Monitoring of the Lac des Allemands Swamp (BA-34-2) Hydrologic Restoration

2020 FINAL REPORT

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INTRODUCTION

The Hydrologic Restoration and Vegetative Planting in the 970 ha Lac des Allemands Swamp (BA-34-2) provided for pre-construction forested and herbaceous vegetation station establishment and data collection in project and reference area swamps beginning in fall of 2016. Monitoring the entire 2017 year provided data for computation of swamp productivity prior to project construction. Monitoring during 2018 - 2020 enabled us to begin measuring the response of the swamp to project completion. Interestingly, measurable project benefits have already manifested.

Specifically, our responsibilities include only the forested swamp vegetation and herbaceous vegetation variables of the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Task Force approved BA-34-2 monitoring plan dated July 2016. The Coastal Protection and Restoration Authority of Louisiana (CPRA) Operations Division has developed a standard operating procedures (SOP) manual entitled "A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-Wetlands: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control" (Folse et al. 2014). Those data collection variables will be monitored through subsequent contracts (years 1–19), such that collection procedures established during our initial pre-construction phase continue to maintain data consistency.

MATERIALS AND METHODS

Project Description

The BA-34-2 project involves increasing the hydrologic exchange between the swamp and Bayou Chevreuil by creating eight gaps in the spoil bank. To capture restoration benefits, sixteen project specific 625 m^2 (25 m x 25 m) forested swamp stations that were established in 2016 containing 1,049 trees which were also sampled in the project (Sites 2-8) and reference (Site 1) areas during 2017 - 2020 (Figure 1).

Planning and Layout of Vegetation Survey

Within each of the sixteen stations, four 2 m x 2 m plots for sampling herbaceous cover and canopy closure were sampled for a total of 64 herbaceous plots and microdensiometer measurements, respectively. Each plot was located roughly 5 m from each station corner pole and situated such that no trees are located in any herbaceous plots.

Methodology
Forested Swamp Vegetation

Sixteen 625 m^2 (25 m x 25 m) forested swamp stations in the BA-34-2 project and reference areas were sampled. The directional corners (NE, NW, SE, & SW) of these stations were marked with 3 m sections of PVC pipe and UTM NAD 83 coordinates were established at the southeast corner of each station with a differential GPS (DGPS) with sub-meter accuracy. The pipe at each of these is painted with three stripes and all 1,049 tree tags are pointed at the three-striped pipe of each station. A tag was fastened to each tree with a 3" deck screw so that the screw could be backed out as the tree gained diameter over the 20-year monitoring effort.

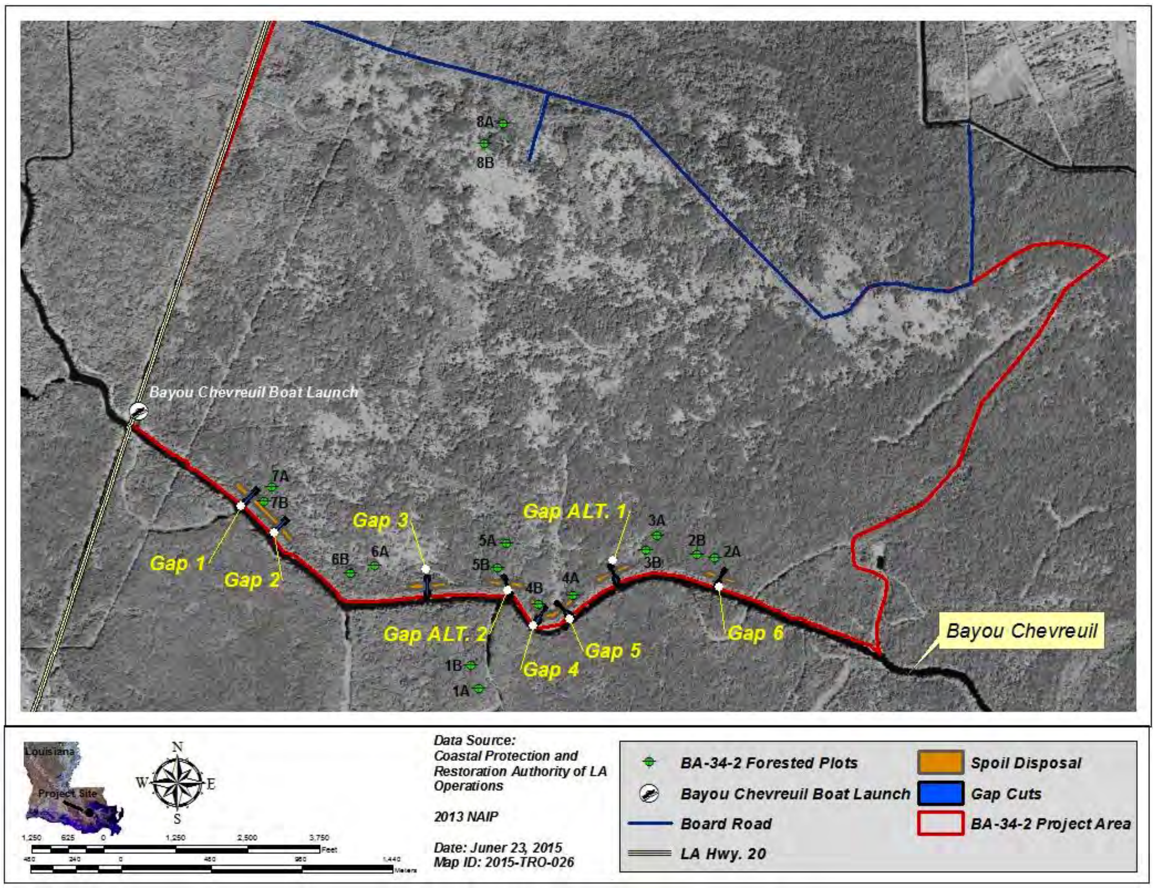

Figure 1. Aerial map showing the location of the sixteen 625 m^2 Stations (eight Sites) established at the BA-34-2 Lac des Allemands swamp restoration project. Locations of the eight gaps are also shown.

In addition, a second screw was placed at the base level of each tag 90 degrees on the backside of each tree to increase accuracy of subsequent annual diameter measurements (Shaffer et al. 2009, 2016). Each tree also is tagged with one strand of bright survey tape; every other year a second strand of survey tape is fitted or removed from each tree to increase the efficiency of locating and measuring all trees. Trees were identified to species, canopy cover was estimated at each of the four 2 m x 2 m herbaceous vegetation plots, diameter at breast height (DBH – actually at 2 m to avoid buttress swell; Shaffer et al. 2009, 2016) was measured for canopy and midstory trees (≥ 4 cm diameter) and herbaceous cover, by species, was estimated within the forested stations at each of the four 2 m x 2 m plots located roughly 5 m from station diagonals. Forested swamp stations were sampled during late fall (October through early December) of 2016 - 2020. In addition, four 0.25 m^2 litterfall traps were randomly deployed at each station once the 2016 canopy leaves had completely fallen from all trees. These traps are swept about every 2 months and roughly monthly during periods of high litterfall until all leaves have fallen (generally mid-March of the following year). The leaves are sorted to the two canopy species *Nyssa aquatic* and *Taxodium distichum*, and Midstory (almost exclusively *Acer rubrum* var. *drummondii*), dried and weighed. Canopy closure was estimated with a microdensiometer at each of the 64 herbaceous plots in the fall of 2016 annually through 2020.

Herbaceous Vegetation

As mentioned above, four specific 4 m^2 (2 m x 2 m) herbaceous plots within each of the sixteen 625 m^2 forested stations were sampled to estimate herbaceous vegetation cover by species in 5 % increments (Shaffer et al. 2009, 2016). Four 2 m PVC stakes permanently mark each plot. Herbaceous plots were sampled each fall of 2016 – 2020.

Soil Strength

Soil cores were collected during fall of 2017 and spring of 2018. Four cores were taken at each of the 16 stations using a battery-powered impact driver with a sharpened aluminum pipe attached to it that was about 30 cm long with a diameter of 3.5 cm. The soil cores were drilled to a depth of 10 cm and all four cores were pooled into a labeled plastic bag. The soil samples were stored in a ventilation oven in the wetlands lab at Southeastern Louisiana University where they were dried for several weeks. Once the moisture had been completely removed from the samples, they were weighed for their dry weight. The dry weight and the volume of the entire soil sample were then used to calculate bulk density.

To calculate the percent organic material within the soil, the samples were burnt in a ceramic kiln at 600 °F for several hours. After burning off all organic material, the samples were returned to the ventilation oven for 24 hours and re-weighed for mineral weight. The percent organic material was then calculated by comparing the mineral weight to the total dry weight.

Chronological Summary of Work

All field trips involved the Chief Scientist (Dr. Gary Shaffer) and two to five seasoned Field Scientists. In 2016, the sites were located near and roughly halfway between the restoration gap locations to crisply capture maximum and minimum project benefits, respectively. Stations within sites were located at least 100 m apart to ensure true replication. In addition, a healthy reference site was located on LSU Island and a site also was located near the northern border (Figure 1), which was conceived unlikely to benefit from the gaps in Bayou Chevreuil (yet it too has benefited). From 2017 through 2020, litterfall traps were swept regularly and all vegetation measurements were repeated during fall. Each year, tree diameter was used to compute tree wood biomass using published regression formulas (Clark et al. 1985, Muzika et al. 1987, Scott et al. 1985). Wood production was calculated as the difference in wood biomass per year. Wood production per tree was then summed by species category per station and then converted to total wood production per square meter per year (g m^{-2} y^{-1}).

Data Processing and QA/QC Procedures

My team has been following EPA QA/QC protocols annually since 2000 (Lee Wilson & Associates 2001). Our results using these procedures are published in international journals (e.g., Shaffer et al. 2009, 2016). In addition, for the BA-34-2 monitoring project, we also are following QA/QC protocols of CPRA, which differ only in formatting templates.

Data Analysis

Forest data were analyzed with the GLM procedure of SYSTAT 13 software. For wood net primary production, because of pseudoreplication, a repeated measures analysis was performed and F values are reported as Hotelling-Lawley Trace statistics. Herbaceous data were analyzed using the non-metric multidimensional scaling procedure of Primer 7. Resemblance matrices were computed using Bray-Curtis similarity.

RESULTS AND DISCUSSION

Soil Strength

The bulk density ranged from 0.052 g/cm^3 at Station 3B to 0.142 g/m^3 at Station 5B (Table 1) and averaged 0.088 g/cm^3 ($\pm$ 0.006 g/cm^3 S.E.). The percent organic matter ranged from 30.57 % at Station 2A to 92.70 % at Station 8A and averaged 61.88 % ($\pm$ 4.60 % S.E.). These soils are extremely weak and quite similar to those of the far more degraded Maurepas swamp located in the Pontchartrain Basin (Shaffer et al. 2009, 2016).

Table 1. Soil bulk density and percent organic matter at the reference site (1) and seven sites located in the des Allemands swamp.

Site	Station	Bulk Density (g/cm^3)	Percent Organic (%)
1	A	0.082	56.47
	B	0.075	62.98
2	A	0.083	30.57
	B	0.095	38.17
3	A	0.079	72.78

	B	0.052	76.83
4	A	0.094	69.22
	B	0.132	49.78
5	A	0.087	58.25
	B	0.142	37.01
6	A	0.073	79.10
	B	0.078	67.80
7	A	0.105	51.76
	B	0.113	54.84
8	A	0.058	92.70
	B	0.065	91.74

Forest Structure

All trees $\geq$ 4 cm diameter were labeled with aluminum tags fastened at roughly 2 m height to ensure measurements were made above all buttresses (Shaffer et al. 2009, 2016). In 2017 (We measure basal area and stem density on a decadal cycle.), basal area differed widely between sites ($F_{7,1032} = 8.64$, $p < 0.0001$) and tree species ($F_{8,1032} = 36.45$, $p < 0.0001$). In general, basal area averaged 53.78 m^2/ha and ranged between 43.14 m^2/ha and 69.41 m^2/ha (Figure 2), nearly double that of most of the Maurepas swamp (Shaffer et al. 2009, 2016). Interestingly, several stations in the project area had higher basal areas than the reference site (Figure 2). Although nine woody species were present, *Acer rubrum* var. *drummondii*, *Nyssa aquatica*, and *Taxodium distichum* accounted for 96.8% of the stems present. Basal areas of these three species differed widely ($F_{2,991} = 122.66$, $p < 0.0001$; Figure 3) and was highly inconsistent across sites (interaction $F_{14,991} = 5.59$, $p < 0.0001$). Basal area of the two main canopy species, *T. distichum* and *N. aquatica*, varied in dominance (Figure 3).

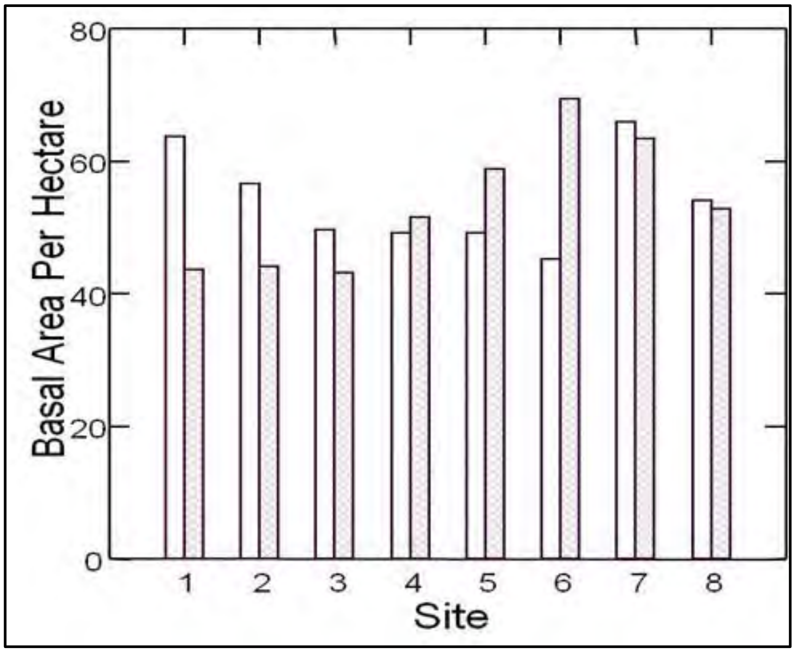

Figure 2. Overall basal area for Stations A (open) and B (hatched) at Sites 1-8 in 2017.

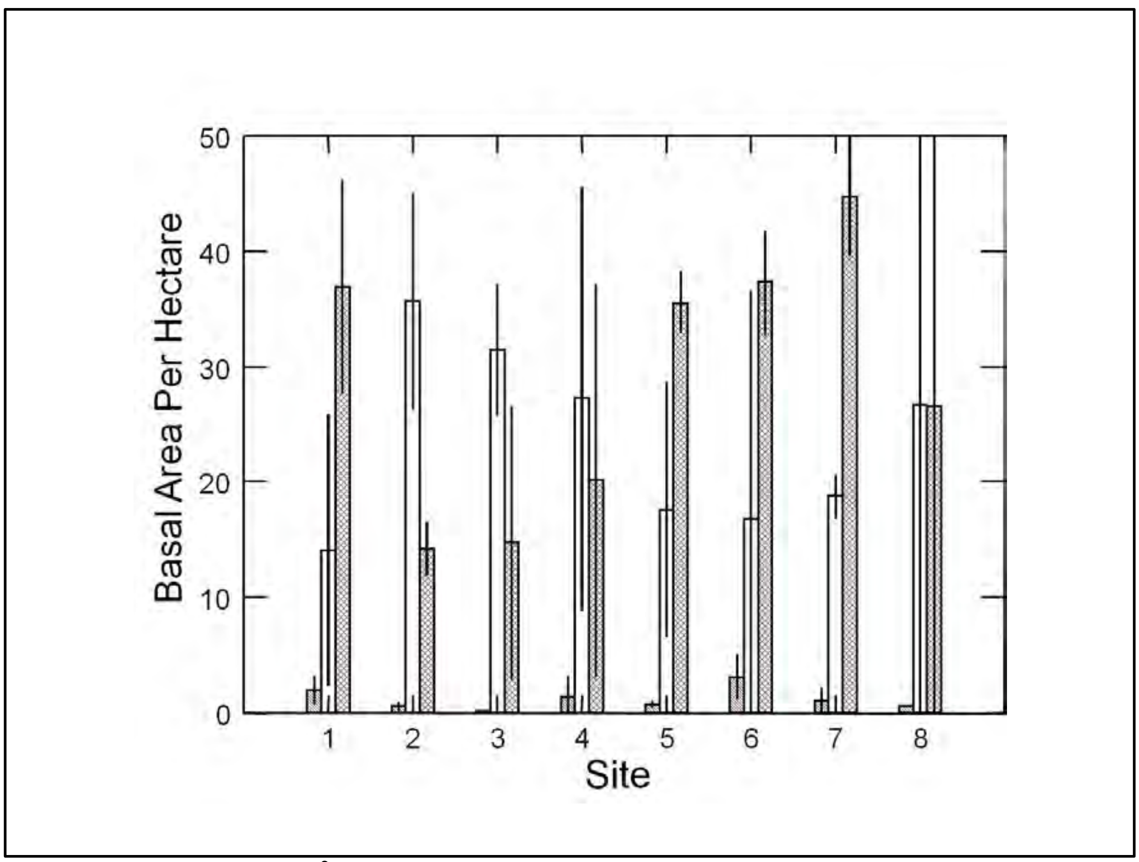

Figure 3. Basal area (m^2/ha $\pm$ S.E.) for the three dominant tree species *A. rubrum* var. *drummondii* (gray), *N. aquatica* (open) and *T. distichum* (hatched) at Sites 1-8 in 2017.

Stem density per station in 2017 averaged 65.5 and ranged between 33 and 104 (Figure 4) and was highest at the reference site. This is the same cite as Conner and Day's (1976, 1992) "natural" site which had stem densities ranging between 880 and 990 stems per hectare. This site now has greater than 1,600 stems per hectare. *Acer rubrum* var. *drummondii* had the greatest number of stems only at Site 6, whereas *Nyssa aquatica* contained the greatest number of stems at five of the eight sites (Figure 5).

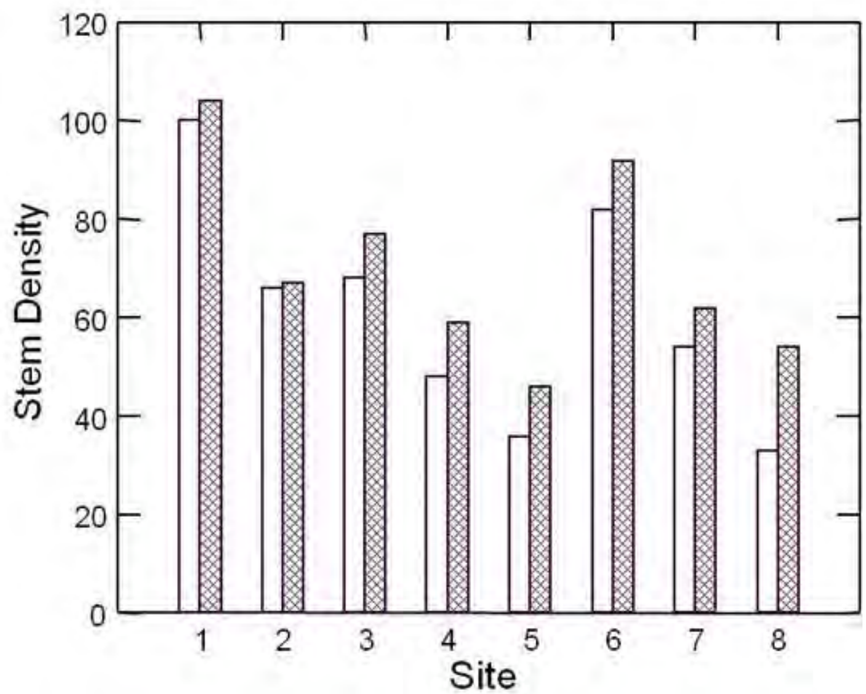

Figure 4. Overall stem density for Stations A (open) and B (hatched) at Sites 1-8 in 2017.

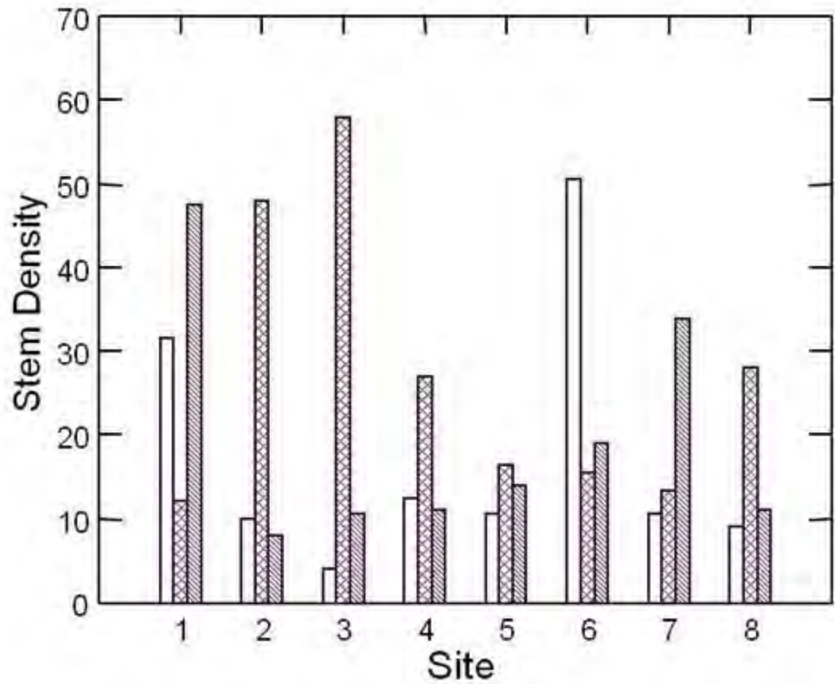

Figure 5. Stem density for the dominant midstory species *Acer rubrum* var. *drummondii* (open), and the two dominant canopy species *Nyssa aquatica* (hatched) and *Taxodium distichum* (stripped) at Sites 1-8 in 2017.

Forest Function

Percent canopy closure was nearly identical for 2016 and 2017 (Figure 6). During 2018 - 2020, canopy closure increased by about 20 percent ($F_{4,280}$ = 53.41, $p < 0.0001$) demonstrating that the forest responded to the hydrologic restoration nearly instantaneously (Figure 6).

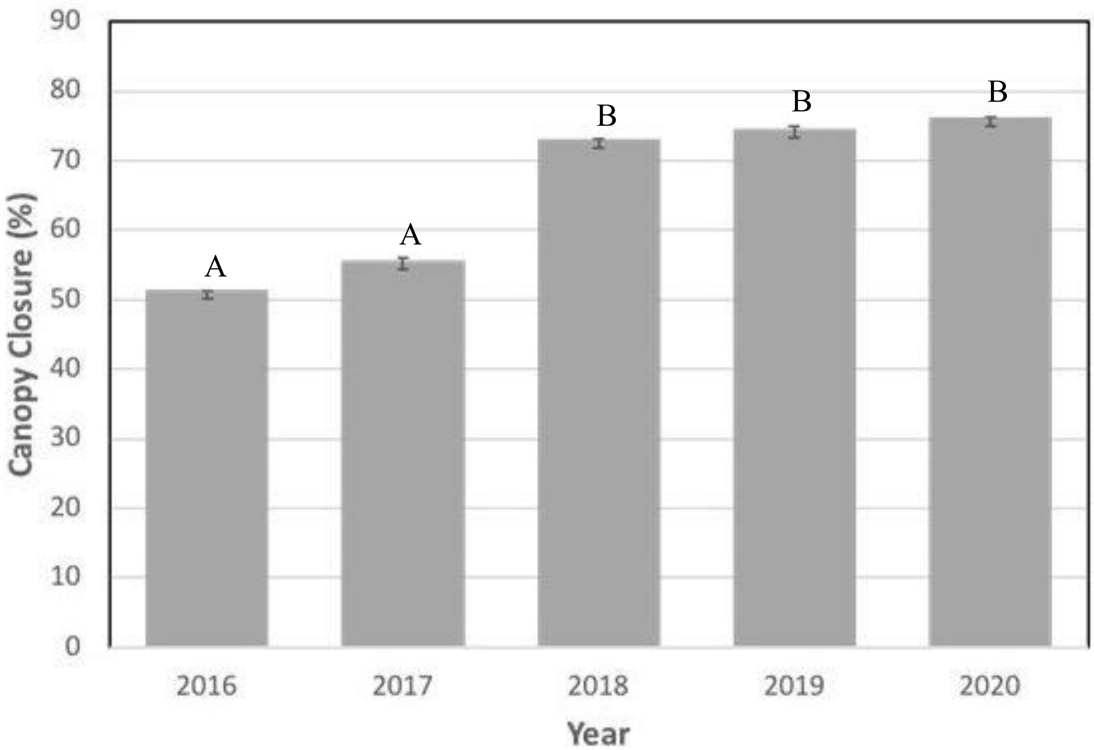

Figure 6. Percent canopy closure for 2016 - 2020. Bars that share letters are not statistically different according to Bonferroni-adjusted mean comparison.

Wood Net Primary Production

Wood net primary production differed across sites ($F_{7,981} = 3.69$, $p = 0.001$; Figure 7) and species ($F_{2,981} = 136.19$, $p < 0.0001$; Figure 8). Importantly, the reference site showed no change in wood NPP between 2017, 2018, and 2019, whereas all seven sites in the des Allemands Swamp experienced a dramatic increase in 2018 (Figure 7), presumably caused by the hydrologic restoration (i.e., increased sheet flow and drainage). The increase in 2019 was not as large, presumably because the sites were far more flooded than during 2018; during 2018, the swamp was completely drained for nearly half of the growing season. All eight sites had their highest wood NPP in 2020. Pooled together, the 2018 - 2020 years had significantly higher diameter increases than the pre-project 2017 season (contrast $F_{1,981} = 11.86$, $p = 0.001$).

Similarly, all three of the dominant species experienced increased wood net primary production in 2018 compared to 2017 (Figure 8). According to Bonferroni-adjusted means, baldcypress had the greatest wood NPP, followed by water tupelo, and the midstory species had the least. Interestingly, the decreased productivity during 2019 compared to 2018 was primarily attributable to baldcypress (Figure 8).

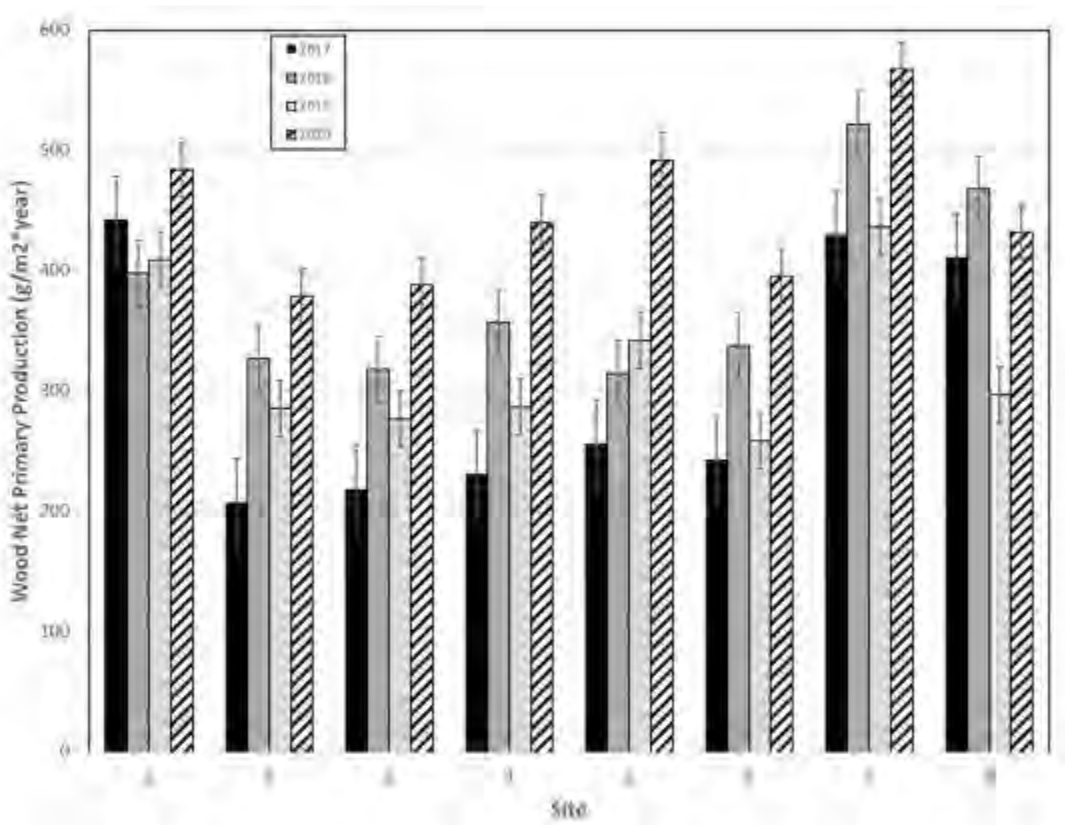

Figure 7. Net primary production (cm ± S.E.) for Sites 1-8 for 2017 (black), 2018 (dark gray), 2019 (light gray), and the 2020 (stripped) growing seasons.

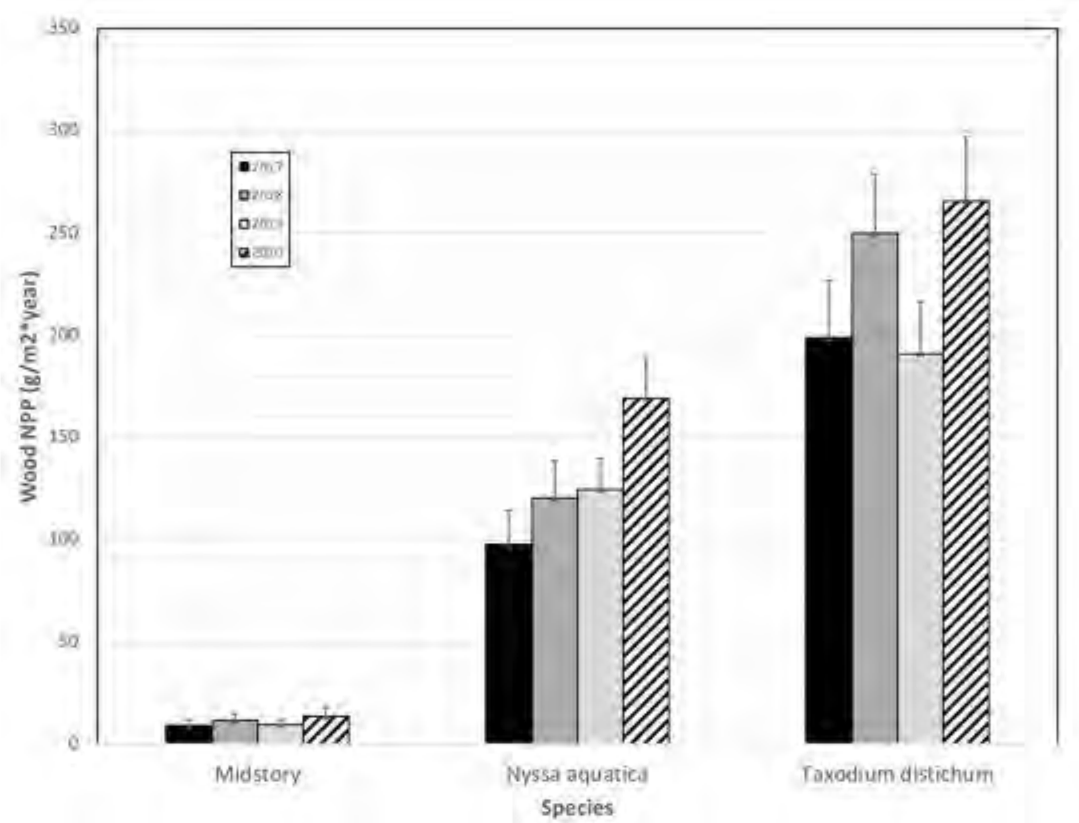

Figure 8. Net primary wood production (cm ± S.E.) for midstory species, *Nyssa aquatica*, and *Taxodium distichum* for 2017 (black), 2018 (dark gray), 2019 (light gray), and 2020 (stripped) growing seasons. Midstory species were nearly all *Acer rubrum* var. *drummondii*.

Leaf Net Primary Production

Leaf net primary production varied significantly across sites ($F_{7,102} = 2.14$, $p = 0.046$), but did not differ across years (Figure 9). Six of the seven Lac des Allemands swamp sites produced more leaf material in 2018 and 2019 than 2017. Tested together, 2018 and 2019, on average, produced a greater amount of leaf tissue than 2017 (contrast $F_{1,102} = 5.31$, $p = 0.023$). We believe that Hurricane Zeta removed substantial leaf litter in 2020 as our traps had oak litter from trees located over 200 m away; also 2020 in general had the highest wood NPP and these two forms of primary production tend to track one another (Shaffer et al. 2009, 2016). In addition, of the dependent variables, litterfall is the noisiest because of the (baldcypress) leafroller and the (water tupelo) forest tent caterpillar; during two of our litter collections most of the tissue in the traps was reduced to the midribs of leaves.

Taxodium distichum produced far more leaf litter than *Nyssa aquatica* and both produced far more litter than midstory species ($F_{2,118} = 257.85$, $p < 0.0001$; Figure 10).

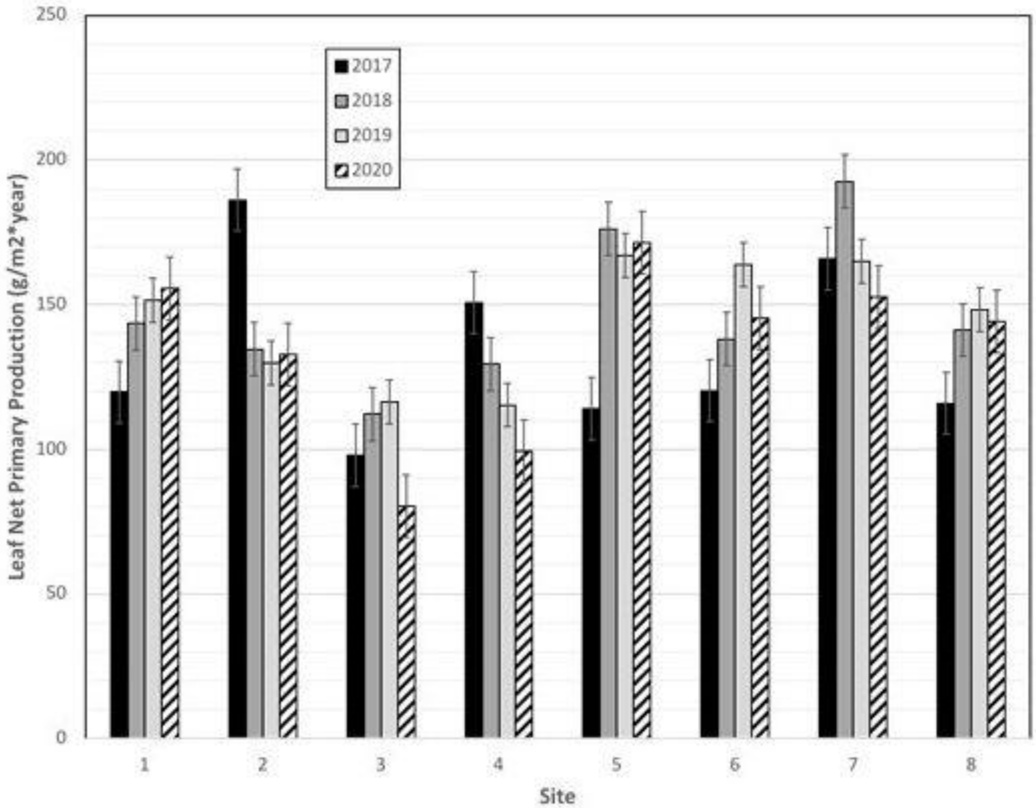

Figure 9. Leaf litter production (g/m^{2}y + S.E.) for each site in the Lac des Allemands swamp during 2017 (black), 2018 (dark gray), 2019 (light gray), and 2020 (stripped) as well as the reference site (Site 1).

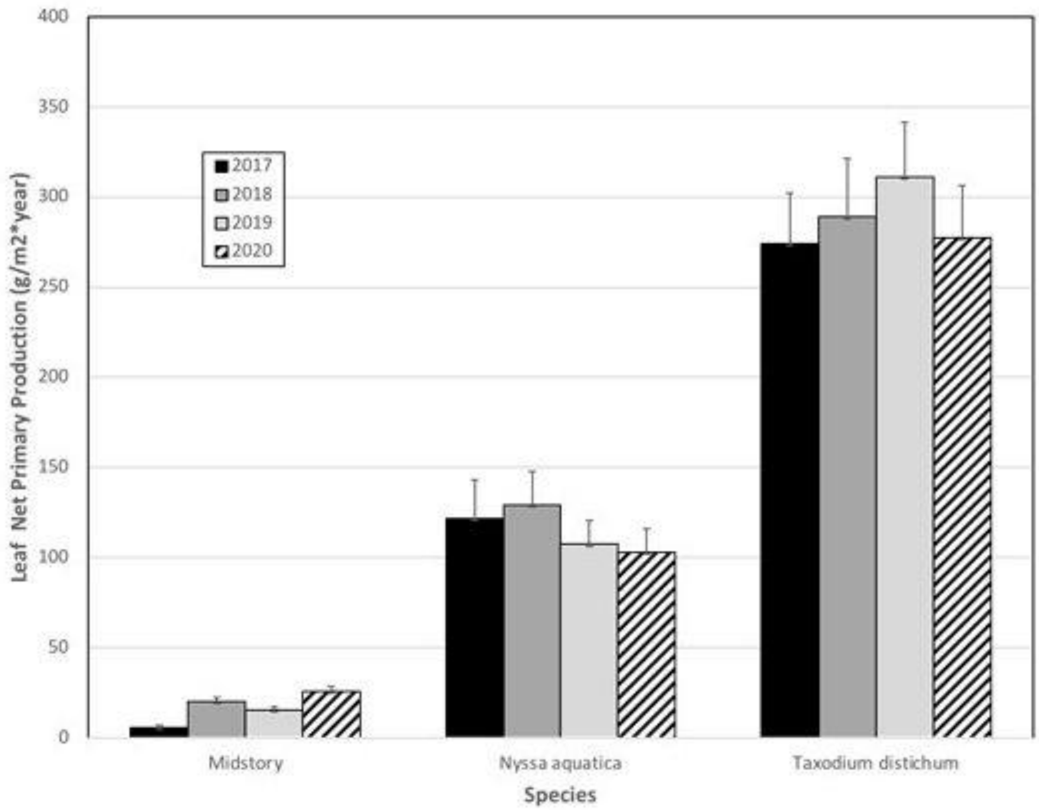

Figure 10. Leaf litter production ($g/m^2y \pm$ S.E.) during 2017 (black), 2018 (dark gray), 2019 (light gray), and 2020 (stripped) in the reference and Lac des Allemands swamp for the two canopy species (*Taxodium distichum* and *Nyssa aquatica*) and midstory species (nearly all of which are *Acer rubrum* var. *drummondii*).

Total Aboveground Primary Production

Total net primary production was obtained by summing wood and leaf production. In general, a clear trend of increased production occurred for the post project construction years compared to 2017 (Figure 11). Post project aboveground production was about half of that measured in the des Allemands swamp in the mid-1970s (Conner and Day 1976, Conner et al. 1981), but comparable to that measured in the 1980s (Conner and Day 1992). Aboveground production in the des Allemands swamp is comparable to that of the healthiest sites in the Maurepas swamp and vastly greater than that of 87% of that swamp (Shaffer et al. 2009, 2016). The distribution between leaf and wood production was remarkably similar within species types across years (Figure 12).

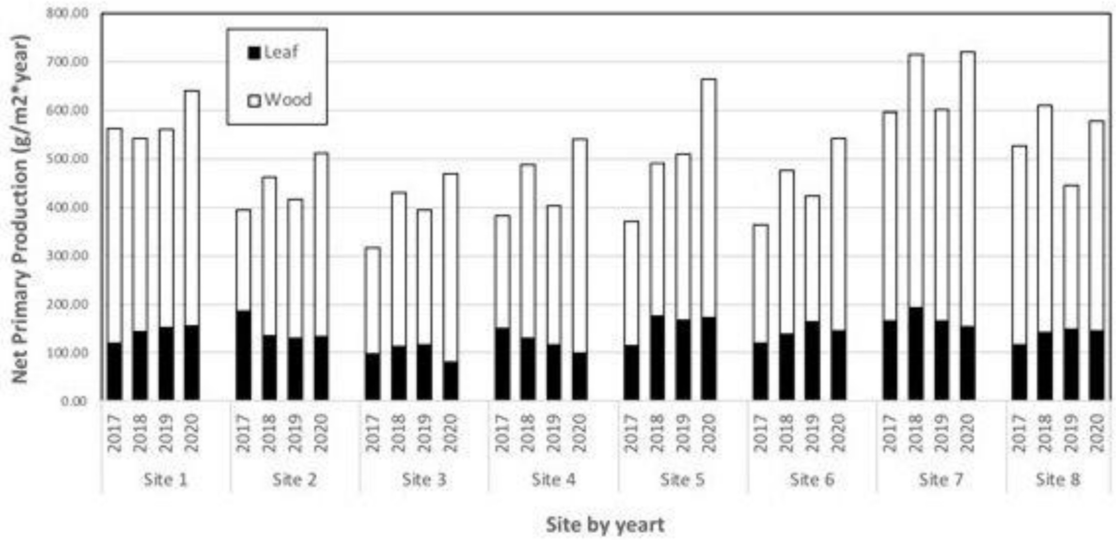

Figure 11. Total aboveground production across sites and year from 2017 – 2020.

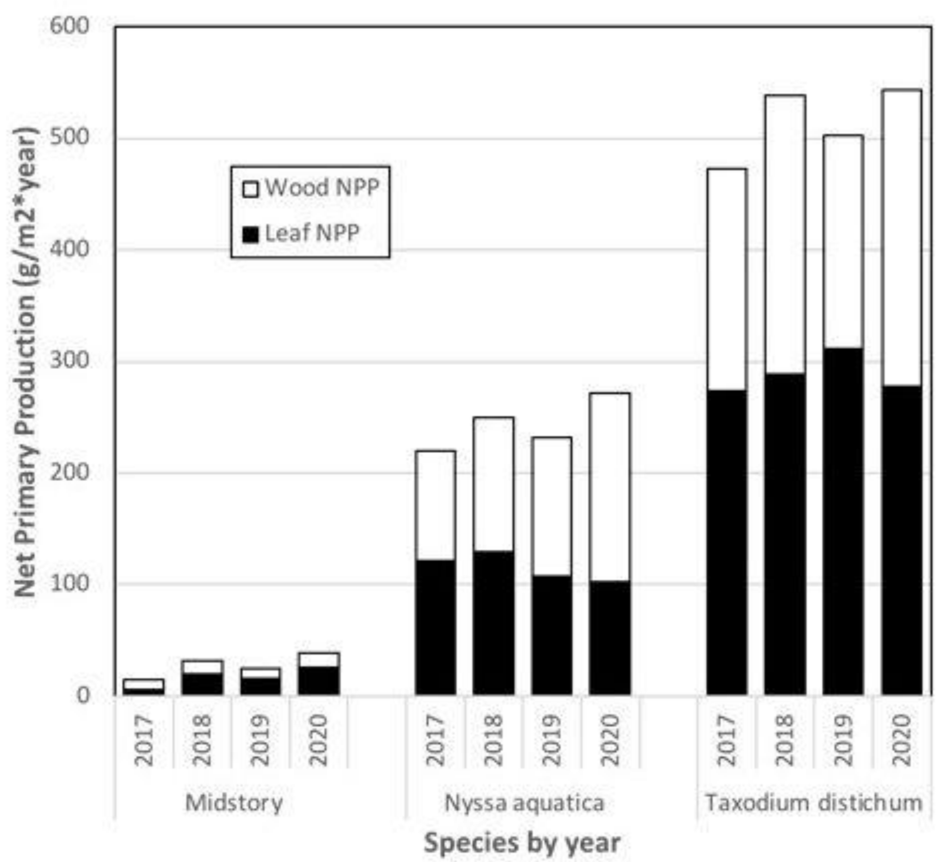

Figure 12. Total aboveground production across years for each species type.

Herbaceous Cover

The Chief Scientist and one Field Scientist estimated herbaceous cover, by species, at all 64 herbaceous plots during fall of 2016 through 2020. The main pattern to date is that 2017 and 2018 were far more similar than 2016, 2019, and 2020 which also closely resembled one another on both axes (Figure 13a). The reference stations (Sites 1A and 1B) were originally dominated by *Panicum gymnocarpon*, but that species is no longer abundant.a species known for its dependence upon sheet flow conditions. Overall, the Lac des Allemands project sites are dominated by *Polygonum punctatum* (Figure 13b). The loop-shaped trajectory of herbaceous cover is very clearly shown when the data are averaged for each year (Figure 14). Note that the pre-restoration years 2016 and 2017 map closely together on the Y axis as do post-restoration years 2018 - 2020. This is a clear indication of stagnant water (2016 and 2017) vs. sheet flow (2018 - 2020). By far the driest year was 2018 where Sites 2-8 had no standing water for nearly half of the growing season (Figure 15) and 2017 was also relatively dry. In contrast, these sites were flooded during all sample dates of 2016 and 2019 and 2020 were also years of high stage, which is presumably why the vegetation grouped together on the X axis for those years. Now that water-level data are available at several of our sites, we will be able to quantify hydrologic conditions more carefully in the future.

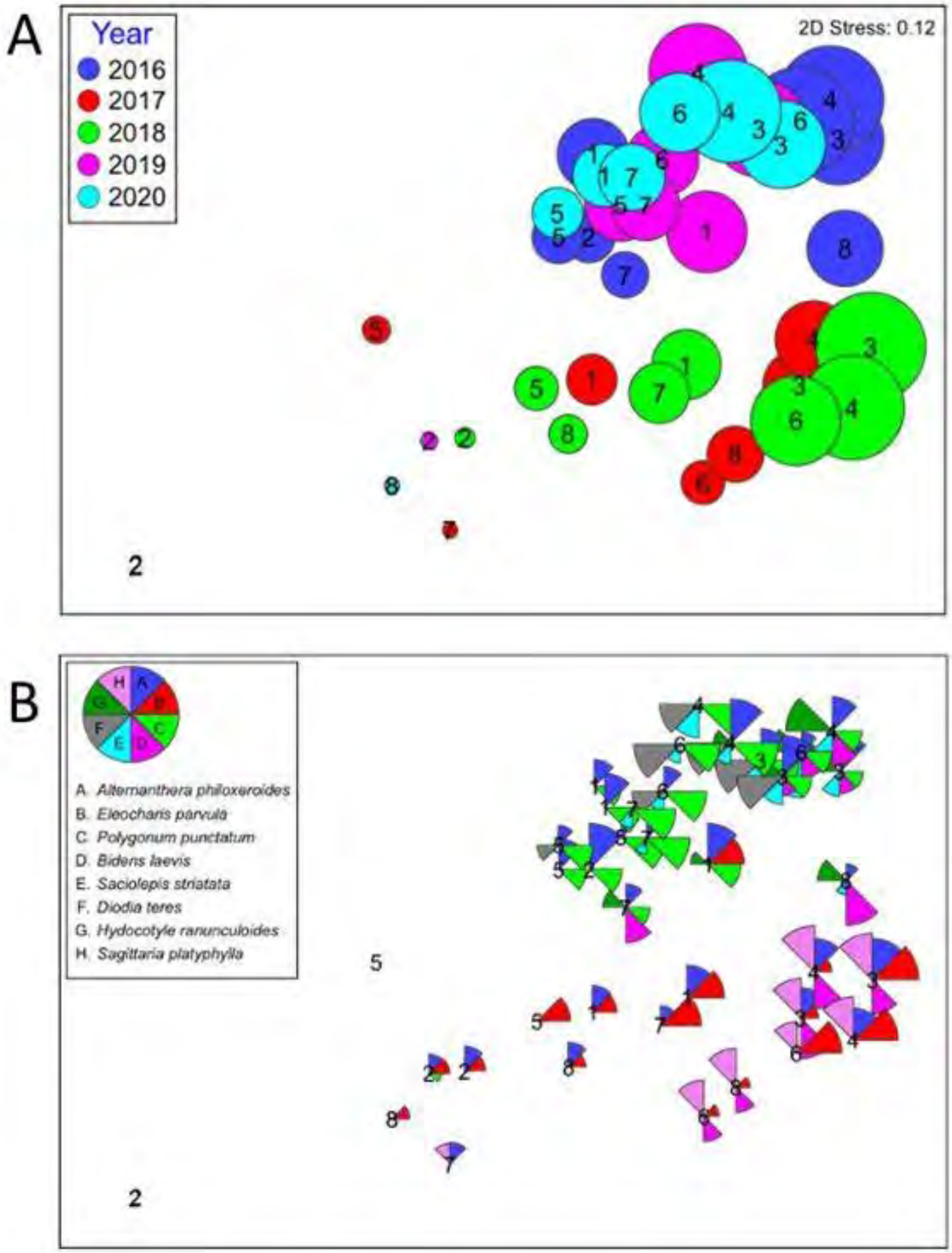

Figure 13. Percent cover of (A) all species and all years (bubble size represents relative total cover) and (B) the same ordination showing only the seven dominant herbaceous species (*Alternanthera philoxeroides, Bidens laevis, Diodia teres, Hydrocotyle ranunculoides, Panicum gymnocarpon, Polygonum punctatum*, and *Sacciolepis striata*). Pie slices reflect relative percent cover of the individual species.

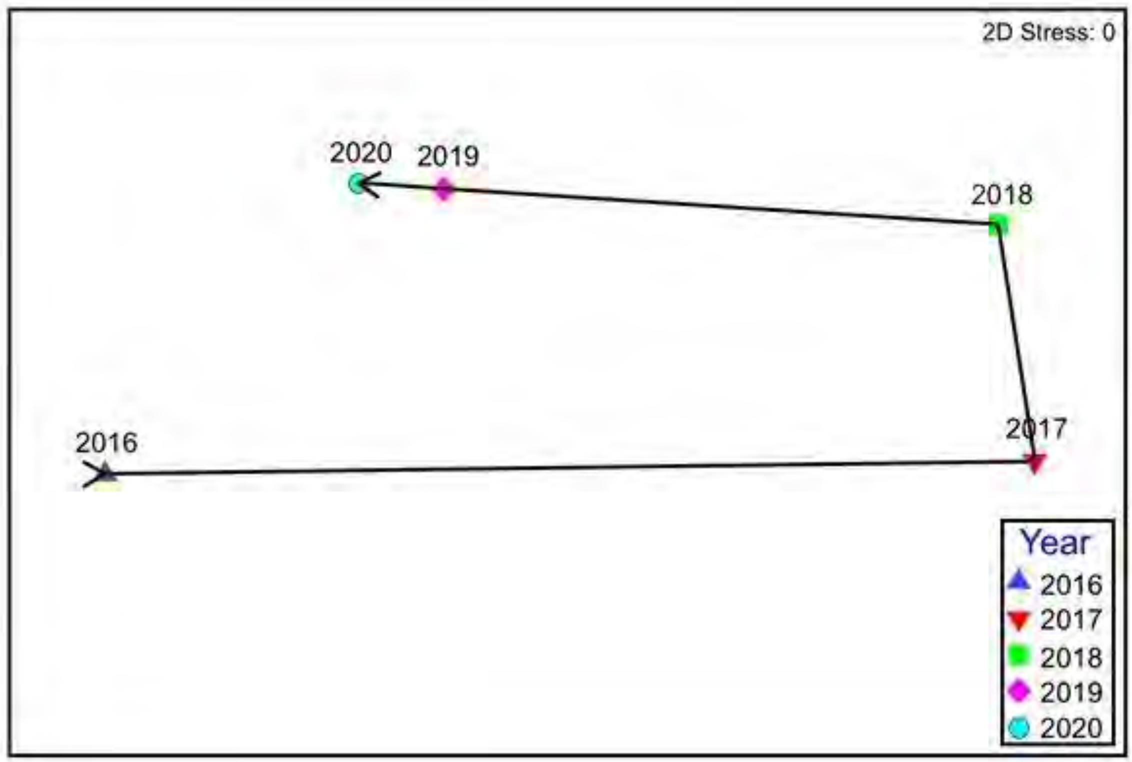

Figure 14. Average percent cover of all herbaceous species demonstrating the overall looped pattern from 2016 to 2020.

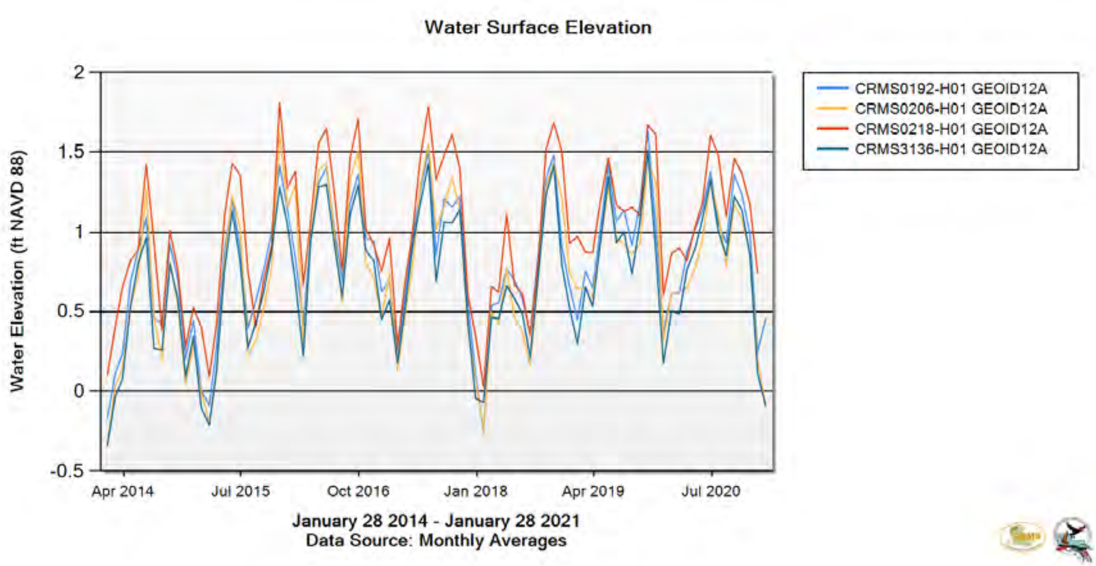

Figure 15. Stage gage records for four CRMS sites near Lac des Allemands swamp showing high water during 2016, 2019 and 2020 and very low water during 2018. The site with the highest stages depicts what the most flooded sites in des Allemands swamp would look like prior to gapping.

DELIVERABLES

Pre-Construction Monitoring Report

This 2020 Annual Report, along with Excel files of all data collected to date, was provided to CPRA, EPA, and The Water Institute of the Gulf (TWIG). Specifically, this report was provided to the following representatives:

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Tim Carruthers (The Water Institute of the Gulf)
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Upon receipt of revisions from CPRA, EPA, and The Water Institute, on the report, we will prepare a final copy of the deliverables described above to CPRA, EPA, and TWIG on or prior to May 31, 2021.

This Monitoring Report was prepared in Microsoft Word format. Data were provided in Excel files as well as the CRMS format.

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