LOXAHATCHEE RIVER SEAGRASS MONITORING & MAPPING REPORT

DRAFT

TASK 4: FINAL REPORT

In Partial Fulfillment of Agreement No. 4600001907

For the Period

October 2009 through September 2010

Respectfully Submitted by:

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Loxahatchee River District

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Executive Summary

Seagrasses are a valued ecosystem component of the Loxahatchee River estuary. Scientists and managers use seagrass condition and distribution to assess the health and condition of the estuary. Further, these data will be used to assess restoration success following modified freshwater inflows resulting from the Comprehensive Everglades Restoration Project (CERP 2001) and the Restoration Plan for the Northwest Fork of the Loxahatchee River (SFWMD 2006).

Between October 2009 and September 2010, Loxahatchee River District's Wildpine Ecological Laboratory staff monitored seagrass every-other-month (bi-monthly) at four sites located within the Loxahatchee River Estuary and at a reference site in the southern Indian River Lagoon. Monitoring was conducted to characterize spatial and temporal variation in seagrass percent cover and canopy height within the Loxahatchee River estuary. Here we use data collected over the past 12 months to evaluate seagrass species composition across the upstream to downstream gradient. Similarly, we characterize spatial and temporal variability among our sampling sites.

In a separate seagrass project during the summer of 2010, we quantified seagrass occurrence and density using *in situ* observations based on a random stratified design that locates sampling points throughout the Loxahatchee River estuary. Results from this project provide landscape-scale, species-specific assessment of seagrasses in the estuary. The 2010 mapping project complements a similar mapping project conducted in 2007.

These ongoing seagrass monitoring projects in the Loxahatchee River Estuary have provided interesting insights into the ecology and dynamics of seagrasses. During the period October 2009 – September 2010 seagrass in the Loxahatchee River Estuary appeared to be relatively healthy, though percent cover values for some species and monitoring sites remain below those observed prior to the September 2004 hurricanes. By comparing seagrass conditions in the Loxahatchee River against those of the reference site and across the upstream-downstream gradient in the Loxahatchee River we were better able to understand the impacts freshwater discharges had on seagrass conditions. The 2010 mapping project provides unprecedented detail on the distributions of seagrasses throughout the estuary. Comparisons of the 2010 and 2007 mapping data help to illustrate, and eventually quantify, the extent and variability in the seagrass distributions throughout the estuary. With the exception of Paddle Grass, the distributions of Johnson's Seagrass, Shoal Grass, Manatee Grass, and Turtle grass were generally similar in 2010 to the observations in 2007. The distributions of Paddle Grass showed marked changes between the 2007 and 2010 surveys.

Introduction

As a valued ecosystem component, seagrasses will be used to assess restoration success following modified freshwater inflows resulting from the Comprehensive Everglades Restoration Project (CERP 2001) and the Restoration Plan for the Northwest Fork of the Loxahatchee River (SFWMD 2006). Seagrasses have been identified as a valued ecosystem component 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 (Montague and Ley 1993; Provancha and Scheidt 2000; Lirman and Cropper 2003; Ridler et al. 2006), which suggests that tracking changes in seagrass occurrence and abundance may provide insights into the ecological health of the broader estuary.

Between October 2009 and September 2010, Loxahatchee River District's Wildpine Ecological Laboratory staff monitored seagrass every-other-month (bi-monthly) at four sites located within the Loxahatchee River Estuary and at a reference site in the southern Indian River Lagoon. Monitoring was conducted to characterize spatial and temporal variation in seagrass percent cover and canopy height within the Loxahatchee River estuary.

In a separate seagrass project, during the summer of 2010, we quantified seagrass occurrence and density using in situ observations based on a random stratified design that locates sampling points throughout the Loxahatchee River estuary. Results from this project provide landscape-scale, species-specific assessment of seagrasses in the estuary. This project complements a similar mapping project conducted in 2007.

Here we use data collected over the past 12 months to evaluate seagrass species composition across the upstream to downstream gradient. Similarly, we characterize spatial and temporal variability among our sampling sites. With the landscape-scale mapping project, we evaluate seagrass distributions throughout the estuary, with generalized comparisons to the results obtained in 2007.

Study Area

Overview

The Loxahatchee River estuary encompasses approximately 400 ha and drains a watershed of approximately 700 km2 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

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 the eastern link to the ocean, the Jupiter Inlet, has been kept permanently open through ongoing dredging projects. This has contributed to 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).

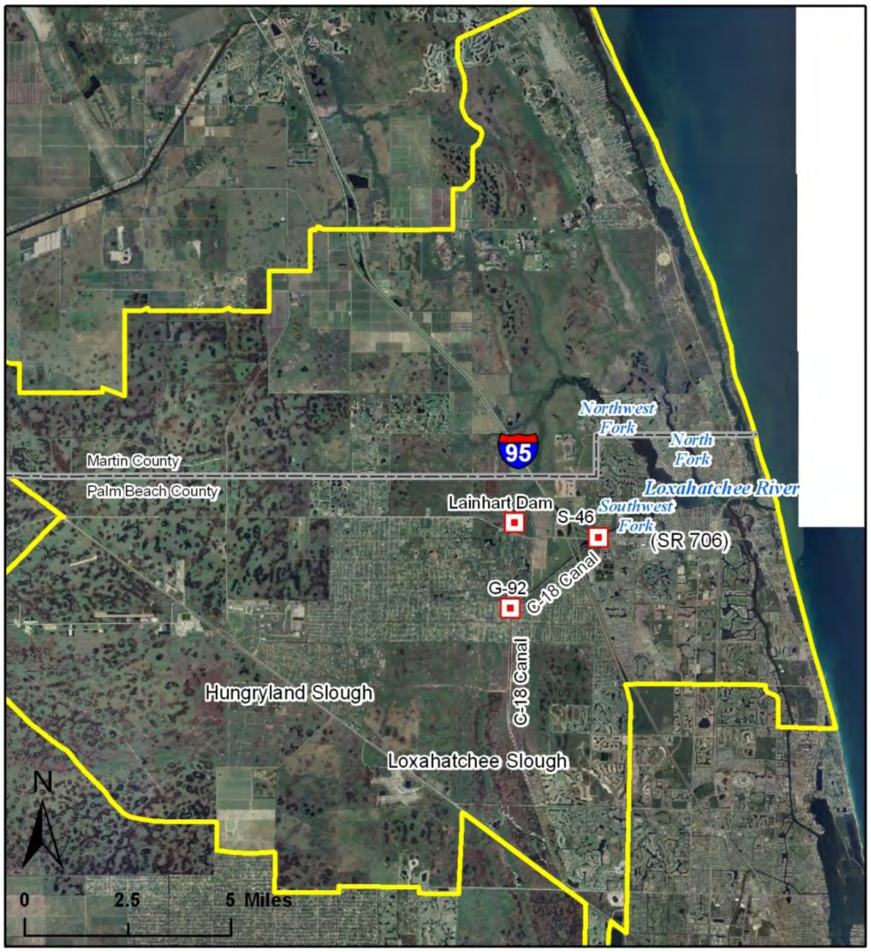

Figure 1. Loxahatchee River watershed and associated features.

Bi-Monthly Seagrass Monitoring Sites

Four seagrass beds in the central embayment of the Loxahatchee River Estuary and a reference seagrass bed in the southern Indian River Lagoon were selected as sample sites based on three primary factors: proximity to the river forks flowing into the estuary, seagrass cover, and seagrass persistence. This project was established following a four year fixed-transect based seagrass monitoring project in the Loxahatchee River which included four of the five sites assessed in the present study. At each sample site the seagrass bed to be monitored was delineated with a GPS to allow random sampling within the defined seagrass patch over time (Figure 2). The North Bay (NB) seagrass bed was 5.29 acres (2.14 ha) and was located at river mile 1.5 in the northern most embayment area approximately 500 meters west of the railroad bridge. This site was the most downstream site so therefore experienced the most stable, marine-like conditions among the four Loxahatchee River sampling sites. North Bay was 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 was residential and mostly composed of red mangroves with occasional seawalls. Six species of seagrass have been found within this bed. Manatee grass, shoal grass, Johnson's grass, turtle grass, paddle grass, and star grass were present during previous studies.

The Sand Bar (SB) seagrass bed was 8.71 acres (3.52 ha) and was located at river mile 1.8 in the central portion of the central embayment. Therefore, the site was directly influenced by water flowing in from the inlet and downstream from both the Northwest, North, and Southwest Forks of the Loxahatchee River. The area was a shallow sand bar adjacent to and south of the main channel in the central embayment. Shallowest portions of the sand bar were intertidal and received considerable foot traffic as people recreated on the sand bar. The site is separated from the shore line by a marginal channel. Five species of seagrass have been found within this area. Johnson's grass, shoal grass, paddle grass, manatee grass, and turtle grass were found at this site during previous studies.

The Pennock Point (PP) seagrass bed was 2.96 acres (1.20 ha) and was located at river mile 2.6 at the far western edge of the central embayment along the eastern shore of the peninsula created by the Northwest and Southwest forks (Figure 1). This site was directly influenced by freshwater flowing downstream from both the Northwest and Southwest Forks of the Loxahatchee River. The shoreline at this location was predominantly undeveloped residential lined by a continuous seawall with some scattered red mangroves. 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. Shoal grass and Johnson's grass were the only two seagrass species recorded at this location during previous studies.

The Northwest Fork (NWF) seagrass bed was 0.97 acres (0.49 ha), and was located at river mile 3.3 in the Northwest Fork of the Loxahatchee River. This site was the most upstream site, and therefore was most affected by freshwater flowing downstream from the Northwest Fork of the Loxahatchee River. The site was characterized as a slight embayment along the western shore with the shoreline being residential and mostly lined by red mangroves with occasional seawalls. The seagrass bed at this site was approximately 175 meters wide and extended 25 meters out from the sandy shore to a typical depth of 1.4 m. Johnson's grass and shoal grass have been found at this site during earlier assessments (e.g., 2007 mapping), though it was not sampled as part of the 2003-2007 transect-based study.

The reference (HS) seagrass bed was 10.79 acres (4.37 ha), and was located in the southern Indian River Lagoon. This site was an excellent reference site because it was located 8 km north of the Jupiter Inlet and was not affected by freshwaters discharged from the Loxahatchee River watershed; thus, the reference site experienced more stable, marine-like salinity conditions than the Loxahatchee River Estuary. The site was 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 received very little public use. The seagrass bed at this site extended approximately 165 meters off shore, and the deep edge of the bed exceeded 1.5 m in depth. During the previous study manatee grass, shoal grass, turtle grass, Johnson's grass, and paddle grass were found at this site.

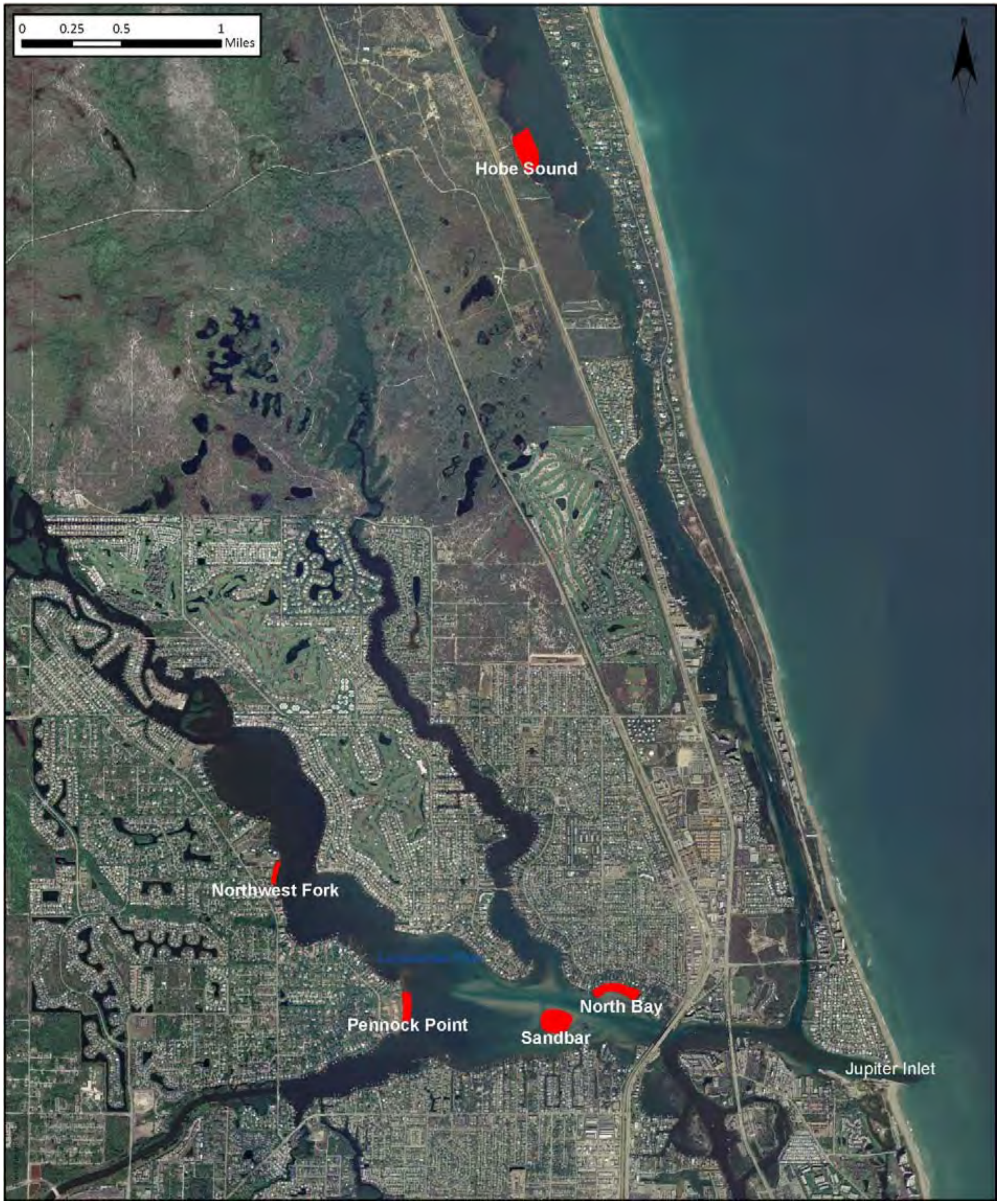

Figure 2. Seagrasses were sampled every other month in the Loxahatchee River at four locations (Northwest Fork, North Bay, Sand Bar, and Pennock Point) and at a reference location in the Indian River Lagoon (Hobe Sound). The red polygons represent the actual size and shape of the seagrass bed monitored at each location.

Landscape-Scale Seagrass Mapping Area

Sample points were sited from just inside the mouth of the inlet to the upstream extent of seagrass in each of the three river forks (North, Northwest, and Southwest) but do not include the Indian River Lagoon (north of the Loxahatchee River) or the southern Intracoastal Waterway (south of the Loxahatchee River). The greatest density of sampling points occurs in the central portion of the estuary known to support the greatest diversity of seagrass (Loxahatchee River District, unpublished data). We did not collect samples in areas known to be too deep to support seagrass growth, or in the navigation channels for safety considerations.

Materials and Methods

Patch-scale (Bi-Monthly) Monitoring Methods

Seagrass beds were monitored bi-monthly for the period October 2009 through September 2010. During each sampling event we assessed percent occurrence for each seagrass species encountered. Divers quantified percent cover of all seagrasses at each site by haphazardly deploying a 1 m^2 quadrat approximately 30 times within each seagrass sampling site. Each 1 m^2 quadrat was subdivided into 25 equilateral 20 cm x 20 cm cells. Seagrass percent cover was assessed by quantifying the number of cells (out of 25) in which each seagrass species occurred. In addition, the number of bare (no seagrass) cells was quantified for each quadrat sampled. These count data (i.e., how many cells had manatee grass) were converted to percent cover data by dividing the number of cells in which the seagrass species occurred by the total number of cells (25). For example, a quadrat in which manatee grass was present in 12 of 25 cells, shoal grass was present in 16 of 25 cells, and 3 cells were bare (i.e., no seagrass present) was recorded as having the following percent cover values: manatee grass 48%, shoal grass 64%, and total seagrass cover 88%. Seagrass canopy height was quantified in each quadrat assessed for seagrass percent cover by measuring the average blade length (distance from substrate to blade tip) of shoots of the dominant canopy-forming seagrass species in each quadrat. In order to facilitate spatial analyses, the position of each quadrat was georeferenced using a mapping-grade GPS (Trimble Navigation Inc. GeoXT or GeoXH).

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 bi-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, data from RiverKeeper water quality stations 40 and 42 (central embayment), 60 (Northwest Fork), and 25 (Hobe Sound) provide monthly or bi-monthly assessments of nutrients in the vicinity of the seagrass sampling sites (see Project RiverKeeper reports at www.loxahatcheeriver.org/reports.php). 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). 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 multiple 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.

Landscape-scale Mapping Methods

Because of depth and limited water clarity typical of the Loxahatchee River estuary, mapping work was performed while snorkeling. Weighted buoys were randomly deployed from a power boat in a manner of even distribution and generally with no two buoys closer than 10 m and up to roughly 100 m in areas with uniform conditions. Each buoy marked a sample point. We then quantifed seagrass presence or absence by deploying a collapsible 9m^2 quadrat at each sample point. The 3 m x 3 m quadrat, dubbed "Quadzilla", is made using four 3 m long (3/4") PVC pipes connected with a 3/8" nylon line running through each side and tied at one corner. Each 3 m side has its middle 1 m length painted black, which allows the deployed quadrat to be divided into nine 1 m^2 cells. A string network defining each of the 9 square meters is attached. One leg is marked with 10 cm segments for measuring water and muck depth.

Figure 4. "Quadzilla", 9m^2 sampling quad.

Because the quad is held together by nylon rope running through the PVC segments and not by fixed elbows at the corners, field crews are able to fold the large quadrat up into one 3m long bundle of PVC poles and carry it while snorkeling between sampling sites.

Within each sample (9 m^2 quadrat) a diver quantified water depth, identified predominant substrate type (much, sand, rock/shell, detritus), quantified muck depth if present, and documented seagrass presence and percent cover. Seagrass presence was assessed within the 9 m^2 quadrat in the following manner. First, bare substrate was scored as the total number of 1 m^2 cells in which no seagrass was present (0 to 9). Next, each seagrass species was scored according to the number of 1 m^2 cells in which it was present (0 to 9). We conservatively defined seagrass presence as the occurrence of at least one seagrass shoot. Each sample, therefore, received a score between 0 and 9 for bare substrate and a score of 0 to 9 for each of the seven seagrass species known to occur in the estuary. Seagrass density was somewhat more subjectively assessed. Within each quadrat a diver visually estimated seagrass density, in cells where seagrass was present, using the following categories: (1) low density (< 5% coverage); (2) moderate density (> 5% but < 90% coverage); and (3) high density (≥ 90% coverage) and illustrated in Figures 5-7.

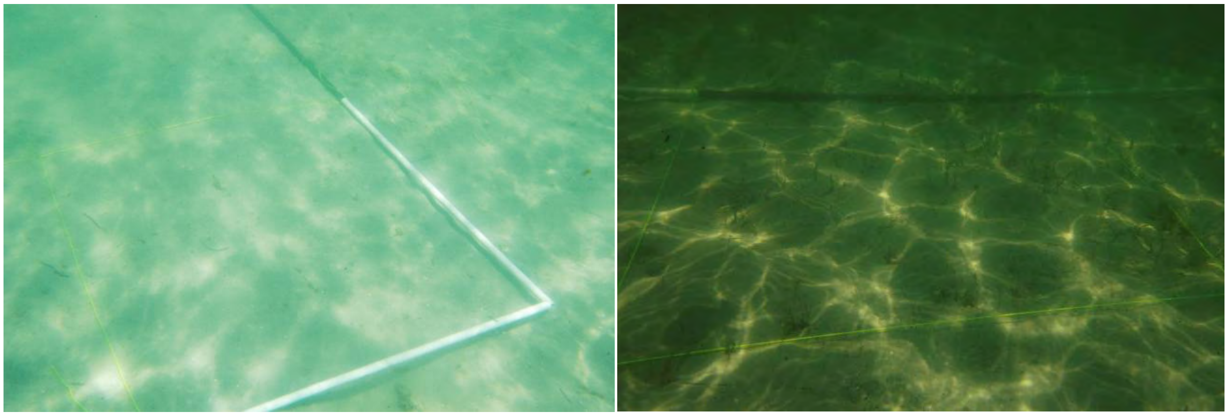

Figure 5. Example of low density seagrass (score = 1), characterized by very sparse conditions equivalent to < 5% seagrass cover.

Figure 6. Example of moderate density seagrass (score = 2). Seagrass cover was > 5% but coverage, but < 90%.

Figure 7. Example of high density seagrass (score = 3), characterized by dense, continuous seagrass cover (≥ 90%). Photos on this page by Jerry Metz

After all of the data was recorded on the field sheet, the sheet was clipped to a buoy marking the sample location and the diver moved to the next sampling site.

Figure 8. Field team of two divers and one GPS operator.

GPS Data Collection

Each sampling site was mapped with a mapping-grade Trimble GPS systems (GeoXT or GeoXH) running Trimble's TerraSync data collection software. The hand-held GPS was used to record the spatial location of each sample point as well as pertinent data (i.e., seagrass percent occurrence, substrate type, etc) while in the field. Each day the GPS was downloaded and the positional data post-processed to maximize accuracy. The data entered into the GPS while in the field is checked by cross-referencing data from field data sheets.

GIS Data Analysis

For illustration purposes we created maps depicting each sample point colorized by a corresponding quadrat score for all seagrasses observed, each species, seagrass density scores, and the soft/muck sediments. For seagrasses we symbolized each sample point according to the following quadrat score: 1) no part of the 9m^2 quadrat had seagrass (0 of the 9 1m^2 cells); 2) one to five of the nine 1m^2 had seagrasses (1-5/9 cells) was categorized and labeled as 'Patchy Seagrass'; and 3) six to nine of the nine 1m^2 had seagrasses (6-9/9 cells) was categorized and labeled as 'Continuous Seagrass'. We used this same categorization for each of the species-specific maps. The soft sediments/muck data was symbolized as sample points having 'no muck' or sandy sediments, samples with less than 10 cm muck depth, and samples having greater than 10 cm muck depth.

We have performed extensive testing to identify an effective interpolation approach that accurately represents the seagrass coverage for the entire survey area from the point data collected in the field. While we continue to refine our data processing approach, we have found the following combination of analysis methods and software settings within the GIS software provides the most accurate and representative maps. However, our work continues to identify the best approach to create the coverage maps. In particular, we have determined that the boundaries the user creates for the GIS data processing is critical for obtaining accurate results.

We have found the Inverse Distance Weighted (IDW) interpolation method available through ESRI's ArcGIS Spatial and 3D Analyst Extensions to be the most effective analysis tool to create the seagrass coverages that best represent the total area occupied by each seagrass species. We use this tool is to assign expected percent cover values for each seagrass species in each grid cell based on interpolation of our actual observations. IDW estimates cell values by averaging values of field-based observations (samples) in the neighborhood of each cell being estimated. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the interpolation process. We perform IDW using six neighborhood points and a weight of four. Points are assessed using a variable search radius. The entire estuary is converted into a grid of 3 m x 3 m cells. The estuary grid used for interpolation is constrained using a polyline-based mask to limit the interpolation to areas that potentially supported seagrass. This polyline limit is critical element of the processing because it provides the boundaries, or limits, of the interpolation. As such, it is important to use all data available to define the locations of the polyline boundary. To define these boundaries we symbolized the seagrass sample points as presence or absence, considered bathymetry, and used aerial imagery to exclude shoreline, mangrove islands, and boat docks. Because light attenuation increases in an upstream manner, shallower depth contours are used in the three forks than in the central embayment. While the manual creation of the polyline boundary is somewhat subjective, it is critical to prevent interpolation beyond logical boundaries and to obtain the most accurate coverage maps. We continue to refine this methodology and the boundary layers so we can make more thorough comparisons between the 2007 and 2010 mapping events, where sufficient overlapping data exists.

After the interpolated grid is computed, we use the Reclassify function to assign an integer to the species scores. This step facilitates visual interpretation of output from the IDW interpolation process into categories. For example, interpolated seagrass scores of 5.0 to 5.99 is assigned 5 indicating that 5 of the 9 cells of the quad contained seagrass. We commonly established the following categories: Continuous Seagrass (defined as cells with interpolated seagrass cover ≥56%; or seagrass scores of 5 to 9), Patchy Seagrass (interpolated seagrass cover ≥11% and <56%; or score of 1-4), and No Seagrass (interpolated seagrass cover <11%, or score of 0).

Results & Discussion

Patch-scale Monitoring

The primary purpose of this study was to generate a more comprehensive understanding of spatial and temporal dynamics of seagrass percent occurrence and canopy height (i.e., measures of seagrass health) within the Loxahatchee River Estuary prior to restoration (augmentation) of freshwater flows to the Northwest Fork of the Loxahatchee River. As such, we assessed seagrass percent cover and canopy height in 870 individual quadrat samples among our five sampling areas during the period October 2009 through September 2010. Seagrasses appeared healthy in the Loxahatchee River, though there are notable differences in seagrass percent occurrence and canopy height among sampling sites. Figure 9 shows percent occurrence of the three dominant seagrass species across the five sampling sites. These data span from June, 2003 through December, 2010, and provide an amazing opportunity to understand temporal dynamics within seagrass beds. It is important to remember that in October 2004 several major storms adversely impacted seagrasses in the Loxahatchee River Estuary (Ridler et al. 2006). Data collected since then document the recovery trajectory that has occurred at each site by each species. Data prior to October 2007 was transect-based, percent cover data collected at each of these sites and is described in previous monitoring reports available at www.loxahatcheeriver.org/reports.php. Previous comparisons of the transect and random-quadrat methods at these sites have demonstrated similar results. Therefore we have combined the data sets in Figure 9.

Today the seagrass bed at North Bay is composed predominantly of shoal grass, manatee grass, and Johnson's grass. Prior to the storms of 2004 this seagrass bed was dominated by manatee grass. It is important to recognize the lack of recovery by manatee grass six years following the disturbance. While manatee grass appears to be mounting a slow and steady recovery, the present occurrence of manatee grass remains about 50% of its pre-disturbance occurrence. Shoal grass appears to have filled the space vacated by the loss of manatee grass, and occurred in approximately 70% of North Bay samples since August, 2010. Johnson's grass showed significant increases in occurrence the two years following the disturbance, but had declined to near pre-disturbance occurrence levels (i.e., ~20%) in 2010. Maximum canopy height within North Bay was generally around 30 cm, with healthy manatee grass forming the tallest canopy. This site had the most stable salinity regime of the Loxahatchee River Estuary sites, which may explain why manatee grass was most abundant among the Loxahatchee River sites.

Shoal grass and Johnson's grass within the Sand Bar seagrass bed appear to have made a full recovery. While manatee grass occurred in 30-40% of Sand Bar samples prior to the 2004 disturbance, manatee grass was found in isolated, small patches occupying less than 10% of samples in 2010. We are somewhat surprised by the lack of recovery of manatee grass at the Sand Bar site, though we are encouraged by the prevalence of shoal grass and Johnson's grass at this site. Johnson's grass showed pronounced seasonality at this site with annual peaks typically occurring in April, though peak abundance in 2008 occurred in February. In general, seagrass canopy height averages around 10 cm at the Sand Bar site except for patches that contain manatee grass where canopy height peaks around 20 cm.

The Pennock Point seagrass bed has never had manatee grass, and appears to have fully recovered following the 2004 disturbance. In 2010 shoal grass occupied roughly 60% of the seagrass patch and Johnson's grass occupied 30% to 70% of the seagrass patch. Johnson's seagrass has exhibited a pronounced increase in occurrence especially since 2008. Johnson's seagrass appears to demonstrate a slightly different seasonal pattern of abundance at Pennock Point relative to the Sand Bar site. Seagrass canopy height at Pennock Point is typically less than 10 cm, with the dominant canopy species being shoal grass. We suggest manatee grass was absent from this site due to the wide fluctuations observed for salinity conditions at this site.

We began sampling the Northwest Fork seagrass bed in October, 2007, so pre-disturbance comparisons cannot be made for this site. In April, 2010 Johnson's grass, the dominant species, occupied over 70% of the patch, while shoal grass consistently occupied 10%-20% of the patch. Canopy height was similar to Pennock Point with shoal grass the dominant canopy species and mean canopy height less than 10 cm. Because of freshwater flowing down the Northwest Fork of the Loxahatchee River, this site had the highest average water color, lowest light penetration, and lowest average salinity condition, and most variable salinity conditions among the seagrass sites sampled.

The reference seagrass bed in Hobe Sound continued to exhibit relatively stable seagrass conditions. Manatee grass occupied nearly 80% of the bed throughout the year. Shoal grass occupied around 40% of the bed for most of the year, and Johnson's grass generally occupied less than 5% of the seagrass bed. Canopy height at Hobe Sound was generally 30 cm – 40 cm with manatee grass as the dominant canopy species. It appears that the relatively stable salinity conditions at this site, due to the lack of freshwater inflows, have allowed manatee grass, a canopy-forming species sensitive to salinity fluctuations, to uniformly dominate this site through time.

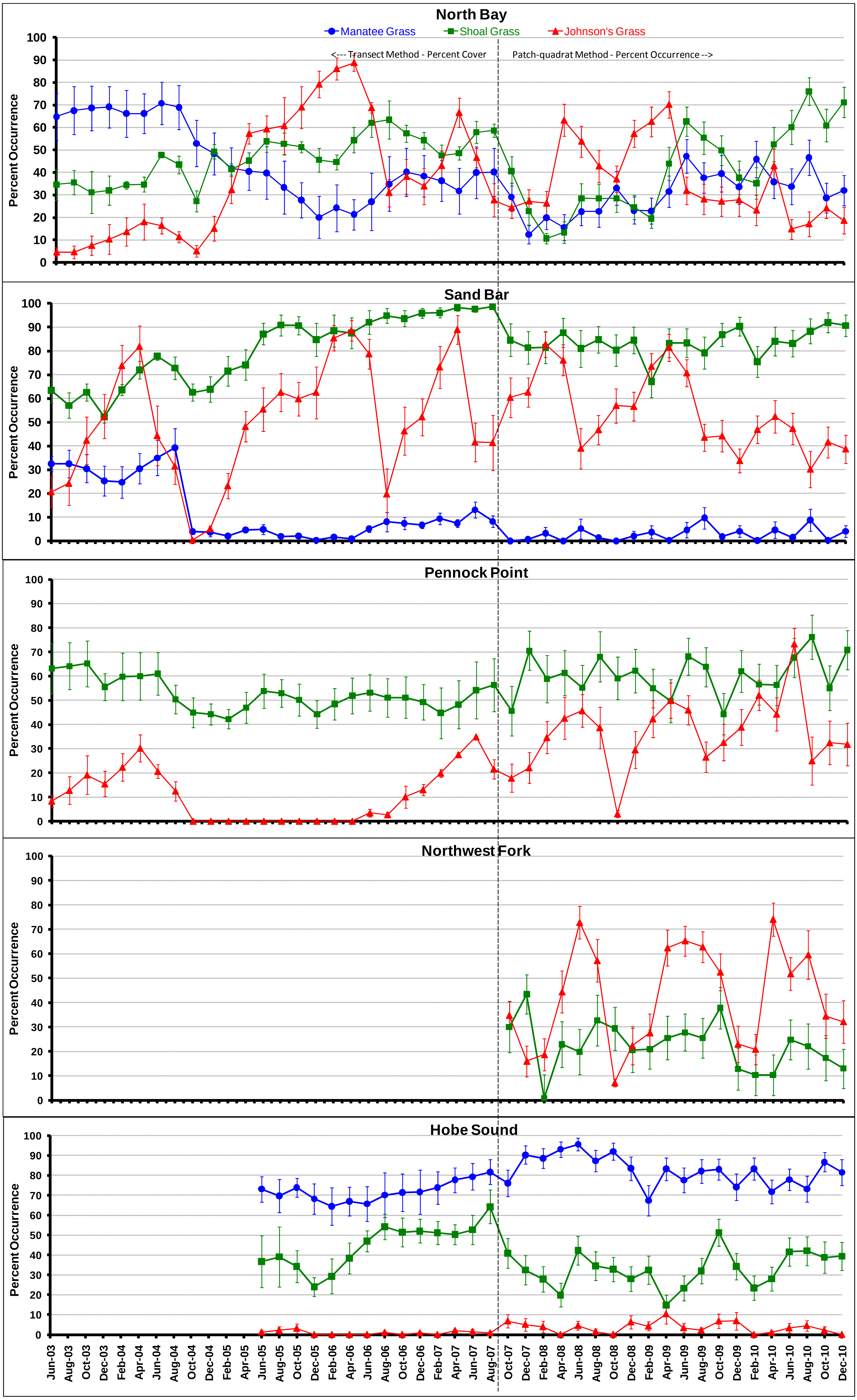

Figure 9. Percent cover (Pre October 2007) and percent occurrence (Post October 2007) data suggest strong differences in seagrass health among Loxahatchee River monitoring sites across the upstream-downstream gradient. Error bars represent ± 1 Standard Error.

Landscape-scale Monitoring

In 2010, the LRD lab staff mapped species-specific seagrass occurrence at 1,667 samples located throughout the Loxahatchee River estuary. Fifty-nine percent of samples included at least one seagrass species while 41% of samples had no seagrass present. Johnson's grass, a Federally listed species as threatened under the Endangered Species Act, was the most frequently encountered seagrass and occurred in 46% of samples. Shoal grass was the second most encountered species occupying 39% of samples. Paddle grass, manatee grass, and turtle grass were infrequently found, and occupied 4%, 3%, and 2% of samples, respectively.

From a spatial perspective, seagrasses extended to approximately 5,800 m upstream into the North Fork, 6,500 m into the Northwest Fork, and 5,400 m into the Southwest Fork, as measured from the mouth Jupiter Inlet (Appendix Figure A1). These limits are likely determined by salinity variability, water clarity, and water depth (bathymetry). Figure A2 presents the seagrass data with the 2008 bathymetry data and helps to illustrate the relationship between seagrass presence and water depth, relative to the distance to the inlet. Figure A3 presents the interpolated seagrass coverage from the point data. Again, we continue to refine these figures to ensure optimum accuracy by manipulating the interpolation boundary limits and settings. Final figures will be included in a forthcoming paper that we intend to submit for publication. Appendix B contains comparative figures from the 2007 mapping project.

In general, seagrass in the Loxahatchee River estuary are found fringing the shoreline in downstream segments of the system (i.e., downstream of river mile 4), or in the shallow portions of the central embayment. In general, the distribution of seagrasses within the Loxahatchee River estuary is assumed to be driven by salinity variability (Ridler et al. 2006) and water clarity (Hall et. Al. 1991, Onuf 1991). LRD's 2010 Datasonde Monitoring Report (www.loxhatcheeriver.org/reports.php) describes the variation in salinity characteristics at several locations in the river and provides insight into the conditions influencing the various seagrass distributions. Undoubtedly water depth and sediment type are factors that influence seagrass distributions. The data presented in Table 1 show a strong negative relationship between seagrass occurrence and water depth and muck depth. Appendix Figure A9 illustrates the locations of samples where muck sediments were encountered.

Table 1. Water depth and muck depth appear to limit landscape-scale occurrence of seagrass in the Loxahatchee River estuary. Data based on 1,667 samples collected in 2010.

Seagrass Score	Seagrass Description	# of Samples	% of Samples	Water Depth (cm)	Muck Depth (cm)
0	Absent	689	41%	158	9.5
1-5	Patchy	181	11%	136	1.3
6-9	Continuous	797	48%	82	0.6

We provide species-specific maps illustrating the samples that contained Johnson's Seagrass (*Halophila johnsonii*), Shoal Grass (*Halodule wrightii*), Paddle Grass (*Halophila decipies*), Manatee Grass (*Syringodium filiforme*), and Turtle Grass (*Thalassia testudinum*) in Appendix Figures A4 through A8. Johnson's Seagrass and Shoal Grass were the most widely distributed seagrass throughout the estuary, and both species extending the furthest upstream (Figures A4 and A5). The distributions of these seagrasses were generally similar to the 2007 observations (Figures B3 and B4). The distribution of Paddle Grass showed the most pronounced changes between 2007 and 2010 (Figures A6 and B5). In

2007 Paddle Grass was present throughout much of the southwest and far southeast portions of the central embayment, but in 2010 Paddle Grass far less common in these areas. Curiously, the occurrence of Paddle Grass in the North Fork appeared greater in 2010 than 2007. Variations in rainfall, the subsequent freshwater flows into the river, and the resulting salinity variability were likely factors influencing the distribution of Paddle Grass between the drought year of 2007, and the extended wet season of 2010 (see LRD's 2010 Datasonde Report). The distributions of Manatee Grass were generally similar between 2007 and 2010 with occurrence limited to central portions of the central embayment (Figures A7 and B6). Lastly, the distributions of Turtle Grass, the rarest species in the Loxahatchee, were largely limited to east portion of the central embayment with isolated occurrences scattered throughout the central embayment (Figure A8 and B7). The scattered occurrences of Turtle Grass in the central part of the central embayment observed in 2007 were far less common in 2010.

Conclusions

Ongoing seagrass monitoring in the Loxahatchee River Estuary has provided interesting insights into the ecology and dynamics of seagrasses. During the period October 2009 – September 2010 seagrass in the Loxahatchee River Estuary appeared to be relatively healthy, though percent cover values for some species and monitoring sites remain below those observed prior to the October 2004 hurricanes. By comparing seagrass conditions in the Loxahatchee River against those of the reference site and across the upstream-downstream gradient in the Loxahatchee River we were better able to understand the impacts freshwater discharges had on seagrass conditions.

The 2010 mapping project provides unprecedented detail on the distributions of seagrasses throughout the estuary. Comparisons of the 2010 and 2007 mapping data help to illustrate and eventually quantify the extent and variability in the seagrass distributions throughout the estuary.

The methods employed in the present study are synonymous with methods being employed throughout the other estuaries in South Florida as part of CERP Monitoring and Assessment Program. Therefore, we expect these results, when combined with results from other systems, will provide a comprehensive understanding of seagrass dynamics across all of the South Florida estuaries.

Recommendations for future work:

1. Continue the seagrass monitoring program to assess long- and short-term trends in water quality in the Loxahatchee River. In particular, we need to better understand differences in salinity envelopes among seagrass patches, so we can determine thresholds that constrain assemblage membership (i.e., what conditions lead to loss of manatee grass). Such data will provide essential information for adaptive management of future restoration activities.
2. We need to better understand how various physical factors interact across the landscape to constrain the occurrence of seagrass. For example, water quality changes significantly across the upstream to downstream gradient, and these changes likely interact to define habitat patches potentially suitable for seagrass.

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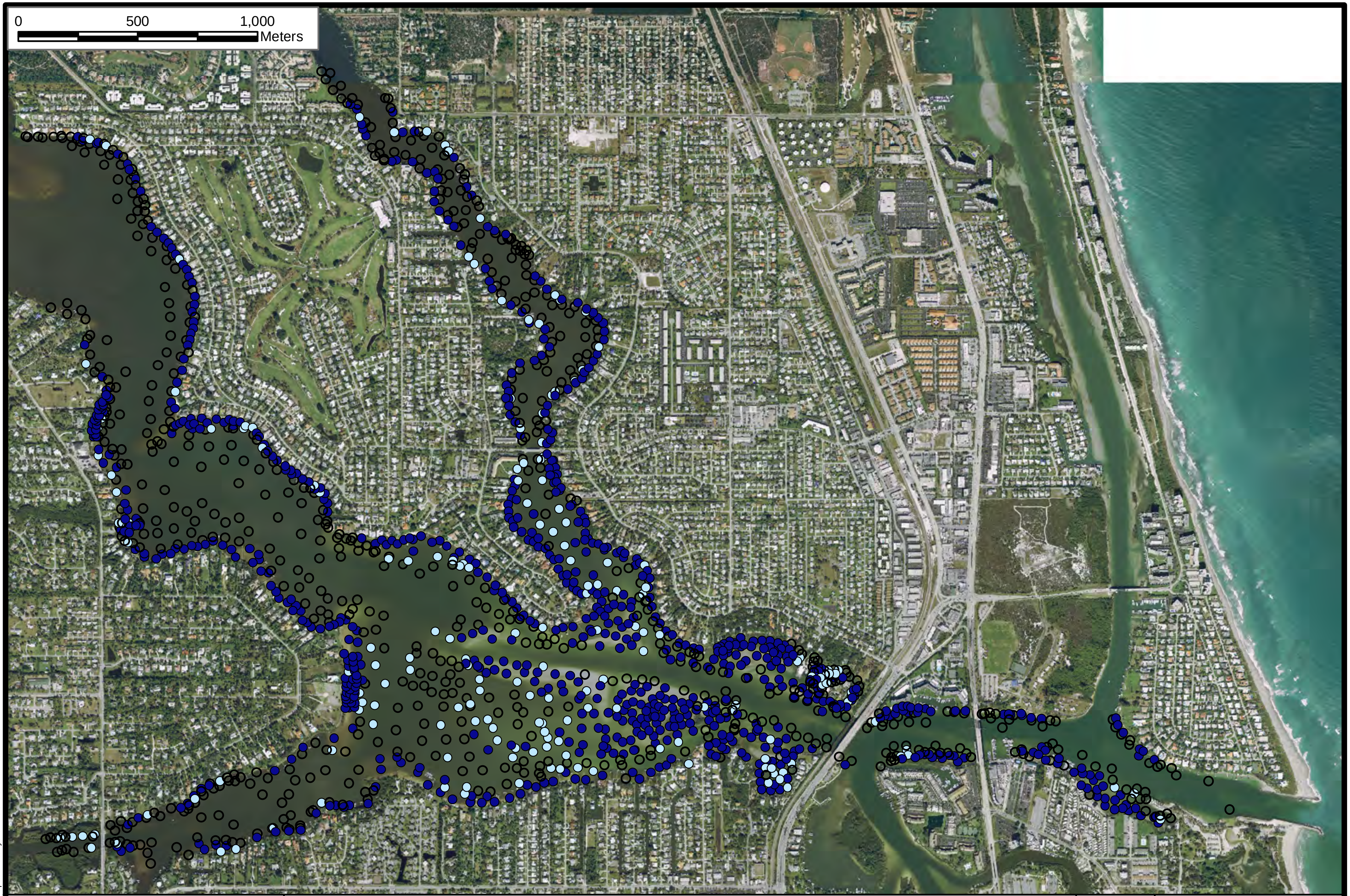
Appendix A

Plots from 2010 Seagrass Mapping Project



Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
(561) 747-5700
www.loxahatcheeriver.org

Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

A1

2010 Loxahatchee River Seagrass Mapping
All Seagrass Species

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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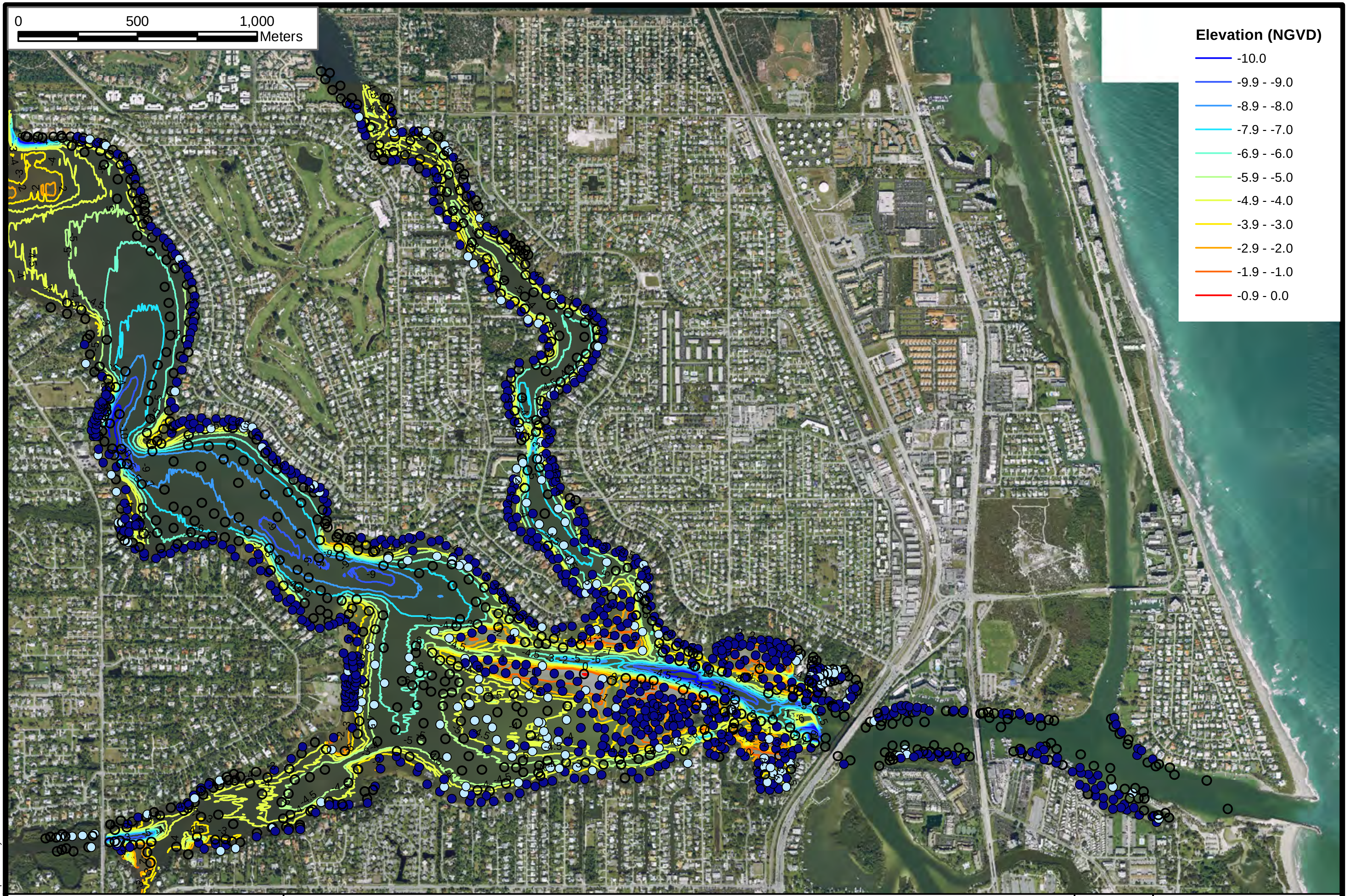

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Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

A2

2010 Loxahatchee River Seagrass Mapping
All Seagrass Species with 2008 Bathymetry

2008 Bathymetry Data from Jupiter Inlet District

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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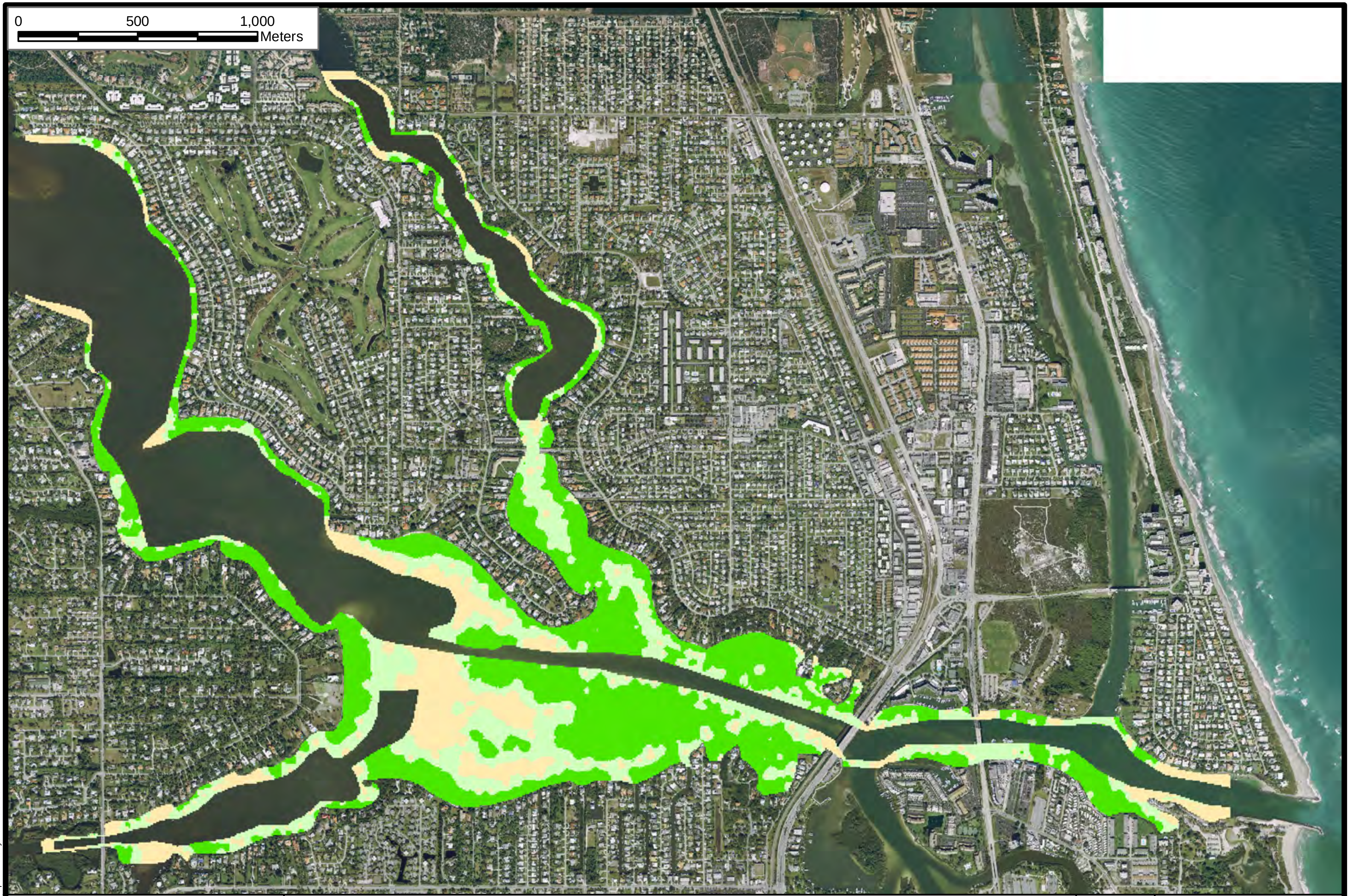

Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
(561) 747-5700
www.loxahatcheeriver.org

- Continuous
- Patchy
- No Seagrass

A3

2010 Loxahatchee River Seagrass Mapping
Interpolated Seagrass Coverage - All Species
~ Subject To Change ~

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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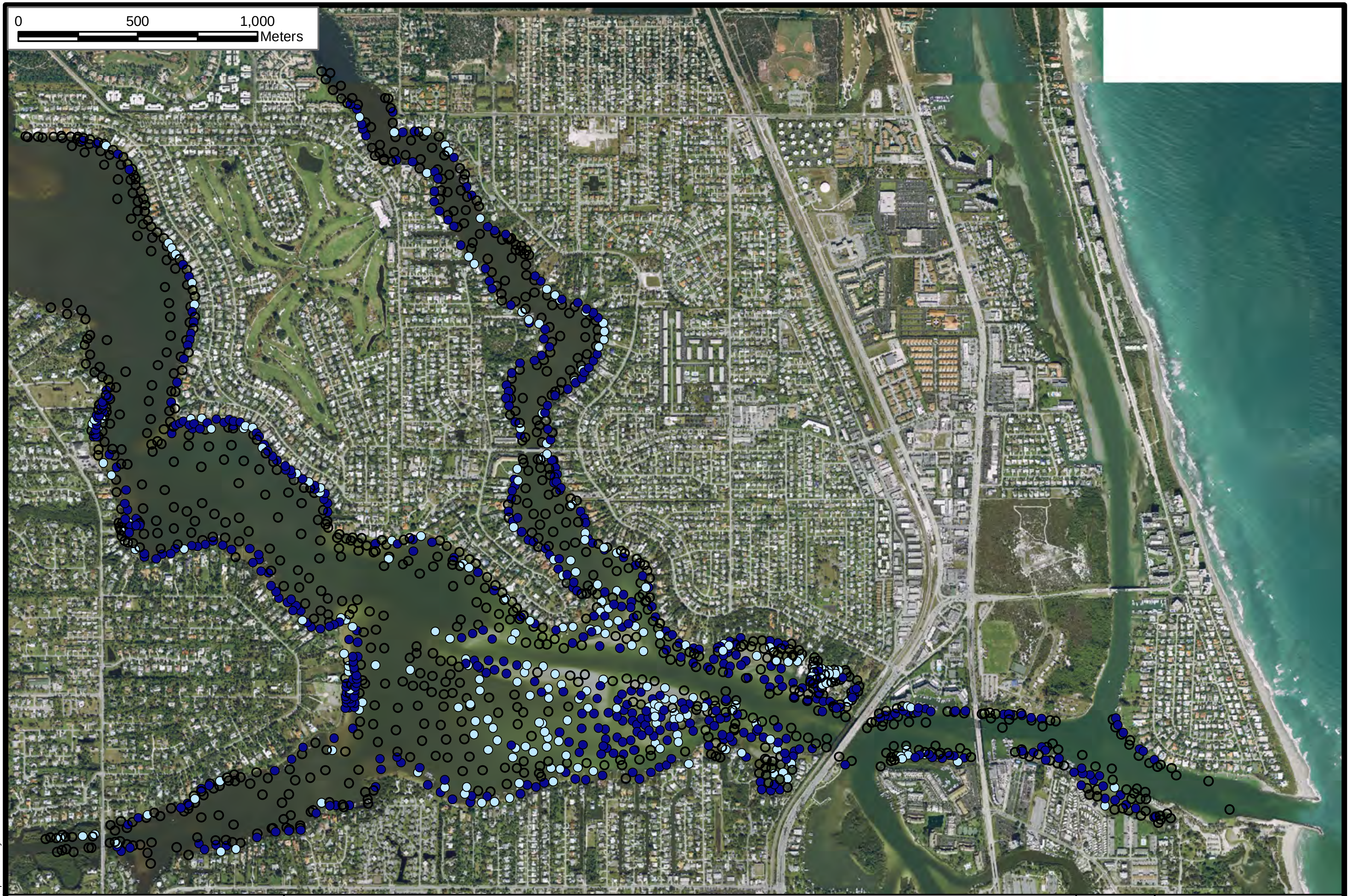

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Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
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Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

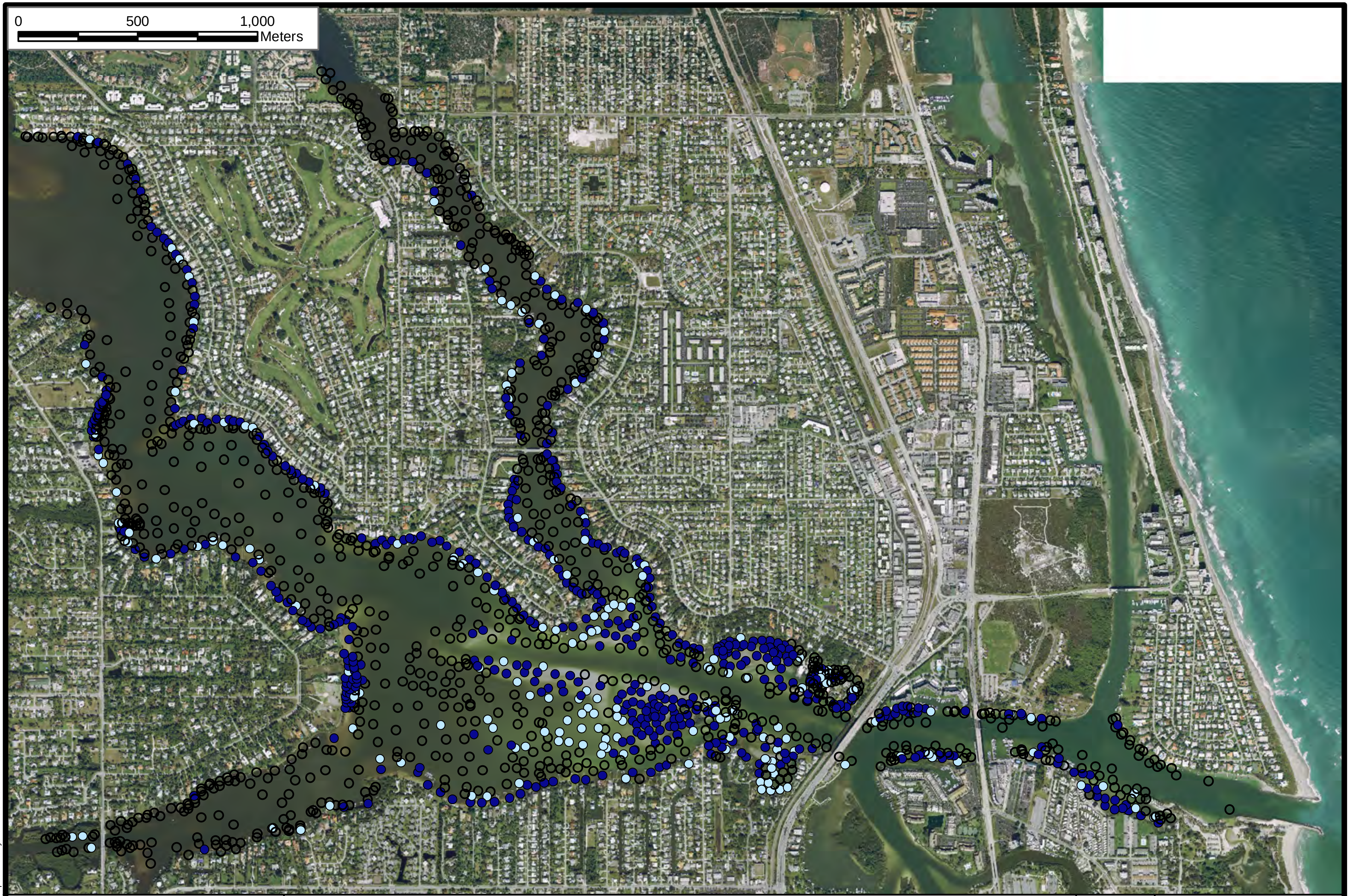
A4

2010 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Johnson's Seagrass (Halophila johnsonii)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH



Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
(561) 747-5700
www.loxahatcheeriver.org

Quadrat Score

- ○ (0/9) No Seagrass
- ● (1 - 5/9) Patchy Seagrass
- ● (6 - 9/9) Continuous Seagrass

A5

2010 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Shoal Grass (Halodule wrightii)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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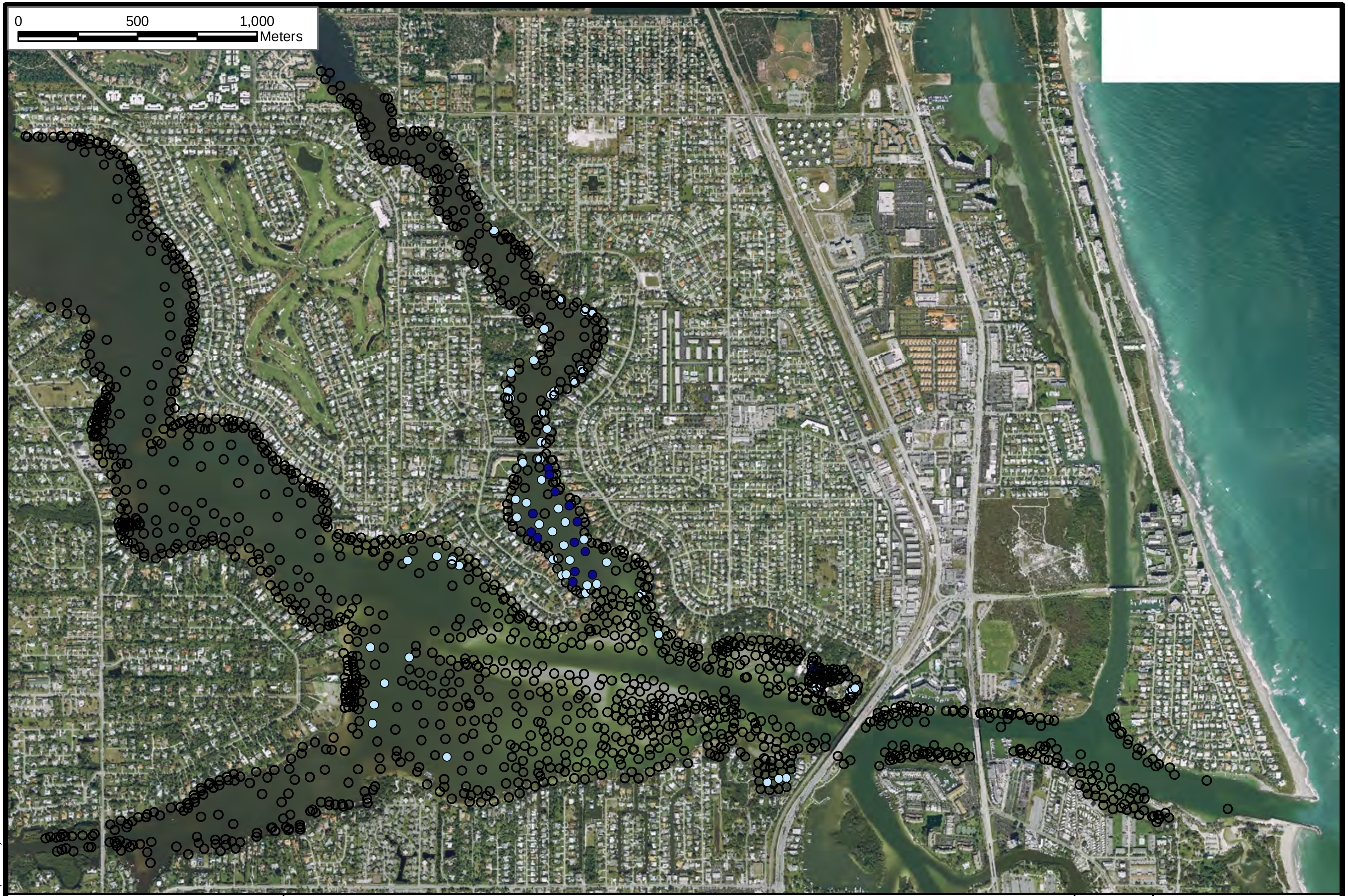

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Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

A6

2010 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Paddle Grass (Halophila decipiens)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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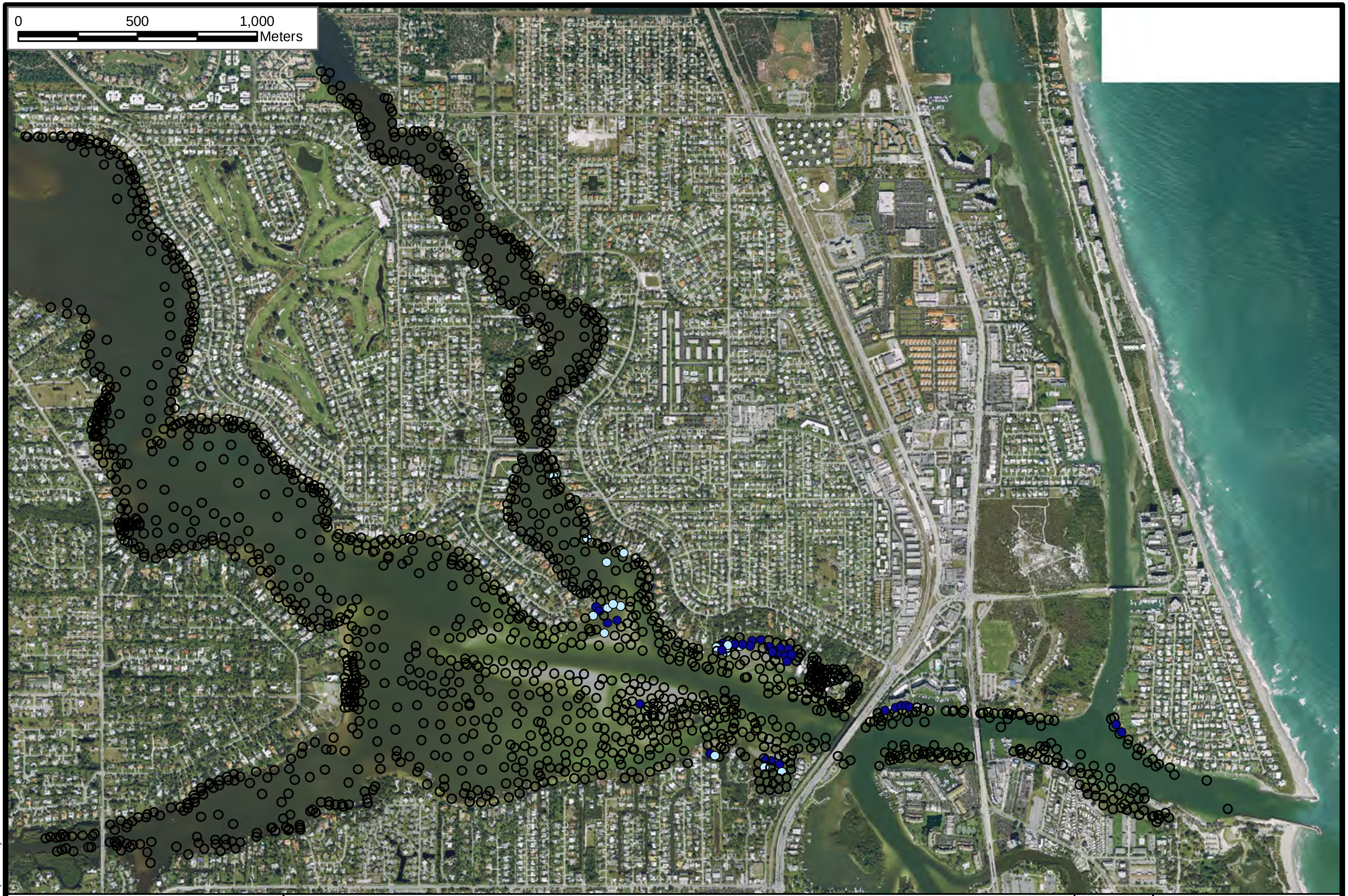

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Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

A7

2010 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Manatee Grass (Syringodium filiforme)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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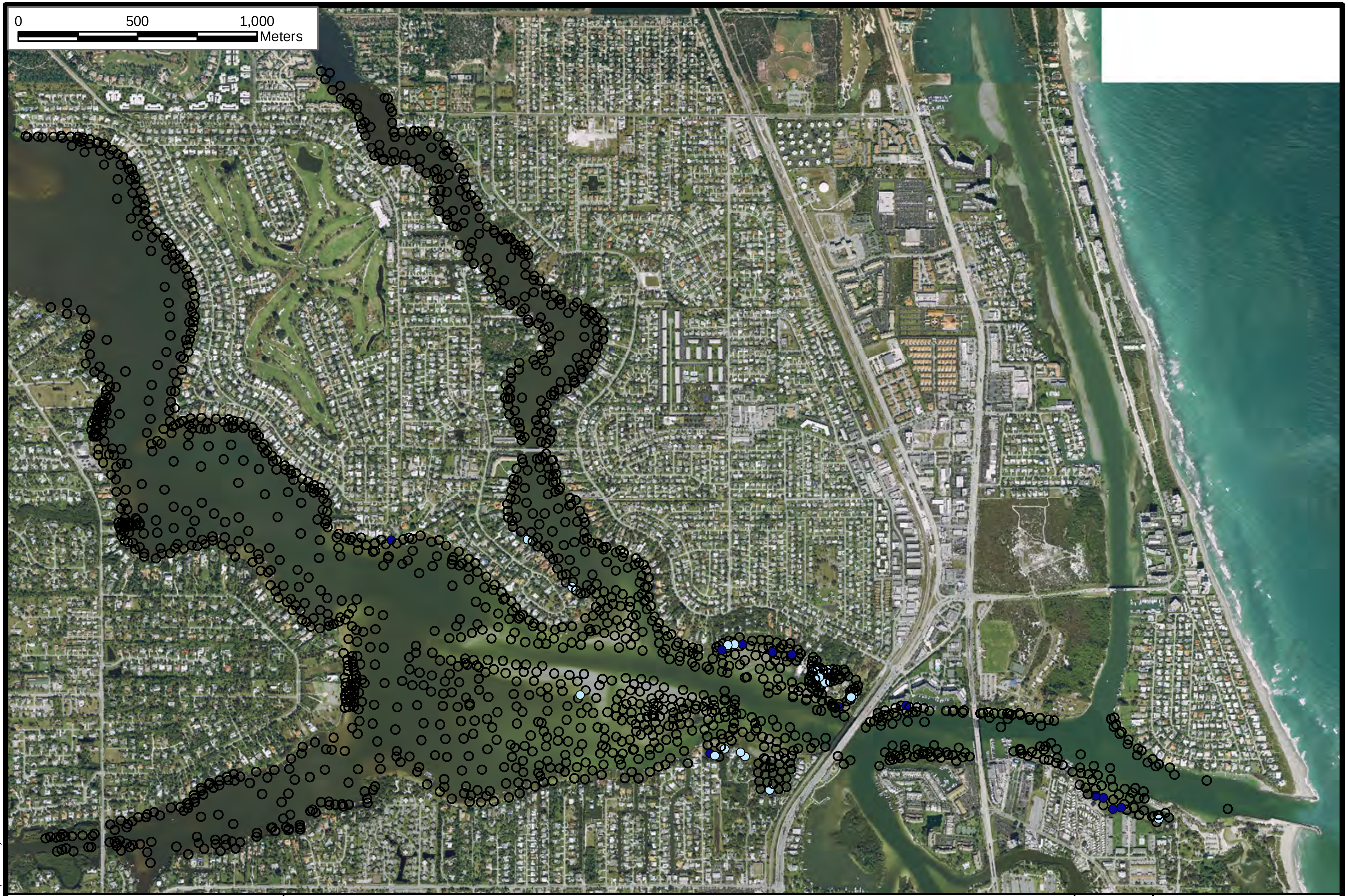

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www.loxahatcheeriver.org

Quadrat Score

- ○ (0/9) No Seagrass
- ○ (1 - 5/9) Patchy Seagrass
- ● (6 - 9/9) Continuous Seagrass

A8

2010 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Turtle Grass (Thalassia testudinum)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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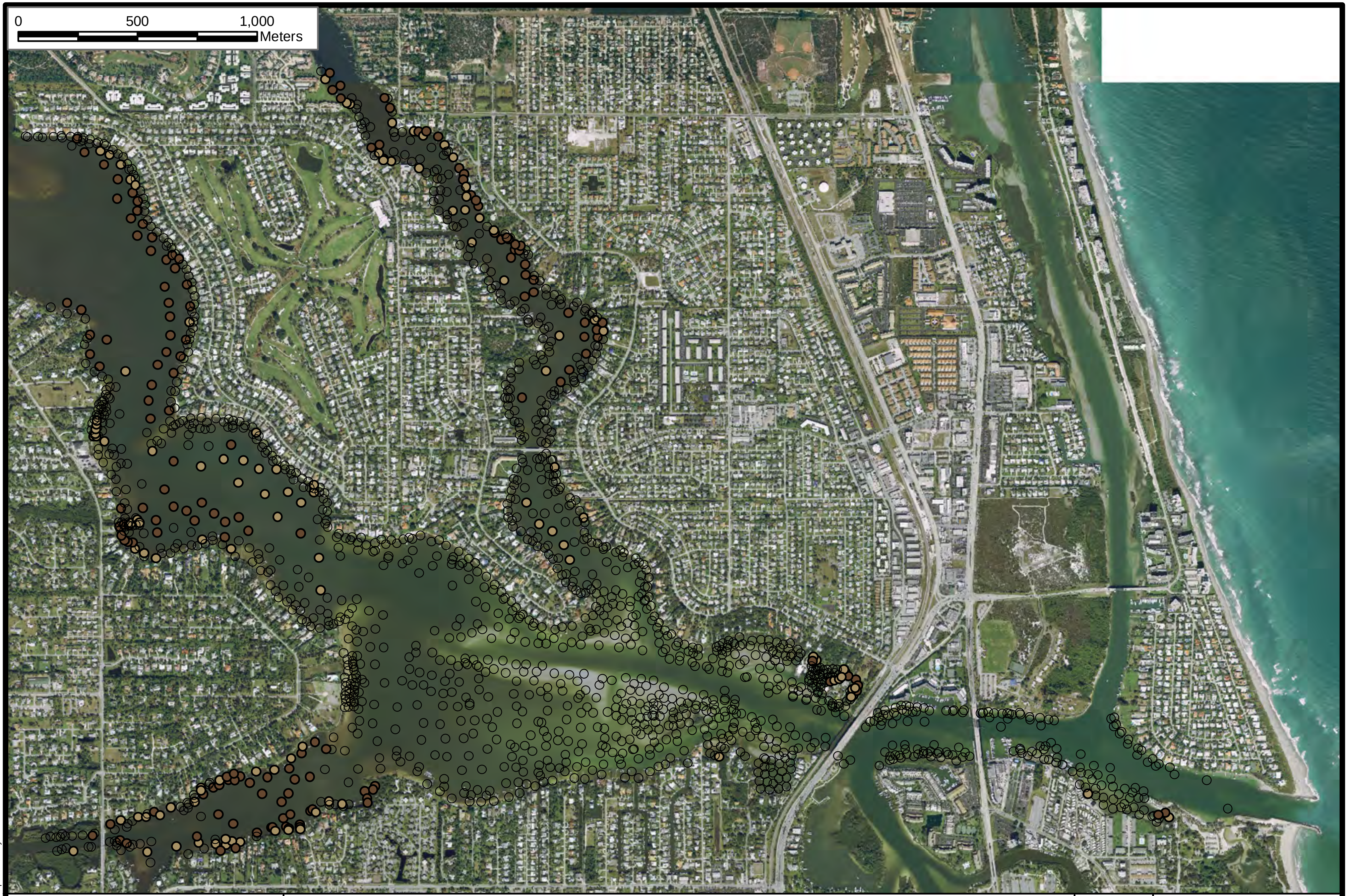

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Muck Depth

- No Muck
- < 10 cm
- 10 - 140 cm

A9

2010 Loxahatchee River Seagrass Mapping
Soft/Muck Sediment Depths

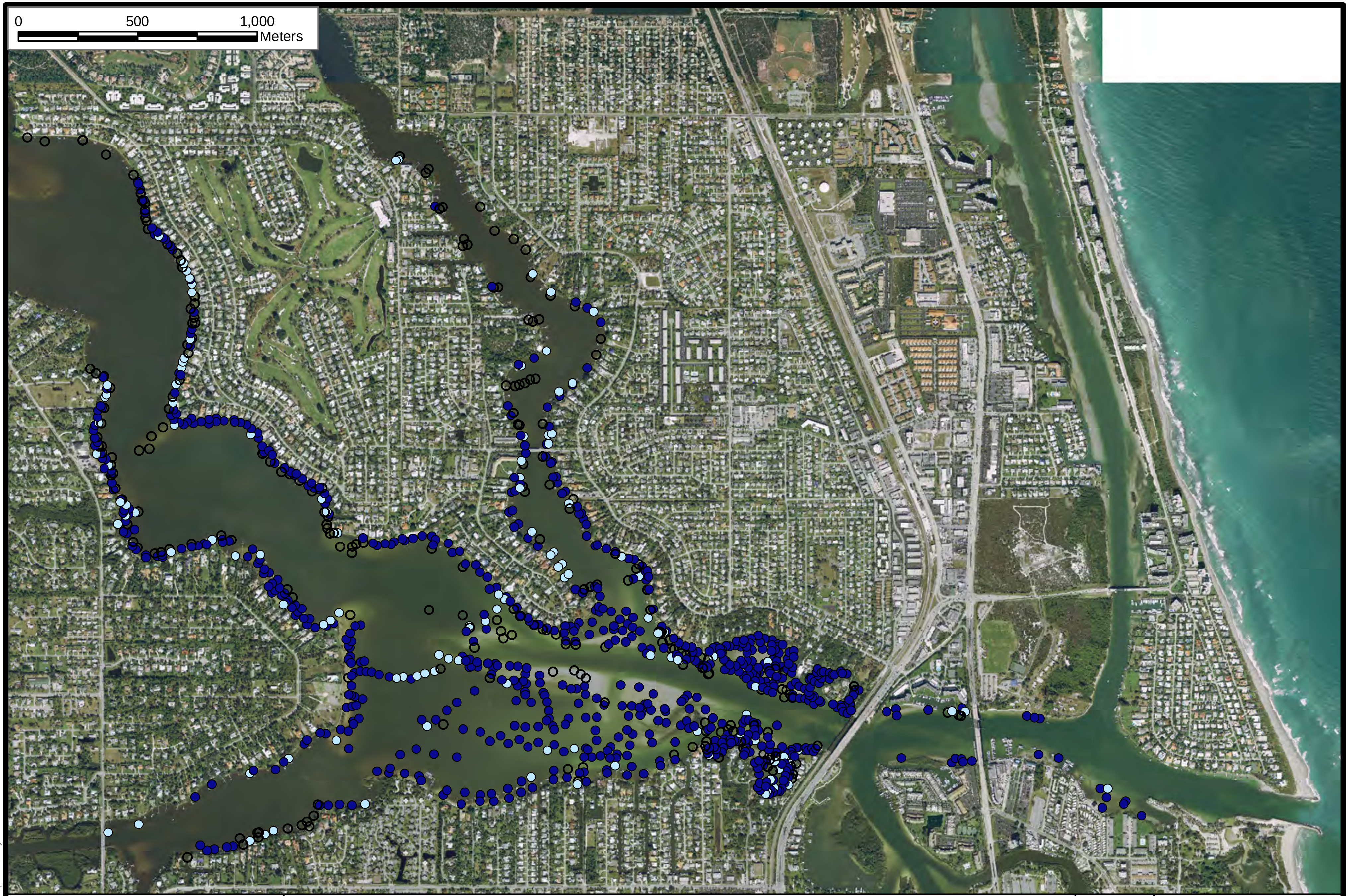
N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

Appendix B

Plots from 2007 Seagrass Mapping Project



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2500 Jupiter Park Drive
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www.loxahatcheeriver.org

Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

B1

2007 Loxahatchee River Seagrass Mapping
All Seagrass Species

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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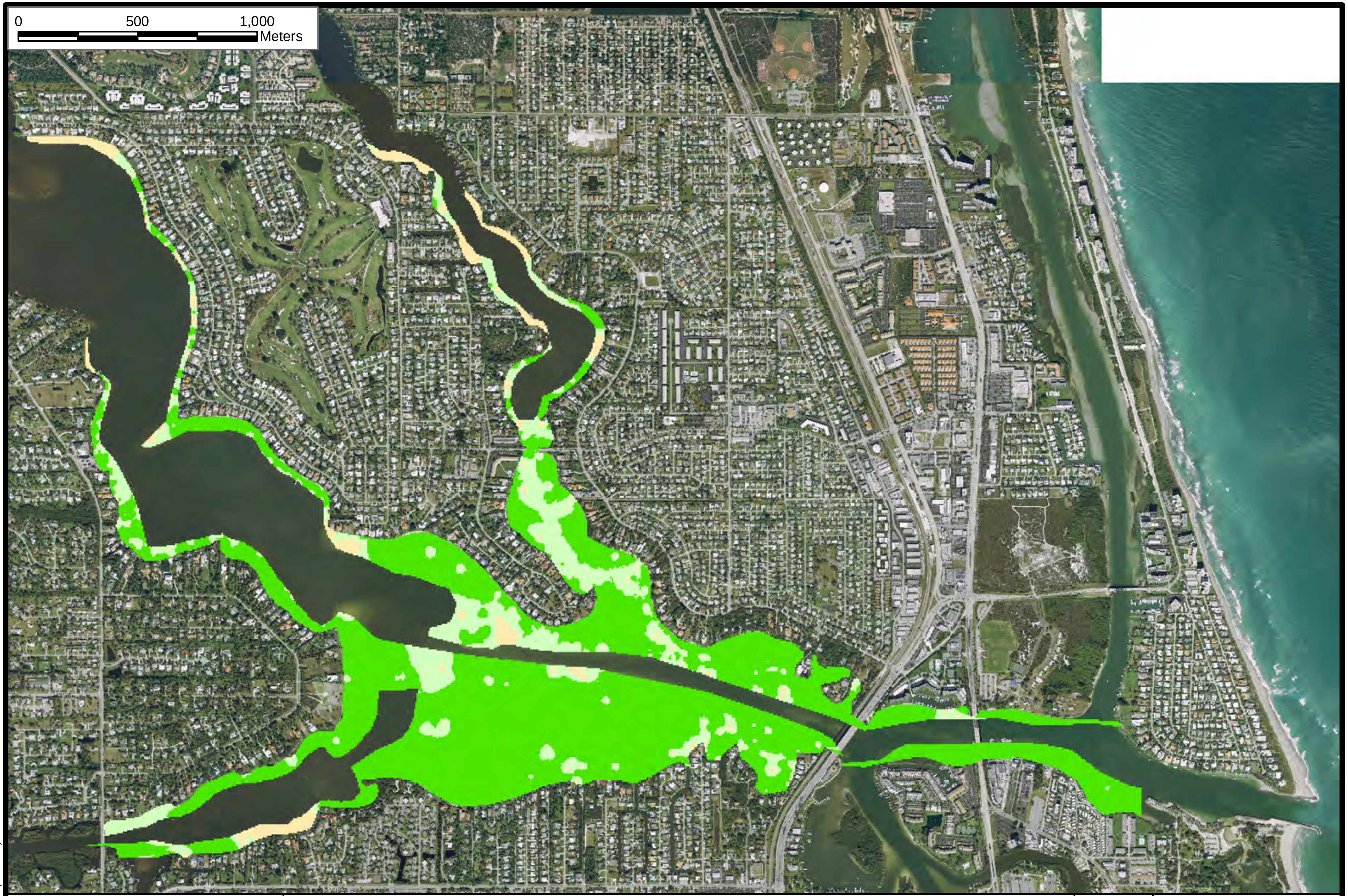

Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
(561) 747-5700
www.loxahatcheeriver.org

Continuous
Patchy
No Seagrass

B2

2007 Loxahatchee River Seagrass Mapping
Interpolated Seagrass Coverage - All Species
~ Subject To Change ~

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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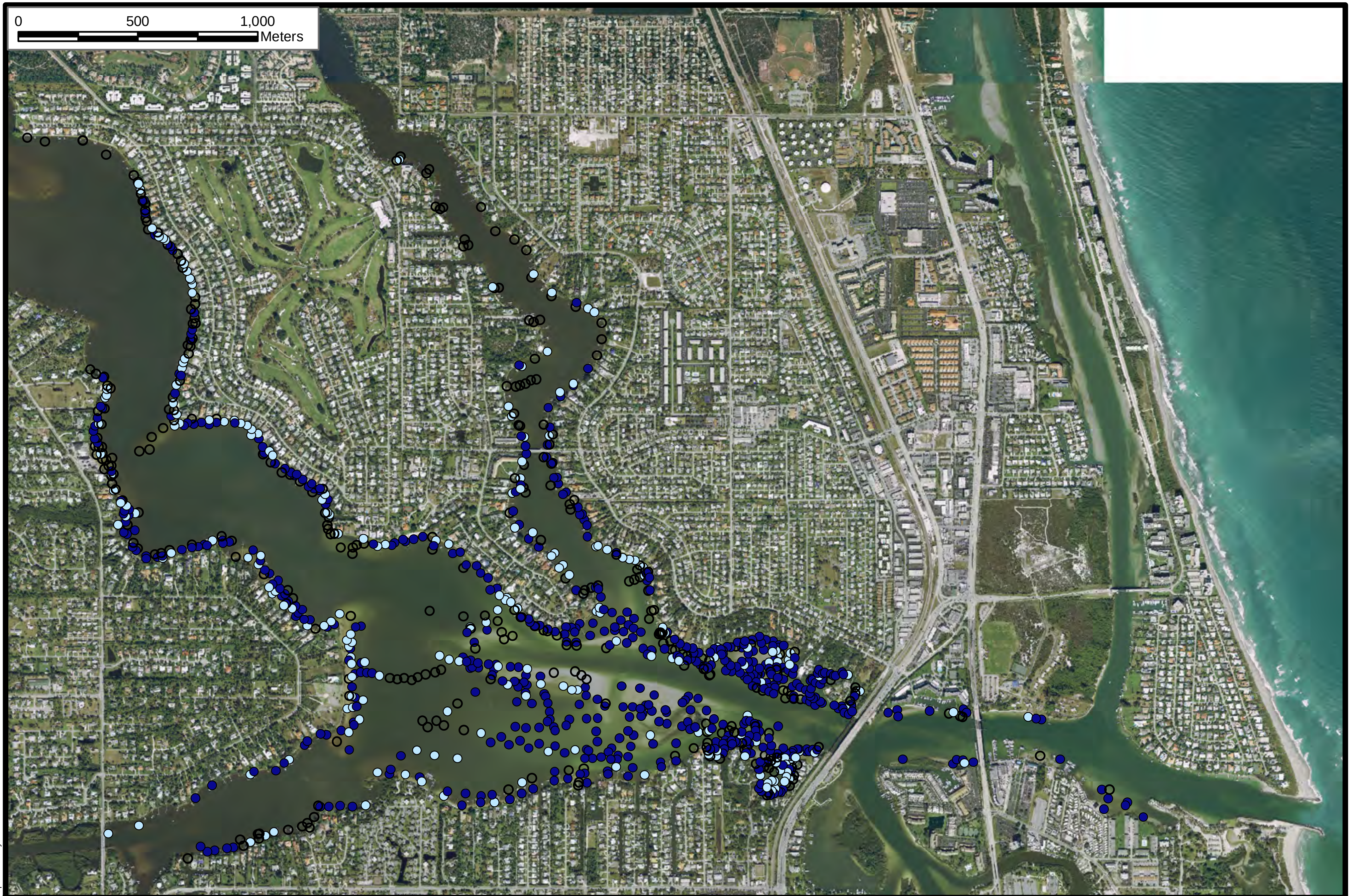

Loxahatchee River District

2500 Jupiter Park Drive
Jupiter, FL 33458
(561) 747-5700
www.loxahatcheeriver.org

Quadrat Score

- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

B3

2007 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Johnson's Seagrass (Halophila johnsonii)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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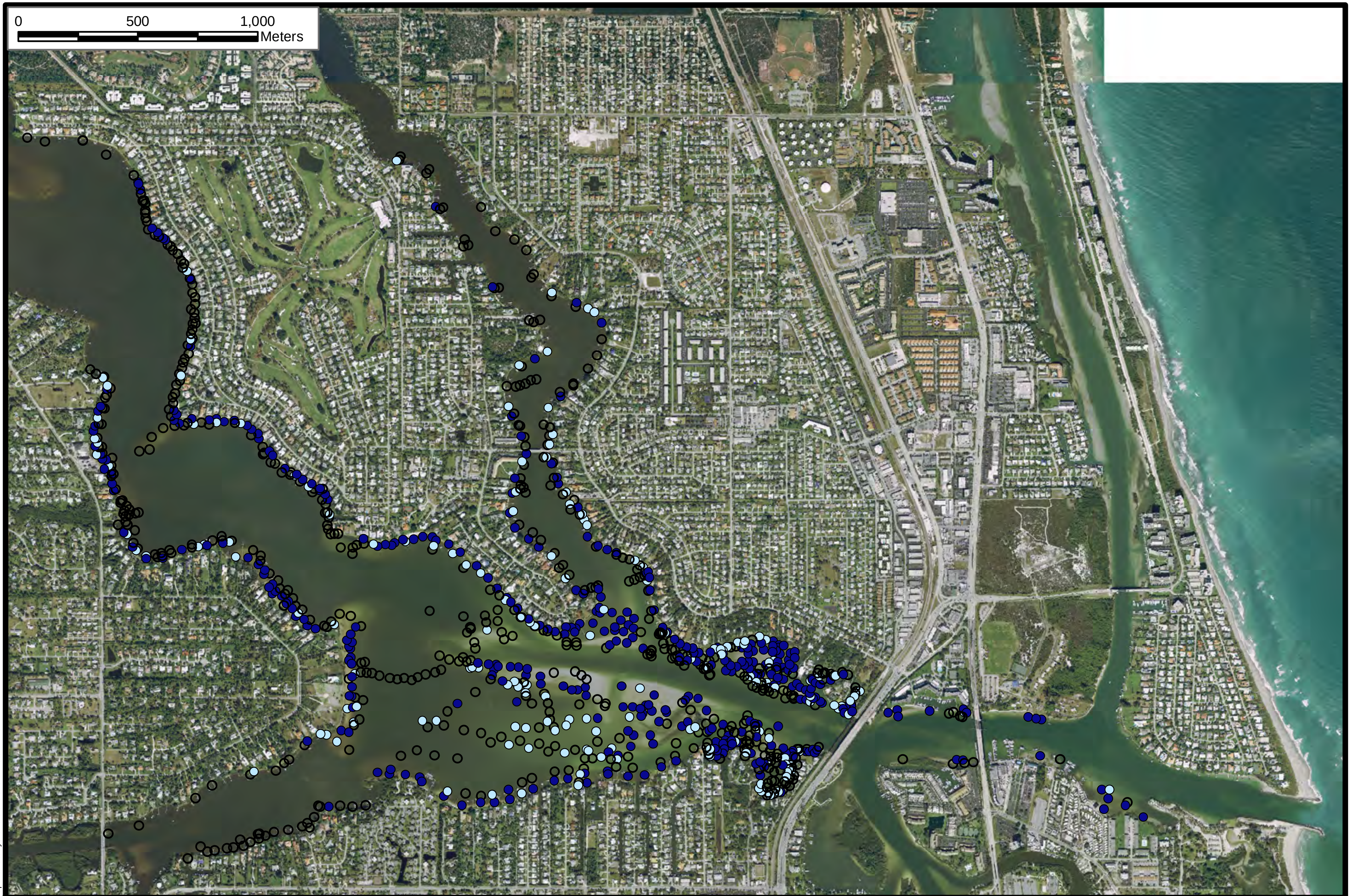

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Quadrat Score

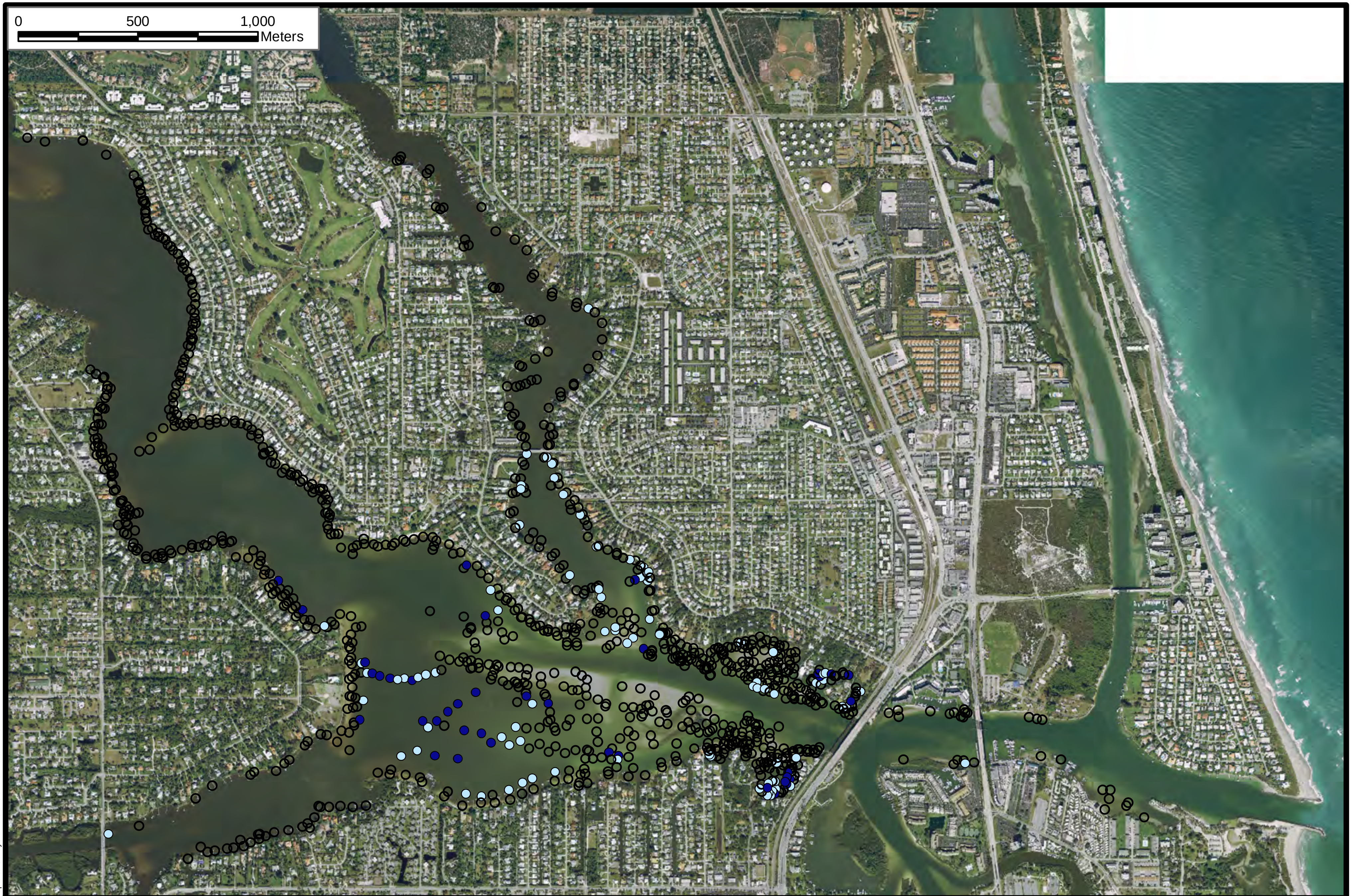
- (0/9) No Seagrass
- (1 - 5/9) Patchy Seagrass
- (6 - 9/9) Continuous Seagrass

B4

2007 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Shoal Grass (Halodule wrightii)

N
Aerial 2009

Date: January 2011
Revised:
Drawn By: BH



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Quadrat Score

- (0/9) No Seagrass
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- (6 - 9/9) Continuous Seagrass

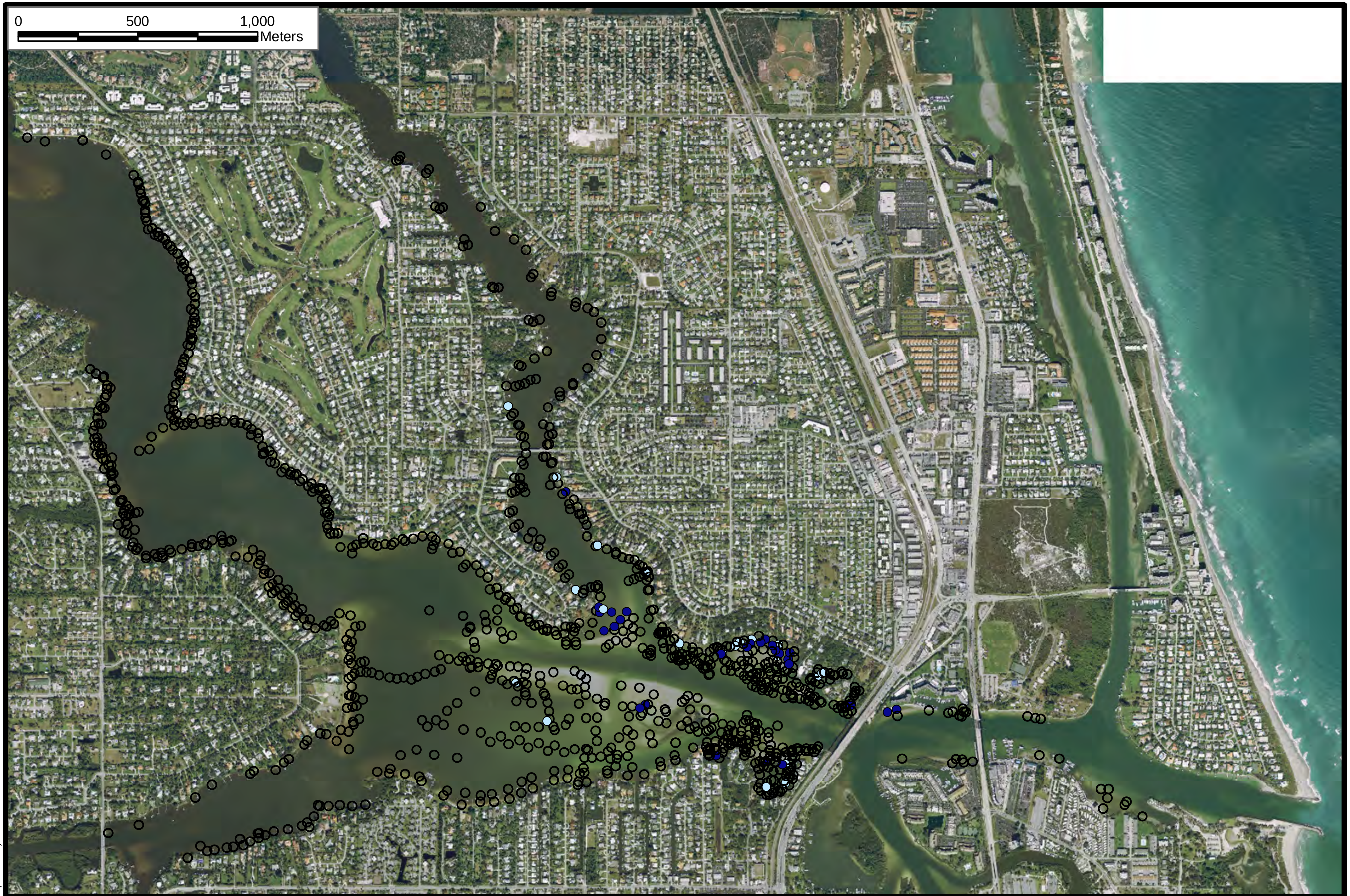
B5

2007 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Paddle Grass (Halophila decipiens)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH



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Quadrat Score

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- (6 - 9/9) Continuous Seagrass

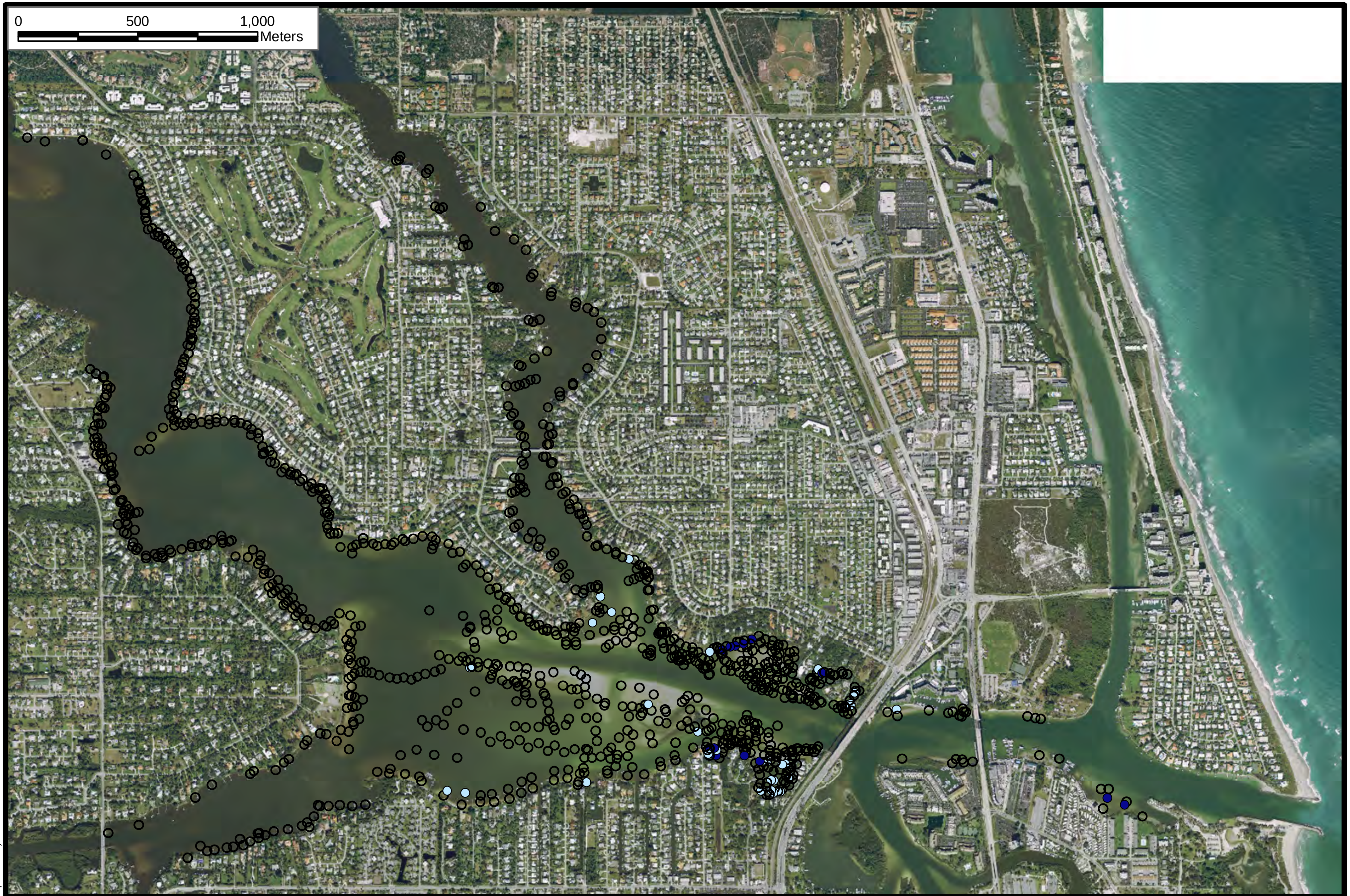
B6

2007 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Manatee Grass (Syringodium filiforme)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH



Loxahatchee River District

2500 Jupiter Park Drive
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(561) 747-5700
www.loxahatcheeriver.org

Quadrat Score

- (0/9) No Seagrass
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- (6 - 9/9) Continuous Seagrass

B7

2007 Loxahatchee River Seagrass Mapping
Species-Specific Seagrass Distribution
Turtle Grass (Thalassia testudinum)

N

Aerial 2009

Date: January 2011
Revised:
Drawn By: BH

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