2014 System Status Report – Loxahatchee River

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Introduction

Multiple agencies, including the South Florida Water Management District (SFWMD), Loxahatchee River District (LRD), Department of Environmental Protection (DEP), Florida Park Service (FPS), and others, have been working to protect and restore the Loxahatchee River, the first of only two Federally designated Wild & Scenic rivers in Florida. The primary threats to the Loxahatchee River are: 1) diminished freshwater flows during the dry-season which leads to saltwater intrusion that harms the freshwater cypress habitat; and 2) flood control releases of freshwater into the estuary during the wet-season. Ongoing restoration efforts seek to provide short- and long-term solutions that increase base flows into the Northwest Fork during the dry season, 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). Conversely, effectively managing (whenever feasible) flood control releases into the estuary during wet season helps to ensure protection of estuary, oysters and seagrasses.

Since 1971, the Loxahatchee River District (LRD) has been working toward its mission to preserve and protect the Loxahatchee River through an innovative wastewater treatment and reuse program and an active river research, monitoring, and restoration program. The river monitoring work, conducted by LRD's WildPine Laboratory, includes:

1. The RiverKeeper water quality project to assess the water quality of nearly 30 parameters (including Total Nitrogen, Total Phosphorus, Chlorophyll a, Fecal Coliform bacteria, etc.) at approximately 40 sites throughout the watershed;
2. The Datasonde project that uses autonomous instrumentation to collect near-continuous (15 or 30 min intervals) data on water temperature, salinity, and pH at 7 sites throughout the Loxahatchee River;
3. Seagrass monitoring and mapping that includes bi-monthly assessment of seagrasses at 5 sites throughout the River, and large scale mapping projects completed in 2007 and 2010;
4. Oyster monitoring that includes assessing oyster recruitment, density, size, and survival throughout the estuary's extant oyster beds as well as completed oyster restoration projects.

LRD has conducted this work to document the condition and ecological health of the river and to identify and prioritize suitable locations for restoration efforts. Over the past 35 years, LRD has contributed significantly to the understanding of the ecology of the Loxahatchee River (see http://www.loxahatcheeriver.org/reports.php). While numerous reports have been written regarding the Loxahatchee River, perhaps none are as comprehensive as the Restoration Plan for the Northwest Fork of the Loxahatchee River (SFWMD 2006), and the subsequent update completed in 2012. These documents characterize the watershed, discuss various restoration alternatives, and identify the preferred restoration flow scenario.

The purpose of this report is to provide a concise characterization of the conditions and findings in the Loxahatchee River Watershed during the evaluation period of January 2005 through April 2013.

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 (Figure 1). 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 Loxahatchee and Hungryland Sloughs and flowed gradually to the Northwest Fork. In the 1930's 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 dry season. Since 1947 the Jupiter inlet, the eastern link to the Atlantic Ocean, was expanded through ongoing dredging projects. Furthermore, 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. These hydraulic modifications promoted increased saltwater flows into the previously freshwater portions of Northwest Fork.

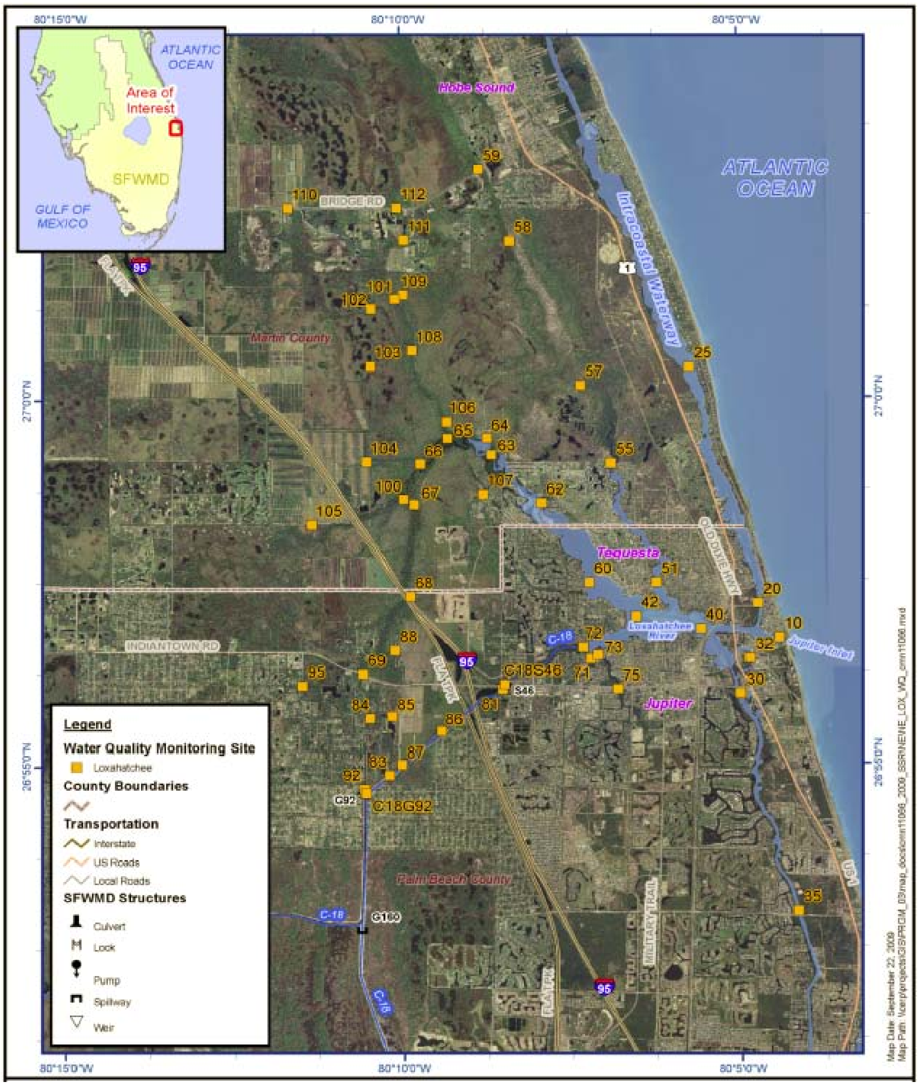


Figure 1. Map of Loxahatchee River Watershed (from 2009 System Status Report).

Hydrologic Analysis

Dry Season – Low Flow

The primary objective of the Restoration Plan Update (2012) is to ensure adequate freshwater flows to provide protection to the freshwater cypress swamp community from saltwater intrusion, particularly during the dry season. The South Florida Water Management District (SFWMD) developed and adopted a Minimum Flows and Levels (MFL) Rule in 2003 (Chapter 40E, Florida Administrative Code). The intent of the MFL criteria is to protect the remaining floodplain swamp community from "significant harm":

> A MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance of the minimum flow criteria occurs more than once every six years. An "exceedance" is defined as when Lainhart Dam flows to the Northwest Fork of the river decline below 35 cubic feet per second (cfs) for more than 20 consecutive days within any given calendar year or when the 20-day moving average salinity measured at River Mile 9.2 exceeds 2 psu [practical salinity units].

Among the most noteworthy observations during this assessment period is the improvement in the numbers of days meeting the MFL. Figure 2 shows the number of days that flow at Lainhart Dam was less than 35 cfs. Beneficial rains and hydraulic conditions resulted in fewer days of low flow in 2008 and 2010. In the spring of 2011, the SFWMD utilized temporary and permanent infrastructure to test the conveyance of supplemental freshwater flows from the L-8 reservoir, through Grassy Waters Preserve then into the Loxahatchee River. The water comes to the Loxahatchee River from Grassy Water Preserve via the C-18 canal through the G-161 water control structure. The SFWMD conducted a 50-day test of supplemental flow from March 1 to April 19, 2011. The supplemental flows provide the additional water needed to maintain a minimum of 35 cfs at Lainhart Dam through much of the dry season. Following the supplemental flow test, an unusually late start to the wet season in the spring of 2011 accounted for the majority of the 80 days of low flow. In the spring of 2012 and 2013, meaningful supplemental flows from Grassy Waters indicated by the days of flow through G-161 helped to ensure the minimum flows were met through the majority of the dry season. The "wet years" and supplemental flow tests clearly demonstrated that the MFL can be achieved with nominal additions of freshwater, and that the minimum flow targets provide the intended protection to the freshwater habitat (further described below).

Figure 2. Counts of respective flow conditions by year from 1/1/2000 through 4/30/2013, Loxahatchee River, Florida. Data from SFWMD DBHYDRO.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013*
					LOW FLOW									
Number of days MFL not met (<35 cfs at Lainhart Dam)	118	162	70	98	151	69	171	134	41	70	2	80	2	13^{+}
Number of days of dry season supplemental Flows from Grassy Waters Preserve Measured at G-161 (*Started 10/2007)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	*0	3	24	39	49	70	85
					FLOOD CONTROL									
Number of days of flood control releases at S-46 greater than 600 cfs	2	15	2	0	17	8	0	1	1	0	1	0	17	NA

*Note: 1/1/2000 through 4/30/2013

+ USGS Station 02277600

Wet Season – Flood Control Releases

During the wet season, the objective for water managers is to minimize the intensity and frequency of flood control releases. Large freshwater releases reduce salinities in the estuary to levels that harm estuarine and marine flora and fauna with oyster and seagrasses being among the most notable. Salinity analysis conducted by LRD in 2008 demonstrated that harmful salinity variability within the estuary was significantly reduced when flows at the primary flood control structure (S-46) were less than 300 cfs. The salinity analysis suggests that seagrasses are likely stressed by salinities less than 15 ppt, which occurs when flow through the S-46 is greater than 600 cfs. These findings suggest that within the Loxahatchee River system a longer duration lower-flow release is preferred to heavy flows for a shorter period (i.e., pulsed flows). LRD communicated these findings to the SFWMD Operations staff and it appears they are managing the system to maintain lower flows whenever feasible. The health and extent of oysters and seagrass throughout the estuary indicate a functional system.

The recent exception to moderated flood control releases was the 17 days of flow greater than 600 cfs following passage of Tropical Storm Isaac in August 2012 (Figure 2). SFWMD water managers had to release huge volumes of water to deal with flooding in some of the western communities. Figure 3 illustrates the relative magnitude of TS Isaac flood control releases relative to other significant storm events. Subsequent assessment of oyster communities indicated severe impacts to oyster reefs in the Southwest Fork and moderate impacts to oysters in upstream reaches of the Northwest Fork. Additional discussion is provided in the oyster section below.

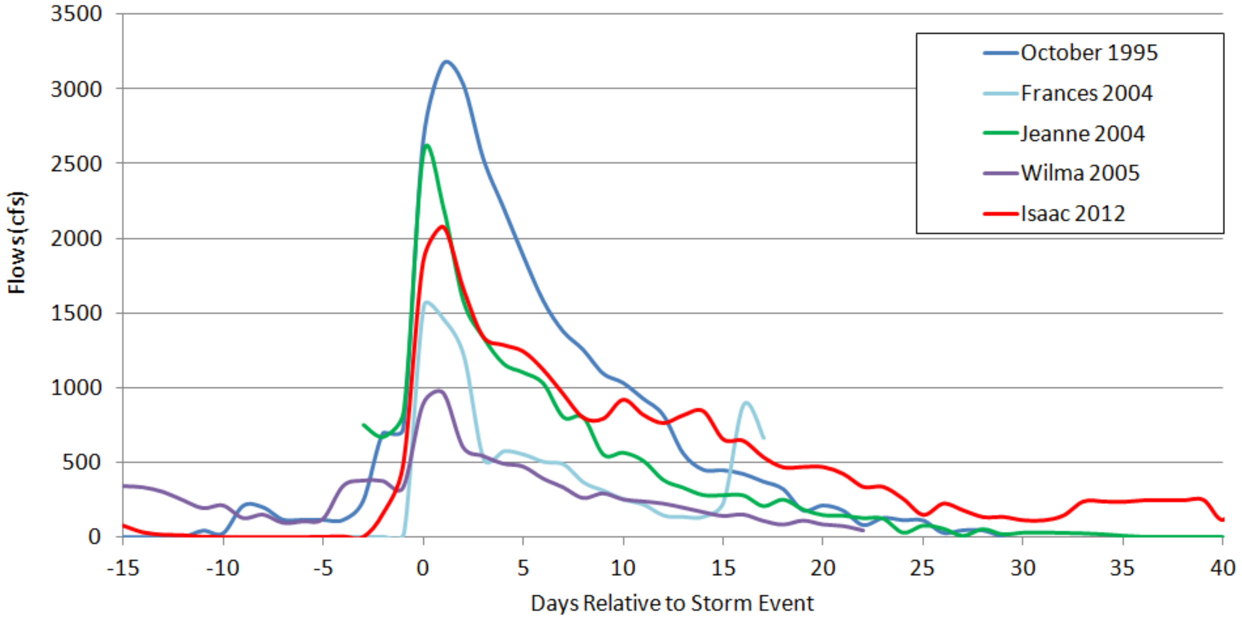


Figure 3. Comparison of storm-related flood control releases from S-46 at Loxahatchee River, Florida.

Salinity

High frequency (15 min interval) datasonde instrument data provides detailed salinity data that improves our understanding of how the estuary functions. From these data the daily minimum and maximum salinity can be extracted. Cumulative distribution plots of the daily minimum and maximum values are created to form a "salinity envelope" that illustrates the total distribution of salinity at a selected location. An example is provided in Figure 4 for the "Oyster Island" site in the middle estuary. These data show that 50% of the time

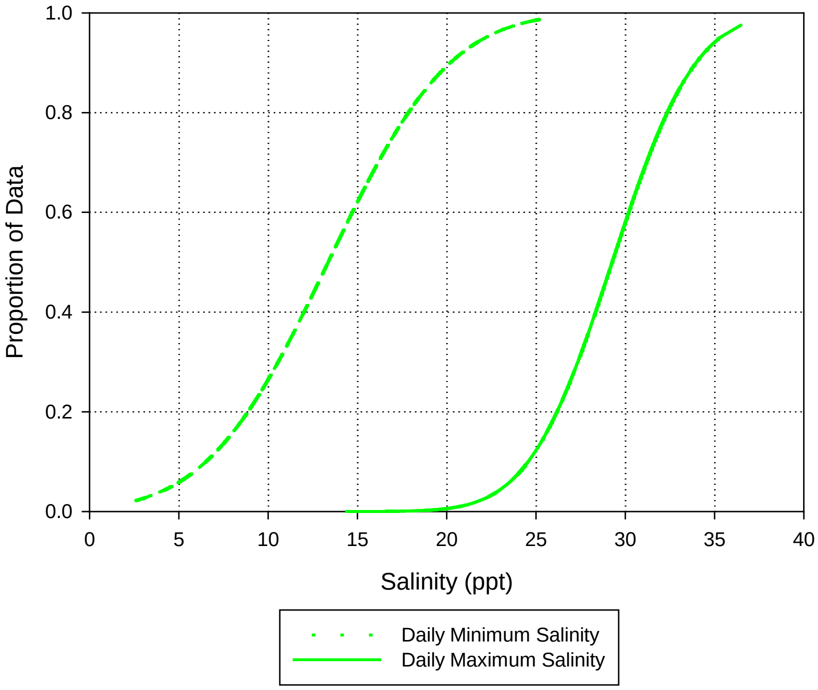


Figure 4. Typical salinity envelope for the Oyster Reef site at river mile 4.1 in the Northwest Fork of the Loxahatchee River, Florida. Dashed and solids lines are the lower and upper bounds of the envelope shown as the cummulative distribution plot of the daily minimum and maximum salinity recorded by a datasonde at 15 min

salinity at Oyster Reef site were greater than 15 ppt and less than 25 ppt (i.e., organisms living at this site typically experienced a salinity envelope of 15-25 ppt). Organisms at this site experienced salinities less than 10 ppt less than 20% of the time. We are convinced such salinity envelopes will further our understanding of organismal responses to salinity conditions in estuaries, which can be highly dynamic.

Salinity envelopes enable comparison between salinity distributions for typical versus atypical conditions at our various sampling sites. For example, during the dry season, we can compare the effects of drought and low freshwater inflows on salinity in freshwater swamp reaches. Figure 5 illustrates a "typical" dry season salinity envelope relative to the unusually dry dry-season and decreased freshwater flows at the Kitching Creek (surface) station. The figure clearly shows dry season salinity envelope is skewed towards much higher salinities for the 'unusually dry' period relative to the 'typical dry' period. For example, daily salinities at this site exceeded 10 ppt during 2% of a 'typical dry' season days whereas salinities exceeded 10 ppt during 40% of 'unusually dry' periods.

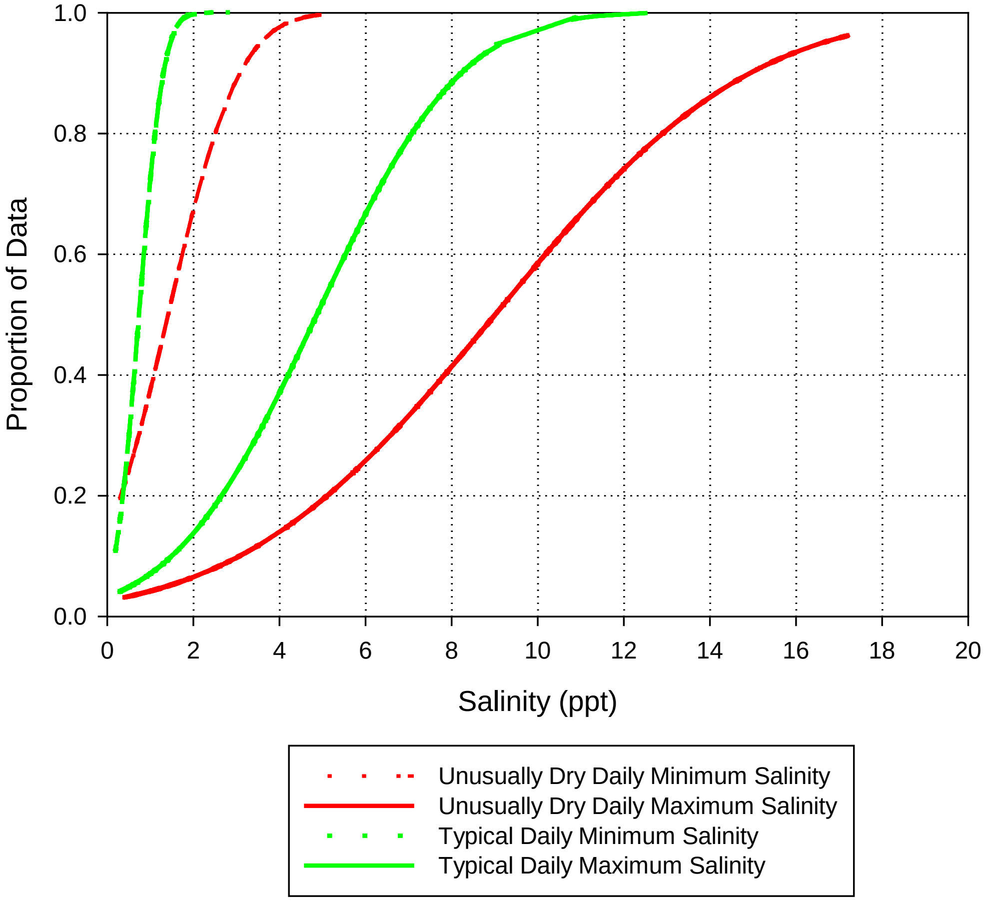


Figure 5. Comparison of dry season (Nov – April) salinity envelopes at the upstream Kitching Creek for "typical" and "unusually dry" years in the Loxahatchee River, Florida. Green lines illustrate the lower and upper bounds of the salinity envelope for a "typical" dry season from Nov 2008 – April 2009. Red lines illustrate the lower and upper bounds of the salinity envelope for the unusually dry dry-season in Nov 2006 – April 2007 showing the increased salinities resulting from the decreased freshwater flows.

Conversely, during the wet season, concern shifts to assessing the effects of flood control releases on seagrasses and associated fauna in the lower estuary. Figure 6 illustrates a typical wet-season salinity envelope at our North Bay site versus an unusually wet wet-season that clearly reduced the salinity distribution. These figures illustrate the magnitude of salinity variation in the estuary, and then monitoring of seagrass and oysters track the subsequent effects to these resources. Generally, the estuary experiences limited periods of harmful low-salinity conditions. The system seems remarkably resilient to such 'normal' perturbations – decimated oysters recover in 12 months, some seagrass species appear to recover despite loss of coverage. However, infrequent, high-magnitude disturbances such as observed following Tropical Storm Isaac appear to have disproportionate, damaging effects on seagrasses (see below for a more thorough discussion). These salinity envelope plots help specifically identify the apparent stressful conditions causing seagrass mortality. Fortunately, we seem to be managing the system well during typical conditions given the extent and health of the resources (oysters and seagrass). Unfortunately, there are no simple solutions for managing the system and protecting the resources during these extreme events.

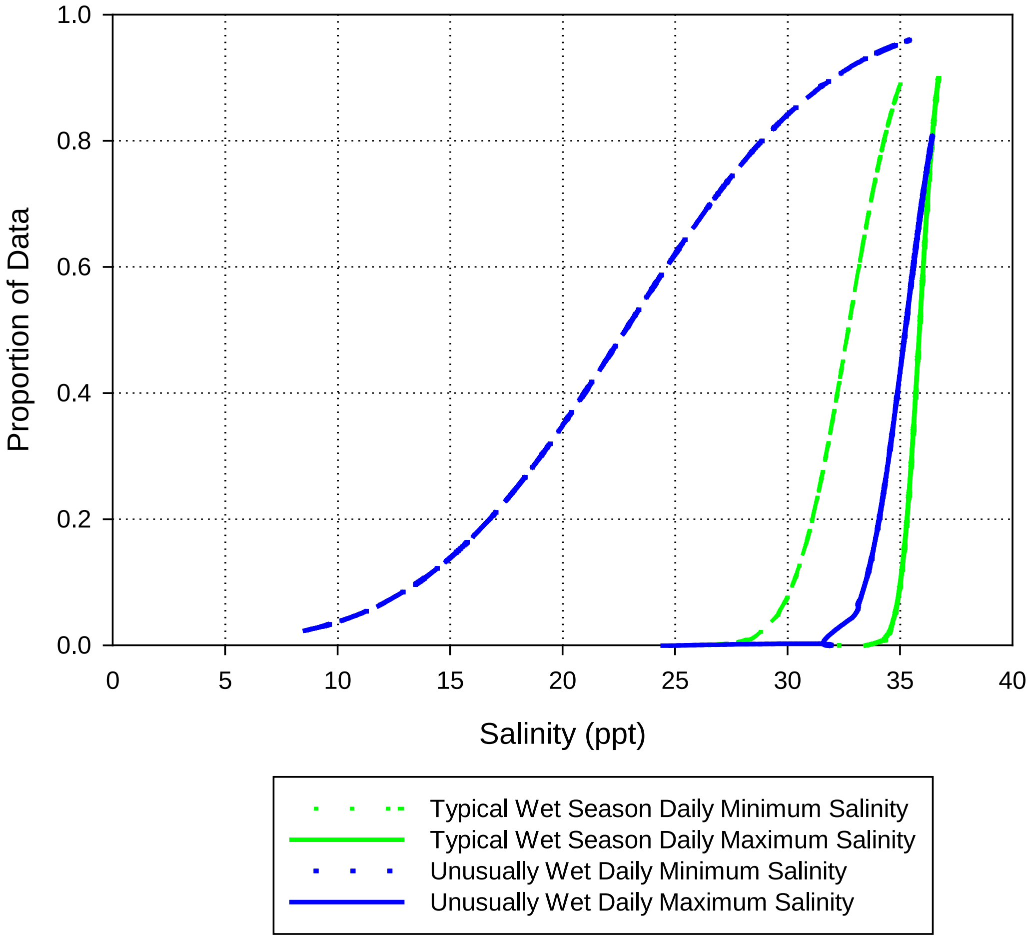


Figure 6. Comparison of wet season (May – Oct) salinity envelopes at the downstream North Bay site for "typical" and "unusually wet" years in the Loxahatchee River, Florida. Green lines illustrate the lower and upper bounds of the salinity envelope for a "typical" wet season from May 2009 – Oct 2009. Blue lines illustrate the lower and upper bounds of the salinity envelope for the unusually wet wet-season in May 2007 – Oct 2007 showing the decreased salinities resulting from the increased freshwater flows and flood control releases.

Oysters

Since 2007, the Loxahatchee River District has monitored oyster recruitment activity in the northwest and southwest forks. From this data, a bimodal recruitment pattern was observed with the first peak of settlement occurring in spring and a second peak occurring in fall. This monitoring also enables evaluation of the magnitude of spawning events. Figure 7 shows that in the NW fork (top pane) we routinely see average spat counts greater than 50 spat per array of 10 shells (i.e. 5 spat per shell). In the SW fork, settlement rates are comparatively lower but there was an episode of intense settlement in the spring and fall of 2012 (Fig 7, bottom pane).

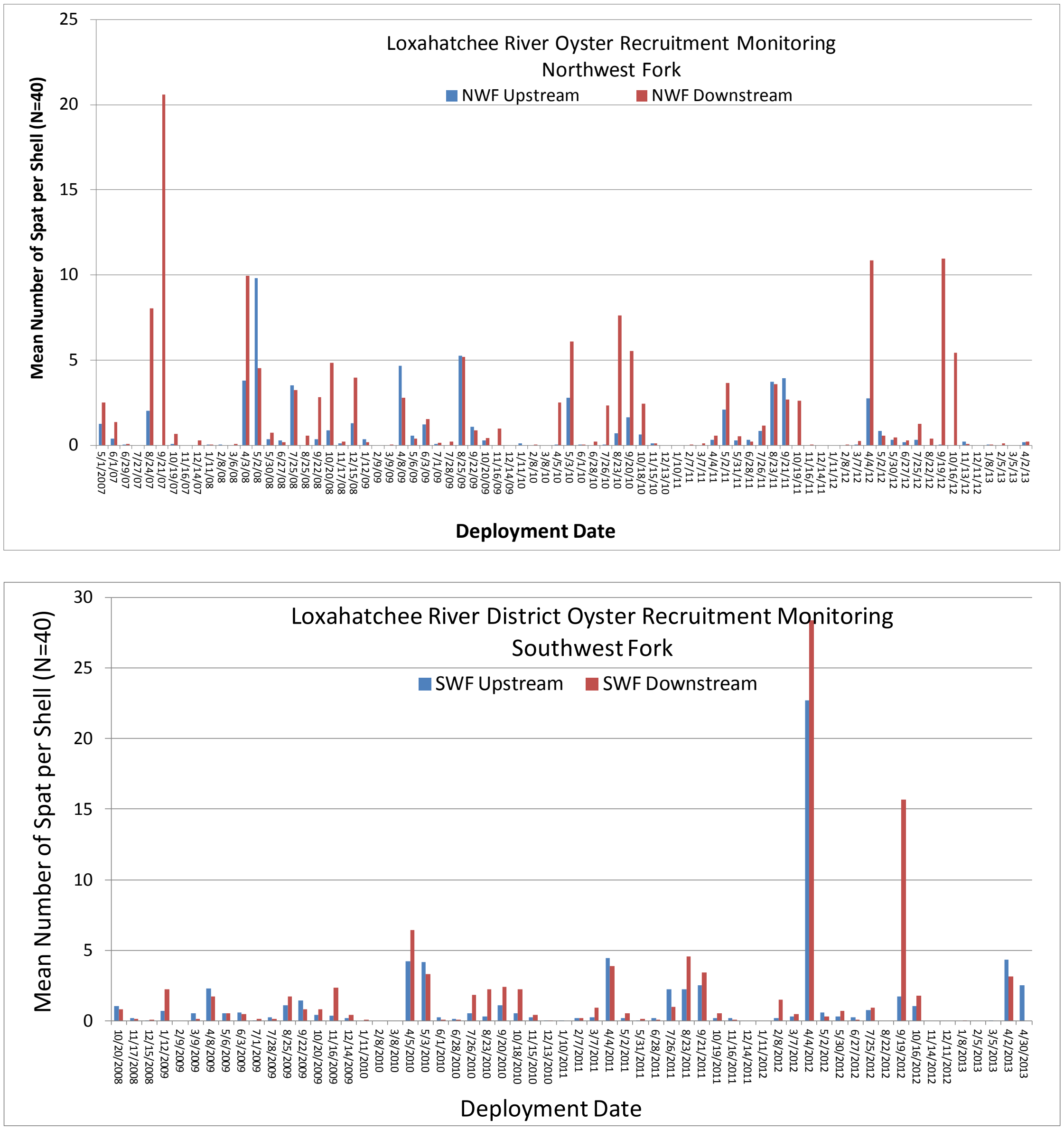
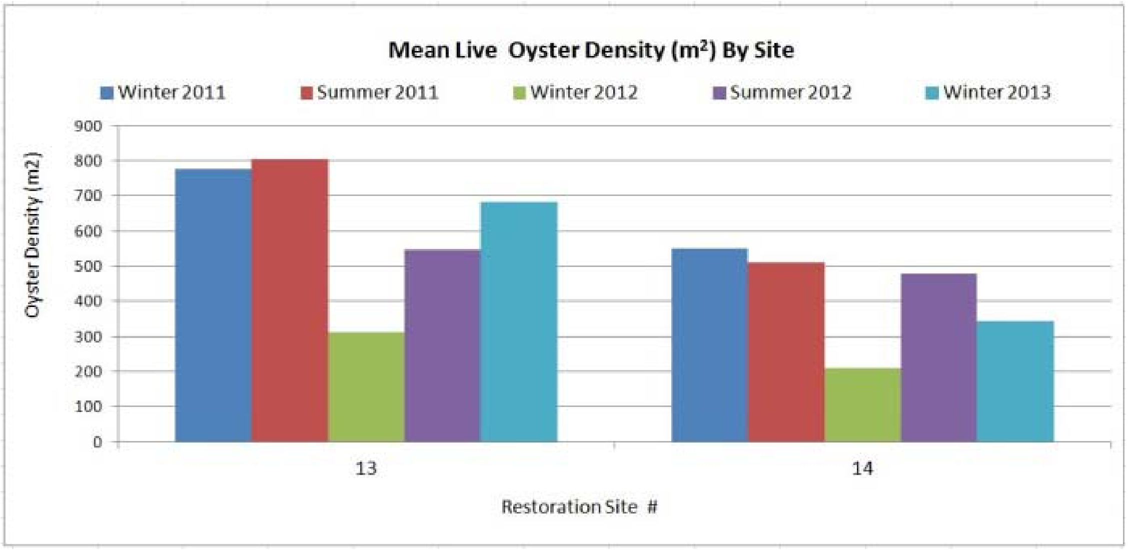


Figure 7. Oyster recruitment monitoring results for the Northwest and Southwest Forks of the Loxahatchee River, Florida.

During the summer of 2010 the Loxahatchee River District partnered with Martin County to obtain ARRA funding from NOAA to restore 5.84 acres of oyster reef. This project was an effort to augment extant natural oyster reefs and provide additional habitat. An added benefit was the pre-mitigation for possible losses of oyster resulting from increased based flows as predicted by the Restoration Plan. Ongoing monitoring of the restoration reefs each summer and winter indicates oyster densities ranging from 300-800 oysters per m^2 and typical shell heights between 25 and 43 mm (Figure 8). As anticipated we are seeing generally decreasing densities (compared to post construction) and increasing average oyster size. The oyster restoration sites are flourishing in terms of both oysters (LRD) and macrofauna (FIU) (reports and publications at www.loxahatcheeriver.org/reports.php.)



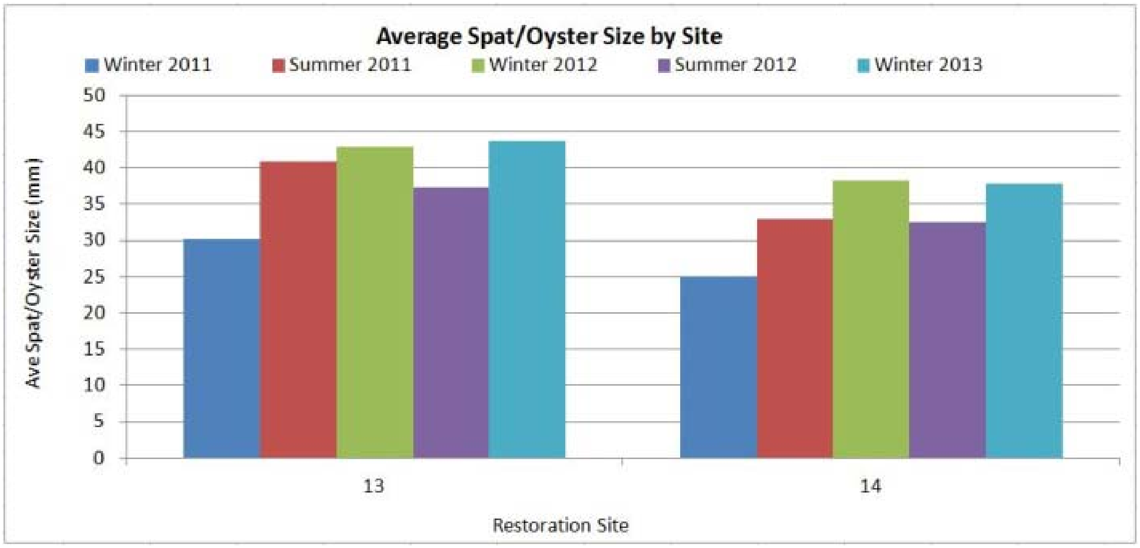


Figure 8. Oyster density (top pane) and size (bottom) by sampling event at the NOAA Oyster Restoration Sites 13 and 14, Loxahatchee River, Florida.

LRD mapped and assessed all oyster beds in the NW and SW fork in 2008. Figure 9 shows the location and areal coverage of oyster beds in the NW Fork (left pane) and the SW Fork (right pane). The approximate total acreage of oysters in the estuary is 15.1 acres, with 13.9 acres (92%) in the NW Fork, and 1.2 acres (8%) in the SW Fork.

Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

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Figure 9. Locations of oyster beds from 2008 oyster mapping project.

In summer 2013, LRD re-assessed the oyster reefs by sampling oyster density, vitality, and size at the exact sample points assessed in 2008. Figure 10 shows the vitality (percent live) at each bed for the NW Fork (left pane) and the SW Fork (right pane). The largest and healthiest oyster beds in the estuary are in the vicinity of the newly constructed oyster restoration reefs shown by the white fill (left pane). In 2013, fewer than 50% of oysters sampled at the upstream oyster beds were alive. Oyster beds in the Southwest fork demonstrated good survival rates despite negative impacts following the flood control releases due to TS Isaac in August of 2012.

Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

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Figure 10. Oyster beds symbolized by Percent Live during the 2013 assessment. NW Fork left pane; SW Fork right pane.

To compare the observations of 2008 to 2013, we computed the relative percent difference in live oysters for each oyster bed. The most notable difference was the reduction in the number of live oysters in the upstream reaches of the NW Fork (Figure 11). These results, albeit a one-time comparison in a highly variable organism, suggest relative decrease in live oysters upstream of Island Way bridge. This decrease in oysters was a predicted outcome of increased flows in the 2006 Restoration Plan. Fortunately, the large scale oyster reef restoration project provided more than double the acreage of oyster beds than are present north of Island Way, and many of those oysters north of Island Way are still viable with 50 to 75 percent live oysters.

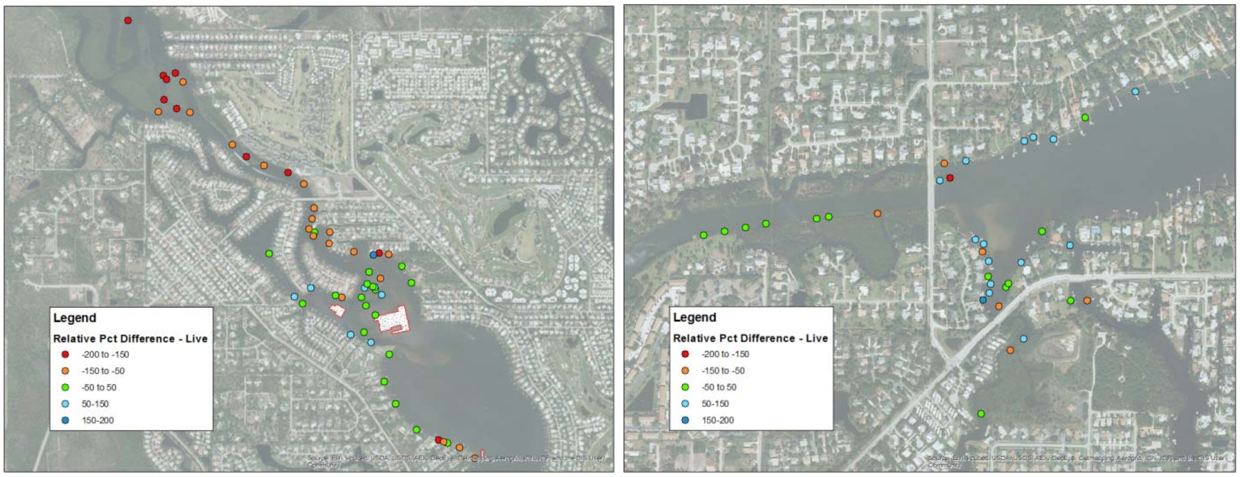

Figure 11. Relative percent difference of the number of live oysters at each oyster bed in 2008 vs. 2013. Green indicates minimal change from 2008 while warm colors (towards red) are decreases in live oysters and cool colors (towards blue) are increases in live oysters between 2008 and 2013.

Another way of visualizing these data is Figure 12 where the oyster beds are spatially grouped moving from downstream (left) to upstream (right). There is a decrease in the relative percent difference in both the total count of oysters and counts of live oysters in the downstream oyster beds (left) then increased towards the vicinity of the oyster restoration reefs (middle), then decreased once more as sampling moved upstream from the area of restoration reefs. The lines show the precipitous decrease in the percent of live oyster in the upstream reaches.

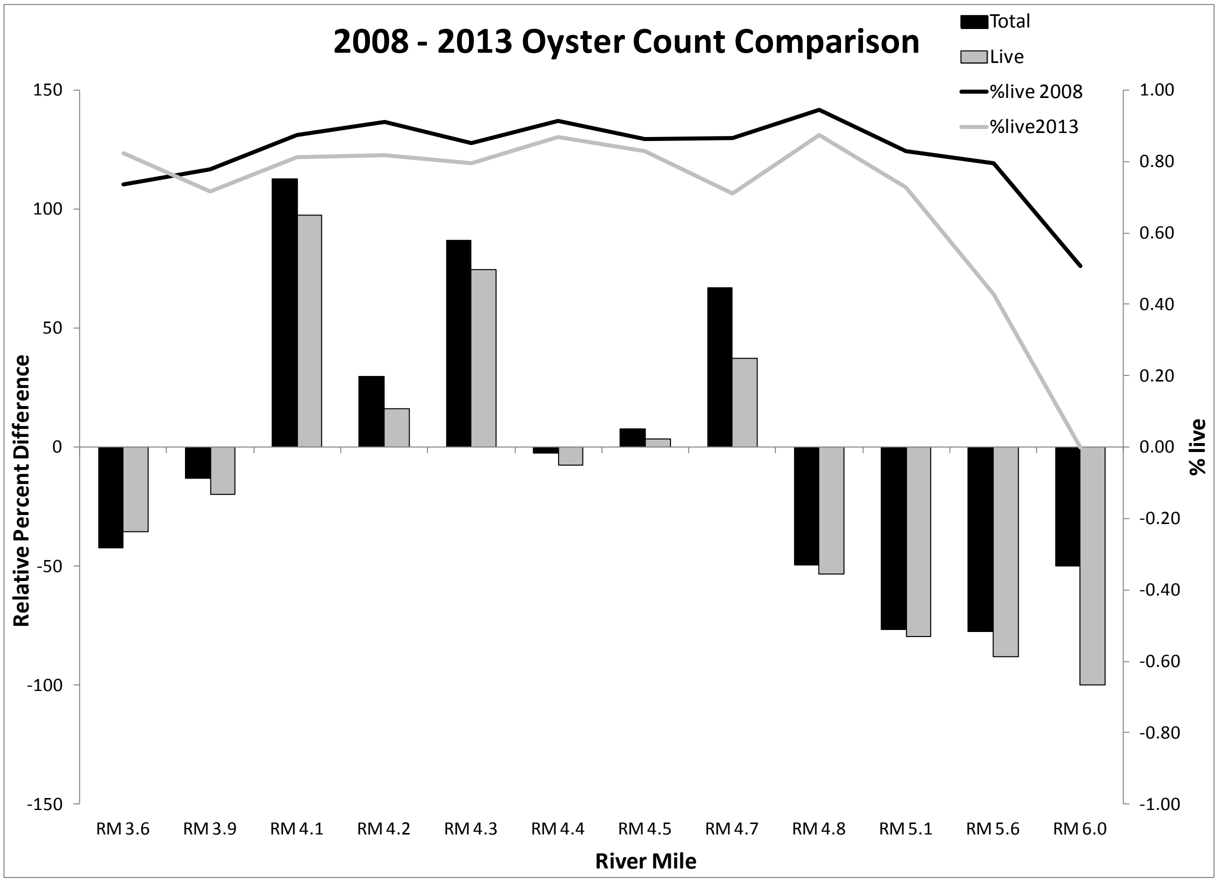

Figure 12. Spatially compartmentalized oyster count comparisons of relative percent difference of total and live oyster counts (bars) and percent live for 2008 to 2013 (lines).

Submerged Aquatic Vegetation (SAV)

Patch-scale Seagrass Monitoring

LRD conducts bi-monthly monitoring of seagrass coverage at 5 sites throughout the estuary (Figure 13). Prior to 2013, LRD had minimal SAV data from the region east of the railroad bridge despite knowledge that expansive seagrass beds existed there. In order to better understand SAV characteristics along the entire salinity gradient, the Inlet site was added in 2013 to extend the SAV monitoring into this region. The Hobe Sound site, located 8 km north of the Jupiter inlet, was previously monitored bi-monthly as the "reference" SAV bed and is now monitored on a semi-annual schedule.

Data from these sites show a clear upstream-downstream gradient of seagrass species composition and cover (Figure 14). The salinity, water clarity, and ground elevation flux (deposition, accretion) are likely the primary contributors to the varied seagrass species composition and coverage at each of the sites. Shoal grass and Johnson's seagrass are the only two species observed at the upstream stations NW Fork and Pennock Point. Johnson's seagrass was greatly impacted at both sites following TS Isaac in 2012 (Figure 14).

The Sandbar site includes primarily Shoal and Johnson’s seagrass with sparse occurrences of Manatee grass and Turtle grass. Initially, until summer 2004, Manatee grass was observed at much higher coverage than currently observed. This coverage decrease was attributable largely to the storms of 2004 and has yet to return to pre-storm levels. This prolonged degradation, perhaps an alternate stable state, may be due to a number of factors, though we suspect changes in bathymetry may be exacerbating recovery. The seasonal pattern observed in coverage of Johnson’s seagrass is most apparent at the Sand Bar site, which peaks each spring and then decreases in the summer and fall. These cycles in coverage may be influenced (at least in part) by the freshwater flows.

Slightly downstream, the North Bay site is composed primarily of Shoal, Johnson’s, Manatee and Turtle grass. Prior to the storms of 2004, the North Bay site supported a small isolated bed of Star grass (*H. engalmanii*) which disappeared as a result of the storms and has not been observed since. Manatee grass coverage at North Bay declined significantly following the storms of 2004. Over 8 years Manatee grass return to 80 percent of pre-storm abundance. It appears that the increase in coverage of Johnson’s grass is the result of this species moving into space left vacant by Manatee grass. Shoaling is the likely cause of overall decrease in coverage for seagrass at this site as there are now unvegetated portions of exposed sandbar that once were occupied by multiple species of seagrass including Manatee grass.

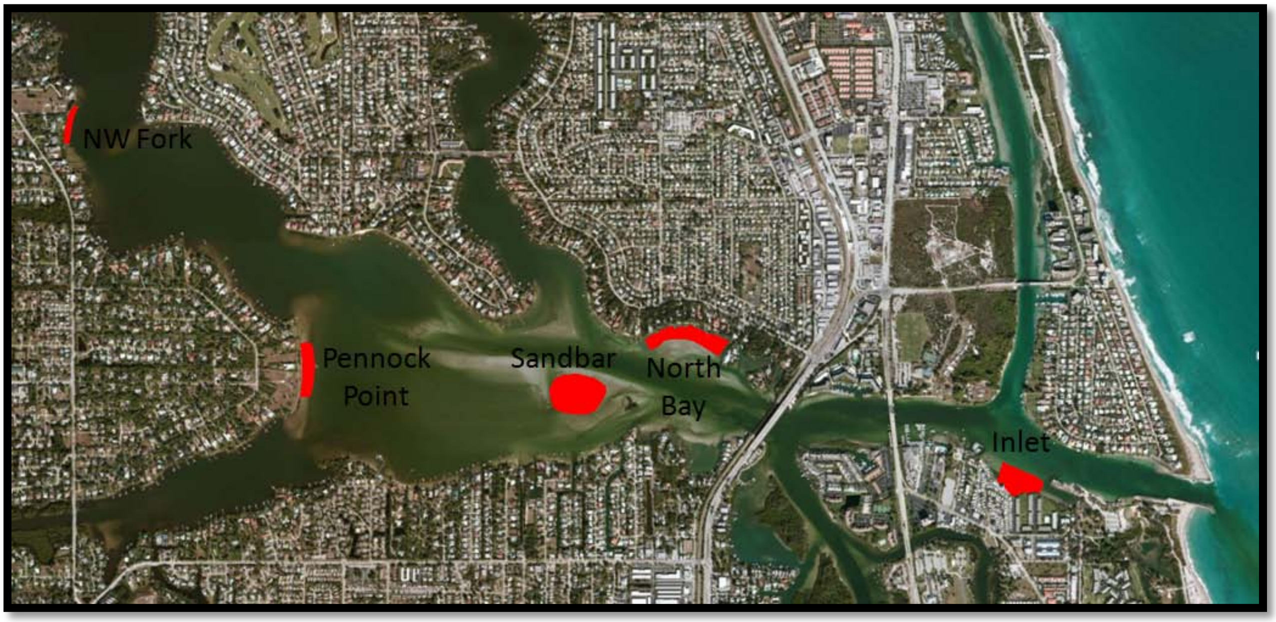

Figure 13. Locations of bi-monthly seagrass monitoring sites in the Loxahatchee River, Florida.

The Inlet site is composed primarily of two species, Shoal grass and Johnson’s grass, with sparse occurrence of Turtle grass (Figure 14). Despite salinity at this site being most “marine-like”, Turtle grass is very sparse and Manatee grass is non-existent; both species are marine-associated, late-stage successional species. The minimal presence of these species suggests that sediment flux due to the high energy nature of this site is occurring too rapidly for these two species to establish a dense bed. Thus, Shoal grass and Johnson’s grass, both known to rapidly colonize disturbed areas, are dominant here.

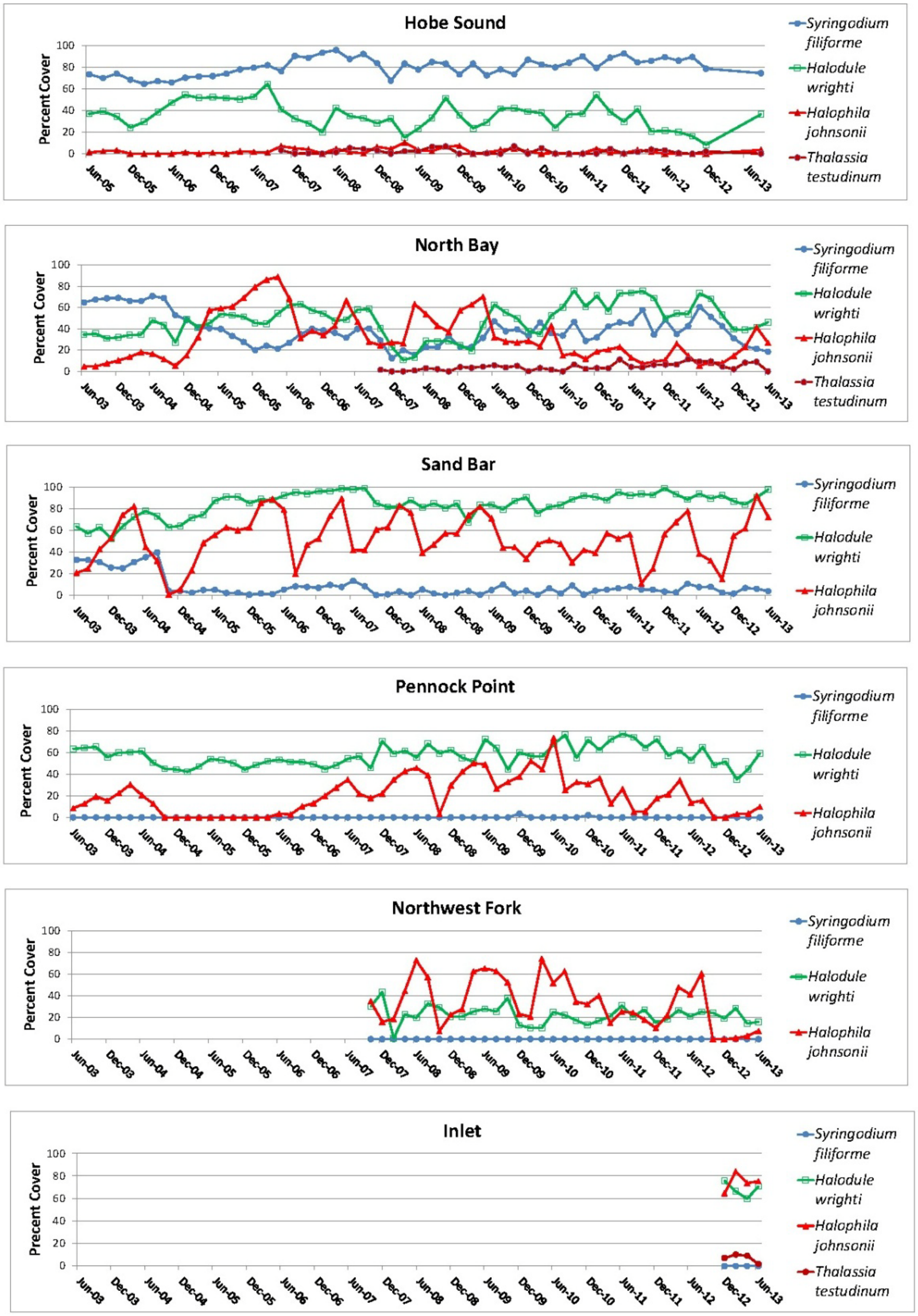

Figure 14. Seagrass percent cover by site and species from June 2003 to June 2013, Loxahatchee River, Florida.

Seagrass Mapping

LRD mapped seagrasses throughout the estuary in 2007 and 2010 using the 9m^2 “quadzilla”. Figures 18 and 19 show the locations of sample points color coded by seagrass coverage for 2010 and 2007. Extensive seagrasses in the estuary indicate a generally functional system.

Seagrasses are most prevalent in the shallow waters of the central embayment, and mostly nearshore in the three forks of the river. The 2007 survey indicated a greater prevalence of paddle grass, a species often associated with low light and higher salinity, in the southwest portion of the central embayment compared to 2010. Species-specific maps are available on the LRD website (www.loxahatcheeriver.org/reports.php). Salinity, water depth (light attenuation), substrate composition and stability (sand, muck, etc.) are primary factors influencing the distribution of seagrass in the estuary. Upstream, seagrasses appear to be largely limited by water depth/clarity and substrate type as seagrass is mainly confined to the sub-tidal littoral zone very near shore. Soft, organic rich (muck) sediments are common just off shore in much of the upper estuary and appears to limit seagrass establishment.

In the middle estuary, water clarity is improved with marine waters reaching up to Pennock Point during high tide Figure 17. Seagrasses in this area extend from the intertidal zone occupied by Shoal and Johnson’s seagrass to water depths of over 1.5 m. Manatee grass, Turtle grass, and Paddle grass have all been observed in the central embayment regions just west of the railroad bridge. Sediments in the middle estuary are typically fine sand and there is clear evidence of shoaling that is reducing water depths thus affecting seagrass distribution and composition. Additionally, current velocities in some portions of the lower estuary are high and the coarse sediment substrate is dynamic with extensive tidal driven sediment transport. In these regions, seagrasses are largely confined to areas protected from the high current velocities. Johnson’s and Shoal grass is prevalent in the lower estuary adjacent to where these conditions persist.

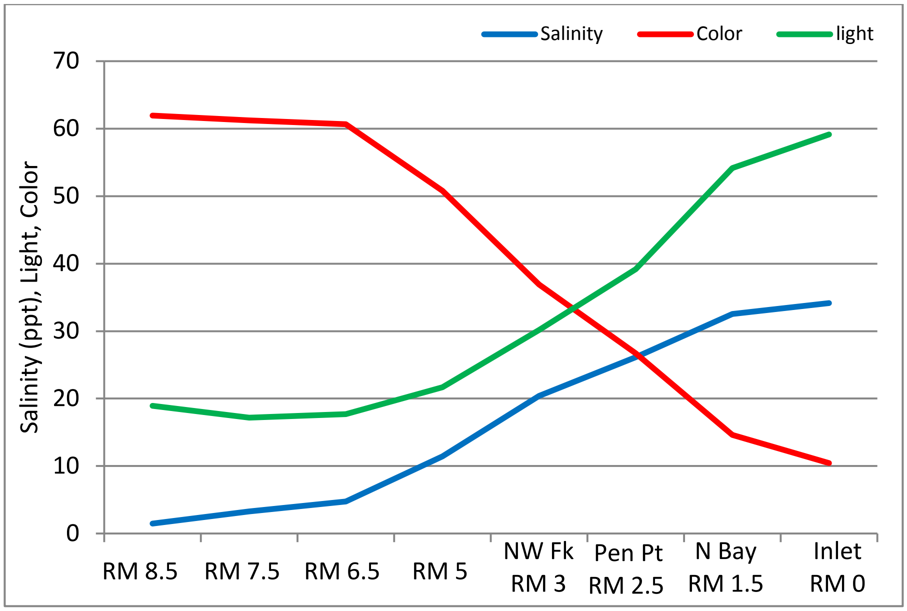

Figure 17. Graph show how Salinity, Color, and Light penetration are related along the salinity gradient. Data are moving from upstream to downstream as graph goes from left to right. Labels show seagrass monitoring sites adjacent to water quality measurements.

Figure 18. 2010 Seagrass survey sampling points color-coded by number of 1m^2 cells of 9m^2 quadrat occupied by seagrass, Loxahatchee River, Florida.

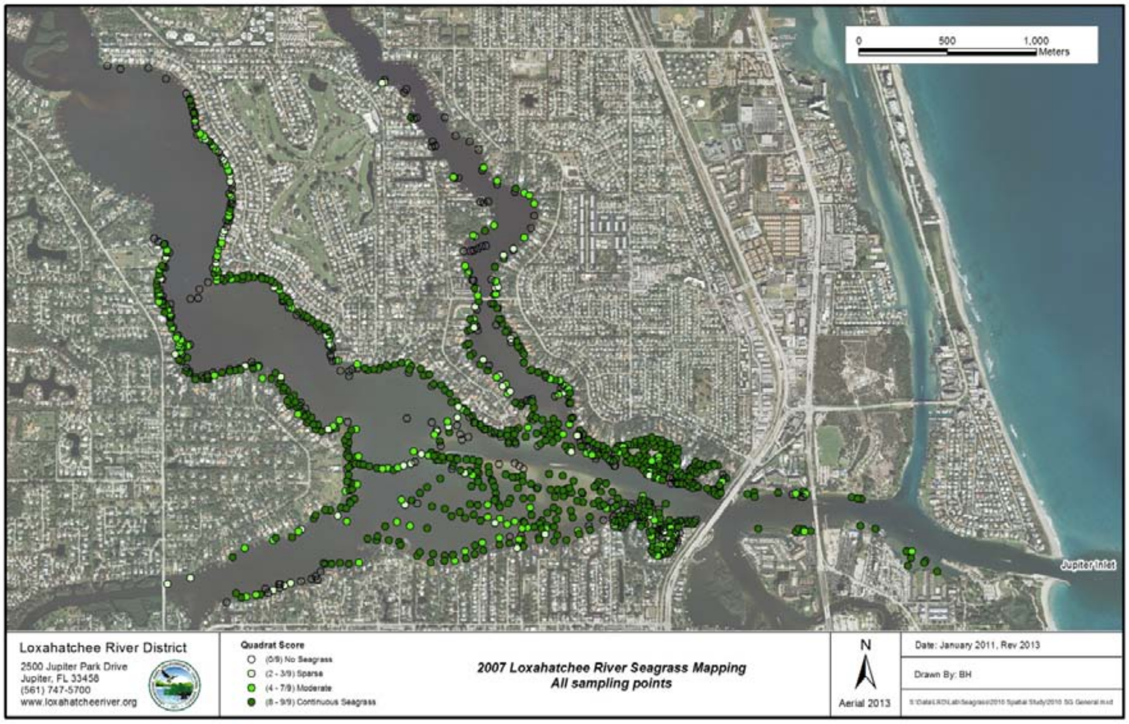

Figure 19. 2007 Seagrass survey sampling points color-coded by number of 1m^2 cells of 9m^2 quadrat occupied by seagrass, Loxahatchee River, Florida.

Tape Grass / Valisneria americana

Tape grass (*Valisneria americana*) has dramatically increased in distribution, primarily throughout the Wild & Scenic segments of the Northwest Fork (i.e., river mile 15 to 8). LRD and SFWMD staff mapped less than 1 acre of Valisneria in 2010, when it was first observed, and then approximately 13 acres in 2013 (Figure 14). Literature and personal communication suggests that salinities in this segment of the river have historically been below lethal thresholds for *Valisneria*, so factors other than salinity must be driving this expansion in coverage. Regardless, the *Valisneria* is flourishing (even flowering) which is a very encouraging observation for the Loxahatchee River (Figure 15).

Figure 15. Comparison of *Valisneria* distribution between 2010 and 2013 as mapped by LRD and SFWMD staff in the Northwest Fork of the Loxahatchee River, Florida.

Figure 16. 2013 Photos of *Valisneria* in the Loxahatchee River, Florida

Water Quality

Staff from the Loxahatchee River District's WildPine Ecological Laboratory collects and analyzes surface water samples for 29 parameters at 39 sites located in the Loxahatchee River, its major tributaries, and associated waters (Figure 20). Most sites are sampled bi-monthly (round symbols) with a subset of between 10 to 15 sites (square symbols) sampled every month. This water quality monitoring program, entitled "RiverKeeper", was developed to identify long-term trends, and to assess compliance with water quality targets established in the Restoration Plan. Most recently, EPA and DEP have established numerical nutrient criteria water quality targets and serve as the new benchmark. Ongoing results from the water quality monitoring program are used to establish baseline conditions prior to modification of freshwater inflows resulting from the Comprehensive Everglades Restoration Project and the Northwest Fork Restoration Plan (CERP 2001; SFWMD 2006).

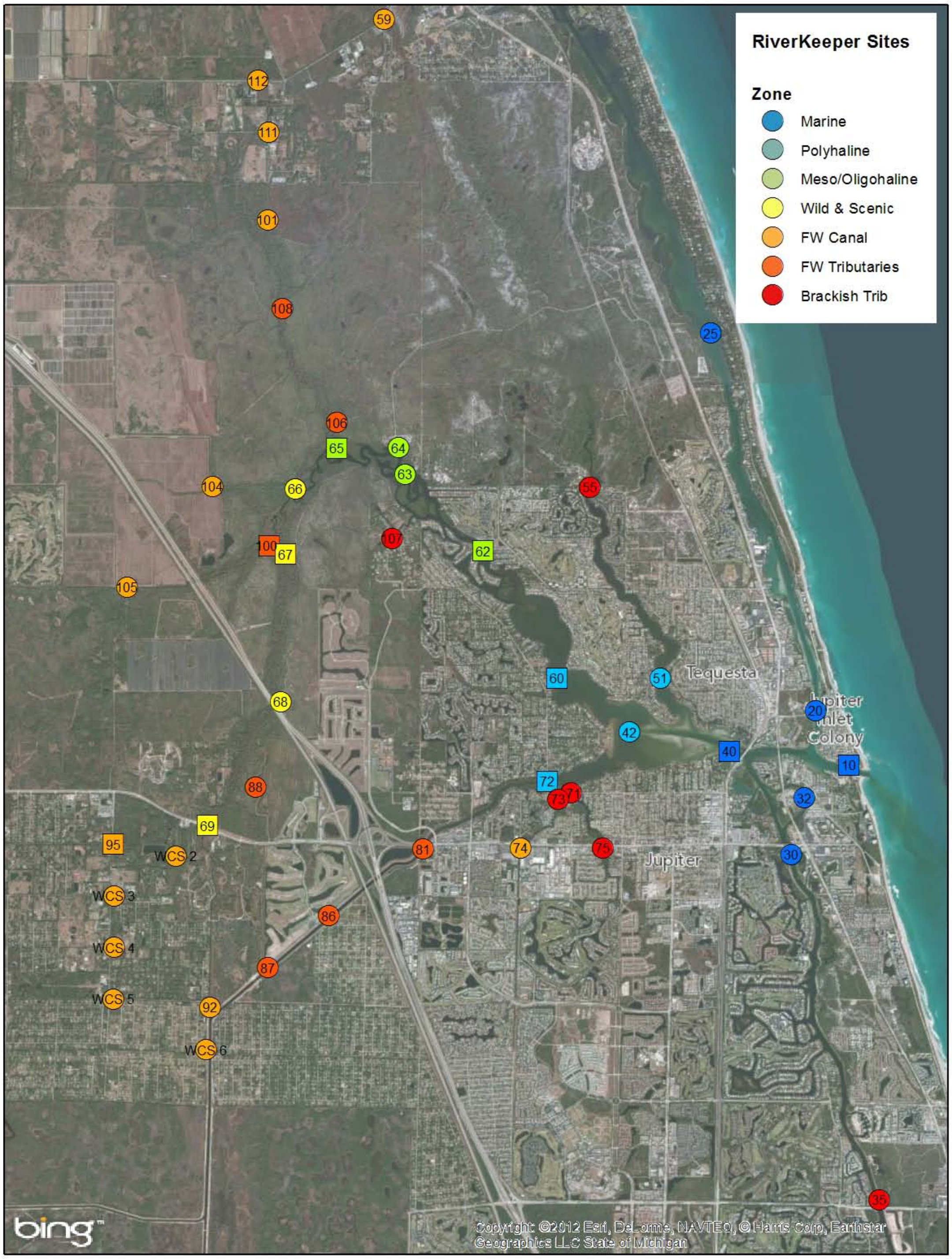

Figure 20. Loxahatchee River District's project RiverKeeper water quality monitoring sites, Loxahatchee River, Florida. Sites with square symbols are sampled monthly, round symbols are sampled bi-monthly.

The Loxahatchee River District has been providing a simplified characterization and overview of the water quality conditions in Loxahatchee River watershed using a “stoplight” assessment. Annual water quality results (geometric mean) for Total Nitrogen, Total Phosphorus and Chlorophyll *a* are scored to the recently established EPA/DEP Numeric Nutrient Criteria (NNC). Fecal coliform bacteria results are scored relative to DEP’s Water Quality Criteria for recreational waters.

Figure 22 shows recent Total Nitrogen results for nearly all sites meet the NNC with no more than 2 exceedances in a 3 year period. Site 59, a freshwater ditch in the northern part of the watershed, off Bridge Road in Hobe Sound, is the only site not meeting the criteria. Site 101, Hobe Grove Ditch in the northwest part of Jonathan Dickinson State Park, has also exhibited high nitrogen results.

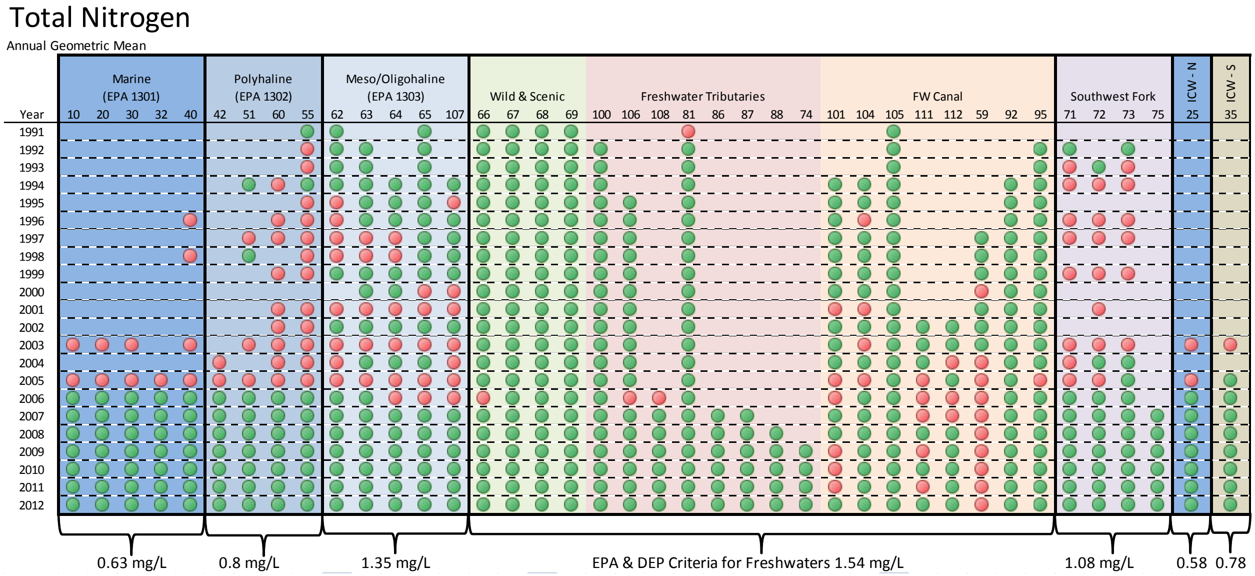

Figure 22. Stoplight plot of annual geometric mean Total Nitrogen by site and year scored relative to FDEP/EPA Numeric Nutrient Criteria values indicated.

Figure 23 shows that five sites in the Loxahatchee River watershed do not meet the NNC for Total Phosphorus. Sites 55 and 60 are in the polyhaline sections of the North Fork and NW Fork and the NNC limit is exceedingly low at 0.03 mg/L. Site 107, a tributary into the NW Fork near the River’s Edge neighborhood has shown persistent Phosphorus issues. In 2012, LRD conducted reconnaissance analysis of key water quality parameters (including phosphorus, fecal coliform bacteria and sucralose) to assess the relative contribution of anthropogenic versus wildlife contributions of nutrients and bacteria. The presence of sucralose at site 107 indicates pollutants from septic systems are making it into surface waters at this site; nonetheless, wildlife (e.g, raccoons and wading birds) also may be contributing to elevated fecal bacteria and phosphorus concentrations. Station 88, the former agriculture site just west of I-95/Turnpike and north of SR 706/Indiantown Road, also indicates persistently high phosphorus results. Pending site development plans include remediation of legacy pollutants. It will be important to ensure that this site is adequately addressed during the redevelopment. Site 75, a brackish tributary named Jones Creek, is an extensive urban drainage basin. Future improvements to increase flushing, adequately treat stormwater inputs, and reduce bacteria counts (e.g. dog waste) would be beneficial.

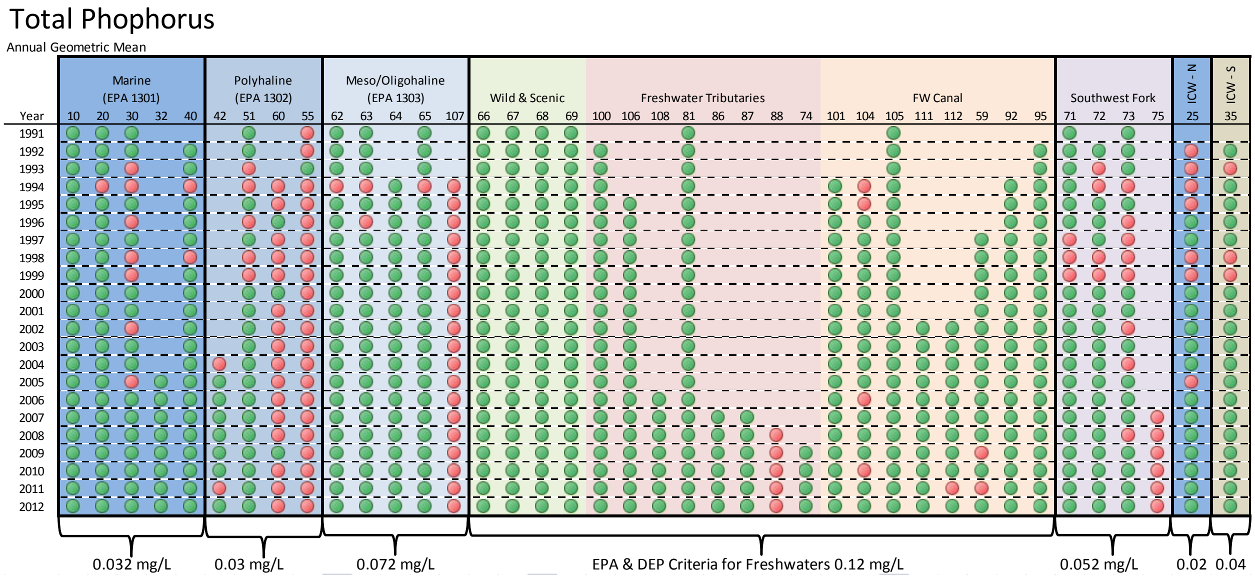

Figure 23. Stoplight plot of annual geometric mean Total Phosphorus by site and year scored relative to FDEP/EPA Numeric Nutrient Criteria indicated.

The NNC for Cholophyll a (Figure 24) is very restrictive in the marine and polyhaline segments of the Loxahatchee River with limits of 1.8 and 4 ug/L. As such, the sampling sites in these areas do not score well relative to the NNC. Based on water clarity, relatively low nutrient levels at many sites, and the extent of seagrasses, these criteria may be impractical and unnecessary. Nonetheless, there are sites that are of genuine concern. For example, annual chlorophyll a values at site 88, the former agriculture site discussed above, regularly exceeds the NNC of 20ug/L. Site 72, at the Loxahatchee River Road bridge over the SW Fork, also exhibits high chlorophyll readings, particularly during the spring and summer months when temperatures rise and there is little flow in the SW Fork. Further, meaningful amounts of nutrients enter the area from Jones and Sims Creeks. Again, additional flushing and stormwater treatment would likely provide benefits to these areas.

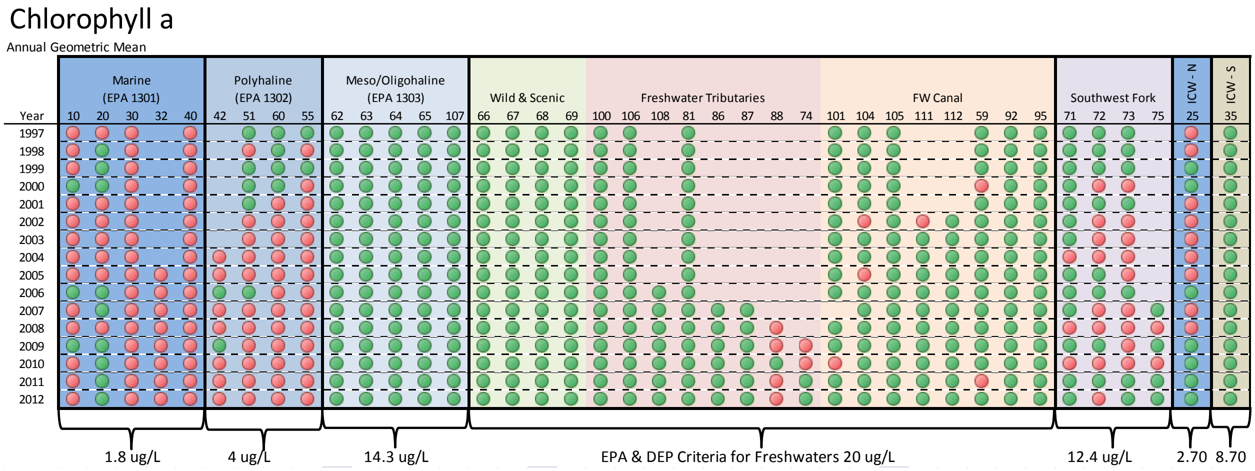

Figure 24. Stoplight plot of annual geometric mean Chlorophyll *a* by site and year scored relative to FDEP/EPA Numeric Nutrient Criteria indicated.

Annual Fecal coliform bacteria counts (Figure 25) exceed DEP's Water Quality Standards for three sites in the watershed. Site 107, the tributary in the NW Fork, has shown chronic issues with very high fecal bacteria and phosphorus concentrations as discussed in the preceding section on Phosphorus. Sites 73 and 75, located in the brackish tributaries that serve as extensive urban drainage areas and flow into the SW Fork, also show frequent problems with fecal bacteria counts. EPA and DEP have established a TMDL for fecal coliform bacteria in this WBID (3226C). Improvements will be required as part of future Basin Management Action Plans (BMAP's).

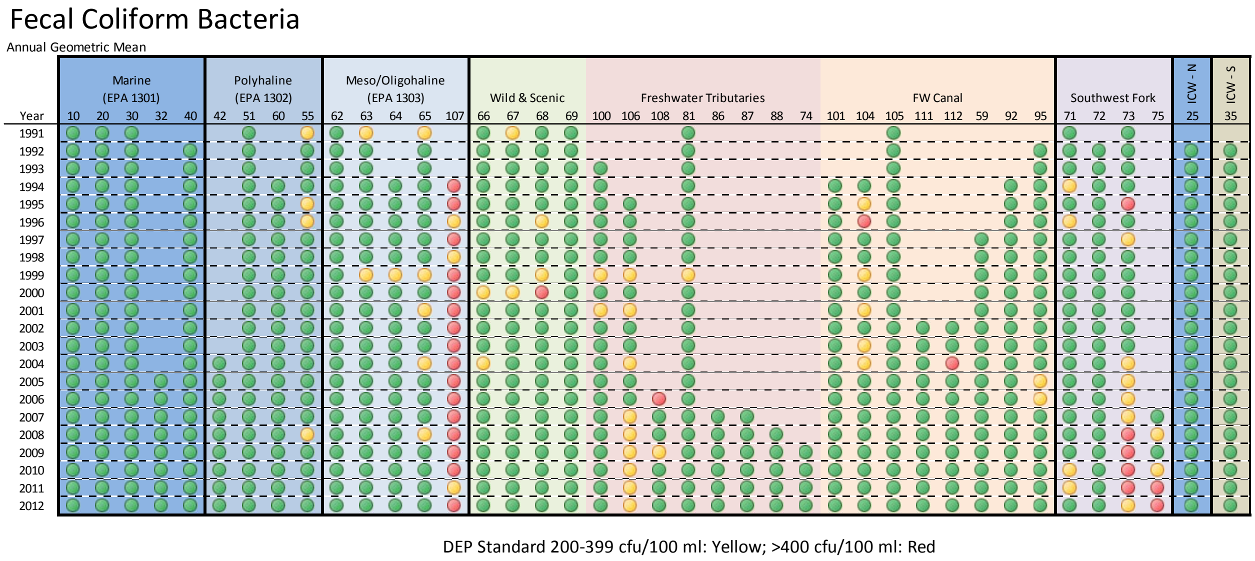

Figure 25. Stoplight plot of annual geometric mean Fecal Coliform bacteria by site and year scored relative to DEP Standard 200-399 cfu/100 ml: Yellow; >400 cfu/100 ml: Red.

Significant Findings for the Loxahatchee River

- Following supplemental flows during the spring of 2011, 2012, and 2013 to help meet the minimum flow targets, extensive salinity monitoring indicates the salinity targets in the cypress habitat were met.

- Analysis of salinity data suggests that moderate flood control releases (i.e., <300 cfs) into the Loxahatchee River estuary through the S-46 structure can appreciably reduce daily salinity variability, which likely reduces the stress and/or harm experienced by seagrasses and oyster reefs.

- In 2010, Martin County and the Loxahatchee River District, with funding from the American Recovery & Reinvestment Act through NOAA, coordinated the successful restoration of over 5.8 acres of oyster reefs in the Northwest Fork of the Loxahatchee River. Just 20 months after the 5.8 acre oyster restoration project, the reef supported almost 5,000 lbs of non-oyster animal biomass (small fish, crabs and shrimp) at the restoration site.

- Tropical Storm Isaac in 2012 resulted in more than 10 inches of rain over 3 days in portions of the watershed, and over 14 days of heavy flood control releases (700 – 2000+ cfs) from the S-46 structure into the Loxahatchee River estuary. Oysters in the Southwest Fork were heavily impacted but elsewhere in the estuary oyster were not significantly harmed. Less than 12 months later, it appears the oysters in the Southwest Fork have recovered. TS Isaac caused significant and sustained decline in manatee grass at the North Bay and Sand Bar sites. Johnson’s seagrass and shoal grass was severely impacted at the Northwest Fork site and has yet to recover. Johnsons’ seagrass has declined at Pennock Point, but appears generally healthy at the other sites.