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Spatial and Temporal Variation of Three Species of Seagrasses (*Syringodium filiforme, Halodule wrightii, and Halophila johnsonii*) in the Loxahatchee River Estuary

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Abstract

A monthly monitoring project was started in June, 2003 to establish baseline abundance and natural seasonal variability for seagrasses in the Loxahatchee River Estuary. The three most common seagrasses encountered in the estuary were *Syringodium filiforme*, *Halodule wrightii*, and *Halophila johnsonii*. In September 2004 hurricanes Frances and Jeanne and remnants of hurricane Ivan impacted the Loxahatchee River, and had large negative effects on seagrasses in the estuary. In the twenty three months that have followed, this project monitored seagrass occurrence, shoot density, and biomass to assess the response of seagrasses following the excessive freshwater discharges. *Halodule wrightii* was least affected by the storms, and *Syringodium filiforme* was most affected by the storms. *Halophila johnsonii* has demonstrated opportunistic characteristics by increasing percent occurrence dramatically over the twenty three month period at both North Bay and Sand Bar while disappearing from Pennock Point and only recently reemerging. Two species, *Thalassia testudinum* and *Halophila engelmannii* disappeared from the monitoring transects at North Bay and have not since reemerged. Nonetheless, nearly all data collected during the summer of 2006 suggest a trend toward pre-storm (i.e., "normal") conditions. It is likely that should these trends continue unperturbed over the next year, the seagrass beds in the Loxahatchee River Estuary are on track to achieve a full recovery.

Introduction

Since June, 2003, staff from the Loxahatchee River District's Wildpine Ecological Laboratory have conducted monthly seagrass monitoring at three sites located within the Loxahatchee River Estuary in order to establish baseline conditions and seasonal growth habits of seagrasses. As a valued ecosystem component, seagrasses will be used to assess restoration success following modified freshwater inflows resulting from the Comprehensive Everglades Restoration Project and the Northwest Fork Restoration Plan (CERP 2001; SFWMD 2006).

Seagrasses have been identified as valued ecosystem components because they fulfill key ecological functions in estuaries. For example, they provide food and refuge from predation for numerous economically and ecologically important species (Zieman 1982; Zeiman et al. 1989; Holmquist et al. 1989; Montague and Ley 1993). Seagrasses also are a critically important component of estuarine productivity (Short et al.1993; Fourqurean et al. 2001). Furthermore, seagrasses have been identified as a biological indicator of water quality and ecosystem health, which suggests that tracking changes in seagrass occurrence and abundance may provide insights into the ecological health of the broader estuary (Montague and Ley 1993; Provancha and Scheidt 2000; Lirman and Cropper 2003).

In September, 2004, fifteen months after the projects inception, south Florida was impacted by three storms, two of which were hurricanes, within a thirty day period. Though no monitoring took place during that month, it was immediately apparent when sampling was resumed in October that rainfall and runoff from the storms had a strong impact on seagrasses in the Loxahatchee River. Since these storms, the seagrass monitoring project has documented the recovery of seagrasses following the storms. In the twenty four months following the storms, some drastic changes in abundance and distribution have occurred when compared to pre-storm conditions. The purpose of this paper is to provide a broad overview of the status and trends of seagrasses in the Loxahatchee River Estuary over the forty month period of June 2003 through September 2006.

Study Area

The Loxahatchee River estuary encompasses approximately 400 ha and drains a watershed of approximately 700 km^2 located in northeastern Palm Beach County and southeastern Martin County, Florida, USA. Freshwater discharges into the estuary from the North Fork, the Northwest Fork, and the Southwest Fork of the Loxahatchee River. The hydrology of the basin has been substantially altered by flood control efforts since the 1950s. Historically (pre-1950), most surface water runoff reaching the estuary originated in the Loxahatchee and Hungryland Sloughs and flowed gradually to the Northwest Fork. In the 1930s the Lainhart Dam, a small fixed-weir dam, was constructed in the Northwest Fork at river mile 14.5 to reduce “over” drainage of upstream reaches of the Northwest Fork during the dry season. In 1958 a major canal (C-18) and flood control structure (S-46) were constructed to divert flows from the Northwest Fork to the Southwest Fork, which increased the intensity and decreased the duration of storm-related discharge to the estuary. Furthermore, since 1947 Jupiter inlet, the eastern link to the ocean, has been kept permanently open through ongoing dredging projects, which increased saltwater intrusion into the primarily freshwater Northwest Fork. Ongoing restoration efforts seek to increase base flows into the Northwest Fork, while not compromising the ecological integrity of downstream reaches (i.e., estuary) nor impairing valued ecosystem components of the estuary such as oysters and seagrasses (SFWMD 2006).

Three seagrass beds in the central embayment of the Loxahatchee River Estuary were selected based on several factors including proximity to the river forks flowing into the estuary, seagrass abundance, seagrass bed persistence, diversity of seagrasses, and a measurable edge of bed. Preliminary surveys were conducted in the central embayment of the Loxahatchee River to identify potential sampling locations where permanent seagrass transects could be established. The first site selected was North Bay (NB) and is located in the northern most embayment area approximately 500 meters west of the railroad bridge (Figure 1). North Bay is characterized as a shallow cove seldom more than one meter deep and is protected from the main boating channel by a sandbar located to the south and running the length of the seagrass bed. The shore line is residential and is mostly composed of red mangroves with occasional seawalls. Interestingly, six species of seagrass have been found within this bed. *Syringodium filiforme*, *Halodule wrightii*, and *Halophila johnsonii* are the dominant seagrasses found here but sizeable patches of *Thalassia testudinum* and isolated patches of *Halophila decipiens* and *Halophila engalmanii* are also present. North Bay has previously been the site of monitoring projects; therefore, components of this seagrass bed have been investigated in the past. Four transect lines were established at this location. Three lines spaced 50 meters apart run southward 100 meters from the shore out past the edge of the bed and onto the top of the sandbar. A bisecting cross line runs eastward from the west line and bisects all three lines at 45 m.

The Sand Bar (SB) site was located in a seagrass bed that occurs on a shallow sand bar adjacent to the main channel in the central embayment (Figure 1). Northern portions of the Sand Bar and associated seagrasses are often exposed at low tides, and receives substantial foot traffic by people that recreate on the Sand Bar at low tide. The Sand Bar is directly influenced by water flowing from both the Northwest and Southwest Forks of the Loxahatchee River. The monitoring transects at this site are located on the south side of the sandbar, which is away from the majority of the foot traffic. *Syringodium filiforme* occurs toward the center of the sampling area, while *H. wrightii* and *H. johnsonii* comprise the north and south outer edges. There are scattered patches of *Thalassia testudinum* located within the bed. However, these patches are extremely sparse, often three to four shoots per patch. A total of five transect lines were established at this site. From a PVC pole centrally located within the main bed, a 100 m line runs northward and extends beyond the

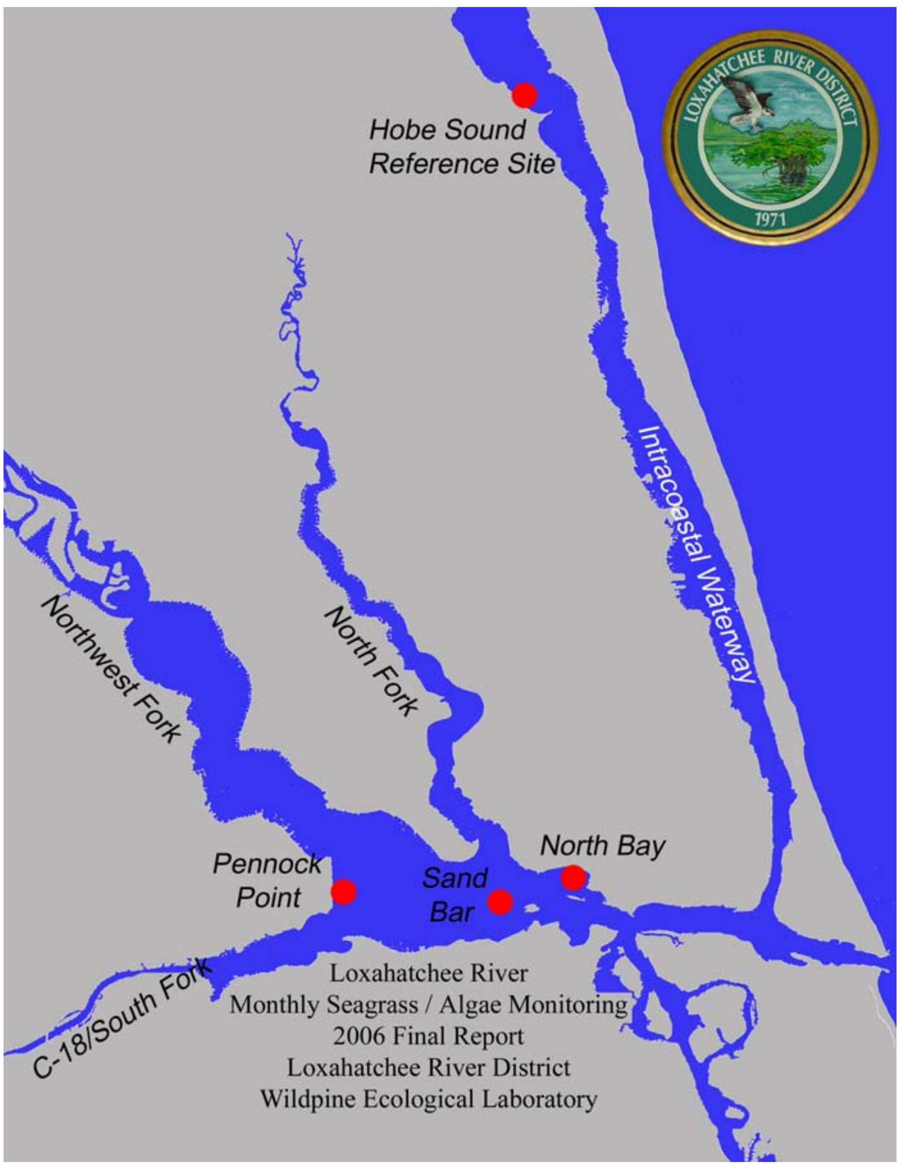

Figure 1. Seagrasses were sampled at three sites (Pennock Point, Sand Bar, and North Bay) in the Loxahatchee River and at a reference site in the Indian River Lagoon (Hobe Sound). Freshwater discharge into the estuary occurs primarily through the Northwest Fork (base flows) and the Southwest Fork (flood control discharges).

edge of the bed and onto the unvegetated portion of the sandbar. Another 100 m line runs south from the center pole and terminates near the edge of a shallow boating channel seldom exceeding 1.7 meters depth. Starting at the center pole and going northward, a series of three 50 m lines running east to west with 25 m of the line residing on either side of the main line make up the remaining transect lines.

Pennock Point (PP) is the site of the third seagrass monitoring station, and is located at the western most edge of the central embayment – on the eastern edge of the peninsula created by the Northwest and Southwest forks (Figure 1). The seagrass bed at this location is smaller than at the other two locations. Initially the shoreline at this location was a sandy beach adjacent to a vacant lot. While the sandy shoreline still exists, a seawall has since been constructed on the site. The seagrass bed at this site is shallow and extends from the sandy shore out fifty meters to a typical depth of 1.5 m. The site is strongly influenced by freshwater flows from both Northwest and Southwest Forks; thus, salinity at this site is highly variable. *Halodule wrightii and H. johnsonii* are the only two seagrass species recorded at this location with *H. wrightii* being the dominant species. Four transect lines were established at this site. Three transects are spaced 50 meters apart and extend 50 meters from shore and bisecting the main line are three lines which run out past the deep edge of the bed. Bisecting these three lines, a 100 meter cross line runs in a north-south direction parallel to and 25 meters from the sandy shoreline.

In June, 2005, a seagrass monitoring station in Hobe Sound (HS) was added as a reference site. This site is located 8 km north of the Jupiter Inlet, and appears to be relatively immune from the freshwaters that drain into the Loxahatchee River and affect the salinity regime and water quality of the central embayment. This seagrass bed is located on the western bank of the Indian River Lagoon adjacent to the sandy shore of a bird sanctuary. Unlike the Sand Bar site, this site receives very little public use. The dense seagrass bed is dominated by *Syringodium filiforme* and *Halodule wrightii* with small patches of *Thalassia testudinum.* While *H. johnsonii* and *H. decipiens* are found here, they are neither abundant nor common – they typically are limited to the deep outer edge. There are three parallel transect lines running from shore towards the main channel that are spaced 150 m apart. The south line is 100 meters long, the middle line is 155 m and the north line is 165 m and all lines extend out past the deep edge of the seagrass bed. The depth at the deep edge of bed often exceeds 1.5 m. There is no bisecting cross line.

Materials and Methods

Monitoring of the seagrass beds is conducted monthly and data collected include seagrass percent occurrence, visual density, canopy height, shoot density, biomass, associated water quality parameters, and photosynthetically active radiation (PAR). Monthly from June 2003 through September 2005, divers assessed the occurrence of all seagrasses by positioning a 0.0625 m^2 (25 cm x 25 cm) quadrat every 1 m along each transect. In each quadrat, the presence (or absence) of each seagrass species was noted. Also, divers enumerated seagrass shoot density and canopy height each month in twelve 0.0625 m^2 quadrats. These samples are located using a random stratified design within each seagrass bed, where the bed is stratified by shallow edge of bed, mid-bed, and deep edge of bed. Seagrass shoot density and canopy height were quantified for *Syringodium filiforme*; however, at Pennock Point they were quantified for *Halodule wrightii* because *S. filiforme* did not occur at this site.

Above- and below-ground biomass of seagrasses was assessed quarterly using commonly employed methods (Duarte 2001, Catchpole and Wheeler 1992). In short, biomass was assessed by collecting six 0.0144 m^2 (12 cm x 12 cm) cores randomly located within the seagrass bed at each seagrass sampling site. Cores were taken to a depth of approximately 15 cm. Sediment and debris was sieved from the core sample, while seagrass material was placed in a labeled, re-sealable plastic bag and held on ice until the sample was processed. In the laboratory, epiphytes were removed by scraping, and seagrasses were separated by species and into living above- and below-ground components. Seagrass material was placed in pre-weighed aluminum pans and dried in an oven at 80 °C for 3-5 days. Biomass was recorded as dry weights to the nearest 0.0001 g. For the present analysis, we report total (i.e., above + below ground) dry-weight biomass.

To better understand and visually describe the conditions of the seagrass beds, a photographic component was incorporated into the project. A digital SLR camera with an ultra wide angle lens was used. The wide angle lens was capable of 100 degree capture and was used to taking close-up photos of seagrasses in the 1 m^2 quadrat. The frame is positioned in reference to the mid-bed pole at all three monitoring sites. A small 25 cm pole is placed in the frame for scale and to orient north in the photo. Unfortunately, water clarity was not sufficient to permit the collection of photographs each month, though every attempt was made to revisit the seagrass beds at high tide when this occurred. Because the photos were taken at the same position each month, a valuable visual record of the status and seasonal changes of the seagrasses has been documented. The photographic record for the peak growing season months June, July, and August is provided for the years 2003-2006 in Appendix A.

Concurrent with seagrass data collection, physical and chemical water quality parameters were evaluated and freshwater discharge into the system was recorded. Throughout the study, temperature, conductivity, salinity, dissolved oxygen, pH, turbidity, chlorophyll a, and Photosynthetic Available Radiation (PAR) were recorded monthly at the time of seagrass sampling in the channel adjacent to each seagrass site and at a site in the middle of each seagrass bed. Furthermore, riverkeeper water quality stations 42 (central embayment) and 25 (Hobe Sound) provide bi-monthly assessments of nutrients in the vicinity of the seagrass sampling sites. Starting in April 2004, salinity, temperature, and depth were recorded every 15 min at the NB and PP sites using a Hydrolab Minisonde 4a positioned at seagrass canopy height (~ 25 cm off the bottom). A Hydrolab Minisonde 4a positioned at seagrass canopy height was added to the Hobe Sound reference seagrass bed in January 2006. Supplemental water quality samples, including water color, were collected every other month in the channel adjacent to the NB seagrass site (i.e., Riverkeeper Station 40). Water quality samples were processed following Standard Methods by the Loxahatchee River District's Wildpine Laboratory, which is certified under the National Environmental Laboratory Accreditation Program. Photosynthetically active radiation (PAR) was assessed by taking 3 replicates of PAR using 3 LI-COR spherical sensors (4 π) simultaneously located at 20 cm, 50 cm, and 100 cm below the water surface. Data were recorded on a LI-COR LI-1400 data logger. Light attenuation coefficient (Kd) was calculated as the slope of natural log transformed PAR values regressed against depth. Following Kemp et al. (2004), the percent of light passing through the water column to seagrasses (PLW) was calculated as $PLW = 100 \exp[(-Kd)(Z)]$, where Kd is the light attenuation coefficient and Z is the depth of seagrass growth. Freshwater discharge into the Southwest Fork was recorded continuously at the S-46 structure, while freshwater discharge into the Northwest Fork was recorded continuously at Lainhart Dam. Discharge from the North Fork generally contributes approximately 6% of mean daily flow into the estuary and was not assessed during this period (SFWMD 2006).

Results

The primary purpose of this paper is to understand the dynamics of seagrasses in the Loxahatchee River Estuary prior to the September 2004 storms (i.e., the natural range of variability), and to understand the temporal progression of seagrasses recovery following a large-scale disturbance. While a separate manuscript (Ridler et al. 2006) identified salinity variability as the most likely mechanism that resulted in the observed decline in *S. filiforme*, the present report will focus more broadly on the temporal and spatial dynamics of seagrasses prior to and following the September 2004 storms.

Percent Occurrence

Prior to the September 2004 storms, *S. filiforme* showed relatively little variability in percent occurrence at the Loxahatchee River central embayment sampling sites (Figure 2). *Syringodium filiforme* typically occurred in ~60% of North Bay samples, 30-40% of Sand Bar samples, and 0% of Pennock Point samples. It is important to note that *S. filiforme* appears always to be absent from the western portions of the Loxahatchee River central embayment, and has never been observed in any Pennock Point samples (Figure 2). Following the September 2004 storms, *S. filiforme* showed both immediate and gradual decline in percent occurrence, though the trend appears to have reversed and *S. filiforme* has been increasing in prevalence, especially during the 2006 summer months. Although sampling was only begun in June 2005 at the Hobe Sound reference site, the relatively high and constant abundance suggest *S. filiforme* did not suffer any appreciable declines following the September 2004 storms. Furthermore, the stability of the post-storm occurrence values at Hobe Sound (around 70%) is quite similar to the pre-storm stability observed at North Bay.

Halodule wrightii was found to be the first or second most abundant seagrass at all four sampling sites, and it was the least affected by the September 2004 storms. Prior to September 2004, *H. wrightii* occurred in 40% to 60% of all samples at each of the seagrass sampling locations. Its relative abundance appears to be somewhat moderated by the abundance of *S. filiforme*, i.e., when *S. filiforme* occurrence was low or absent then *H. wrightii* occurrence was around 60%, but when *S. filiforme* occurrence was high then *H. wrightii* occurrence was around 40%. Following the September 2004 storms, *H. wrightii* showed a slight and immediate decline in occurrence, but began an immediate and sustained recovery at North Bay and Sand Bar sites. In September 2006, *H. wrightii* occurred in nearly 100% of samples at Sand Bar and 60% of samples at North Bay. Nonetheless, *H. wrightii* has not shown any measurable recovery at Pennock Point – occurrence values have remained relatively constant since October 2004. The occurrence of *H. wrightii* at the reference site (Hobe Sound) has increased steadily from around 25% in December 2005 to approximately 50% in September 2006.

Halophila johnsonii, the federally threatened seagrass, has shown the greatest variability in occurrence among the sampling sites over the monitoring period. Prior to the September 2004 storms, *H. johnsonii* was most abundant at the Sand Bar site and least abundant at North Bay, though occurrence at these sites was strongly seasonal. For example, *H. johnsonii* occurred in 20% of Sand Bar samples at the end of the 2003 summer, increased to 80% of samples in March 2004, and declined to 30% of samples in August 2004. This seasonal pattern of occurrence suggests a winter growth period, and is repeated at North Bay and Sand Bar over the 2005-2006 winter. It should be noted that immediately following the September 2004 storms, *H. johnsonii* disappeared from Pennock Point and did not reappear until October 2005, though mean percent occurrence values remain far below that observed prior to the storms. Finally, data appear to suggest that *H. johnsonii* competes with *S. filiforme* and its much taller canopy for light. If prolific beds of *S. filiforme* shade out *H. johnsonii*, which seems very likely, then the effect of the storms on *S. filiforme* may have indirectly benefited *H. johnsonii* by opening up space and increasing light availability. Finally, it should be noted that *H. johnsonii* is able to grow at shallower depths than other seagrass species in the Loxahatchee River Estuary and is often encountered at the shallowest edge of bed.

The most diverse site within the Loxahatchee River Estuary has historically been North Bay. In addition to *S. filiforme*, *H. wrightii*, and *H. johnsonii*, *Thalassia testudinum, Halophila decipiens*, and *Halophila engelmanni* have been found at this site. Following the September 2004 storms, small, isolated patches of both *T. testudinum* and *H. engelmanni* disappeared and as of September 2006 they have not returned. *H. decipiens* first appeared in 12/04 and started to establish itself until it reached peak occurrence of 2.2% in February 2005. It disappeared from the transect lines in May 2005 and has not reemerged.

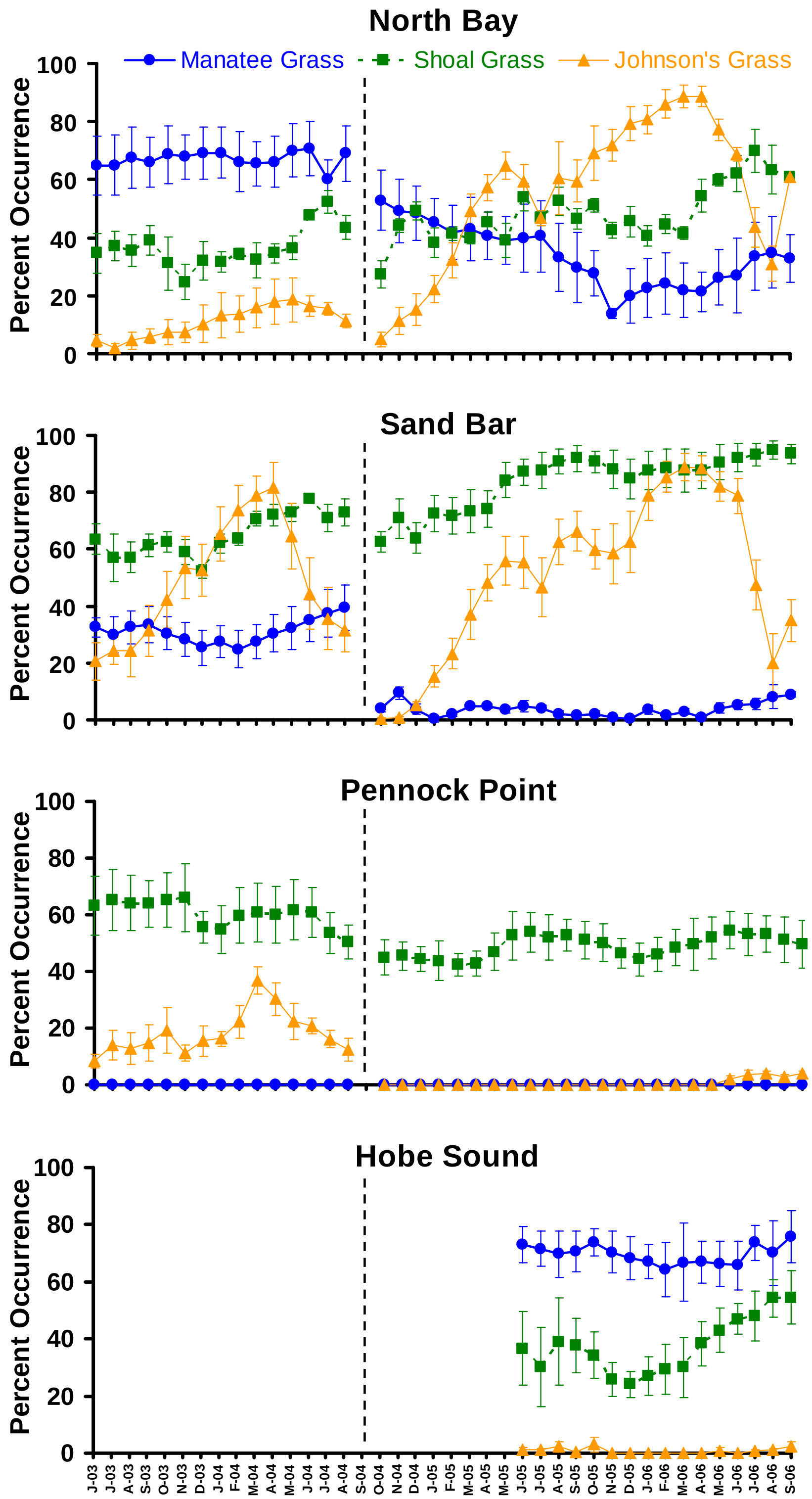

Figure 2. Seagrass occurrence (percent of quadrats occupied) shows clear differences between the reference site in the Indian River Lagoon (Hobe Sound) and the Loxahatchee River sites. Also, there are clear differences among Loxahatchee River sites along an upstream-downstream gradient. The vertical dotted line indicates the occurrence of the 2004 storms (vertical dotted line). Error bars represent ± 1 Standard Error.

Shoot Density & Canopy Height

Similar to occurrence data, observed seagrass shoot densities suggest a relatively natural range of variability prior to the September 2004 storms (Figure 3). Probably more interesting is the dichotomy between the response of *S. filiforme* and *H. wrightii* following the storms. *Syringodium filiforme* shows a significant decline following the storms, and a somewhat modest recovery during the summer months of 2006 (Figure 3). While *S. filiforme* shoot densities increased during the summer months of 2006, these values remain far below the peak values observed prior to the 2004 storms. Unlike *S. filiforme*, *Halodule wrightii* shoot densities appear to have made a full recovery by April 2005 and have exhibited natural, seasonal variability since then. The temporal variability of *H. wrightii* and *S. filiforme* shoot density suggests a seasonal cycle which is consistent with observations of these species in other areas of the Indian River Lagoon (Gilbert and Clark 1981) and may be responding to warmer temperatures, though increased light availability may also explain the pattern (Short et. al. 1993). Across all Loxahatchee River Estuary sites, seagrass shoot density, as measured for *S. filiforme* or *H. wrightii*, is at its lowest during the winter months (November – February) when the water is cooler and the photoperiod shorter, and is at its peak late summer when water temperatures are warmer and day length is longer. A similar trend is observed for seagrass canopy height.

Syringodium filiforme canopy height at North Bay and Sand Bar showed strong seasonal patterns prior to the September 2004 storms, with obvious peaks occurring at the end of the summer growing season. After the September 2004 storms, *S. filiforme* canopy height remained depressed at North Bay and Sand Bar until the summer growing season of 2006, when canopy height returned to the pre-storm levels. Halodule wrightii canopy height values were less affected by the September 2004 storms, and a return to pre-storm conditions appears to have occurred by the summer of 2005.

Biomass

Seagrass biomass is a function of the relative abundance (occurrence), shoot density, canopy height, and the amount of energy stored in below ground roots. Peak seagrass biomass was typically observed in August (Figure 4) when shoot density and blade lengths are at their peak. Prior to the September 2004 storms, a considerable amount of among site variability was observed. For example, peak biomass was nearly 150 g m^{-2} at North Bay but it was only 25 g m^{-2} at Sand Bar and 11 g m^{-2} at Pennock Point. Much of the disparity between North Bay and Pennock Point is because *S. filiforme* is absent from Pennock Point and *Halodule wrightii* constitutes 100% of the seagrass biomass at that site. In August 2004, immediately prior to the September 2004 storms, seagrass biomass was nearly identical at North Bay and Sand Bar (~66 g m^{-2}), though Pennock Point supported only 6.7 g m^{-2} of seagrass biomass at this time. Following the September 2004 storms, seagrass biomass declined to near zero and the majority of seagrass biomass collected since the storms has been due to the accumulation of *H. wrightii*. Interestingly, the reference site in Hobe Sound shows a similar biomass trend from August 2005 through August 2006 that was quite similar to that observed at North Bay during the period August 2003 through August 2004.

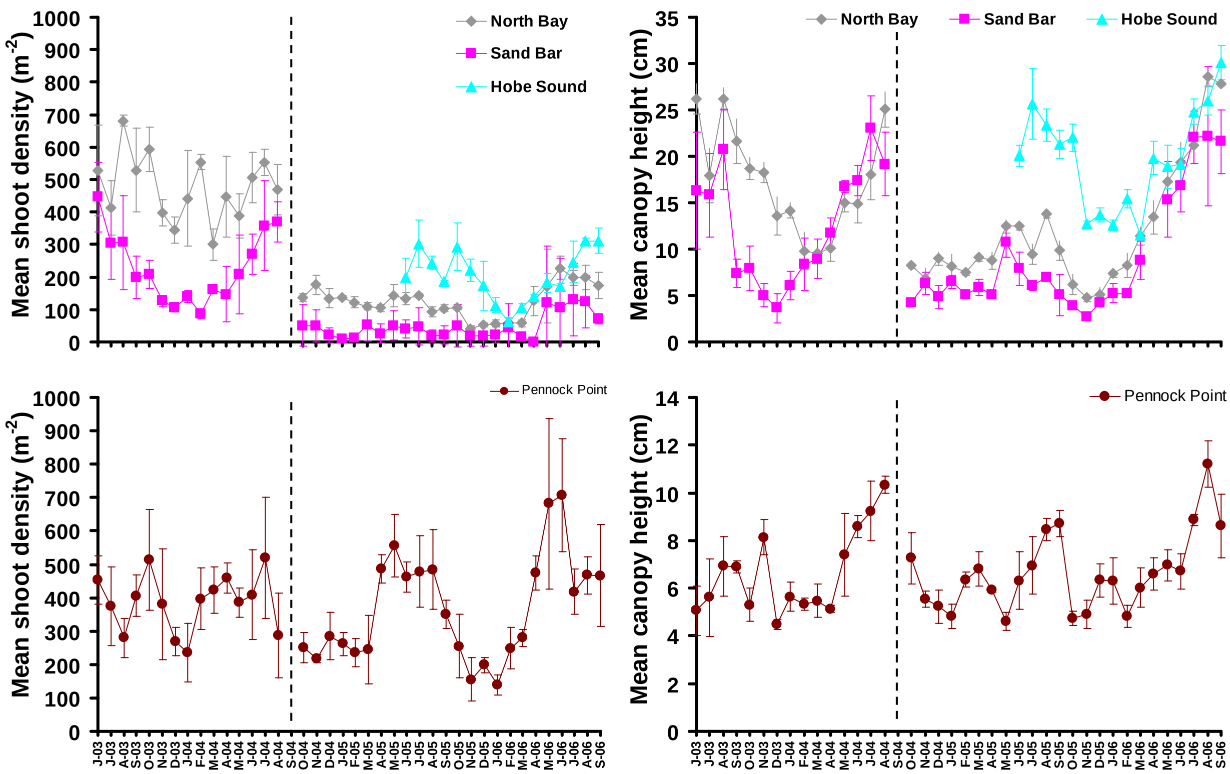

Figure 3. Seagrass shoot density and canopy height reveal impacts of the 2004 storms (vertical dotted line) as well as seasonal peaks due to the summer growing season. It appears that the health of individual plants, measured as canopy height, has recovered more completely than the health of the population, which may be inferred from shoot density estimates. Note that *Syringodium filiforme* was assessed at North Bay, Sand Bar, and Hobe Sound while *Halodule wrightii* was assessed at Pennock Point (*S. filiforme* was absent there). Error bars represent ± 1 Standard Error.

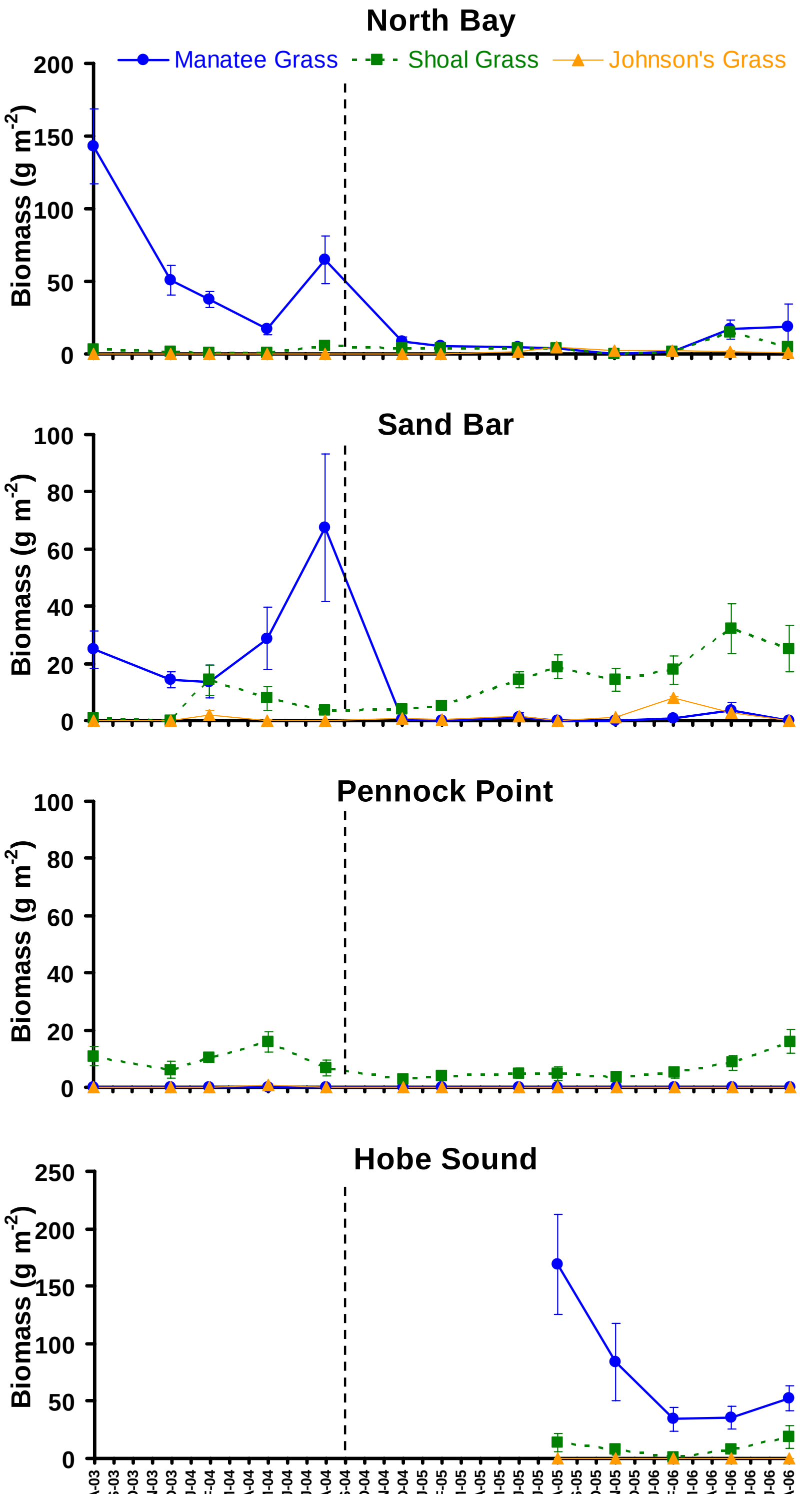

Figure 4. Seagrass biomass shows a general trend of increasing during the summer and decreasing during the winter. In the Loxahatchee River manatee grass comprises the majority of seagrass biomass, and was significantly reduced following the 2004 storms (vertical dotted line). Error bars represent ± 1 Standard Error.

Discussion

Ongoing seagrass monitoring in the Loxahatchee River Estuary has provided interesting insights into the ecology and dynamics of seagrasses in South Florida, and has yielded novel insights into how and when seagrasses are stressed by excessive freshwater discharges (Ridler et al. 2006). Based on LRD's seagrass monitoring in 2000 and 2002 (Ridler et al. 2003), the monitoring period August 2003 through August 2004 appears to represent a relatively 'normal' period (i.e., no lagging negative effects due to excessive freshwater), and serves as a baseline to understand natural variability in the system. Similarly, ongoing monitoring in the southern Indian River Lagoon (Hobe Sound) serves as a reference site that is immune to excessive freshwater discharges. By comparing the pre-storm period and the reference site, we can begin to understand natural seasonal dynamics of seagrasses in the southern Indian River Lagoon and the Loxahatchee River Estuary.

In addition, because seagrass monitoring has continued without interruption for 23 months following the September 2004 storms, these data provide excellent documentation of seagrass recovery following an extreme freshwater discharge event. For example, these data show the near complete loss of *S. filiforme* following the storms of September 2004. Subsequent to these storms, June 2005 was an unusually wet season followed by hurricane Wilma in October 2005. Throughout the post-storm monitoring period substantial changes to the composition of all three of the seagrass beds have been documented. At North Bay, two species, *Thalassia testudinum* and *Halophila engelmanni*, disappeared while another, *Halophila decipiens*, emerged and has since also disappeared. We documented *Halophila johnsonii*, an opportunistic species, increase to cover nearly 90% of the bed while *Syringodium filiforme* gradually declined. During the summer of 2006, this pattern has reversed with *S. filiforme* increasing and *H. johnsonii* is decreasing. We also documented the near extinction and current recovery of *S. filiforme* from the Sand Bar monitoring site while *H. wrightii* and *H. johnsonii* continued to proliferate. Also documented is the local extinction, reemergence, and sustained slow recovery of *H. johnsonii* at the Pennock Point site while *H. wrightii* remained essentially unchanged throughout the sampling period. In particular, these data suggest the occurrence of *Halodule wrightii* and *Halophila johnsonii* may be dynamically influenced by both freshwater discharges, i.e., salinity regime and water quality, and competition with *S. filiforme* for light. Furthermore, these data clearly demonstrate the long time periods necessary for seagrasses to recover following such large and extensive losses. For example, after 23 months *S. filiforme* has not completely recovered at North Bay or Sand Bar, and *H. johnsonii* has not completely recovered at Pennock Point.

Furthermore, in the 23 months following the September 2004 storms it appears that the health of individual plants (i.e., inferred from canopy height) has recovered more completely than the health of the population (i.e., inferred from shoot density and biomass). Ridler et al. (2006) suggested that secondary stressors such as sulfide toxicity or disease acting on stressed *S. filiforme* likely drove the long-term decline observed for *S. filiforme* at North Bay and Sand Bar. Indeed, if sulfide toxicity or a disease agent affected the health of *S. filiforme*, a full recovery of seagrasses at North Bay and Sand Bar may be quite slow. Based upon the current trends of seagrasses at the reference site and in the Loxahatchee River Estuary, it appears that seagrass beds within the Loxahatchee River Estuary are on their way to recovery following the September 2004 storms. Given the dynamic and slow nature of seagrass recovery, we suggest monitoring should continue, unchanged, for at least one more year to document (the hopeful) complete recovery of seagrasses in the Loxahatchee River Estuary.

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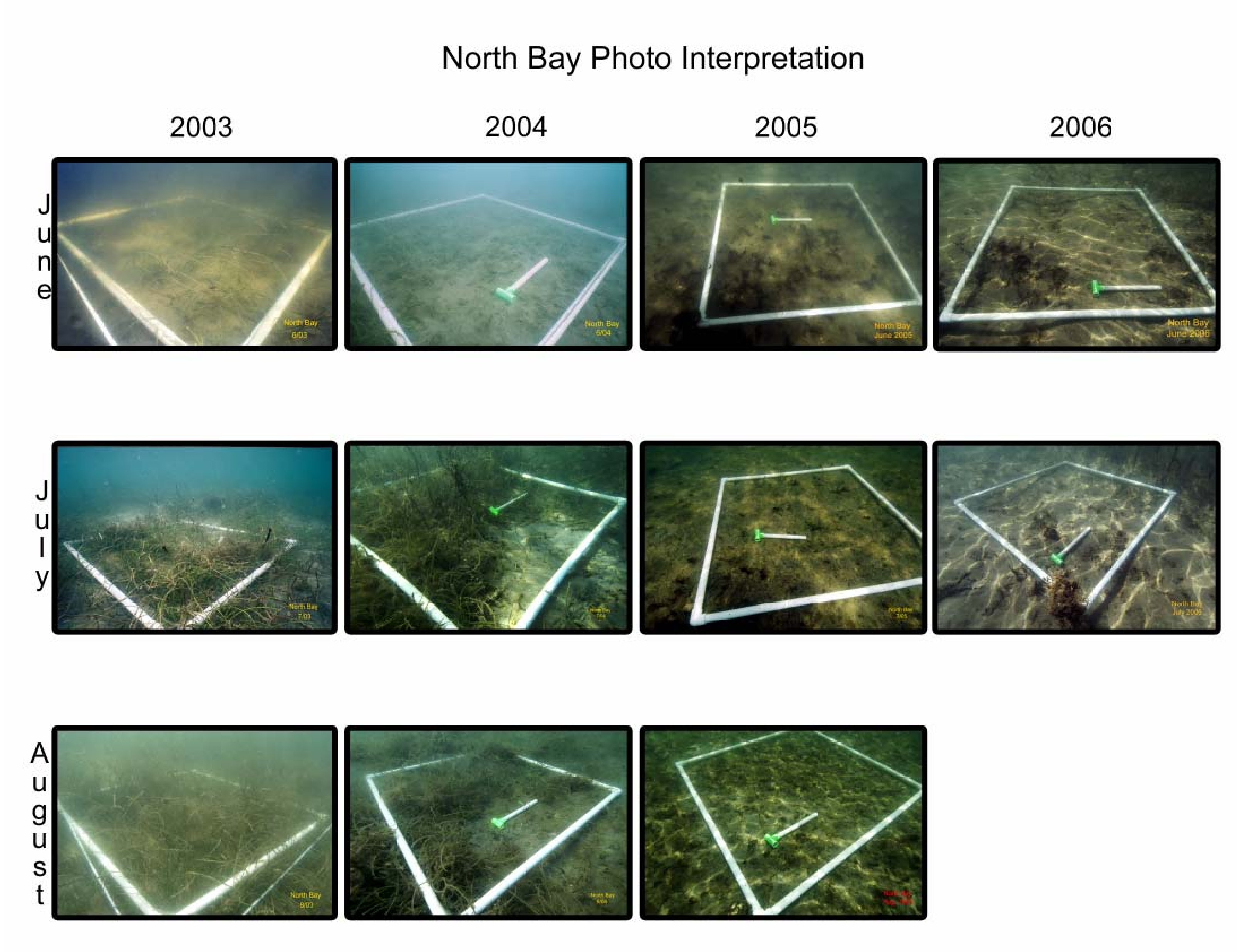
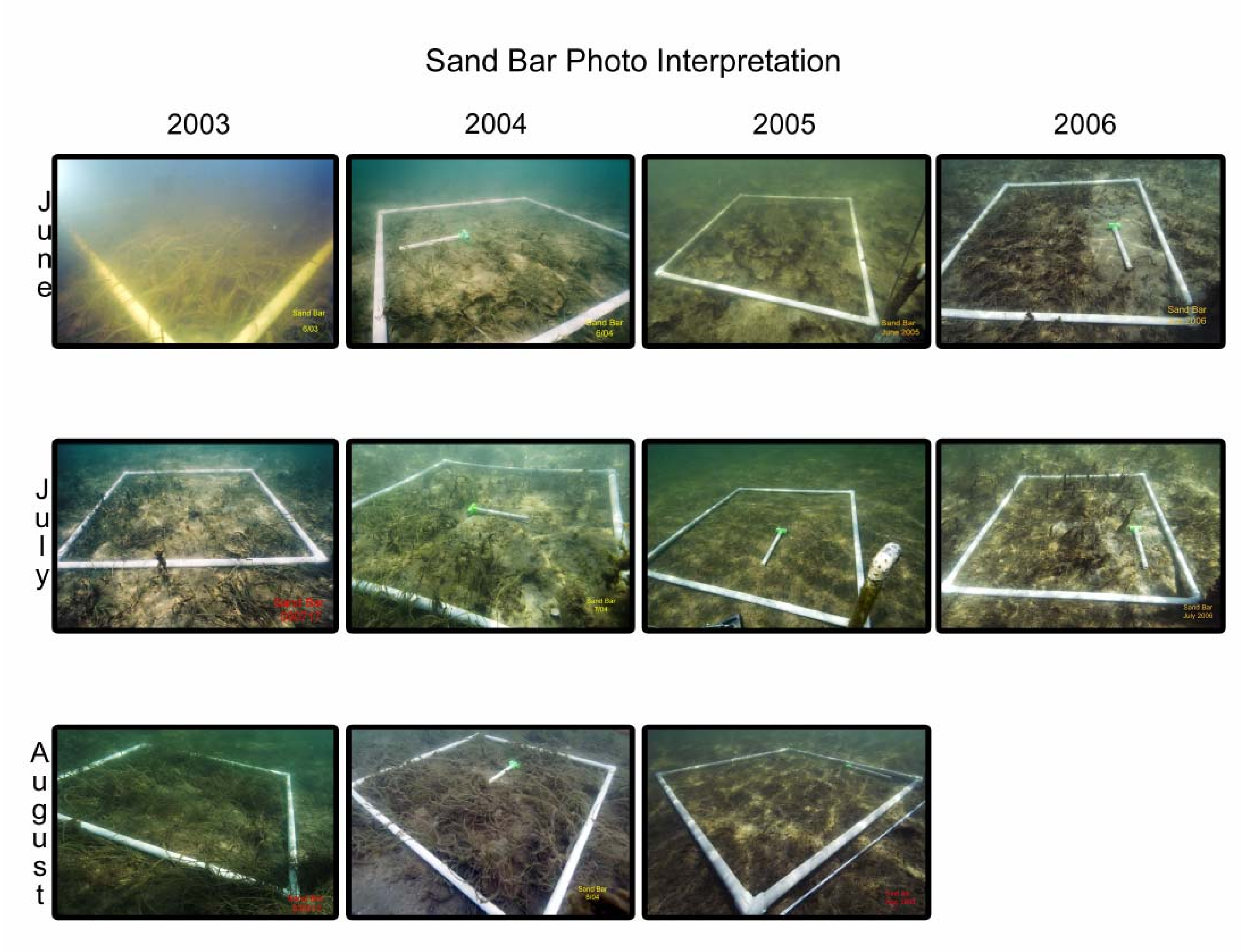
Appendix A. Seagrass Photos



Appendix A. Seagrass Photos, Continued



Appendix A. Seagrass Photos, Continued