Bayou St. John Urban Marsh

Monitoring Report 2014 – 2019

Pontchartrain Conservancy

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Pontchartrain Conservancy

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Acknowledgements

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Executive Summary

Historically and in its natural state, Bayou St. John (BSJ, bayou) drained from high ground near the Mississippi River, toward Lake Pontchartrain (lake). Today, the bayou's elevation is several feet lower than the lake and exists mostly within the flood protection levee system - functioning more like a pond than a bayou. In spite of this, BSJ still has ecologic and aesthetic qualities that are highly valued by the community.

The New Orleans Levee District (OLD) began a dredging project at the mouth of BSJ in 2013 to improve water flow when the floodgate is open. This is part of a series of projects intended to improve the bayou's hydrological and ecological function. The dredging project was an opportunity to use sediment beneficially for marsh creation, so the Pontchartrain Conservancy (PC) worked with OLD and developed a plan for marsh creation by building retaining walls on either side of the bayou at its mouth and placing dredged material behind them to create two marsh areas. A total of 2, 800 cubic yards of dredge material was used to build the two marsh sites. Further, much of the filling, moving and placement of bags to build the retaining walls was done by hand by PC staff and many, many volunteers contributing more than 1, 500 hours of work in total. The area was planted in March and April of 2014 and by May 2014, a 0.44-acre marsh had been created and construction work was complete. The new marsh was called the BSJ Urban Marsh.

The PC designed a monitoring plan to study the development of the marsh, including changes in vegetation, elevation, and soil properties. A total of 42 permanent monitoring plots were set up in June 2014. All monitoring plots were located inside the retaining walls, although some marsh was developing naturally, outside the retaining walls. A previous monitoring report (Henkel et al. 2019), described the construction of the marsh in detail and also discussed the marsh's development from June 2014 to February 2017. This report is an update and describes the monitoring results and activities in and around the marsh from February 2017 to December 2019.

After five years of development, the BSJ Urban Marsh is still a young, but resilient intermediate marsh in fair condition in a very dynamic environment. The marsh is home to a surprisingly high number of plant species occurring in low abundances. The plant species planted when the marsh was constructed (*Spartina patens, Spartina alterniflora, Schoenoplectus californicus*) are still the dominant species in the marsh, though a shift in the plant community has occurred. *S. patens* and *S. alterniflora* are decreasing in abundance, as *S. californicus* and *Panicum repens* are increasing. Other marsh properties (i.e. elevation, soil properties) have been slow to change, but this is not uncommon when compared to other regional constructed marshes. It's likely that in the next few years we will detect more changes in these properties across the marsh.

The BSJ Urban Marsh is an example of a type of wetland creation project that can be implemented along the armored south shore of Lake Pontchartrain. Creating fringing marsh habitat, even in small patches, provides habitat for fish, invertebrates, birds, and other animals. Increasing the amount of fringing marsh along the south shore is one of the ten Pontchartrain Coastal Lines of Defense outlined by the PC as a priority for both increasing storm surge protection and establishing critical habitat for priority species.

Highlights

- Overall elevation ('NAVD 88) is higher on the west side (0.29'NAVD88) of the Bayou St. John (BSJ) Urban Marsh than on the east side (0.03'NAVD88)
- There has been no statistical change in elevation at BSJ Urban Marsh at the 5-year mark – similar to other constructed marshes at this age (Bucktown Mitigation Marsh)
- Mean total vegetative cover (TC; %) is the same on either side of the marsh
- Mean TC across the marsh has been increasing since 2016 - up to ~45% TC in 2019
- Despite some variability early, species richness has increased in the marsh since 2017 – up to mean 3.1 species per site in 2019
- Mean species richness is the same on either side of the marsh
- Since its construction, 54 distinct plant species have been identified at BSJ Urban Marsh- including 23 herbaceous species, 21 grasses, 3 vine species, 1 tree species, 3 shrubs and 3 subshrubs
- According to floristic quality index (FQI) analysis, the marsh was healthiest on the west side of the marsh in 2015- before a major wrack deposition event smothered the plant community
- The marsh plant community changed after the wrack deposition event, and has been recovering and rebounding ever since
- Bulk density (BD; g cm^{-3}) remains high (> 1.0 g cm^{-3}) across the vast majority of sites across the marsh, but BD is lower on the east side compared to west side
- There has been no change in mean BD across years
- Soil organic matter (OM; %) remains low overall across the vast majority of sites across the marsh (29 out of 42 sites < 5.0 %) – similar to some other constructed marshes (PO-17 LaBranche) at the 5-year mark
- There has been no change in OM across years

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Background

In 1982, Bayou St. John (BSJ) was designated by the Louisiana Legislature as a “Historic and Scenic River,” which “requires protection and preservation of its aesthetic, scenic, recreation, fish, wildlife, ecological, archaeological, botanical and other natural and physical features” (LDWF 2020). The historic significance of BSJ cannot be overstated, because it was this bayou that allowed the first French Settlers to approach the Mississippi River through Lake Pontchartrain (“the lake”) to settle New Orleans in 1718 (Freiberg 1980). Subsequently, commerce on BSJ was so significant that the Carondelet Canal was dug to extend BSJ to the heart of New Orleans’ commerce in the French Quarter (Boudreaux 1982). BSJ is now about four miles long stretching from the lake to the now filled Carondelet Canal, which has been converted to a pedestrian greenway called the Lafitte Greenway. BSJ once again connects Lake Pontchartrain the heart of New Orleans.

The modern-day mouth of BSJ is a man-made landscape. In the 1930s, the lakefront was filled in behind a seawall to form the Lakeview neighborhoods. In 1962, a dam was built at the old shoreline at Robert E. Lee Blvd. (Ward 1982). In the 1980s, the Orleans Levee District’s (OLD) predecessor filled in the end of the BSJ with sand for a ground-level bridge that was never built. Then, in 1992 higher levees were constructed along with the current "sector gate" flood control structure. Because BSJ is lower in elevation than the lake, the gates were kept closed most of the time, but recent improvements to BSJ allow the gate to be used more frequently for environmental enhancement.

In spring 2013, OLD began a dredging project to unplug the mouth of BSJ at Lake Pontchartrain and improve water flow inward when the floodgate is open (**Appendix A**). This dredging project was part of a series of projects intended to improve BSJ hydrological and ecological functions. The waterway’s history and environmental status are summarized in the Bayou St. John Comprehensive Management Plan (LPBF 2006a), which calls for these types of improvements, including constructing wetlands along the banks of the bayou. PC seized the opportunity to partner with OLD and others in order to construct two small marsh wetlands flanking either side of BSJ just south of the lake, using the dredged sediments from the mouth of BSJ. The project and our continued involvement (described in this report) compliment the proposals in the PC *Comprehensive Habitat Management Plan for The Lake Pontchartrain Basin* (LPBF 2006b), which recommends restoration of the littoral shoreline of Orleans Parish, including the mouth of BSJ, and Jefferson Parish. Further, this work supported the mission of the PC “to drive environmental sustainability and stewardship through **scientific research, education, and advocacy** (www.scienceforourcoast.com).”

You can read about the construction of the BSJ Urban Marsh and the first three years of monitoring (2014-2017) in the report titled “Bayou St. John Urban Marsh: Summary of Construction and 2014 to 2017 Monitoring” (Henkel et al. 2017). This document will serve as an update to the previous document, and describes monitoring and activities through 2019. All background information presented in the previous report remains valid.

Current objectives

The PC Coast and Community Program continues its work in the BSJ Urban Marsh. We have four main objectives:

1. Continue to track the development of the marsh (elevation, vegetation, soils)
2. Make this data and our assessments publicly available in the form of a report
3. Work with our own PC Education and Advocacy programs, as well as community groups to make the BSJ Urban Marsh readily accessible to the public

4. Use the ‘Lessons learned’ to improve the efficiency and resiliency of this and other urban marsh creation/restoration projects

Methods

Study site and design

The BSJ Urban Marsh is a 0.44-acre constructed marsh located at the mouth of BSJ, on the edge of the Lakeview neighborhood in New Orleans, LA and Lake Pontchartrain. The marsh flanks the east and west side of the bayou. Forty-two permanent monitoring plots were set up in June, 2014 and monitored quarterly for one year (**Figure 1**, *left*). These sites have been monitored biannually (February, August) since August, 2015. In each plot elevation, vegetation and soil sample data is collected. Elevation measurements and soil samples are collected only in August. Vegetation is surveyed in February and August. Additionally, surface salinity data collected by the PC Water Quality Department, water level data from US Army Corps of Engineers (USACE) gauge #85625 at West End, LA and bird observation data from ebird.org, were also incorporated into the discussion of the results from our analysis. The data collection methods for each of these parameters are described below. All monitoring plots are located inside the retaining walls described in Henkel et al. 2017 (**Figure 1**, *right*), although some marsh developed independently outside the containment dikes during the construction of the marsh.

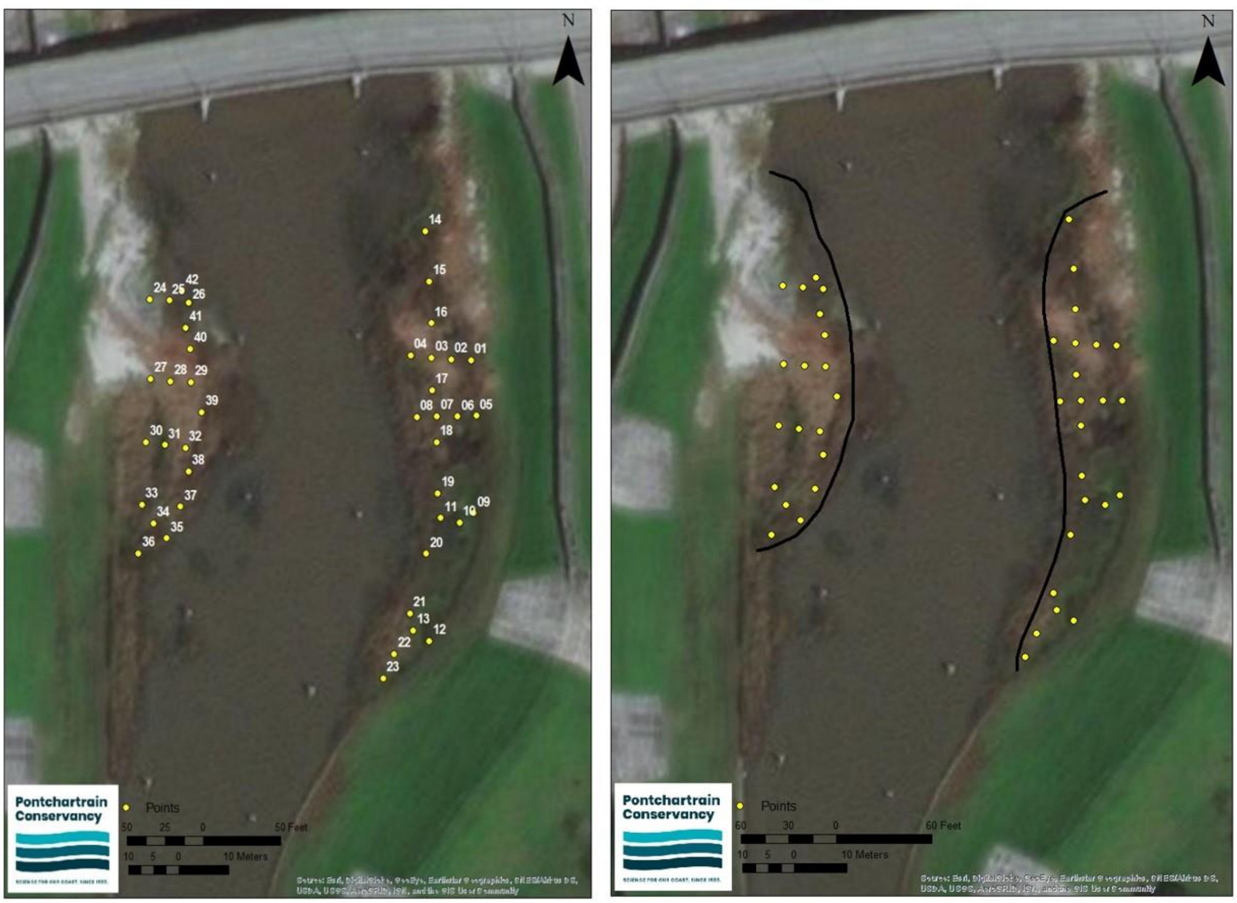

Figure 1 *Study sites across the Bayou St. John Urban Marsh*

Elevations

Elevation measurements were taken at all forty-two plots using a Trimble Geo Explorer 6000 GeoXR GPS attached to a Zephyr Model 2 GNSS receiver (**Figure 2-A**). Capable of real time kinematic (RTK) data collection, this survey grade GPS system provided latitude, longitude, and elevation with a horizontal precision of less than two inches and vertical precision of less than three inches.

Vegetation

Herbaceous vegetation was measured at all forty-two plots using a 1-m^2 PVC quadrat (Wikum and Shanholtzer 1978) (**Figure 2-B**). In each plot, total percent cover, percent cover by species and species richness was assessed. Only live plants were considered. The Floristic Quality Index (FQI) (Cretini et al. 2011, Cretini et al. 2012) were calculated using the vegetation data collected in August of each year. FQI assessments incorporate abundance and quality of species. FQI are scored from 0 – 100. In general, the FQI is an indication of native vegetative quality for an area: generally, 1-19 indicates low vegetative quality; 20-35 indicates high vegetative quality and above 35 indicates "Natural Area" quality (Herman et al. 2017; Wilhelm and Rerich 2017). FQI analyses was adjusted for Louisiana by Cretini et al (2017), whereas, and FQI score of 0-38 indicates a poor-quality site, 38-71 indicates a fair quality site, and an FQI score > 71 indicates a high-quality site.

Figure 2 *Elevation measurements were taken using a Geo Explorer 6000 GeoXR GPS attached to a Zephyr Model 2 GNSS receiver (A); vegetation was surveyed using a modified Braun-Blanquet 1-meter squared method (B)*

Soil properties

The bulk density (BD; g cm^3) and organic matter (OM; %) content of the soil was determined for each monitoring station as described above. One sediment core was collected at each site using 5-cm diameter PVC corers. The corer was 1-meter long and was pushed into the soil to a depth of 20 cm, or until refusal. The depth to which the core penetrated was recorded. Extracted soil cores were placed in individually labeled plastic bags, and transported on ice to the laboratory at Louisiana State University. Sediment samples were dried at 60^{o}C to a constant weight (g), recorded (± 0.01 g), and used to calculate dry BD by dividing dry weight by volume of the core sample, corrected for core length. After drying and weighing, sediment samples were homogenized using a mortar and pestle. To determine percent OM using the loss on ignition method (Dean 1974), two 4.0 g subsamples of each sediment sample were weighed out and burned at 550 °C for 4 hours. For each subsample, post-fire weight was subtracted from pre-fire weight. Subsamples were averaged by site and multiplied by 100 for a final determination of % OM.

Analysis

All statistical analysis was conducted in SAS 9.4 and for all tests a significance value of $p = 0.05$ was used. Elevation, percent cover, species richness, percent OM, and BD were analyzed using analysis of variance (ANOVA) in a 2 * 5 factorial design to determine if the factors were significantly different by marsh area (2 areas-east side, west side), time (5 years-2014, 2015, 2016, 2017, 2018, 2019), or the interaction of marsh area and time, followed by post hoc comparison testing using the Tukeys procedure if significant differences were found. In addition, elevation, OM and BD data was interpolated across the study area using the Splining with Barriers procedure in Esri ArcGIS 10.5. for a more visually complete picture of conditions across the marsh

Results

Elevation

There was no significant difference in mean ground elevation for the interaction of marsh area and years. There was also no significant difference in mean ground elevation across the main effect of years at the BSJ Urban Marsh. Mean elevation from 2014 – 2019 ranged between 0.04 'NAVD88 (± 0.13' SE) to 0.30 'NAVD88 (± 0.15' SE). However, there was a significant difference in mean ground elevation between marsh areas ($F_{1, 248} = 6.62$; $p = 0.0107$). The western marsh had a higher mean ground elevation (0.29 'NAVD88 ± 0.07' SE) than the eastern marsh (0.03 'NAVD88 ± 0.07' SE). At individual sites across the western marsh, ground elevation ranged between -0.99' to 2.85 'NAVD88, and across the eastern marsh ground elevation ranged between -2.7' to 3.89 'NAVD88. The interpolation of ground elevation data across the BSJ Urban Marsh showed exactly where and possibly why the eastern marsh is generally lower and the western marsh is generally higher in ground elevation (**Figure 3**). In short, the eastern marsh contains an interior ponded area that was never filled with dredge sediment during construction, which explains the overall lower elevation across the marsh on the east side. In contrast, the western marsh's most lake facing sites fluctuate wildly in elevation (**Figure 4**). Wave action scours out parts of this area and then deposits *a lot* of shell material in mounds elsewhere (**Figure 5-A & 5-B**). These shell mounds and the sites located in this area contribute to the overall higher ground elevation on the western side.

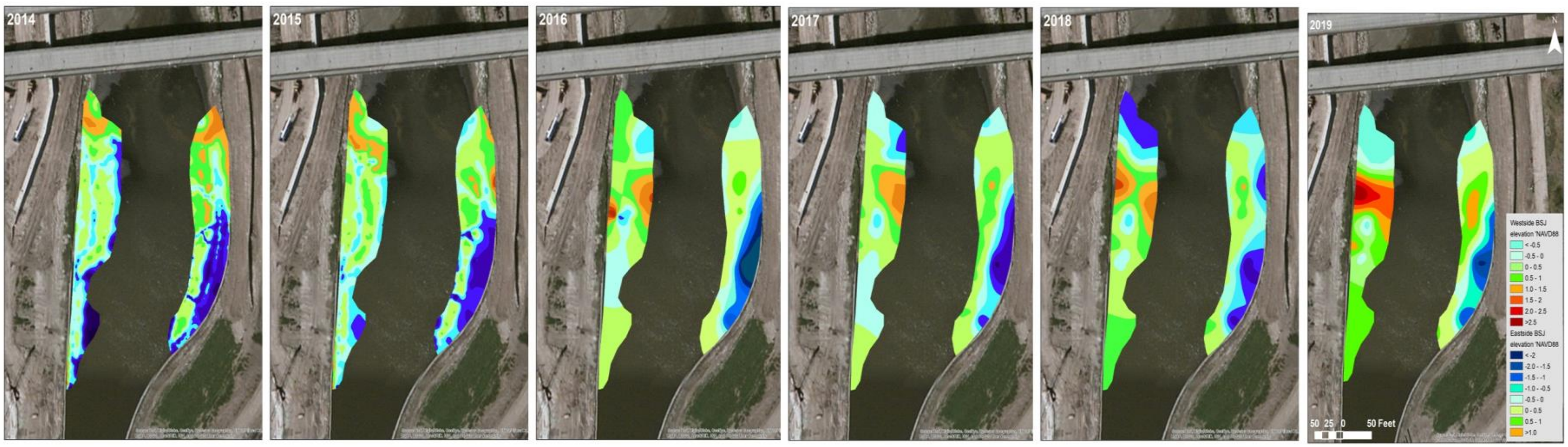

***Figure 3** Interpolation of ground elevation data across the marsh from 2014-2019*

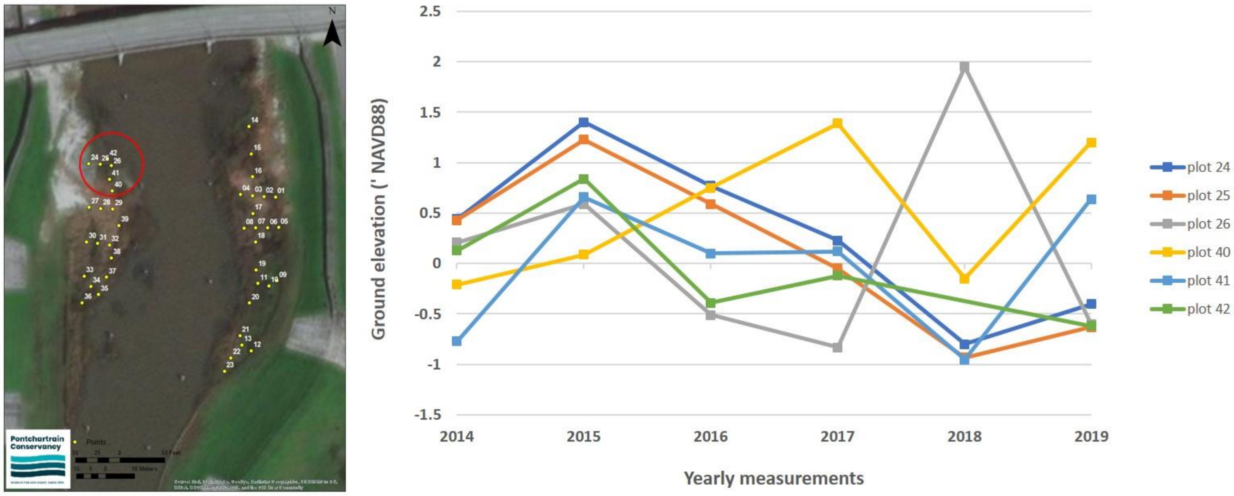

__Figure 4__ Ground elevation at select sites (red circle on left) on the west side of the Bayou St. John Urban Marsh from 2014-2019

__Figure 5__ The photos depict areas of erosion (A) and deposition (B) of sediment and shells on the west side of the Bayou St. John Urban Marsh

Vegetation cover

Despite some variability, there was no significant difference in the interaction of total vegetative cover at the peak of the growing season by area and year (Summer, **Figure 6**; Winter, **Appendix C**). There was also no significant difference in mean TC for the main effect of marsh areas - the east and west side of BSJ (**Figure 7**). However, there was a significant difference in mean TC for the main effect years ($F_{5, 250} = 6.09$; $p < 0.0001$). At individual sites across all years, TC ranged between 0 – 100%. Mean TC across years at BSJ Urban Marsh ranged between a low of 20.3% (± 3.7% SE; 2014) to a high of 44.5% (± 4.3% SE; 2019). Mean TC in 2019 was significantly different compared to TC in 2014. Despite variability for the first three years of monitoring, mean TC now appears to be increasing year over year (**Figure 8**).

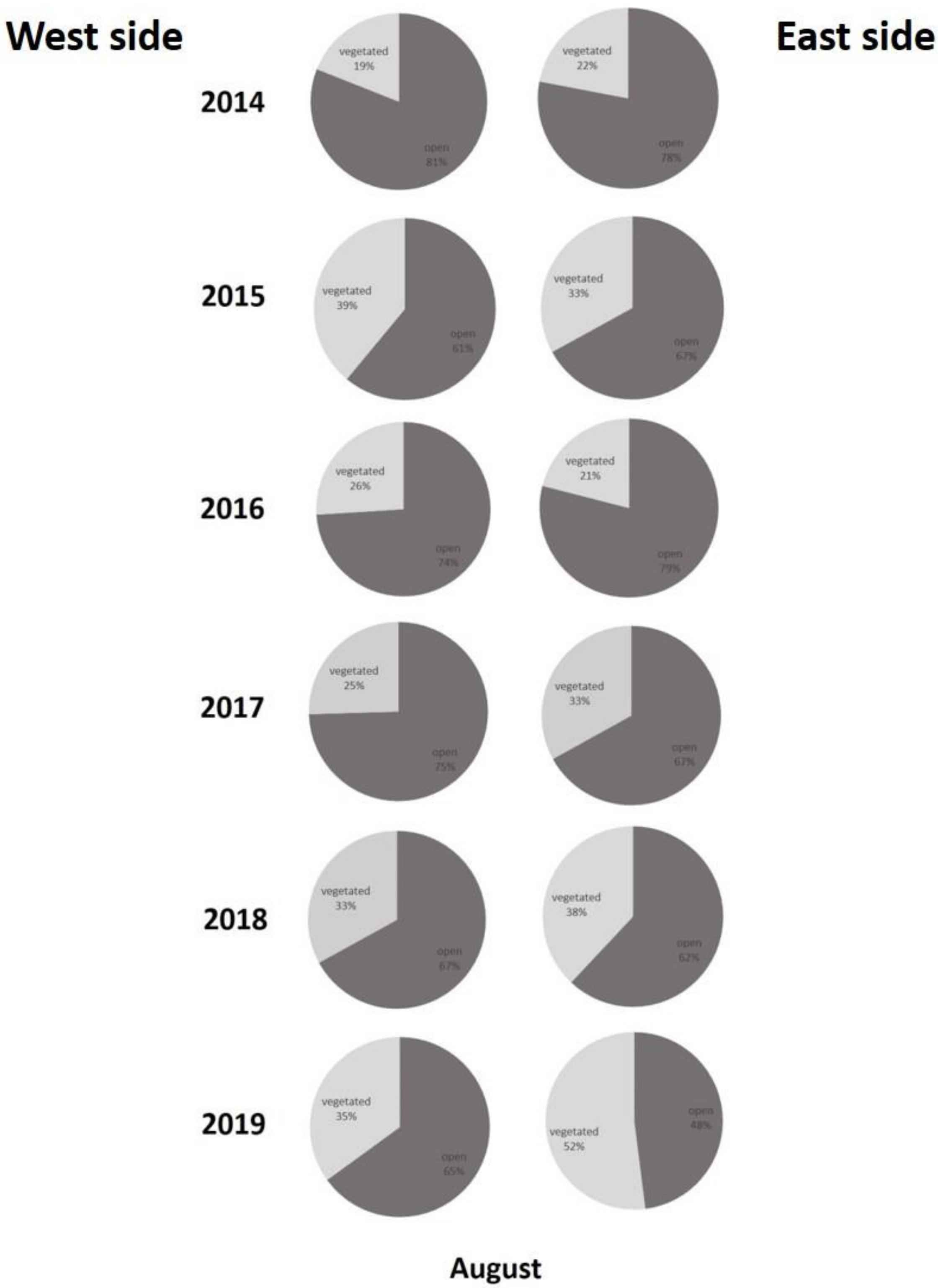

Figure 6 *Total vegetative cover at Bayou St. John Urban Marsh across areas (east and west) and years (2014 - 2019). Light grey = vegetated, dark grey = unvegetated*

Figure 7 *Pictures depict vegetative cover at Bayou St. John on the west side (A) and east side (B) of the bayou.*

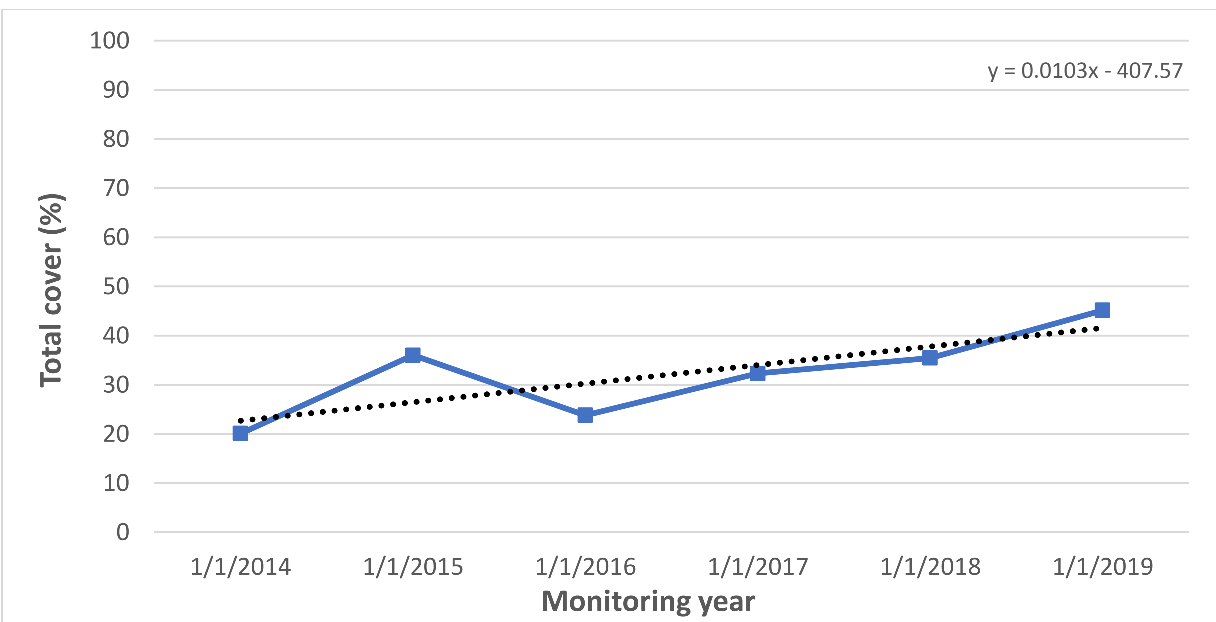

Figure 8 *Total vegetative cover across the Bayou St. John Urban Marsh from 2014 - 2019*

Species

There was no significant interaction of species richness by area and year. There was also no significant difference in species richness for the main effect of marsh areas. However, there was a significant difference in species richness for the main effect of years ($F_{5, 249} = 3.69$; $p = 0.0031$). At individual sites across all years, species richness ranged between 0 – 7 species per site. Mean species richness across years at the BSJ Urban Marsh ranged between a low of 1.7 (± 0.18 SE; 2014) to a high of

3.1 (± 0.27 SE; 2019). Species richness in 2014 was significantly different and lower compared to all other years. Despite some variability, the trend indicates that mean species richness across the marsh is increasing (R^2 = 0.44; **Figure 9**).

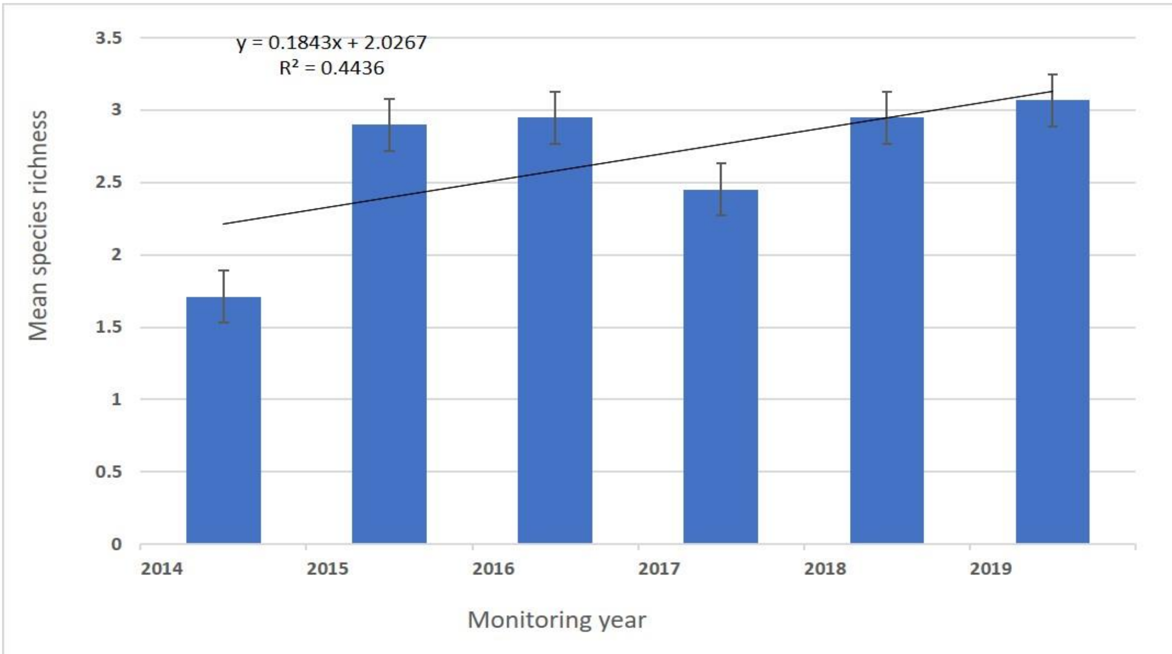

Figure 9 *Mean species richness across the Bayou St. John Urban Marsh*

Since its construction, fifty-four distinct plant species have been identified at the BSJ Urban Marsh (**Appendix B**). Of these species, many exhibit "flashy" growth patterns and are not found during each monitoring event (**Figure 10**). Some species were identified in earlier years and have not been seen in recent years. A minority of species (13 out of 54; 24%) were considered invasive; a majority of species (39 out of 54; 77%) were found in low abundances (< 1% TC). Of the twelve species that occur at higher abundances (>5%), three (*Spartina alterniflora, Spartina patens, Schoenoplectus californicus*) were planted and were the dominant species when the marsh was constructed. Despite their relative abundance, *S. alterniflora* and *S. patens* have been decreasing in abundance over time, while *S. californicus* has been increasing in abundance. The other nine abundant species (*Phragmites australis, Panicum repens, Pontederia cordata, Cyperus oderatus, Alternanthera philoxeroides, Mikania scandens, Vigna luteola, Kosteletzkya virginica, Ipomoea sagittata*) colonized the BSJ Urban Marsh naturally. Of those nine species, three are considered invasive (*P. australis, P. repens, A philoxeroides*). *P. repens* and *V. luteola* have been increasing in abundance in recent years.

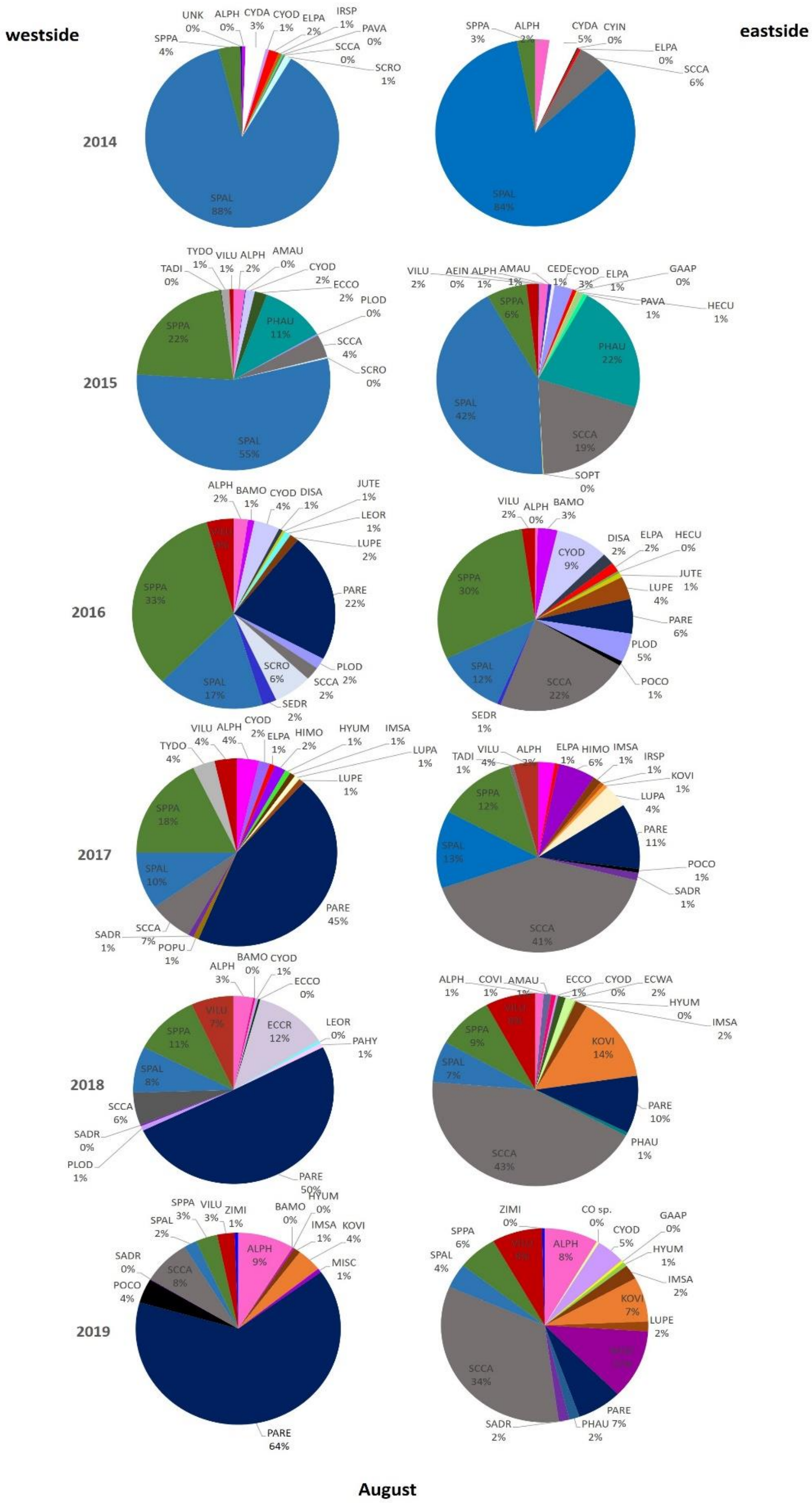

__Figure 10__ Plant species and their coverage at Bayou St. John Urban Marsh from 2014-2019 delineated by west and east side of the bayou (for a complete list of plant names see __APPENDIX B__)

Floristic quality index

There was a significant interaction of FQI assessment by marsh area and years ($F_{11,249}$ = 3.06; p = 0.0007; **Figure 11**). This interaction was primarily driven by the main effect years. The FQI assessment on the western side of the BSJ Urban Marsh in 2015 (33.5 ± 4.6 SE) was higher and different than the FQI assessment on the western side in 2017 (14.6 ± 2.8 SE), 2018 (13.2± 2.5 SE) and 2019 (12.8 ± 2.6 SE), as well as 2016 on the eastern side (16.7 ± 3.2 SE). FQI assessments at individual sites across all years ranged between 0 - 77.9. The highest FQI assessment at an individual site occurred in 2015. In the most recent year (2019), FQI assessments at individual sites ranged between 0 – 63.0.

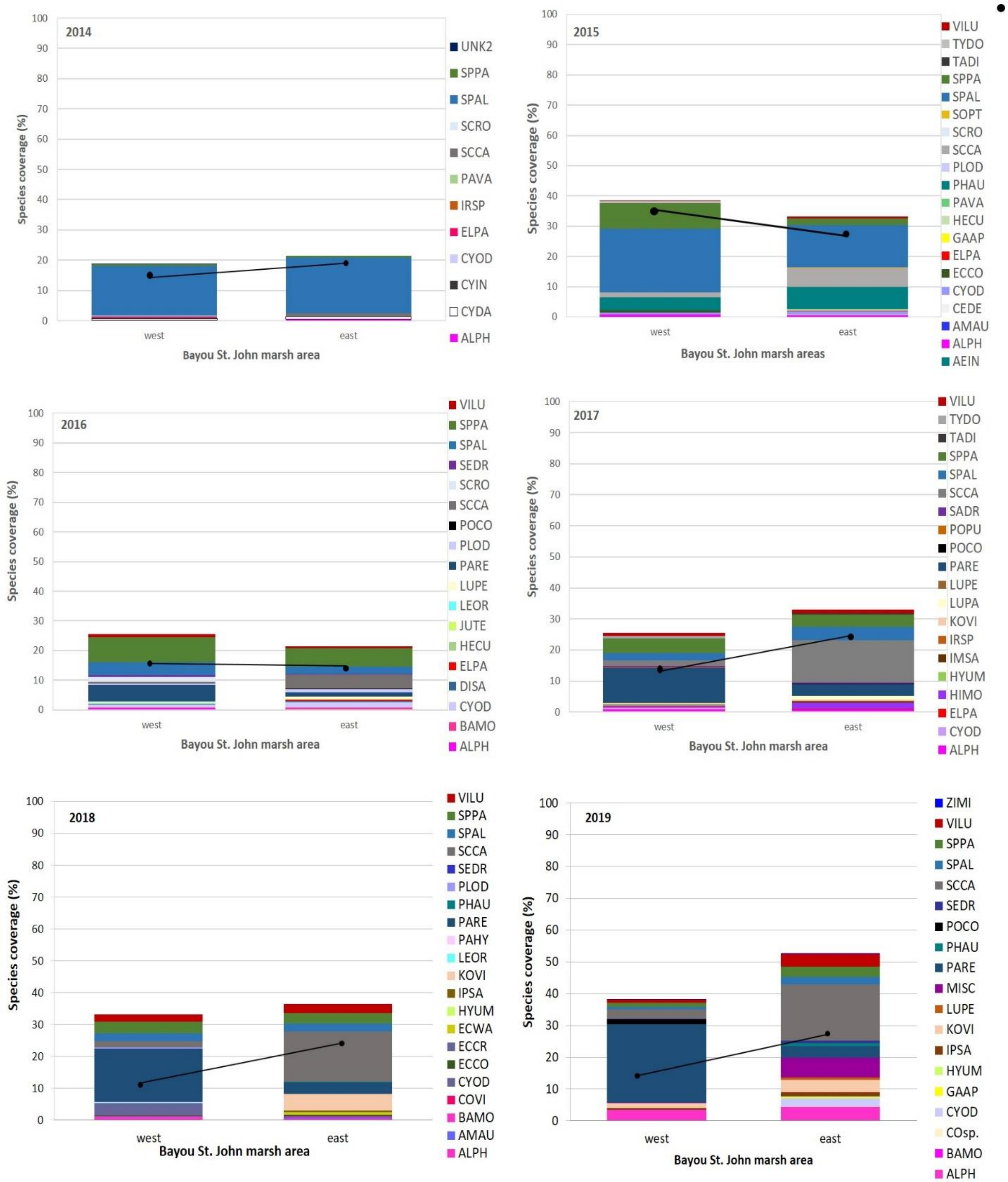

Figure 11 *Floristic Quality Indices (FQI) from 2014 - 2019 at Bayou St. John Urban Marsh delineated by west and east side of the bayou. Black dots overlaying bars on chart indicate FQI value (for a complete list of plant names see* ***APPENDIX B****)*

Soils

Bulk density

There was no significant soil BD interaction by area and year. However, there was a significant difference in mean BD across the main effects - years ($F_{5, 249}$ = 5.58; p < 0.0001) and areas ($F_{1, 249}$ = 41.59; p < 0.0001) at the BSJ Urban Marsh (**Figure 12A and 12B**, respectively). Mean soil BD from 2014 – 2019 ranged between 1.11 g cm^{-3} (± 0.04 SE) to 1.55 g cm^{-3} (± 0.09 SE). BD at individual sites ranged between 0.31 g cm^{-3} to 3.32 g cm^{-3}. Mean soil BD the first year (2014) was lower and statistically different than BD in 2017 and 2018. Fully 83% of soil BD measurements were > 1.0 g cm^{-3}. Mean soil BD across the eastern marsh (1.19 g cm^{-3} ± 0.03 SE) was lower and statistically different than mean soil BD on the western marsh side (1.51 g cm^{-3} ± 0.04 SE). On the eastern side soil BD at individual sites ranged between a low of 0.31 g cm^{-3} to a high of 1.81 g cm^{-3}. On the western side soil BD at individual sites ranged between a low of 0.73 g cm^{-3} and a high of 3.32 g cm^{-3}. The interpolation of soil BD data across the BSJ Urban Marsh showed where and potentially why the eastern marsh has generally lower soil BD than the western marsh (**Figure 13**). In short, the same ponded area on the eastern side of the marsh not filled with dredge material during construction also had the lowest soil BD, likely contributing to overall statistically lower soil BD on the eastern side of the BSJ Urban Marsh. In contrast, the western marsh's most lake facing sites that retain re-worked shell and sandy lake sediments likely contribute to the overall higher soil BD on the western side. Further, the interpolation shows that soil BD was lower across a larger area of the marsh in 2014 compared to subsequent years, though the area appears to be expanding again in 2019.

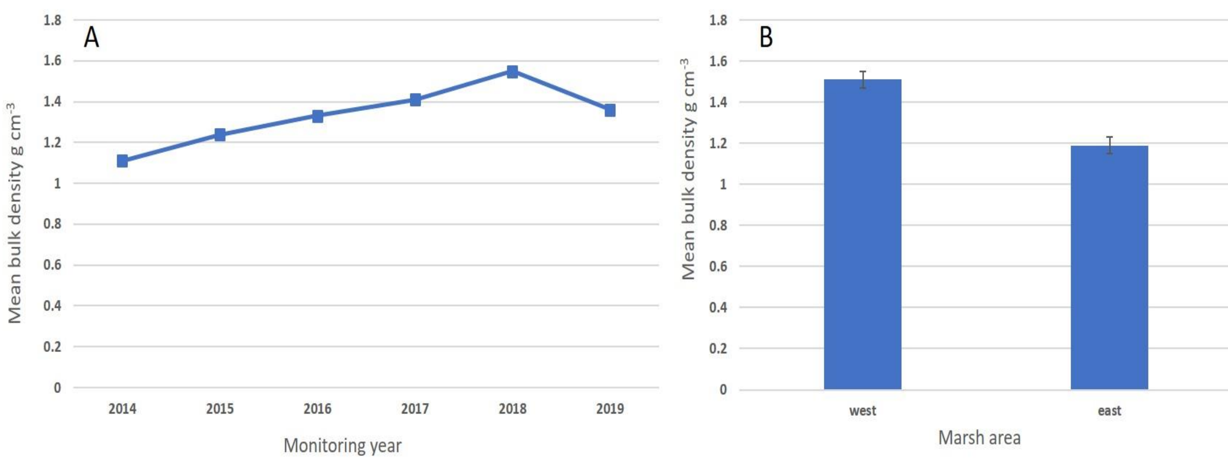

Figure 12 *Soil bulk density (g cm^{-3}) across years (A) and across marsh areas (B) at the Bayou St. John Urban Marsh*

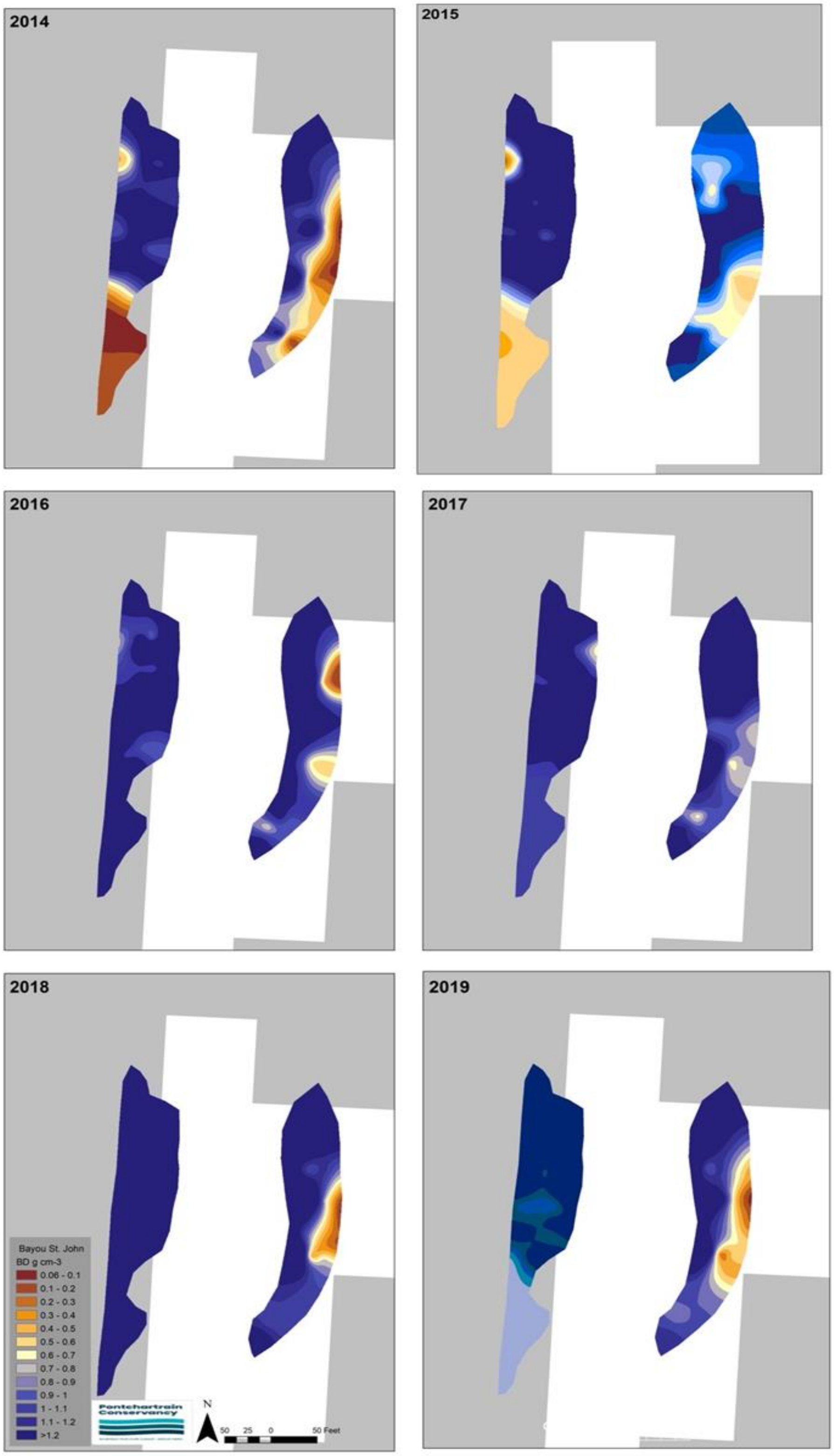

Figure 13 *Interpolation of soil bulk density (g cm^3) across the Bayou St. John Urban Marsh from 2014-2019*

Organic matter

There was no significant percent soil OM interaction by area and year. There was also no significant difference in mean percent soil OM across the main effect of years only. Mean percent soil OM from 2014 - 2019 ranged between a low of 2.85 to 4.80 %, and percent soil OM at individual sites ranged from 0.17 % to 21.96 %. However, there was a statistical difference in percent soil OM across marsh areas ($F_{1, 249} = 46.25$; $p < 0.0001$) at the BSJ Urban Marsh (**Figure 14**). Soil OM across the western marsh (1.81 % ± 0.03 SE) was lower and statistically different from soil OM on the eastern marsh side (5.01 % ± 0.42 SE). On the eastern side soil OM ranged between a low of 0.40 % to a high of 21.96 %. On the western side OM ranged between a low of 0.17 % and a high of 7.84 %. The interpolation of soil OM data across the BSJ Urban Marsh showed where and possibly why the eastern marsh had generally higher OM than the western marsh (**Figure 15**). In short, the same ponded area on the eastern side of the marsh with lower elevation and lower soil BD, had higher soil OM. In contrast, the western marsh's most lake facing sites, which tend to retain highly mineral lake sediments, likely contribute to the overall lower soil OM on the western side.

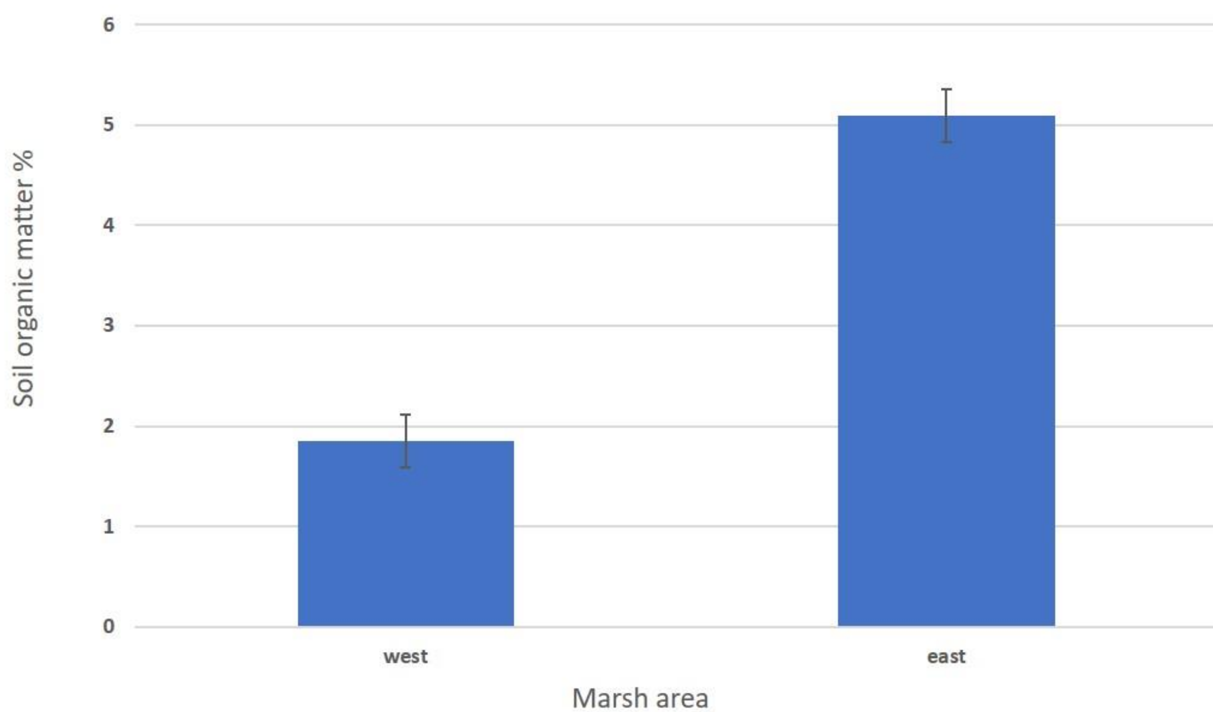

Figure 14 *Soil organic matter (%) across the Bayou St. John Urban Marsh by area*

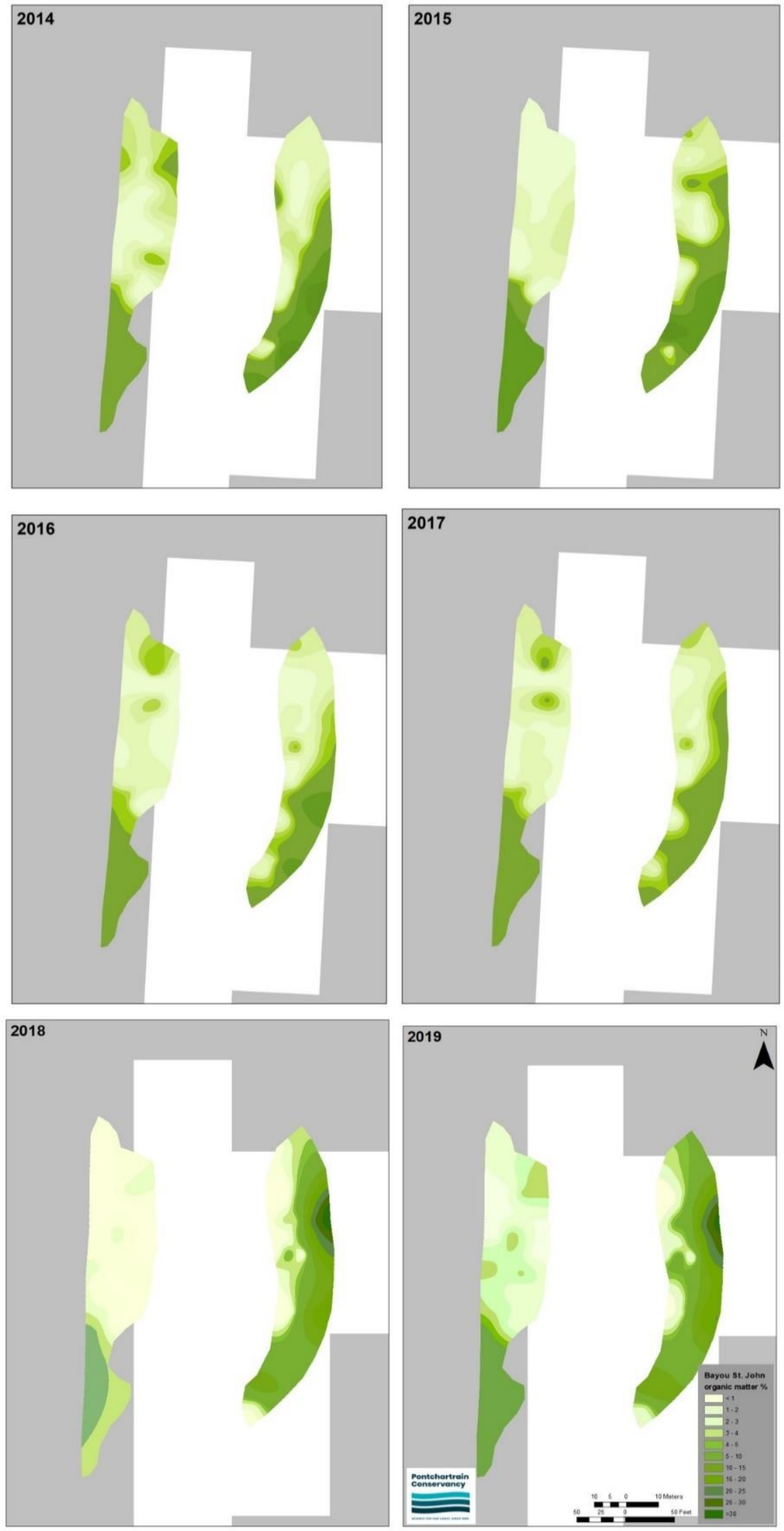

Figure 15 *Interpolation of soil organic matter (%) across the Bayou St. John Urban Marsh from 2014-2019*

Discussion

State of the marsh

The BSJ Urban Marsh serves as an example of the type of small wetland creation projects that can be implemented along the mostly armored south shore of Lake Pontchartrain. Increasing the amount of fringing marsh along the south shore is one of the ten Pontchartrain Coastal Lines of Defense outlined by the PC as a priority for both increasing storm surge protection and establishing habitat that serves as a nursery for aquatic juveniles. The constructed marsh at the mouth of BSJ is an early successional (5-year old) intermediate marsh in fair condition. The marsh is in fair condition despite containing plant species such as *S. patens* and *S. californicus* that are actually indicators of healthy intermediate marshes (Visser et al. 2000). This is because these species occur at relatively low abundances throughout the BSJ Urban Marsh even though they are the dominant species. Moreover, ground elevation and soil properties have been slow to change since marsh construction-but this is not uncommon. Notwithstanding some differences, the BSJ Urban Marsh is similar to other regional constructed marshes in some aspects, including soil bulk density and percent OM (LaBranche PO-17), elevation change and *S. alterniflora* cover (Bucktown Mitigation Marsh) (**Table 1.).** Despite its' state, the BSJ Urban Marsh provides valuable habitat, refuge and food for other species, and increases the accessibility of wetland habitats to the public in an urban environment. The BSJ Urban Marsh is a unique environment, more or less developing as expected. Discussed below are some interesting trends and recommendations gleaned from five years of monitoring.

Table 1. *Comparison of factors (elevation - 'NAVD 88, total cover - %, Spartina alterniflora cover - %, Floristic Quality Index, species richness, soil bulk density – g cm^{-3}, soil organic matter - %) between three regional constructed marshes at 5-years post construction in southeast Louisiana. Data for Bucktown Marsh from Hillmann and Lopez 2020; data for LaBranche PO-17 from Hillmann and Richardi 2011*.

Regional Constructed Marshes 5-years Post-Construction			
	BSJ Urban Marsh	**Bucktown Marsh**	**LaBranche PO-17**
Year	2019	2010	1999
Elevation (' NAVD 88)	No mean change	Min. mean change (~ 1 cm)	Mean decrease by ~ 1.5'
Total cover (%)	45%	~75%	~65%
S. alterniflora cover (%)	decreasing	decreasing	increasing
FQI	FQI 28	NA	FQI 65
Species richness	26	12	11
Bulk density (g cm-3)	>1.0	~0.50	~1.0
Organic matter (%)	< 5.0 %	10-30 %	~8.0 %

Vegetation

The BSJ Urban Marsh contains some of the plant species associated with healthy intermediate marshes; including *S. patens*, *S. californicus*, and to a lesser extent, *S. alterniflora*. These species were planted when the marsh was first constructed in 2014, and are still some of the most dominant plant species in the marsh. Yet the marsh is not considered "healthy." The abundance of *S. patens* and *S.*

alterniflora has decreased in recent years. Their dominance has been replaced by an increased abundance by *S. californicus* and *P. repens,* which colonized naturally. Other species have also colonized naturally and occur sporadically and at low abundances (<1%). We likely were able to detect all these species due to the large number of sampling sites (n=42). Changes in community membership and abundance of species can negatively impact FQI assessments by replacing 'high value' wetland plant species with less valuable plants. The end result being lower FQI scores and marsh assessments. This appears to have happened at the BSJ Urban Marsh in 2015/2016. Heavy wrack deposit in the winter of 2015/2016 smothered most of the existing vegetative community, which was replaced by a similar, but different plant community (Henkel et al. 2017). Although some individual FQI scores are in the healthy range (> 71), the overall average is weighed down by a few unvegetated/open water sites with FQI scores of 0. Therefore, the overall state of the marsh should consider not only FQI assessments, but also TC values, elevation, soil properties, ecosystem services provided, resiliency and site history.

Concomitant to the plant community changes described above, mean total vegetation cover values have also never surpassed 50% at the BSJ Urban Marsh. This is unlike mean cover values at the Bucktown Mitigation Marsh (75%) and PO-17 LaBranche (65%) at the 5-year mark. Some of this may be attributed to the "wrack deposition event" at the BSJ Urban Marsh, but it's also likely that low mean cover at BSJ is partially due to direct impacts from Lake Pontchartrain and flooding on the marsh, which result due to the specific location, elevation, construction materials, and dimensions of retaining wall at the BSJ Urban Marsh. For instance, the retaining wall at the Bucktown Mitigation Marsh was constructed with rip-rap, and extends 5-10 meters wide (**Figure 16-A & 16-B**), compared to the retaining wall at the BSJ Urban Marsh, which was constructed with sand-filled burlap bags and extends 2-5' wide (**Figure 16-C & 16-D**), or the BSJ marsh may just be more exposed to direct impacts from the lake. We can see these differences when comparing Bucktown and BSJ marshes; both marshes are resilient, but there is an area on the western side of BSJ that is continually eroded, then built up with shells and lake sediments. This cycle suppresses vegetation from establishing and reduces overall mean vegetative cover. There is no such area at the Bucktown Mitigation Marsh that gets similarly disturbed.

Figure 16 *Comparison and close-ups of the retaining walls used at the Bucktown Marsh (~10' wide border of rock, A & B) and at Bayou St. John Urban Marsh (~2' wide border of sand filled bags, C & D)*

Flooding

A second factor that suppresses total cover at BSJ Urban Marsh is the amount of time the marsh is flooded (**Figure 17**). The overall elevation of the marsh at BSJ is lower than at the Bucktown Mitigation Marsh and at LaBranche PO-17. All three marshes border Lake Pontchartrain. Due to its lower elevation, the BSJ Urban Marsh is flooded a greater percent of the time (at some sites > 75% flooded) compared to the other marshes. This means that the vegetation there is inundated with water more frequently and longer than vegetation in the other marshes. This is stressful for plants. Despite wetland plants tolerating flooded conditions better than terrestrial plants (Jackson and Colmer 2005), inundation is still a stressor and reduces overall productivity. Predictably, total cover values will be reduced, and subsequently wetland assessments will be negatively impacted. This is discussed at length in Henkel et al. (2017) and still applies today.

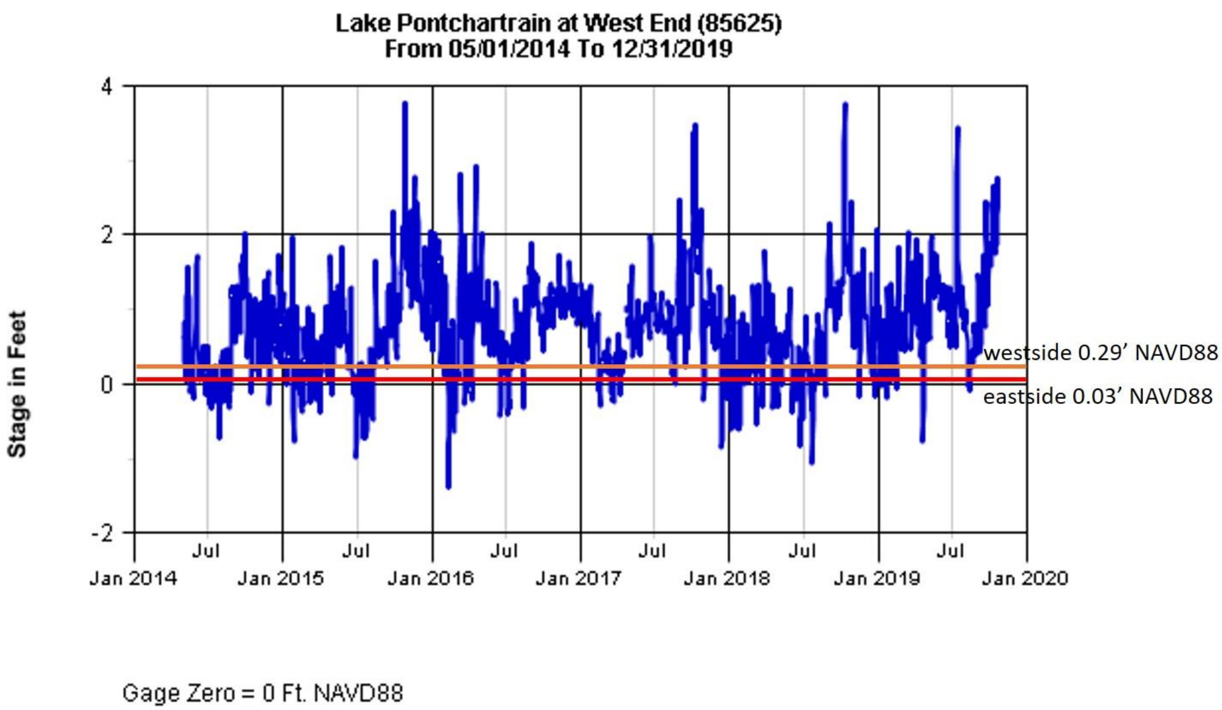

Figure 17 *Water levels in Lake Pontchartrain in the vicinity of the Bayou St. John Urban Marsh from 2014-2019*

Elevation and soils

Elevation has been slow to change at the BSJ Urban Marsh; year to year overall elevation differences are still hard to detect, but differences between areas are becoming apparent. At the five-year mark, this is similar to what was observed at the Bucktown Mitigation Marsh. At this stage, the Bucktown Mitigation Marsh had settled only ~1 cm overall according to SET measurements taken at the time (Hester and Willis 2011), although elevation differences were seen across the different marsh areas. At PO-17 LaBranche, the marsh had settled ~1.5' by five years post-construction. At BSJ Urban Marsh there was no overall change in elevation. Clearly, the true range of normal marsh elevation settling post-construction is more variable than we first expected, and is likely connected to the type of sediment being used in marsh construction. The BSJ Urban Marsh was created with high mineral sand excavated from the mouth of BSJ. Five years later, the westside is higher in elevation than the east side.

Ponded areas on the east side and sediment deposition on the west side appear to explain these differences. In the beginning, we actually noticed a lot of scouring on the west side, and tried to "fix" this by fortifying the retaining wall there and replanting that area of the marsh. On May 20, 2017, using volunteers and equipment donated be Entergy, the PC tried to repair the retaining wall using Flex MSE Bags (formerly Deltalok Bags), moving some sediment back into place and then re-planting. This was done to prevent further erosion of the northwest side of the marsh to stabilize the area. Although *some* plants became established, overall this effort was not successful. The retaining wall breached, again. We are still not completely clear why this particular area simultaneously has sites that erode, and also has others that are sites of intense sediment deposition.

Soil characteristics have been similarly slow to change and appear related to the same factors. For instance, we found BD to be lower on the east side than the west side of the marsh. This is likely also related to the ponded areas on the east side of the marsh that were not filled with high mineral dredged sediments, and the high rate of shell and sediment deposition on the west side. In fact, BD unexpectedly increased for the first four years across the entire marsh – contrary to what we expected. We expected decreasing BD, year over year, as decomposing vegetation integrated into soils. But these processes sometimes take some time before they become detectable; BD at PO-17 LaBranche also continued to hover at ~1.0 g cm^{-3} five years after construction and did not drop discernably until six years post construction. Finally, in 2019 there appears to be a change; BD is beginning to lower at the BSJ Urban Marsh.

Ecosystem services

Creating fringing marsh habitat, even in small patches, provides habitat for fish, invertebrates, birds, and other animals. This is an important concept in landscape ecology – the idea of 'habitat patches.' Habitat patches are any discrete area with a definite shape, and spatial configuration used by a species for breeding or obtaining resources (Bowman et al. 2017). Therein, habitat patches provide ecosystem services. Individual habitat patches then become part of a larger 'habitat corridor', which enables species distribution across a wider area. This is what we have created at BSJ and what we want to create along the armored shoreline of the south shore - valuable habitat in a highly urbanized environment. Over the past five years we've observed many different bird species wading along the marsh edge (**Appendix D**), seen fishes in the ponded areas, spotted an alligator in the bayou and ran into this snake on the marsh (**Figure 18**)! The use of this habitat patch by animals shows that wetlands don't have to be considered 'high value' according to their plant species and cover values to be resilient and provide important ecosystem services.

Figure 18 *Bayou St. John Urban Marsh has provided critical habitat for many species, including this snake*

Other activities

We've already discussed that the BSJ Urban Marsh is flooded for a large percentage of time throughout the year, and how this flooding likely impacts overall plant productivity in the marsh. Flooding also brings wrack, and marine debris (**Figure 19**); the amount of which depends on marsh location and body of water. Lake Pontchartrain is part of a dynamic, shallow-water estuary surrounded by a highly urbanized environment, especially on the south shore of the lake. The amount of marine debris can be voluminous. Community involvement was necessary to construct the marsh, and is also necessary to maintain it, at least to the degree that the marsh remains accessible and not dangerous because of debris.

Figure 19 *Pictures depict the high-water line from a recent water event (A) and debris deposited in the marsh (B)*

Community involvement is key, and has taken many forms at the BSJ Urban Marsh. Between 2018 and 2019, the Pontchartrain Conservancy hosted one large corporate service-learning event at the marsh. On December 6, 2019, 30+ Shell Corporation employees gathered at the marsh to learn about the bayou's history, the lake's water quality, the marsh creation project and to give back by clearing the area of marine debris (**Figure 20**). Over 50+ bags of debris were removed from the marsh that day.

Figure 20 *Shell Corporation volunteers spent a day picking up debris at the Bayou St. John Urban Marsh in December 2019*

As great as it is getting adults out into this marsh so they can help keep it clean, it's even more important to engage with children. Early, hands-on education and advocacy about the importance of these habitats will increase the likelihood of environmental stewardship later. This concept is so fundamental that it is part of the PC mission statement. Towards that end, the PC regularly guides marine debris removal with SE Louisiana grade school students at BSJ Urban Marsh (**Figure 21**).

Figure 21 *Tchefuncte Middle School students learning about wetlands and removing marine debris at Bayou St. John Urban Marsh*

As mentioned previously, an entire management plan was developed for BSJ (LPBF 2006b), with goals, objectives, actional tasks and partner organizations. The Orleans Levee Board was one of those partner organizations, and dredging the mouth of the bayou and the creation of the BSJ Urban Marsh partially fulfilled several goals and objectives of this plan. Specifically, Goal 2 aims to "enhance the estuarine habitat in and along Bayou St. John." Recently, the University of New Orleans (another partner organization), has been pushing to continue work on Goal 2, by tackling action item 2.1e: "create one-half to one-acre islands in wide sections of the bayou like those that were originally present." In 2019, UNO Professor Malay Hajra and MS student Miyra Rosa consulted with the PC Coast and Community Director Dr. John Lopez to identify suitable locations for island and wetland creation along BSJ (**Figure 22**). These locations have now been identified; hopefully funding will be procured soon so planning and construction can commence in the near future.

Figure 22 *University of New Orleans (UNO) Professor Malay Hajra (left and right) and UNO Masters student Miyra Rosa designed plans for further restoration of Bayou St. John further upstream from the marsh*

Lessons learned

The following are lessons learned throughout the five-year life of the BSJ Urban Marsh construction and monitoring project. These lessons may be applicable to future marsh creation projects, and could help increase the efficiency of planning, construction, monitoring and maintenance of those projects.

- Total construction costs for a constructed ½ acre urban marsh using dredged sediments is approximately $150,000
- Total time to create a ½ acre constructed urban marsh from the planning stage through final marsh planting is approximately 2 years
- Using the sand bag system (i.e. DeltaLok bags) for building marsh retaining walls is sufficient, but not as resilient as rip-rap. Some erosion will occur.
- Marsh erosion depends on retaining wall materials and breadth of wall, marsh placement, wind and wave action.
- Approximately 2, 000 cubic yards of dredged sediment were used to fill the ½ acre marsh
- Approximately 7, 500 sand bags are enough to create retaining walls for a 1/2-acre marsh.
- Approximately 4, 000 plant plugs (*S. alterniflora, S. patens, S. californicus*) are enough to stabilize the newly constructed marsh. Thereafter, many species will colonize the marsh naturally.
- Approximately 1, 550 hours of combined staff hours and manual labor were necessary to create the BSJ Urban Marsh.
- Depending on the proximity of a constructed marsh to the lake, the marsh may become the repository for marine debris and wrack.
- It's important to factor in marsh maintenance (i.e. monitoring, marine debris removal, intermittent re-planting) into the overall marsh construction plans and costs.

- Corporate, neighborhood and student volunteers are critical for completing marsh maintenance tasks and fostering community involvement.
- Initial Education and Outreach costs are approximately $30, 000.
- Monitoring (vegetation, elevation, soils) should commence as soon as construction and planting is completed.
- The constructed marsh should be monitored seasonally for one year and then twice a year thereafter.
- We started with an overabundance of sampling sites (42 per ½ acre). Forty-two sites *per acre* is the high-density standard (Ferguson and Hebert 2000). Even less dense sampling may be adequate depending on the data.
- On the contrary, elevation measurements (that are quick and easy) should be taken at more points across the marsh (beyond sampling sites) for a detailed view of elevation change across the marsh.

Recommendations

After five years of monitoring, we settled on the following recommendations. These recommendations adapt the current BSJ Urban Marsh monitoring and maintenance protocols and activities. These changes increase the robustness of the BSJ dataset, and the efficiency of data collection and marsh maintenance. Recommendations below.

- Reduce the number of the established sampling sites by half (from 42 to 21; **Figure 23**)
- Add four new sites (to the reduced list) on the west side of the BSJ Urban Marsh, *outside* the retaining wall (**Figure 23**)
- Take soil salinity measurements during each marsh monitoring survey
- Re-survey the marsh extent (boundary) at BSJ annually, including marsh growing outside the retaining walls, to get annual estimates of marsh size
- Take two elevation surveys annually: 1) the usual elevation survey at sampling sites for summary statistics and analysis and 2) multiple other points randomly distributed across the marsh for detail
- Work with neighborhood groups to increase marine debris removal in the marsh
- Work towards installing a bench, trash receptacle and signage on either side of the marsh
- Update the BSJ Comprehensive Management Plan to reflect projects completed, re-prioritize remaining objectives and action items.

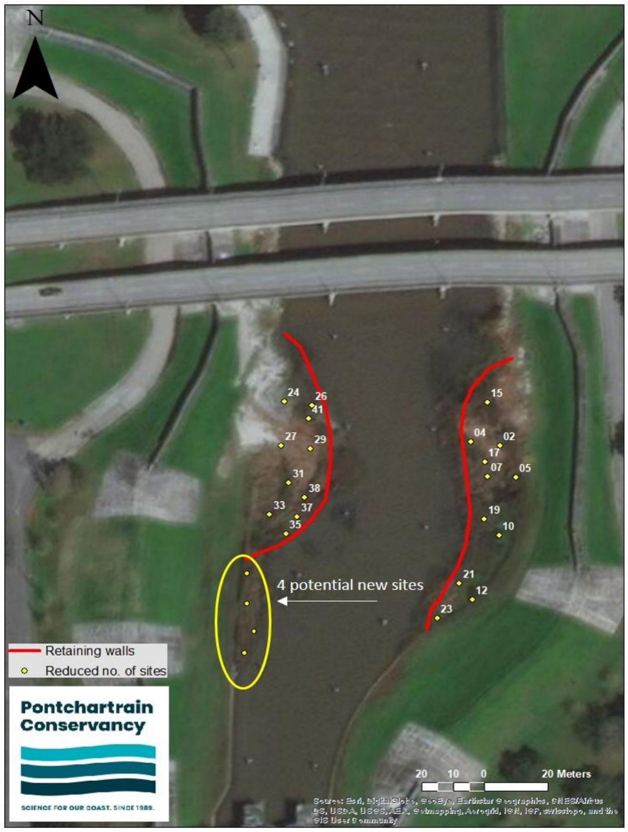

Figure 23 *The map depicts a reduced sampling scheme, plus four new sampling sites at Bayou St. John Urban Marsh*

Implementing these recommendations increases data collection efficiency, streamlines data collection protocols between projects, and enables us to answer several important questions about this particular marsh. For instance, we don't know whether this created marsh is static or growing. A re-survey of the marsh boundary will clarify that. Further, taking multiple elevation points across the marsh (beyond sites) will clarify the elevation interpolation with more detail – similar to the Bucktown Mitigation Marsh. We also don't know whether soil salinity is decreasing at the BSJ marshes as at other marshes. Surface salinity has been decreasing in the lake since the closure of the Mississippi River Gulf Outlet in 2009 (**Figure 24**). Sustained decreases in surface water salinity eventually leads to lower soil salinity and fresher plant communities. We believe this is happening at the Bucktown Mitigation Marsh, and it may be happening here – but, we don't know. Incorporating soil salinity measurements can help clarify that. Finally, this particular marsh collects a lot of debris due to its unique positioning in relation to the lake. The PC incorporates marine debris removal at the BSJ Urban Marsh into several educational and volunteer activities throughout the year. The marsh needs even more attention. We recommend becoming more proactive with neighborhood groups, so that they shoulder more responsibility for keeping this area clean.

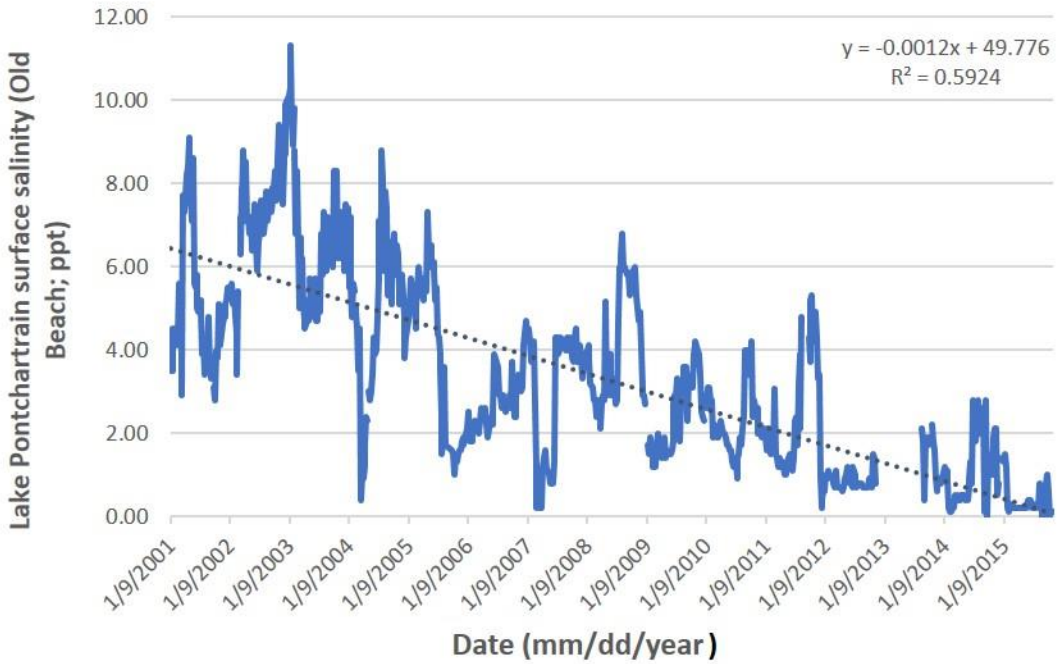

Figure 24 *Surface salinity of Lake Pontchartrain water 2014 - 2019*

Conclusions

The creation of the BSJ Urban Marsh has been a success; the marsh is resilient and beginning to function as a wetland. We met the goal of re-establishing fringing marsh habitat along the south shore of Lake Pontchartrain, even if at a small scale. Located in a highly urbanized environment, this marsh is a place people can enjoy, where they can relax and learn about wetlands. People are fishing and birding near the marsh, plants are colonizing the marsh and animals find precious refuge, habitat and food there. The monitoring revealed interesting dynamics for a developing wetland, indicating that the BSJ Urban Marsh is a unique environment, yet similar in some aspects to the other created marshes in the region. Most importantly, the monitoring showed that we can expect much variability for factors like elevation, TC and soil properties – at least throughout the first five years post-marsh construction. Marsh stability for these factors generally occurs after six to seven years; therefore the next few years at BSJ Urban Marsh will be very informative. This wetland has persisted despite the waves and wind driven tides from Lake Pontchartrain. The resiliency of this marsh is an impressive feat considering the retaining walls were built with sand bags, not rip-rap. It's a testament to the quality work from hundreds of volunteers that constructed and maintain the marsh. The BSJ Urban Marsh is one in a small chain of created, restored or remnant marshes fringing the south shore of Lake Pontchartrain that includes the Lincoln Beach marshes, Bucktown Mitigation Marsh, Lake Villa Pond, the Kenner Boat Launch marsh and LaBranche PO-17. Conserving, restoring and creating these types of habitats establishes lost habitat and contributes to storm protection. BSJ Urban Marsh can be a model for how to create wetlands in high energy environments.

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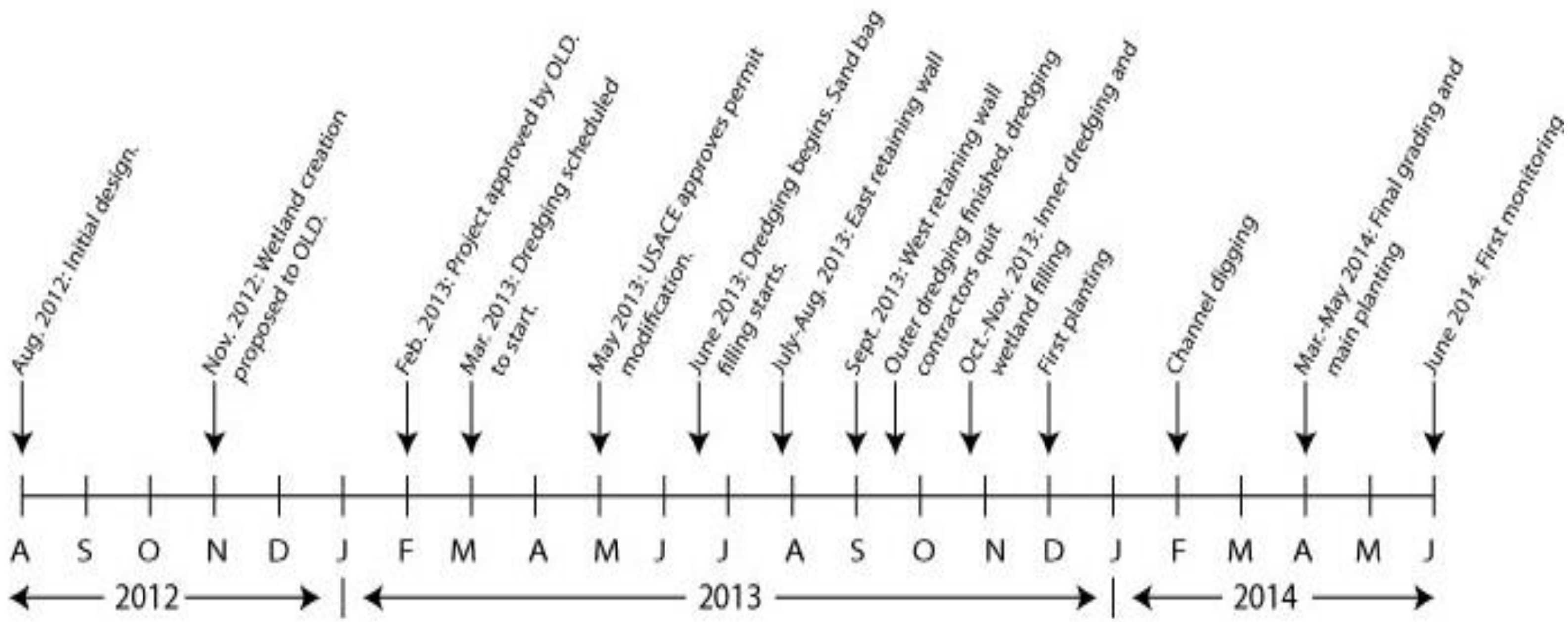
Appendix A: Timeline of Bayou St. John Urban Marsh planning and construction



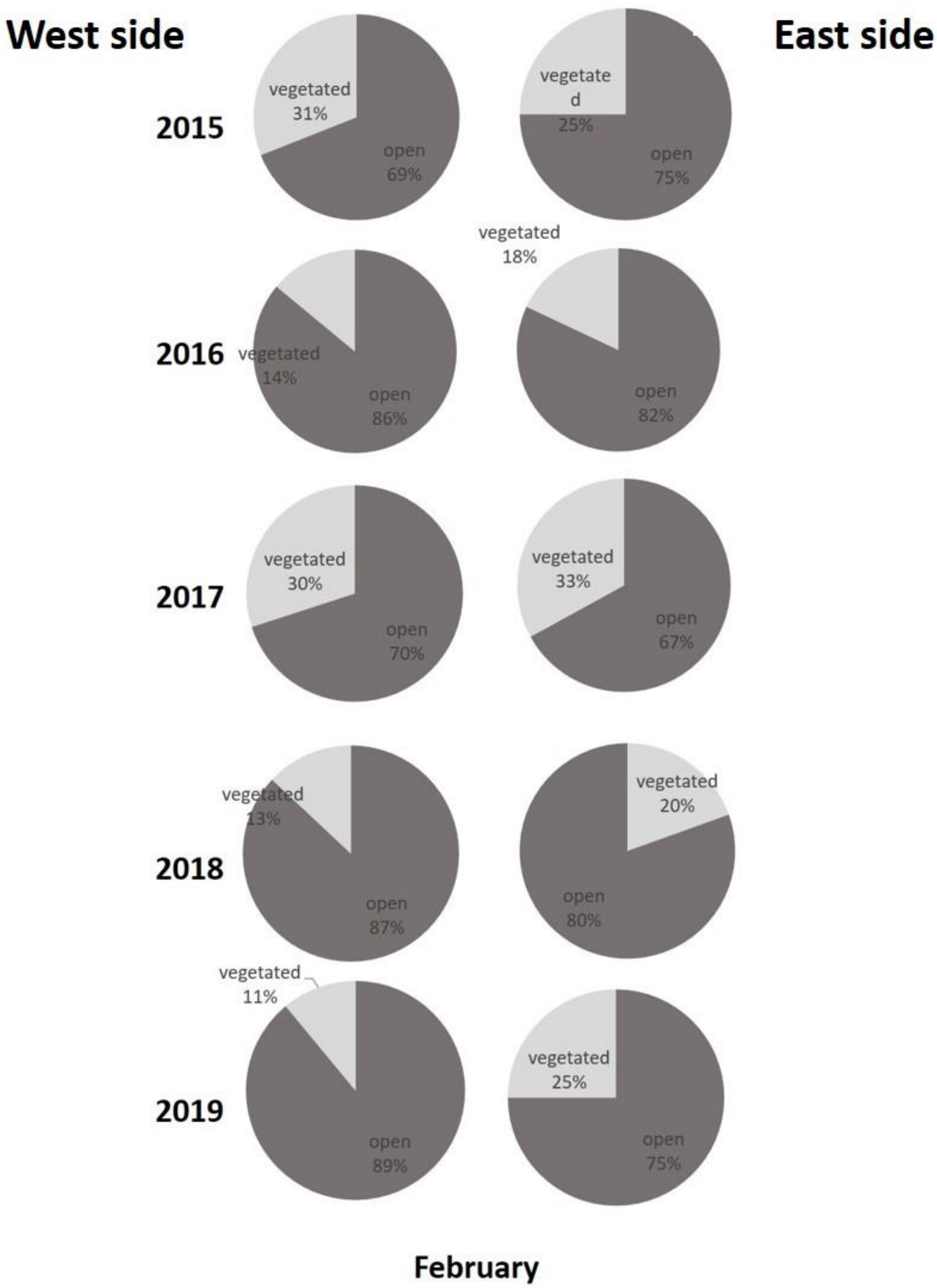
Appendix B. Complete list of plant species identified at Bayou St. John Urban Marsh 2014-2019

USDA symbol	*Scientific Name*	Common Name	Type
AEIN[b,c]	*Aeschynomene indica*	Indian joinyvetch	forb/herb
ALPH[a,b]	*Alternanthera philoxeroides*	alligatorweed	forb/herb
AMAU[c]	*Amaranthus australis*	southern amaranth	subshrub
BAHA[b]	*Baccharis halimifolia*	eastern baccharis	shrub
BAMO[b]	*Bacopa monnieri*	herb of grace	forb/herb
BORO[b]	*Bolboschoenus robustus*	sturdy bulrush	graminoid
CEDE4[b,c]	*Ceratophylum demersum*	coontail	forb/herb
COsp[a,b]	*Colocassia sp.*	elephant ear	forb/herb
CYDA[a,b]	*Cyndon dactylon*	bermudagrass	graminoid
CYIN[a,b]	*Cyperus involcratus*	umbrella plant	graminoid
CYLE7[a,c]	*Cyclospermum leptophyllum*	marsh parsley	forb/herb
COVI3[b]	*Commelina virginica L.*	Virgina dayflower	forb/herb
CYOD[b,c]	*Cyperus odoratus L.*	fragrant flatsedge	graminoid
DISA[c]	*Digitaria sanguinalis L.*	hairy crabgrass	graminoid
ECCO[a,c]	*Echinochloa colona L.*	jungle rice	graminoid
ECCR[a,c]	*Echinochloa crus-galli L.*	barnyard grass	graminoid
ECWA[c]	*Echinochloa walteri*	coast cockspur grass	graminoid
ELPA5[b,c]	*Eleocharis parvula*	dwarf spikerush	graminoid
GAAP2[c]	*Galium aparine*	stickywilly	forb/herb
HECU[b,c]	*Heliotropium curassavicum*	salt heliotrope	forb/herb
HIMU3	*Hibiscus mutabilis L.*	Dixie rosemallow	shrub
HYUM[b]	*Hydrocotyle umbellata L.*	manyflower marshpennywort	forb/herb
IMCA[c]	*Impatiens capensis Meerb.*	jewelweed	forb/herb
IRIS[b]	*Irus sp.*	Iris	forb/herb
IPSA[b]	*Ipomoea sagittata Poir.*	saltmarsh morning glory	vine
JUEF[b]	*Juncus effusus*	soft rush	graminoid
JUTE[b]	*Juncus tenuis*	poverty rush	graminoid
KOVI[b]	*Kosteletzkya virginica L.*	Virginia saltmarsh mallow	forb/herb
LEOR[b]	*Leerzia oryzoides*	rice cutgrass	graminoid
LUPA[b]	*Ludwigia palustris (L.) Elliott*	marsh seedbox	forb/herb
LUPE5[a]	*Ludwigia peploides*	floating primrose	forb/herb
MISC[b]	*Mikania scadens*	climbing hempweed	vine

PAHE[b]	*Panicum hemitomon*	maidencane	graminoid
PAM11O[b]	*Paspalum modestum Mez.*	water papspalum	graminoid
PARE[a,b]	*Panicum repens*	torpedo grass	graminoid
PAVA[b]	*Papspalum vaginatum*	seashore papspalum	graminoid
PHAU7[a]	*Phragmites australis*	common reed	graminoid
PIST2[b]	*Pistia stratiotes L.*	water lettuce	forb/herb
PLOD[b,c]	*Pluchea oderata*	sweetscent	subshrub
POCO14[b]	*Pontedaria cordata*	pickerelweed	forb/herb
POPU[b,c]	*Polygonum punctatum Elliott*	dotted smartweed	forb/herb
RAMU2[a,b,c]	*Ranunculus muricatus L.*	spiny buttercup	forb/herb
SALA[b]	*Sagittaria lancifolia*	bulltongue arrowhead	forb/herb
SCCA11[b]	*Schoenoplectus californicus*	california bullrush	graminoid
SEDR[b]	*Sesbania drummondii*	poisonbean	subshrub
SOPT[c]	*Solanum ptycanthum*	West Indian nightshade	forb/herb
SOSE[b]	*Solidago sempervirens L.*	seaside goldenrod	forb/herb
SPAL[b]	*Spartina alterniflora*	smooth cordgrass	graminoid
SPPA[b]	*Spartina patens*	wiregrass	graminoid
TADI[b]	*Taxodium distichum L. Rich*	bald cypress	tree
TAOF[a,b]	*Taraxacum officinale F.H. Wigg.*	common dandelion	forb/herb
TRCA5[a,c]	*Trifolium campestre Schreb.*	field clover	forb/herb
TYDO[b]	*Typha domingensis*	southern cattail	forb/herb
VILU[b]	*Vigna luteola*	deer pea vine	vine
ZIMI[b]	*Zizaniopsis miliacea*	giant cutgrass	graminoid

*a = invasive, b = perennial, c = annual, USDA= United States Department of Agriculture
Data retrieved from USDA Natural Resource Conservation Service Plant database : https://plants.usda.gov/java/nameSearch

Appendix C: Total cover (%) on the west and east sides of Bayou St. John Urban Marsh in February 2015-2019 (marsh created in May 2014)



APPENDIX D: List of the fifty-nine bird species observed at the mouth of Bayou St. John from 2018-2019 (www.ebird.come)

Common name	Scientific name
American Coot	*Fulica americana*
American Crow	*Corvus brachyrhynchos*
American Goldfinch	*Spinus tristis*
American Kestrel	*Falco sparverius*
Barn Swallow	*Hirundo rustica*
Belted Kingfisher	*Megaceryle alcyon*
Black-and-white Warbler	*Mniotilta varia*
Black-bellied Whistling-Duck	*Dendrocygna autumnalis*
Black-crowned Night-Heron	*Nycticorax nycticorax*
Blue Jay	*Cyanocitta cristata*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Blue-headed Vireo	*Vireo solitarius*
Brown Pelican	*Pelecanus occidentalis*
Carolina Chickadee	*Poecile carolinensis*
Cattle Egret	*Bubulcus ibis*
Chimney Swift	*Chaetura pelagica*
Cliff Swallow	*Petrochelidon pyrrhonota*
Common Grackle	*Quiscalus quiscula*
Cooper's Hawk	*Accipiter cooperii*
crow sp.	*Corvus sp.*
Double-crested Cormorant	*Phalacrocorax auritus*
Downy Woodpecker	*Dryobates pubescens*
Eastern Kingbird	*Tyrannus tyrannus*
European Starling	*Sturnus vulgaris*
Fish Crow	*Corvus ossifragus*
Forster's Tern	*Sterna forsteri*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Green Heron	*Butorides virescens*
Gull-billed Tern	*Gelochelidon nilotica*
Herring Gull	*Larus argentatus*
House Sparrow	*Passer domesticus*
Laughing Gull	*Leucophaeus atricilla*
Least Tern	*Sternula antillarum*
Little Blue Heron	*Egretta caerulea*
Mallard	*Anas platyrhynchos*
Marsh Wren	*Cistothorus palustris*
Mississippi Kite	*Ictinia mississippiensis*
Monk Parakeet	*Myiopsitta monachus*
Mourning Dove	*Zenaida macroura*
Northern Mockingbird	*Mimus polyglottos*
Orange-crowned Warbler	*Leiothlypis celata*
Purple Martin	*Progne subis*
Red-breasted Nuthatch	*Sitta canadensis*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-billed Gull	*Larus delawarensis*
Rock Pigeon	*Columba livia*
Royal Tern	*Thalasseus maximus*
Ruby-crowned Kinglet	*Regulus calendula*
Savannah Sparrow	*Passerculus sandwichensis*
Snowy Egret	*Egretta thula*
Song Sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Spotted Sandpiper	*Actitis macularius*
swallow sp.	*Hirundinidae sp.*
Swamp Sparrow	*Melospiza georgiana*
Turkey Vulture	*Cathartes aura*
Yellow-crowned Night-Heron	*Nyctanassa violacea*
Yellow-rumped Warbler	*Setophaga coronata*