Sabine River Riparian Vegetation Assessment Related to Flow Modifications

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Introduction

Riparian areas are "transitional semi-terrestrial areas regularly influenced by freshwater [from rivers], usually extending from the edges of water bodies to the edges of upland communities" (Naiman and others, 2005). Riparian floodplains provide many ecosystem services, such as flood attenuation, nutrient cycling, CO_2 sequestration, sediment deposition, timber production, recreation, and wildlife habitat (Sharitz and Mitsch, 1993). Floodplains in the southeastern United States are undergoing reduction in size and changes in composition as agriculture, urbanization (Simmons and others, 2007), deforestation (Osterkamp and Hupp, 2010), impounded reservoirs (King and others, 1998), and other industrial activities encroach upon these ecosystems (Sharitz and Mitsch, 1993). Bottomland hardwood forests and deepwater alluvial swamps associated with floodplains have developed along rivers in the southeastern United States due to the distinct hydrology, topography, and soils (Wharton and others, 1982; Osterkamp and Hupp, 2010). Bottomland hardwood wetlands are "dominated by woody species that have morphological adaptations, physiological adaptations, and/or reproductive strategies enabling them to achieve maturity in an environment where the soils within the root zone may be inundated or saturated for various periods during the growing season" (Sharitz and Mitsch, 1993). Cowardin and others (1979) classify bottomland hardwoods as forested wetlands.

As floodwaters overtop banks, the water velocity slows down dramatically, leading to deposition of the coarsest materials closest to the bank, while finer materials are dropped out of suspension farther away from the bank as floodwater velocities continue to slow (Wharton and others, 1982). Overbank deposition, the main source of aggradation on floodplains, leads to microtopographic variations on the floodplain as these differing sediments distribute unevenly across the landscape (Sharitz and Mitsch, 1993; Osterkamp and Hupp, 2010). During flooding, bottomland hardwood trees reduce water velocities allowing for sediment and nutrient deposition, bank stabilization and minimized erosion in the floodplain, as well as storing water that is released to the river later thereby increasing low flows (Wharton and others, 1982).

During floods, microtopographic variations within the floodplain create differing hydroperiods across the landscape that determines the species composition within the floodplain (Wharton and others, 1982; Titus, 1990; Sharitz and Mitsch, 1993; Hodges, 1997; Wall and Darwin, 1999; Almquist and others, 2002; Naiman and others, 2005; Battaglia and Sharitz, 2006; Glaeser and Wulf, 2009; Kupfer and others, 2010; Osterkamp and Hupp, 2010). The hydroperiod refers to the flooding magnitude, frequency, timing, and duration (Naiman and others, 2005). Considerable variation exists among bottomland hardwood tree species in their tolerance to flooding (Broadfoot and Williston, 1973; Wharton and others, 1982; Kozlowski, 2002). Morphological and physiological adaptations allow these species to be present in these flood-prone areas. These adaptations include development of aerenchyma tissue and adventitious roots, buttressing, pneumatophores, and changes in metabolic rates and stomatal opening/closing (Kozlowski, 2002). Trees without these adaptations will be restricted to the higher topographic areas of the floodplain, such as levees, that are less flood-prone than the lower topographic areas that may be inundated a certain amount of time, especially during the growing season.

The downstream effects of dams on the hydrological, geomorphological, biological, and connectivity aspects of rivers and floodplains have been extensively researched (Williams and Wolman, 1984; Johnson, 1994, 1998; King and others, 1998; Brandt, 2000; Katz and others, 2005; Dixon and Turner, 2006; Gordon and Meentemeyer, 2006; Graf, 2006). Dams can store large amounts of water behind them and effectively control the hydrological regime of an entire river system (Williams and Wolman, 1984). Depending on climate, geomorphology, and the operation of the impounded reservoirs, various deleterious effects may result from the installation of dams, including a reduction in flood peak discharge, duration, frequency, and total annual discharge, as well as altered timing of floods, and increased low flows (Williams and Wolman, 1984; Phillips, 2003). Hydrologic alterations, such as these, can seriously harm floodplain communities by reducing sediment and nutrient delivery, and by reducing the biodiversity of wetland-adapted plants and animals (Graf, 2006).

Rivers have characteristic sediment regimes that are dependent on climate, hydrology, geology, and planform configurations (Brandt, 2000). As water flows into an impounded reservoir, sediments fall out of suspension as the water velocity slows down, effectively trapping sediment behind the dam (Williams and Wolman, 1984; Graf, 2006). Brandt (2000) found that many large reservoirs had sediment trapping efficiencies of nearly 99%. This sediment trapping efficiency of impounded reservoirs causes severe geomorphological change downstream of dams as water coming out of the dam is nearly pure and sediment "hungry" (Brandt, 2000). Bank and bed erosion, incision, changes in planform and bed material size, slope change, and scouring of pool and riffle sequences may occur (Williams and Wolman, 1984; Brandt, 2000; Graf, 2006). These changes result in reduced bar formation, disconnection from floodplains, wider and deeper channels, and loss of instream habitat essential for biota (Brandt, 2000; Graf, 2006). Johnson (1994) found that downstream of dams in the Platte River, reduced sediment loads incised channels and reduced flooding allowed vegetation to establish on bars creating stable islands, essentially changing the planform of the river from braided to a single channel system. Anderson and Mitsch (2008) found that returning a more natural flooding regime to a bottomland hardwood forest along the Olentangy River in Ohio increased productivity of the forest.

Changes in the hydrological and sediment regimes will lead to changes in vegetative and wildlife communities of river floodplains since they are so intimately related and dependent on those processes (Graf, 2006). Riparian plant species are selective as to where they establish because they are sensitive to changes in flooding frequency and duration (Jones and others, 1996; Denslow, 2002; Battaglia and Sharitz, 2006; Glaeser and Wulf, 2009; Kupfer and others, 2010), as well as soil types (Battaglia and Sharitz, 2006). Relating topographic variation to flooding frequency and duration, several authors have noted that minor changes in elevation of only a few meters or even centimeters can alter the composition, richness, and diversity of species that exist (Titus, 1990; Sharitz and Mitsch, 1993; Wall and Darwin, 1999; Naiman and others, 2005; Glaeser and Wulf, 2009; Kupfer and others, 2010). Titus (1990) found that vegetative communities changed from flood-tolerant to flood-intolerant with an elevational difference of only 20 cm in a Florida swamp.

This project will relate minor differences in topography within the nearest 500 meters of the Sabine River floodplain to changes in hydrology and vegetation in that zone where flooding occurs most frequently. The floodplain actually extends much wider than 500 meters, about 1,500−4,800 meters depending on location. However, any changes in vegetation communities caused by altered flows downstream of dams should be evident in this zone. The basis for our study addresses the question "What flows are needed to maintain a healthy riparian system?" To further analyze this, two more questions were developed: "Has Toledo Bend Dam altered the flooding regime downstream?" and "What is the condition of the vegetative communities in the floodplains along the Lower Sabine River?" It is essential to understand whether flood regimes (i.e., timing, peak size, duration, and magnitude) are altered because of the role that hydrology plays as the "master variable" of ecological communities (Dixon and Turner, 2006). In order to assess flows needed to maintain riparian health, unaltered ecosystems within the same ecoregion with the same hydrogeomorphology are needed for comparison. The Sabine River has no such unaltered analog. If unavailable, researchers resort to historical data. Unfortunately, there is no historical vegetation data for Sabine River floodplains, so we lack necessary information to perform a traditional riparian health assessment. Instead, research findings in this study convey a "snapshot" of the community composition at the present time that were formed by past forces acting upon these species (Kupfer and others, 2010). Forces such as geomorphology, climate, hydrology, and soils, shape species composition by preventing the establishment and growth of those species that are not able to withstand the pressures of that environment (Kupfer and others, 2010). From this snapshot we assume areas in the floodplain that primarily support wetland species are subjected to periods of inundation frequently enough to restrict upland species dominance.

Project Objectives

By comparing observations with information obtained from the literature, we endeavor to better understand characteristics of a healthy floodplain on the Sabine River. The long-term goal of this project is to predict the flows (timing and duration) needed to benefit the most riparian plant species, and those providing the most function and value to the ecosystem.

We tested the hypothesis that Toledo Bend Dam has reduced flooding downstream, thereby inundating the floodplain less. If this were occurring, we would expect to see a shift in community composition that results in a greater frequency and dominance of flood-intolerant species as conditions become more favorable for these species. Reduced flooding would allow flood-intolerant species to germinate and become established beyond the point when they are most vulnerable to flooding (Glaeser and Wulf, 2009; Kupfer and others, 2010). From this knowledge we developed our reasoning for using three different topographic plot groups (Levee, Mid-floodplain, and Slough) for the vegetation plots. We assumed a reduction in flooding would affect the areas of highest relative elevation the most as these areas would be flooded the least.

Objective 1: At each survey site (3 total), (a) estimate approximate floodplain width based on aerial photography and topographical data, (b) observe plant species composition in the understory and overstory, and (c) categorize them into wetland classifications (FACW, OBL, etc). See description of wetland classifications in Table 1.

Objective 2: Develop ranking system to evaluate riparian plant species based on wetland classifications that ranks flood-dependent wetland species (dispersal or survival) higher than non-wetland species. Further assess plant species found in the site survey according to wildlife value, and rare, endangered, or non-native status. Identify additional important species not located in the study sites.

Objective 3: Analyze past hydrographs for flood frequency and duration into the floodplain. Determine whether there were changes in the number, timing, or size of overbank flow events pre- and post-dam construction[1].

[1] *We stated in the contract that hydrological data collected by other teams in the Instream Flow program would be used to tie the tree data to local groundwater table. Given groundwater data were not available at our sites, efforts were spent on flood events rather than low flow events that could be related to groundwater availability in the floodplain.*

Objective 4: Use literature to link ecology of key riparian species with flood pulses. Determine if age (diameter) class distribution in survey sites reflects an "unhealthy" change in riparian vegetation in recent past. If the occurrence of wetland-dependent species is declining, we would expect more upland species in younger age classes and to only find older specimens of wetland species that depend on flood pulses.

Table 1. Wetland Classifications (2010).

Indicator	**Wetland Occurrence**
Obligate (OBL)	>99%
Facultative Wetland (FACW)	66-99%
Facultative (FAC)	33-66%
Facultative Upland (FACU)	1-33%
Upland (UPL)	<1%

Study Area Description

The Sabine River begins in Hunt County near Dallas, Texas, and flows southeast towards Louisiana before turning south and forming the border between Texas and Louisiana. The study area below Toledo Bend Dam is completely within the Gulf Coastal Plain ecoregion (Phillips, 2008). The area has a humid subtropical climate, and precipitation varies from 44 in. near the headwaters in northeast Texas to 56 in. at its mouth on Sabine Lake (Sabine River Authority of Texas, 2008). The Sabine River has an annual discharge of approximately 6,800,000 acre-feet, the greatest discharge of any Texas river (Texas Instream Flow Program & Sabine River Authority of Texas, 2010). The Sabine River drains a total area of 9,756 square miles, 75% of which is upstream of Toledo Bend Dam (Phillips, 2003).

For several miles below Toledo Bend Dam, the river is convergent (major tributaries including Anacoco Bayou and Big Cow Creek), sinuous, meandering, and flow is strongly influenced by dam operations (Phillips, 2008). Further downstream, the river transforms from a single thread channel to a single thread channel with multiple distributaries at high flows, to a fully divergent distributary system beginning 29 river miles upstream of Sabine Lake (Phillips, 2008). The lower portion of the river is highly sinuous, deltaic, with only a minor influence of dam releases on flows (Phillips, 2008). For a complete description of the geomorphology and geomorphic zones of the Sabine River below Toledo Bend Dam, see Phillips (2003, 2008).

Toledo Bend Dam construction was completed in 1969 by the joint efforts of the Sabine River Authority of Texas and Sabine River Authority, State of Louisiana (Sabine River Authority of Texas, 2010). The dam creates Toledo Bend Reservoir, located at river mile (RM) 147 upstream of Sabine Lake, according to the Sabine River Authority-TX (SRA-TX) mapping services. Toledo Bend is the largest impounded body of water in the southern United States, covering a surface area of 185,000 acres and a storage capacity of 4,477,000 acre-feet (Sabine River Authority of Texas, 2010). The reservoir capacity is about 1.2 times the annual inflow, indicating sediment trap efficiency is close to 100% (Phillips, 2003). The primary purpose of the reservoir is hydropower generation, along with water supply and recreation, but it is not designed or operated to be a flood control reservoir (Phillips, 2003). Three sites were studied in this project: Anacoco Bayou, Big Cow Creek, and Sabine Island. Anacoco Bayou is the furthest upstream, and Sabine Island is the furthest downstream. Anacoco Bayou and Big Cow Creek sites are both on the Texas side, while the Sabine Island site is on the Louisiana side.

The Anacoco Bayou site is located near RM 98, which is downstream of the confluence with Anacoco Bayou from the Louisiana side (Figure 1). Although owned by a forestry company, this site has not been logged in the last 60 years. The Sabine River at this site, located within Geomorphic Zone 2, is a convergent, single channel system that is strongly influenced by dam releases (Phillips, 2008). Overbank flow is occasional, but there is low floodplain connectivity (Phillips, 2008). An elevational difference of 9.33 feet exists between the lowest and highest plots at this site, which is up to 74.9 feet above sea level. The slough plots were selected from an area that resembled a "bowl" (see Appendix D).

The Big Cow Creek site is located near RM 83 further downstream of Anacoco Bayou but upstream of the confluence with Big Cow Creek (Figure 1). This site is also owned by a forestry company and was logged in 1950. The Sabine River at this site, located within Geomorphic Zone 3, is a convergent, single channel system that has multiple channels at high flows, and is strongly influenced by dam releases (Phillips, 2008). Overbank flow is occasional, and there is moderate floodplain connectivity (Phillips, 2008). An elevational difference of 8.46 feet exists between the lowest and highest plots at this site, which is up to 57.2 feet above sea level (see Appendix D).

The Sabine Island site is located near RM 20, the furthest downstream of the other sites (Figure 1). This site is within the Sabine Island Wildlife Management Area on the Louisiana side, managed by the Louisiana Department of Wildlife and Fisheries. The Sabine River at this site, located within Geomorphic Zone 6, is set in a deltaic coastal plain, is fully divergent with multiple distributary channels, and experiences only a minor influence from the dam at low flows (Phillips, 2008). This area is called Sabine Island because an anastamosed channel of the Sabine River surrounds this area creating an island. Overbank flow is common with extensive floodplain connectivity (Phillips, 2008). Being in a deltaic coastal plain, an elevational difference of only 2.44 feet exists between the lowest and highest plots at this site, which is only 4 feet or less above sea level (see Appendix D).

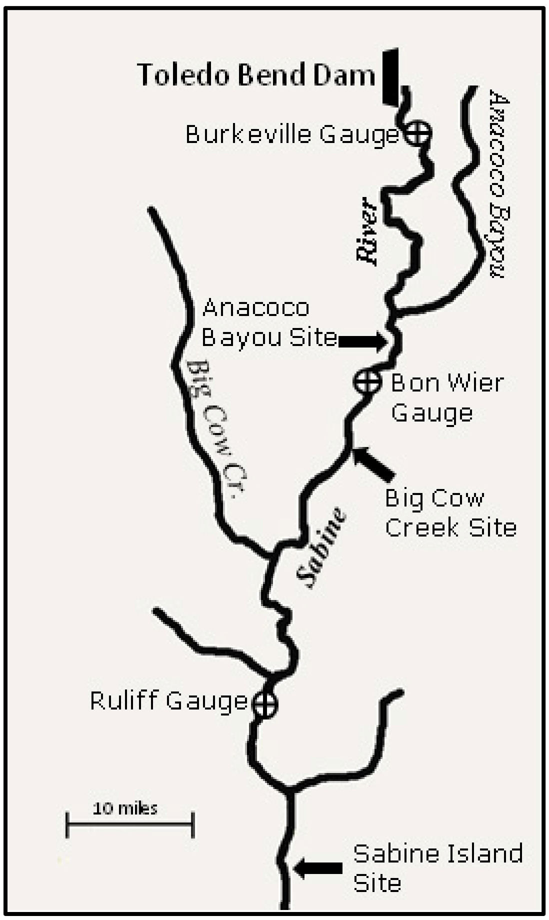


Figure 1. Map showing locations of USGS gauges and study sites along lower Sabine River

Methods

Hydrological Analysis

River discharge data for three gauging stations located on the lower Sabine River (Table 2) was downloaded from the USGS daily stream flow website (U.S. Geological Survey, 2001). Impoundment of Toledo Bend Dam began in 1966; therefore, we excluded the Burkeville gauge from analysis due to insufficient pre-dam data. In our analysis, floods were defined as periods when discharge equaled or exceeded bankfull discharge for that particular gauge based on the relationship between stream height and elevation near the gauge (Table 2).

For each flood event, we determined the peak discharge, total discharge and duration until the point when the water levels dropped below bankfull discharge. We then aggregated all events that occurred in 5-year periods to evaluate trends in flood frequency, duration, and peak and total discharge in those periods before and after dam construction. Finally, we counted the number of floods recorded in each calendar month to evaluate whether the seasonality of flood occurrence had shifted after dam construction.

Table 2: USGS Gauges along Lower Sabine River

USGS Gauging Stations	Year Installed	Bankfull Discharge (cfs)	SRA-TX River Mile	Miles Downstream of Dam
Burkeville (08026000)	1955	35,000[1]	139	8
Bon Weir (08028500)	1923	26,000[1]	91	56
Ruliff (08030500)	1924	13,300[2]	35	112

[1] (Devine-Tarbell&Associates, 2008)
[2] (Hayes, 2009)

Riparian Species Database

Each species was ranked according to the following parameters.

1. wetland classification (Table 1)
2. native or invasive
3. common, rare, or endangered,
4. deciduous or evergreen,
5. wildlife value description (if known)
6. flood or drought tolerance (if known)

Information about parameters 1, 2, 3, and 4 was taken from the USDA PLANTS database (USDA & NRCS, 2010). Information about wildlife value (parameter 5) originated from Burns and Honkala (1990). Drought tolerance information was taken from USDA PLANTS database (USDA & NRCS, 2010) and classified into four categories (high, medium, low, none). Flood tolerance information was taken from (Hook and Brown, 1973; Hook, 1984; Ortego, 1986; Burns and Honkala, 1990), as well as inferring flood tolerance from wetland indicators (U.S. Fish and Wildlife Service, 1996). Uncommon native species that depend on high water tables, and that are of high value to wildlife, were ranked highest. Appendix A lists all species expected to occur in our study sites according to the Greater Edwards Aquifer Alliance (Hayes, 2009). A second list contained all plant species that were observed and recorded within our plots at our study sites appears in Appendix B. These two lists were compared to examine differences in the number of species for each wetland classification, as well as richness and diversity.

Site Selection[2]

Potential study areas were screened for past management history based on available silvicultural records. Only those areas logged at least 60 years ago, and not disturbed since were eligible for our surveys. The possibility for conducting detailed inundation mapping for these floodplains was beyond the scope of this study. Instead, we used topographic data derived from a Digital Elevation Model (DEM) to determine elevation differences within selected areas of the floodplain. Other authors have noted the value in using topographic gradients as surrogates for hydrologic gradients when extensive floodplain inundation mapping was not conducted (Townsend, 2001; Denslow, 2002; Osterkamp and Hupp, 2010). Elevation data, accurate to the nearest 5 meter horizontal resolution and 0.1 meter vertical resolution, were downloaded from the Louisiana Atlas Statewide GIS (Atlas, 2006), and converted to ESRI ArcMap format.

Riparian habitat was characterized by establishing replicate 100 m^2 plots in a stratified random approach within three topographic zones at three selected sites along the lower Sabine River. In general, topographic zones of interest were levees, sloughs, and mid-floodplains within 500 m of the river. First, we found suitable locations near road or boat access points on land where we were granted access. Second, we selected potential areas within 500 m from river and about 800 m of river distance. A histogram of all elevations in that area was generated. Third, five potential mid-floodplain sampling plots were identified from the DEM representing average elevations. Similarly, five potential slough sampling plots were identified at elevations two standard deviations below average and five potential levee sampling plots were identified at elevations two standard deviations above average. Only three of those five plots were actually surveyed, the other two served as alternates should the on-site evaluation show some plots should be excluded. Final starting points for those three plots per zone were randomly selected on-site within 30 m of the predetermined GPS points acquired from the DEM. Once GPS points for each plot were acquired, elevations for each plot were determined from the DEM data (see Appendix D).

Vegetation Survey

To determine baseline riparian vegetative conditions, detailed studies that characterize the riparian habitat were conducted in the three stratified topographic zones described above, (3 plots × 3 zones for a total of 9 plots per site). Key riparian vegetative indicators included: age class distribution, richness and diversity, density, and % canopy cover. This information was linked back to overbank requirements for the maintenance of a healthy riparian ecosystem.

In each plot, all single trunked, woody, perennial vegetation (trees) with a diameter at breast height (DBH) of greater than 3cm within the sample area were measured to the nearest 0.5 cm and recorded by species into one of the following size class categories: 3-15cm, 16-25 cm, 26-35 cm, 36-45cm, 46-55cm, 56-65cm, 66-75cm, 76-85 cm, 86-95 cm and greater than 95cm. Demographic shifts among the ten most common tree species will be evaluated based on size class distribution within survey plots with the assumption that species with fewer smaller diameter specimens might be declining in

[2] *It was stated in the contract that TWDB would allocate sites for our survey. However, these were not chosen for us. Instead, we expended additional efforts to select new sites based on the original study criteria. This was done in close communication with TWDB, SRA, and TP&W officials.*

recent years due to lowered seedling recruitment and survival. Saplings or seedlings found in the shrub or herb survey will be assigned an estimated diameter value of 1 cm and included in size class distribution evaluation.

Shrub composition and relative abundance was surveyed using a line intercept method along the diagonal line of each plot. Shrubs were classified as all multi-trunked, woody perennial vegetation and also all single trunked woody perennial vegetation less than 3cm DBH. The linear distance, to the nearest 0.5cm, that each species intersects the line was recorded. Percent coverage of each species was calculated by dividing the total linear distance of each species by the total distance surveyed (1400cm). Overlapping canopy of different species was recorded according to distance each species intersects the line transect. Total distance with no shrub canopy was also recorded. Total percent shrub canopy cover, or dominance, was calculated according to the following formula: 1 – (no shrub linear intercept distance / 1400).

Herbaceous vegetation composition was surveyed using a line point intercept methodology. A 1-meter-long 1/8 inch diameter "pin" was set vertically every one meter along the 14-meter diagonal line of each plot, starting at zero. All species of herbaceous vegetation, woody vines and woody seedlings that touch the pin was recorded. Frequency was measured as the number of pins touched in each plot. Percent cover, or dominance, of each species was calculated using the formula: # pins touched by species / 15. Any species of herb or shrub of notable interest that was not observed in our line intercept was recorded in the notes section of the datasheet.

Results and Discussion

Hydrological Analysis

At Bon Weir (USGS gauging station 08028500), there appears to be no difference in the relationship between flood duration and total discharge before (1926-1965) and after (1971-2005) the dam was built (Figure 2, left). Floods of the same discharge last the same number of days. However, there are six more floods above 1,000,000 ft^3 of total discharge before the dam than after. More research is needed to determine why large floods occur less often at Bon Weir after the dam was built. We found a very different trend at the Ruliff station (USGS gauging station 08030500, Figure 2, right). There, the relationship between flood duration and total discharge has shifted since the dam was built, such that post-dam floods of equal duration have less total discharge. This change in flooding is expected after dam development due to the storage capacity of dams and that dams can release high flows over a longer duration. It is unclear whether the longer time of inundation, up to 30 days, has an effect on bottomland hardwood forests on the Sabine River.

The timing of flooding inundation can have a significant impact on vegetative communities, especially during the growing season when species are more vulnerable to flooding stress (Kozlowski, 2002). Flooding in a natural system occurs in winter and early spring, before the growing season begins (Devine-Tarbell&Associates, 2008). Monthly trends at Bon Weir follow a similar monthly pattern pre- and post-dam construction, with greater flooding occurring in winter and early spring compared to summer months (Figure 3, left). However, floods now occur more frequently in the winter months. No floods have occurred during the summer months (July-Sept) since the dam was built. At Ruliff, however, the flood season appears to extend further into June than it did before dam construction (Figure 2, right), and extends further than it does at the Bon Weir station. Flooding during the growing season causes significant stress on vegetation that could result in greater mortality (Wharton and others, 1982; Kozlowski, 2002).

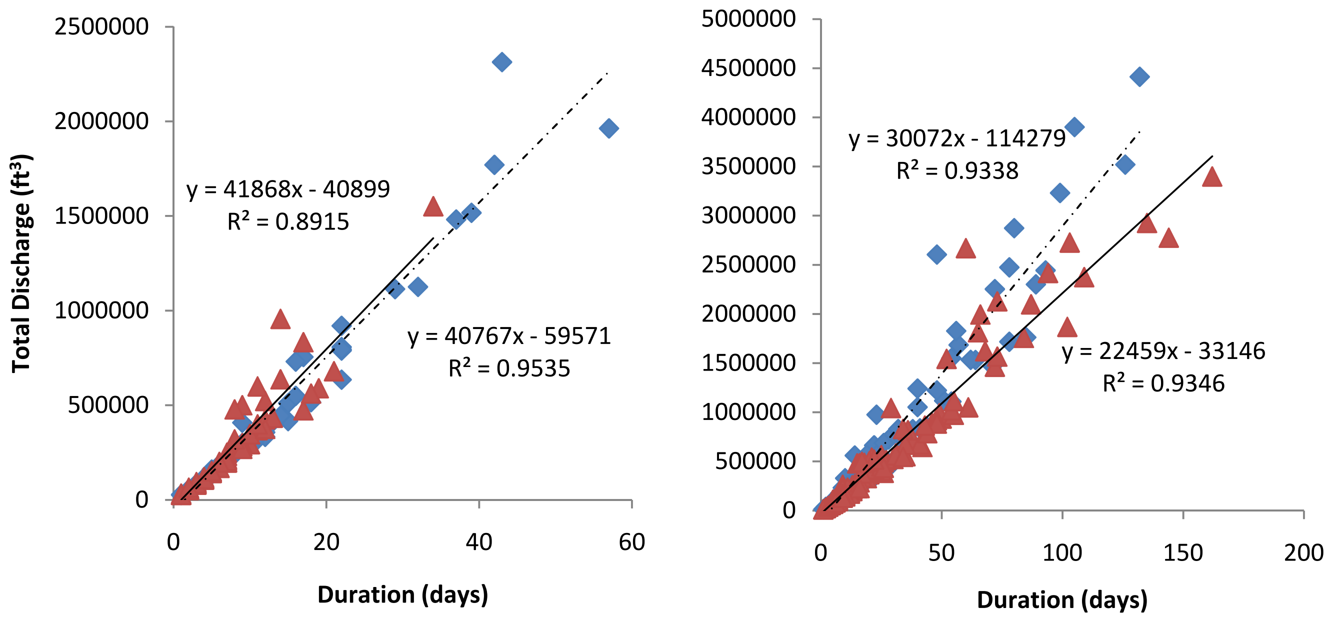


***Figure 2**. The relationship between duration (in days) vs. total discharge (ft^3) at Bon Weir and Ruliff gauges before (blue diamonds) and after (red triangles) dam construction at Bon Weir (left) and Ruliff (right). Solid lines represent relationship after dam construction; dash dotted line represents before construction.*

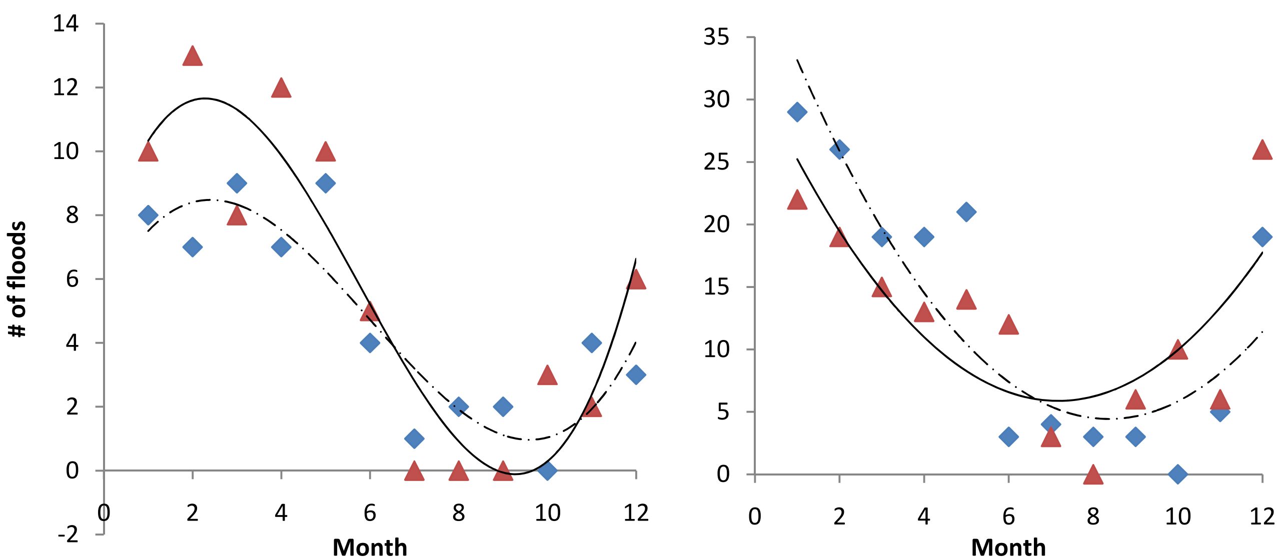


***Figure 3. Number of floods by month at Bon Weir (left) and Ruliff (right)**.*

There was no difference in peak discharge at either site (Figure 4a and b), meaning that Toledo Bend Dam had no effect on the flood intensity. This may seem surprising given that dams can reduce the hazards of floods by reducing peak flows (Williams and Wolman, 1984; Brandt, 2000; Graf, 2006), though this relates to the operation of the dam as a hydropower facility that maintains high water levels and when floods occur, large volumes of water must be released to protect the integrity of the dam. If flood peaks had been lower after dam construction, we would expect less of the floodplain to be inundated by floods, thus reducing the total area of bottomland hardwood forests experiencing such flood pulses.

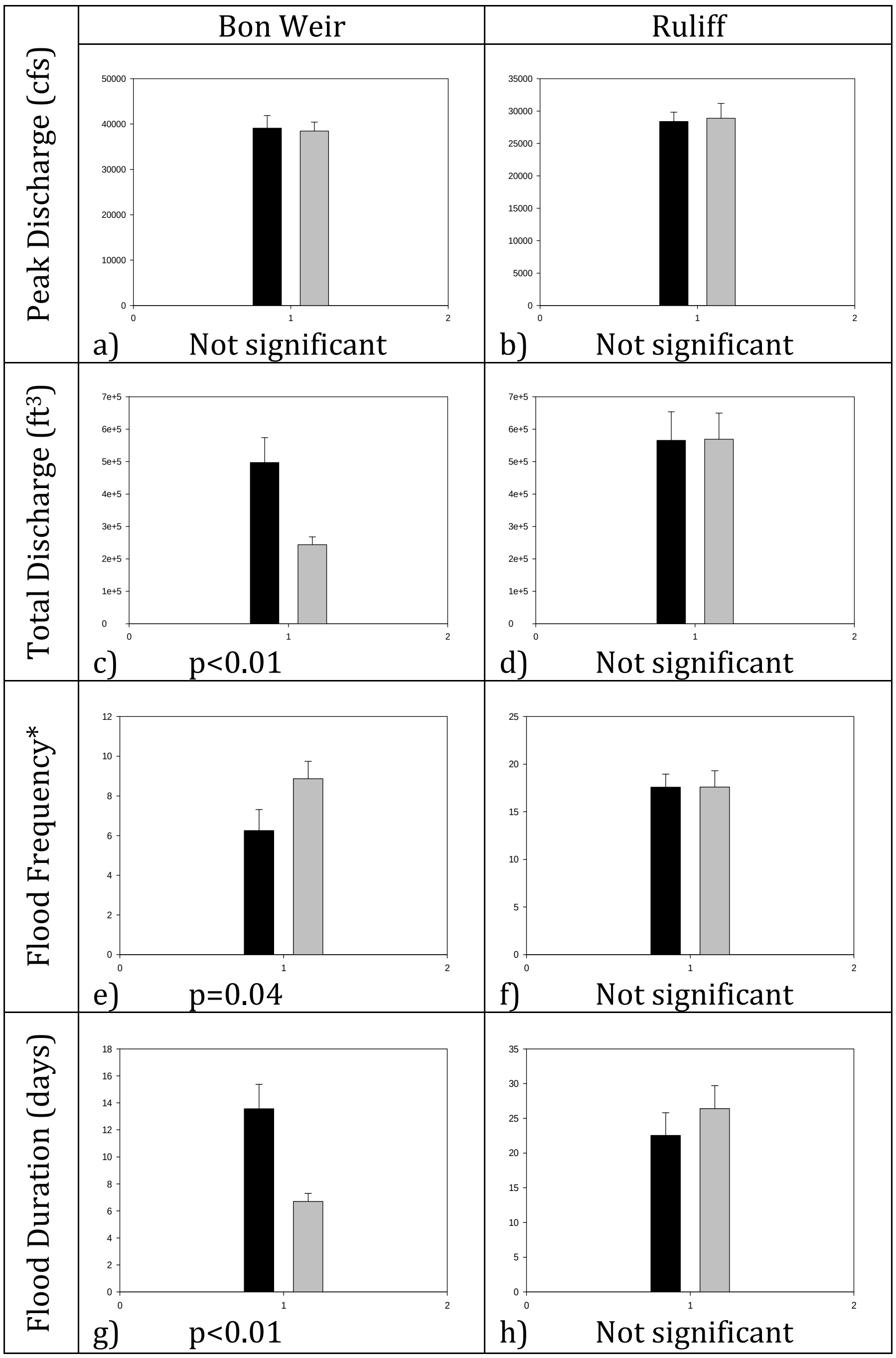


Figure 4. Pre-dam (black) and post-dam (gray) average differences in peak discharge (a,b), total event discharge (c,d), flood frequency per 5 yr interval (e,f), and flood duration (g,h) at Bon Weir (left) and Ruliff (right) gauging stations. Means and standard errors are computed at five year intervals.

Another important variable for bottomland hardwood forests is event size or magnitude, measured as total flood discharge. Total discharge wasn't altered at Ruliff (Figure 4d), but there was a significant post-dam decrease in magnitude of floods at Bon Weir (Figure 4c, $p<0.01$). Again, we attribute this to Toledo Bend Dam having the capacity to store a certain amount of floodwaters. This effect can also be seen in Figure2 showing several flood events of greater magnitude prior to dam construction. Since bottomland hardwood forests depend on very large floods to inundate vast expanses of the floodplain, deposit sediment, and deliver nutrients, there is a potential for impacts on health in this zone of the river as described in the introduction section.

There was no change in

flooding frequency at Ruliff (Figure 4f), but there was a significant increase at Bon Weir (Figure 4e, p=0.04) after the dam was built than before. Likewise, there was no significant difference in flooding duration at Ruliff (Figure 4h), but there was a significant decrease after the dam was built at Bon Weir (Figure 4g). This may be related to operation of the dam releasing high flow pulses for hydroelectric power generation. Hydroelectric dams, such as Toledo Bend, maintain water levels at a high point with a large potential energy head when producing electricity. Dams can have large storage capacities and when water levels return to desired levels following a flood, dams will cease releasing floodwaters downstream, resulting in floods of shorter duration. Combined with the results described above, we conclude that flood patterns changed at the Bon Weir station, 56 miles downstream of the dam, but have returned to near normal conditions by 83 miles downstream at the Ruliff station. Although there were more floods at Bon Weir after the dam was built, these floods had less total discharge and shorter duration.

There was no evidence of differences among any of the variables examined at Ruliff, which is likely due to the location of this gauge far downstream that has greater tributary inputs than Bon Weir and located in a deltaic coastal plain with extremely low elevations. Although there is evidence of floods extending into the growing season at Ruliff, it is unknown if the vegetative communities of the floodplains have been affected.

Riparian Species Database

The first list created consisted of species that we would expect to find based on Hayes (2009) (see Appendix A). The second list created consisted of species that were observed and recorded within our plots at our study sites (see Appendix B).

The expected species list named 50 tree species that could occur in the Sabine River floodplain, while we observed 39 tree species in our plots (Table 3). There are similarities between the two lists, only with fewer species observed in nearly all categories. Based on our ranking system, observed tree species scored 22% lower than expected (134 compared with 171.5). Of the 21 wetland (OBL to FACW-) tree species we expected to find, 18 species were observed. One species that we observed at the Anacoco Bayou site that we did not expect to find was Chinaberry (*Melia azedarach*), an invasive species (USDA & NRCS, 2010). Only one individual of Chinaberry was observed in our plots and very few were observed outside our plots.

Table 3. Comparison of tree species richness for each wetland indicator group. Numerical ranking of wetland indicator shown for each category in parentheses and summarized for each group as the "rank total".

Wetland Indicator	Expected Species	Observed Species
FACU- (1.5)	1	1
FACU (2)	7	5
FACU+ (2.5)	2	0
FAC- (2.5)	0	1
FAC (3)	15	12
FAC+ (3.5)	4	2
FACW- (3.5)	3	4
FACW (4)	9	7
FACW+ (4.5)	1	0
OBL (5)	8	7
TOTAL	50	39
Rank Total	171.5	134

The expected species list named 17 shrub/sapling species that could occur in the Sabine River floodplain, while we observed 22 shrub/sapling species in our plots (Table 4). Both lists are very similar, particularly when considering the wetland species (OBL to FACW-). Both lists contained three OBL species and nine total wetland species. Based on our ranking system, observed shrub species scored 26% higher than expected (73.5 compared with 58.5). Chinese privet (*Ligustrum sinense*) wasn't observed in our plots even though it was among the expected species list, while Southern arrow-wood (*Viburnum dentatum*) was not expected but was observed at the Big Cow Creek site.

Table 4. Comparison of shrub/sapling species richness for each wetland indicator group. Numerical ranking of wetland indicator shown for each category in parentheses and summarized for each group as the "rank total".

Wetland Indicator	Expected Species	Observed Species
FACU- (1.5)	2	2
FACU (2)	1	1
FAC- (2.5)	1	1
FAC (3)	3	7
FAC+ (3.5)	1	2
FACW- (3.5)	1	2
FACW (4)	5	4
OBL (5)	3	3
TOTAL	17	22
Rank Total	58.5	73.5

Substantially lower species composition was observed in the herbaceous layer than expected; there were 45 herbaceous species on our expected list and only 18 species were observed (Table 5). Based on our ranking system, observed herbaceous species scored 60% lower than expected (63 compared with 156). There were 22 wetland (OBL to FACW-) species on the expected list, while only eight wetland species were observed. In fact, the three OBL species we observed were none of the nine that were on the expected list. More research is needed to explain whether the decline in herbaceous species diversity is related to flow alterations. This may be attributed to the location of plots, since all of the OBL herbaceous species observed in our study were at the furthest downstream site, Sabine Island. Only two upland (FACU+ to UPL) species were encountered in our plots, even though the expected list contained nine upland species.

To our knowledge there are no rare or endangered plant species in floodplains throughout the region. There were only common plant species expected (Appendix A) and likewise only common species were observed in our study sites (Appendix B). We observed a high diversity of deciduous species, 74% of those we expected to find (Table 6). There were seven fewer evergreen species observed than we expected (Table 6), including all members of the genus *Pinus* on the expected list. Of the four observed evergreen species, three were of the genus *Ilex*, and the remaining was dwarf palmetto (*Sabal minor*).

Table 5. Comparison of herbaceous species richness for each wetland indicator group. Numerical ranking of wetland indicator shown for each category in parentheses and summarized for each group as the "rank total".

Wetland Indicator	Expected Species	Observed Species
UPL (1)	1	0
FACU (2)	7	2
FACU+ (2.5)	1	0
FAC- (2.5)	4	0
FAC (3)	7	7
FAC+ (3.5)	3	1
FACW- (3.5)	2	1
FACW (4)	9	4
FACW+ (4.5)	2	0
OBL (5)	9	3
TOTAL	45	18
Rank Total	156	63

Table 6. Comparison of deciduous vs. evergreen species within expected and observed lists.

	Expected Species	Observed Species
Deciduous	57	42
Evergreen	11	4

Drought tolerance information can provide insight to the type of species that are present in this area, which can then be related to hydrological variables. We would expect wetland species to be more intolerant of drought, as they require periods of saturation or inundation for germination and survival. Therefore, if there are more drought tolerant species present than expected, it is possible that a community shift is occurring that favors non-wetland species. Among the observed species, we found exactly the same proportions of drought tolerant species to those on the expected list with a greater number of species in the "low" tolerance group than any other (Table 7). A total of 22% of species (expected and observed) were highly drought tolerant, 26% were moderately drought tolerant, 40% had low drought tolerance, and 12% were not tolerant at all.

Table 7. Drought tolerances for all species within expected and observed lists.

Drought Tolerance	Expected Species	Observed Species
High	14	9
Medium	17	11
Low	26	17
None	8	5

Vegetation Analysis

The ten most frequently occurring tree species among all three sites were, in decreasing order: American hornbeam (*Carpinus caroliniana*), Red maple (*Acer rubrum*), Sweetgum (*Liquidambar styraciflua*), Chinese Tallow (*Sapium sebiferum*), Water oak (*Quercus nigra*), Hickory (*Carya sp*), American holly (*Ilex opaca*), American elm (*Ulmus Americana*), Persimmon (*Diospyros virginiana*), and Bald cypress (*Taxodium distichum*) (Table 8).

Bald cypress (*T. distichum*), a common OBL tree species, was present at all but one site, and was the tenth most frequent tree species with thirteen individuals. Bald cypress was by far the most dominant among all trees with a total basal area of 4.42 m^2. American hornbeam (*C. caroliniana*) had the greatest frequency with 69 individuals among all sites, twice as many as the next most frequent species, red maple (*A. rubrum*). American hornbeam is a FAC species that is a small, slow-growing, short-lived tree (Burns and Honkala, 1990), which is quite evident in our study by a low dominance of 0.32 m^2. American hornbeam is very tolerant of shade (Burns and Honkala, 1990) and was a major component of the understory on the levees and mid-floodplain areas, but was absent in the sloughs.

Chinese Tallow (*S. sebiferum*), an invasive FAC tree, was the fourth most frequent species with 29 individuals among all sites. Chinese tallow also had a low dominance of 0.11 m^2, most individuals having a diameter of 3−5 cm. Chinese tallow is a species of concern because it is notorious for reproducing quickly and outcompeting native species to create a monoculture (Barrilleaux and Grace, 2000; Butterfield and others, 2004; Webster and others, 2006; Zou and others, 2009). In addition, Chinese tallow has a tolerance to flooding that equals that of bald cypress (*T. distichum*), and also has a greater salinity tolerance than bald cypress (Conner, 1994). Serious ecological consequences could result from the proliferation on Chinese tallow in these forests, particularly in regards to species composition and community health of the floodplain forests of the Sabine River. Another invasive species, Chinaberry (*Melia azedarach*), was found at the Anacoco Bayou site. Only one individual was observed in our plots, but there were a few observed outside of the plots.

The ten most frequently occurring shrub/sapling species among all three sites were, in decreasing order: Chinese Tallow (*Sapium sebiferum*), Yaupon Holly (*Ilex vomitoria*), American Hornbeam (*Carpinus caroliniana*), Dwarf Palmetto (*Sabal minor*), Southern arrow-wood (*Viburnum dentatum*), Red Maple (*Acer rubrum*), Water Oak (*Quercus nigra*), Hop-hornbeam (*Ostrya virginiana*), Buttonbush (*Cephalanthus occidentalis*), and Carolina Buckthorn (*Frangula caroliniana*) (Table 8). Of 24 total species found in the shrub/sapling survey, only nine species are considered wetland species (6 FACW, 3 OBL). Of these nine species, six were tree saplings, indicating that regeneration may be occurring, especially for red maple (*A. rubrum*), for which seven saplings were found. Two crimsoneyed rosemallow (*Hibiscus moscheutos*) individuals were observed outside our slough plots at the Big Cow Creek site. Crimsoneyed rosemallow is an OBL subshrub species that has minimal tolerance to drought (2010). This was an interesting find given that there were few wetland species in the sloughs of the Big Cow Creek site.

The ten most frequently occurring herbaceous species among all three sites were, in decreasing order: Poison Ivy (*Toxicodendron radicans*), Trumpet creeper vine (*Campsis radicans*), Savannah Panic-Grass (*Phanopyrum gymnocarpum*), Muscadine vine (*Vitis rotundifolia*), Narrow-fruit Horned Beaksedge (*Rhynchospora inundata*), Greenbriar (*Smilax bona-nox*), *Polygonum sp*, Shortbristle Horned Beaksedge (*Rhynchospora corniculata*), Sensitive fern (*Onoclea sensibilis*), and Greater Bladder Sedge (*Carex intumescens*) (Table 8). Half of these species are wetland species (3 OBL, 2 FACW). All three OBL species and one FACW were only present at Sabine Island, the other FACW only present at Big

Cow Creek. Poison ivy (*Toxicodendron radicans*) was present at all sites, and occurred along the ground as well as climbing up trees and shrubs.

Table 8. Frequency and dominance of 10 most frequent tree, shrub, and herbaceous species among all sites. Dominance of trees is reported as basal area; whereas dominance of shrubs and herbs are reported as percent canopy cover. OBL species are indicated by "**". FACW species are indicated by "*". All other species are FAC or above (refer to Table 1 for classification scheme).

Tree Species	All Sites Combined		Anacoco Bayou		Big Cow Creek		Sabine Island	
	Freq	Basal Area (m2)	Freq	Basal Area (m2)	Freq	Basal Area (m2)	Freq	Basal Area (m2)
Carpinus caroliniana	69	0.32	31	0.11	17	0.056	21	0.15
*Acer rubrum	34	0.37	0	0	13	0.08	21	0.29
Liquidambar styraciflua	34	0.9	11	0.13	14	0.46	9	0.33
Sapium sebiferum	29	0.11	0	0	2	0.01	27	0.1
Quercus nigra	28	0.56	12	0.24	11	0.16	5	0.17
Carya sp	21	0.42	21	0.42	0	0	0	0
Ilex opaca	16	0.08	15	0.07	1	0.006	0	0
*Ulmus americana	14	0.49	7	0.26	0	0	7	0.22
Diospyros virginiana	14	0.05	4	0.01	7	0.04	3	0.008
**Taxodium distichum	13	4.42	3	3.31	0	0	10	1.11
Shrub/Sapling Species	**All Sites Combined**		**Anacoco Bayou**		**Big Cow Creek**		**Sabine Island**	
	Freq	**Canopy Cover**	**Freq**	**Canopy Cover**	**Freq**	**Canopy Cover**	**Freq**	**Canopy Cover**
Sapium sebiferum	12	63%	1	0.40%	3	13%	8	50%
Ilex vomitoria	11	49%	6	36%	5	14%	0	0
Carpinus caroliniana	10	35%	2	4%	2	16%	6	15%
*Sabal minor	9	51%	0	0	0	0	9	51%
Viburnum dentatum	7	66%	0	0	7	66%	0	0
*Acer rubrum	7	36%	0	0	3	26%	4	10%
Quercus nigra	4	15%	0	0	0	0	4	15%
Ostrya virginiana	3	10%	2	9%	0	0	1	1%
**Cephalanthus occidentalis	2	8%	2	8%	0	0	0	0
Frangula caroliniana	2	25%	0	0	0	0	2	25%
Herb Species	**All Sites Combined**		**Anacoco Bayou**		**Big Cow Creek**		**Sabine Island**	
	Freq	**% Cover**	**Freq**	**% Cover**	**Freq**	**% Cover**	**Freq**	**% Cover**
Toxicodendron radicans	17	113%	5	33%	1	6%	11	73%
Campsis radicans	13	86%	0	0	11	73%	2	13%
**Phanopyrum gymnocarpon	13	86%	0	0	0	0	13	86%
Vitis rotundifolia	9	60%	6	40%	3	20%	0	0
**Rhynchospora cf inundata	8	53%	0	0	0	0	8	53%
Smilax bona-nox	6	40%	0	0	4	26%	2	13%
Polygonum sp.	5	33%	2	13%	0	0	3	20%
**Rhynchospora corniculata	5	33%	0	0	0	0	5	33%
*Onoclea sensibilis	4	26%	0	0	0	0	4	26%

Insights about tolerance of flooding can be gained by investigating how tree, shrub, and herbaceous species were distributed among the three topographic zones: sloughs, mid-floodplain, and levees (Figure 5). Across the board, OBL species were most common in the sloughs and least common on the levees. This may indicate that only the lowest topographic zones of the floodplain are suitable for wetland plants. This was contrary to our expectation that minor differences in elevation within the first 500 m of the floodplain would result in only minor differences in tree species composition. Given the very small difference in elevation among plots and the fact that the entire surface of the floodplain should experience similar hydrologic conditions, we had expected to see OBL species dominant in all three topographic zones. It is possible that groundwater is less accessible to plants as elevations increase. More research is needed to determine whether groundwater is shallow enough to sustain wetland OBL species on levees during low flow periods. This hypothesis is further substantiated by the relatively few FAC or FACU species occurring in the sloughs.

One notable exception was Chinese Tallow (*Sapium sebiferum*), a FAC species found in sloughs that, as mentioned earlier, has a high flood tolerance that nearly equals that of bald cypress (*Taxodium distichum*) (Conner, 1994). A major difference between the shrub dataset and the tree dataset is that FACU species appeared in all plots, and had greater canopy cover in the sloughs than the levee areas. More research is needed to determine if non-wetland species are expanding into the slough areas due to more favorable hydrological conditions needed for germination and survival.

We expected wetland species (OBL, FACW) to occur more frequently in the sloughs than the mid-floodplains or levees, while non-wetland species (FAC, FACU) exhibited a reverse relationship of having greater frequency in the levee and mid-floodplain plots than the sloughs. It was surprising, though, to find such a strong trend with such minor elevation changes − especially since OBL species were so rare on levees. This suggests more frequent flooding or shallower groundwater tables could displace FAC and FACU trees with more OBL species, except in the case of Chinese tallow, which grows well even when flooded (Conner, 1994). Not only were OBL species more frequent in sloughs, they were also more dominant in sloughs than the levees or mid-floodplains, and the same held true for FACW species (Figure 5). The OBL trees had the greatest dominance among any of the other indicator groups because of thirteen very large Bald cypress trees that strongly influenced this result.

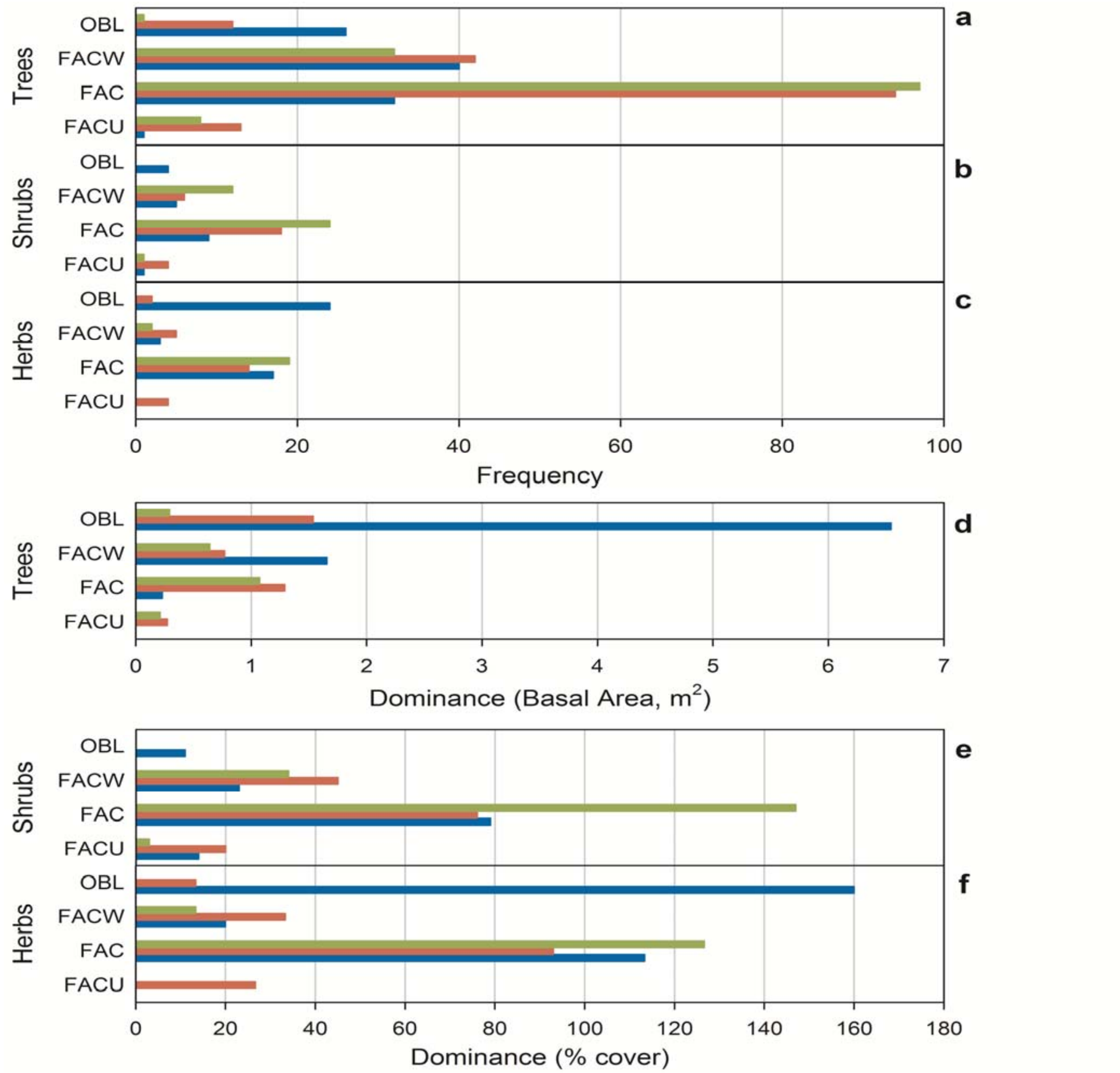


Figure 5. From top: tree frequency, shrub frequency, herb frequency, tree dominance, shrub dominance, and herb dominance of individuals in four major wetland indicator classifications among all sites grouped by topographic zone: levee (green), mid-floodplain (red), and slough (blue). In trees, dominance is measured as the total basal area (m^2) in all plots combined. In shrubs and herbs, dominance is measured as % canopy cover in all plots combined.

In general, all three sites showed decreasing diversity of wetland tree species with increasing elevation. From this we can assume that the hydroperiod for supporting wetland species falls within the narrow difference in elevation between sloughs and levees, 2.07−9.33 feet, depending on the site. Although this suggests small changes in flooding after the dam was built could have altered the species composition on the floodplain, more research is needed to determine whether there is a link between the dam operation and vegetation trends. Sites with higher elevations also have greater diversity of tree species than low-lying areas dominated by FAC and FACU types (Figure6). Lower species richness in the slough areas of floodplains has been documented by others, since there are only a few tree species that are adapted to areas of more frequent inundation and soil anoxia (Hodges, 1997; Glaeser and Wulf, 2009; Kupfer and others, 2010).

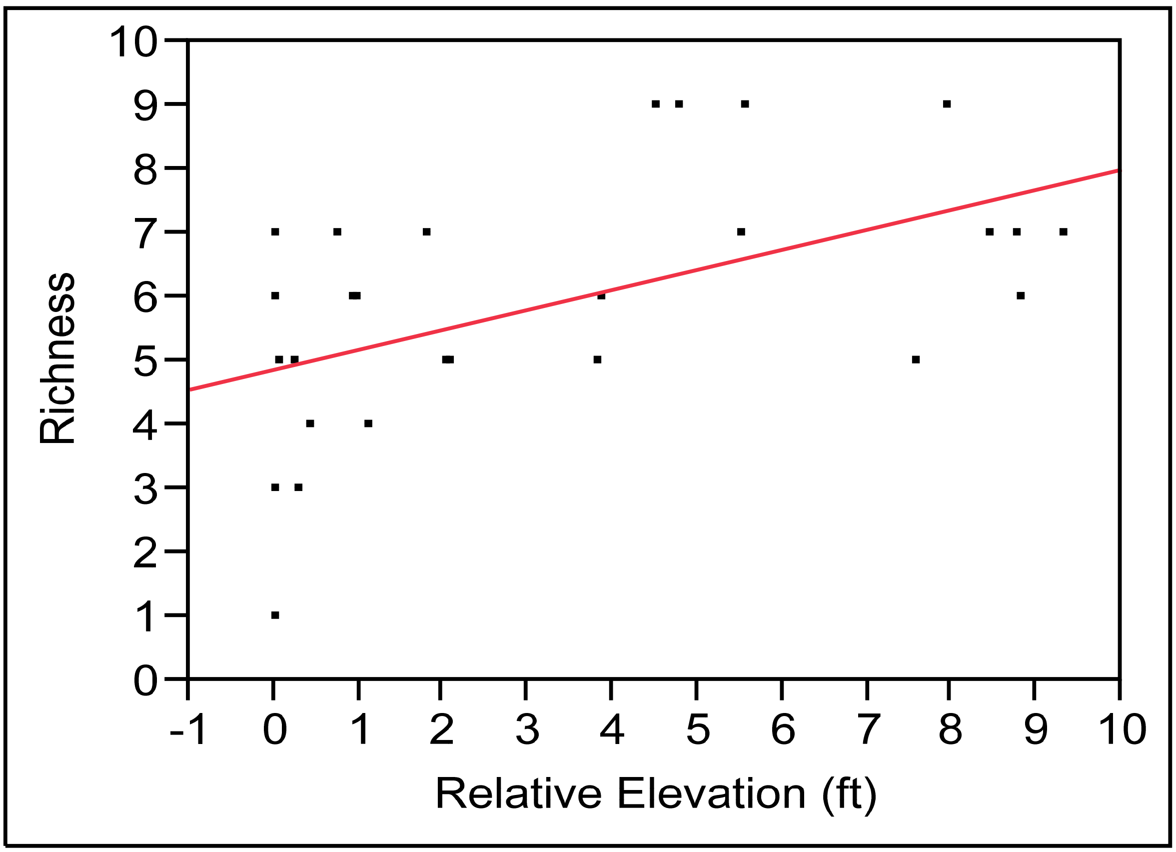
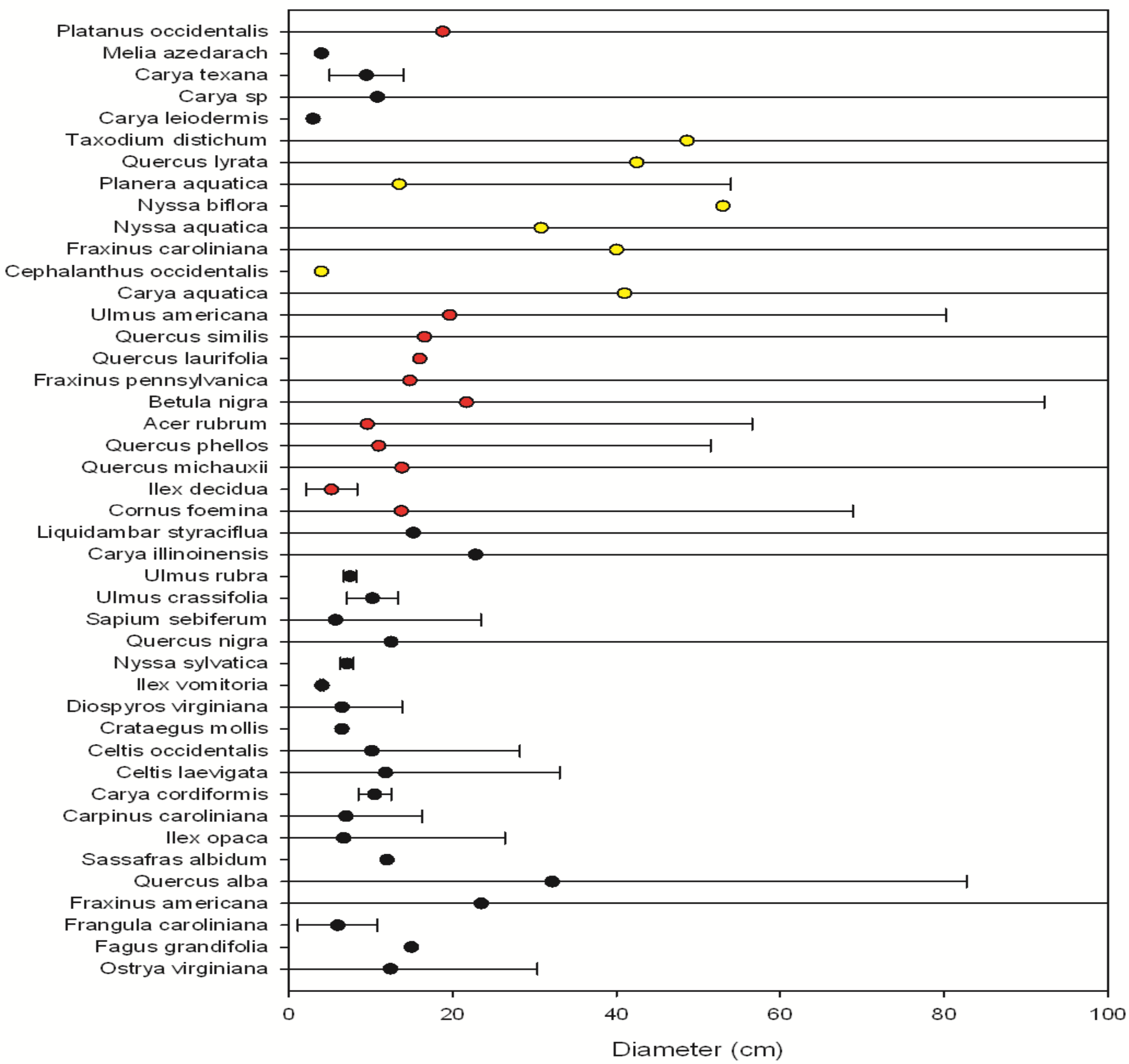


Figure 6. The relationship between tree species richness and relative elevation of plots for all sites combined.

Further support for the potential decreasing trend in wetland species post-dam construction is evident in the size class distributions (Figure 7). OBL species are, on average, larger than all other species. Two conclusions can be drawn from this: first, many of the OBL trees were very large, mature individuals, and second, that there were very few OBL saplings and/or small, young trees. Recruitment may have been reduced or eliminated in the time since the dam was built, possibly leading to decline of several OBL species. If these OBL species are in decline due to hydrologic alteration, they could be replaced over time by non-wetland species once the older, larger OBL individuals die, leading to a change in forest composition (Glaeser and Wulf, 2009; Kupfer and others, 2010).

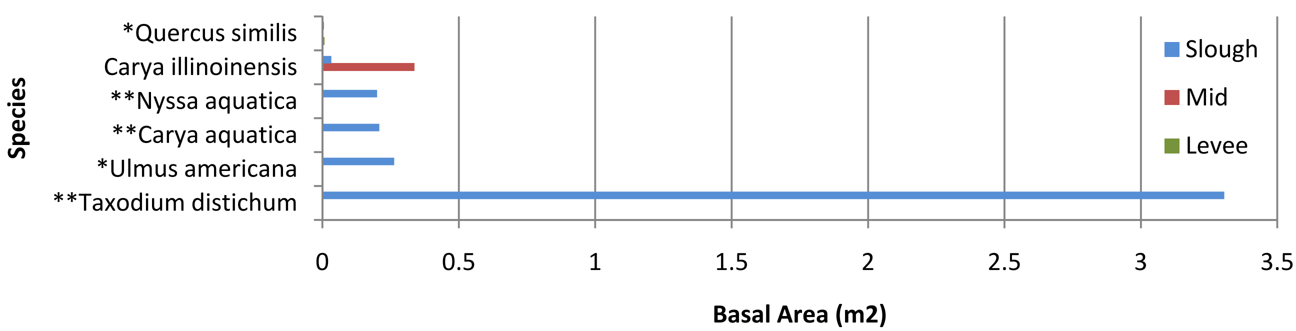
Figure 7. Size distribution, in cm, of OBL (yellow), and FACW (red) tree species as compared with all other trees observed. Error bars represent standard deviations of the mean size of individuals.



Anacoco Bayou

At Anacoco Bayou, non-wetland tree species (FAC and FACU) were excluded from the sloughs, while the wetland tree species (OBL and FACW) were restricted to the sloughs (Figure 8, top). On the basis of dominance (total basal area), half of the tree species (3 of 6) that occurred in the sloughs were OBL, two were FACW, and only one FAC was present. There was also greater tree species richness on the levees than the sloughs at Anacoco Bayou (Figure 8, bottom). We found two FACW trees on the levees and/or the mid-floodplains that were excluded from the sloughs.

Only one OBL shrub species was found at Anacoco Bayou, buttonbush (*Cephalanthus occidentalis*), which like trees was restricted to the slough areas (Figure 9). We also found one FACW species, possumhaw holly (*Ilex decidua*), but that species was only present on the mid-floodplains. The slough areas at this site were characterized by very large bald cypress (*Taxodium distichum*), yet there were no saplings or seedlings present that we could see. More research is needed to determine if and why regeneration at this site has been reduced for the large, common OBL tree species at this site, such as bald cypress (*T. distichum*) and water tupelo (*Nyssa aquatica*). Furthermore, only five total herbaceous species were found, three of which were exclusive to the slough areas (Figure 10). Of the herbs, only one, American Buckwheat Vine (*Brunnichia ovata*), was a wetland species (FACW). Two individuals of the genus *Polygonum*, known to be OBL, were present but unable to be identified down to species.



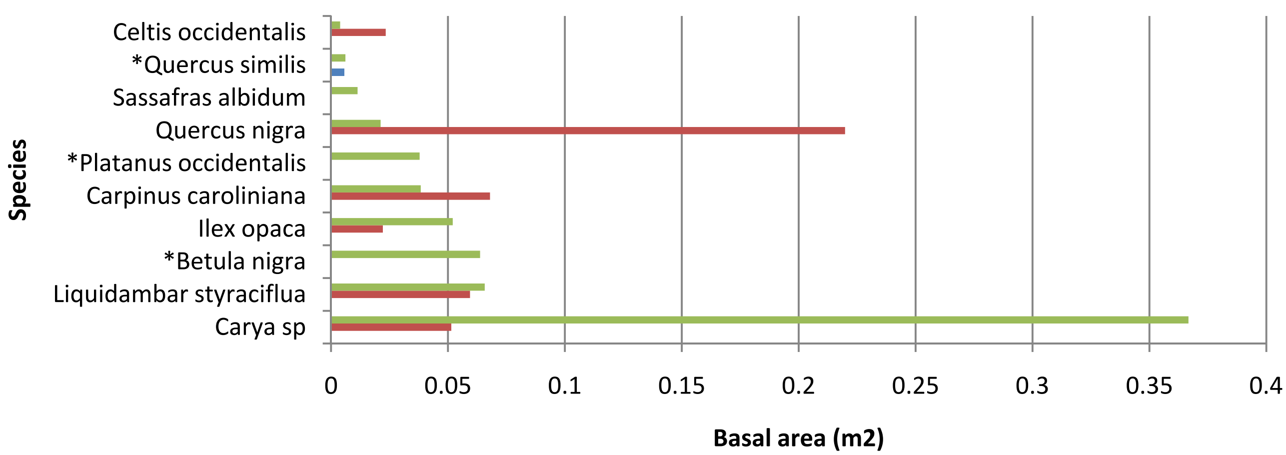


Figure 8. At Anacoco Bayou site, dominance of all tree species found in the (top) slough and (bottom) levee plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the total basal area (m^2) in all plots combined.

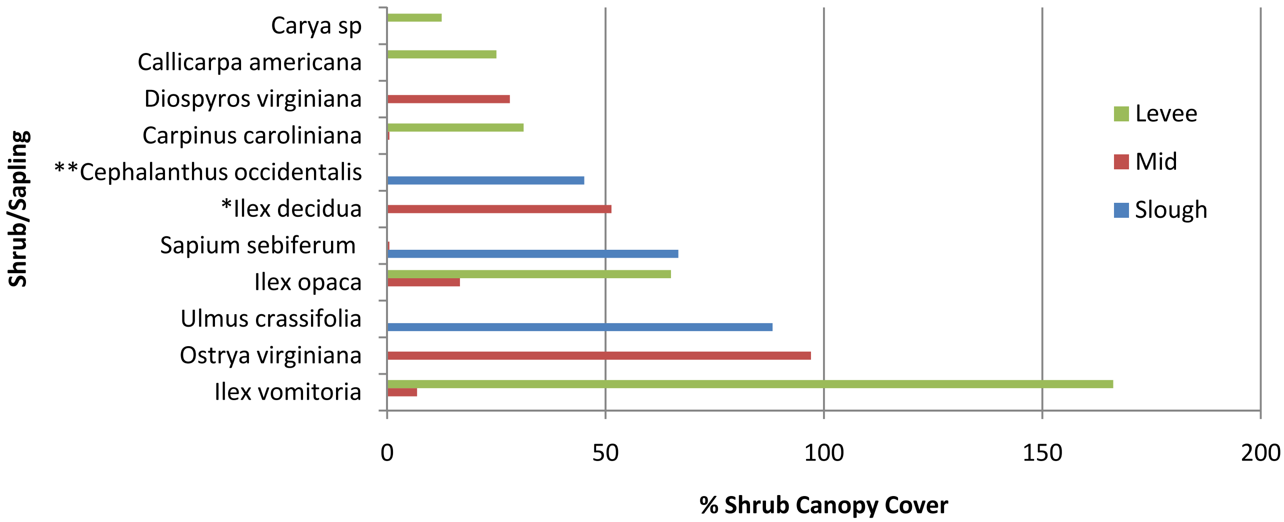


Figure 9. At Anacoco Bayou site, dominance of all shrub/sapling species found in all topographic plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the % shrub canopy cover in all plots combined.

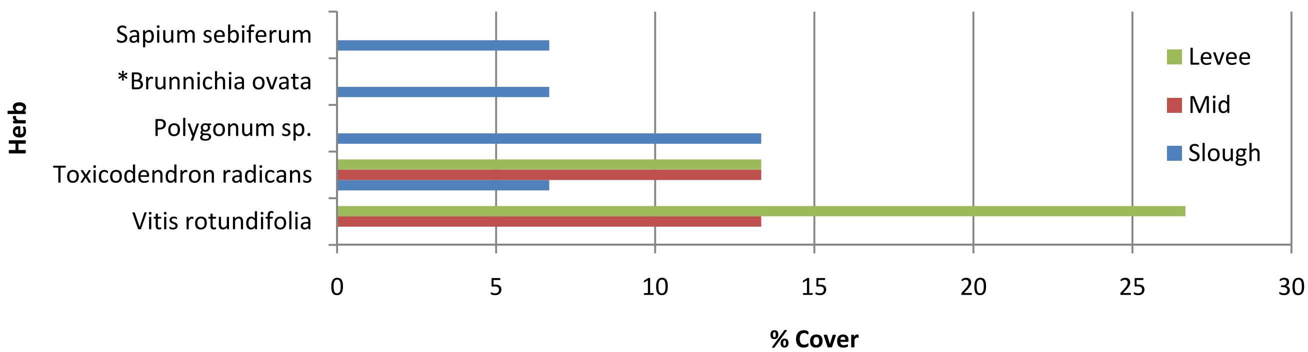


Figure 10. At Anacoco Bayou site, dominance of all herbaceous species found in all topographic plots. FACW species are indicated by "*". Dominance is measured as the % cover in all plots combined.

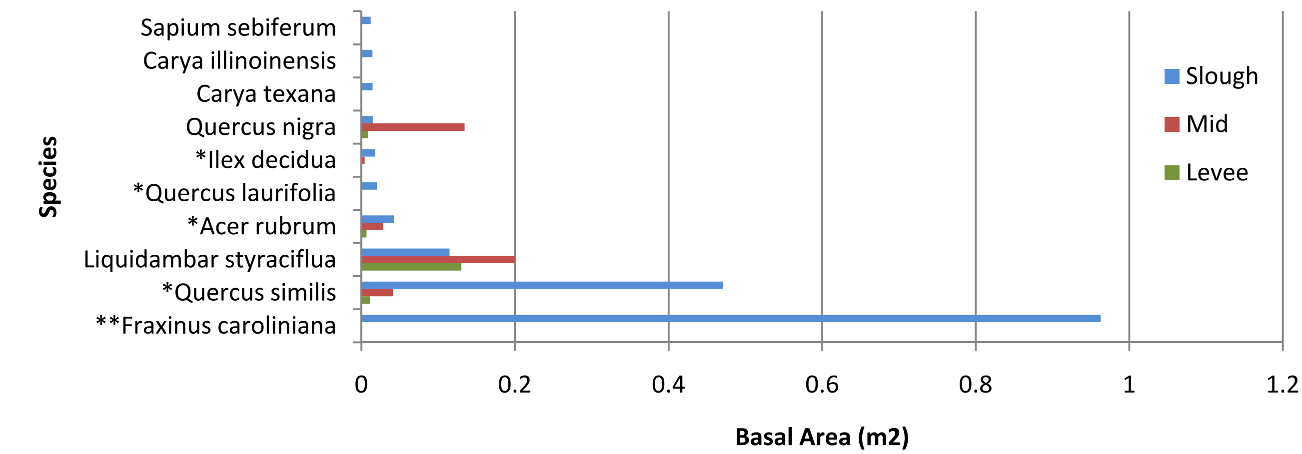
Big Cow Creek

At Big Cow Creek, less than half of the tree species present were wetland species, including only one individual OBL tree, Carolina Ash (*Fraxinus caroliniana*), which was so large that it dominated the overall trend (Figure 11). Interestingly, of the five FACW tree species, Red Maple (*A. rubrum*), Laurel Oak (*Quercus laurifolia),* and Bottomland Post Oak (*Q. similis*) dominated the sloughs and were least dominant on the levees, while Sycamore (*Platanus occidentalis*), and River Birch (*Betula nigra*) were not present in the sloughs. This reveals a pattern similar to Anacoco Bayou of Sycamore and River Birch occurring exclusively on the levees and mid-floodplains, while non-wetland tree growth was restricted in the sloughs.

There were also no OBL shrubs or herbs found at Big Cow Creek either. Four FACW species were present (Figure 12 and 13), all of which were tree saplings: Two FACW tree saplings, red maple

(*Acer rubrum*) and possumhaw holly (*Ilex decidua*) were restricted to the sloughs and mid-floodplains, while the other two FACW saplings, sycamore (*Platanus occidentalis*) and willow oak (*Quercus phellos*) were only present on the levee areas. This is a similar finding in the tree analysis for sycamore (*P. occidentalis*) which occurred exclusively on the levees and mid-floodplains. Southern arrow-wood (*Viburnum dentatum*) is a FAC shrub that had the greatest dominance of any shrub or sapling found at Big Cow Creek, and was only present on the levees.

Only three FACW species were found in the herbaceous survey, two of which were actually tree seedlings, bottomland post oak (*Quercus similis*) and swamp chestnut oak (*Q. michauxii*) rather than herbs and only occurred on the levee areas within our plots (Figure 13). This indicates some tree regeneration is occurring at this site, the extent of which is unknown. The third FACW species, greater bladder sedge (*Carex intumescens*), only occurred within the mid-floodplain plots. Trumpet creeper vine (*Campsis radicans*), a FAC species, had more than three times the dominance of the rest of the species that occurred within the slough areas.



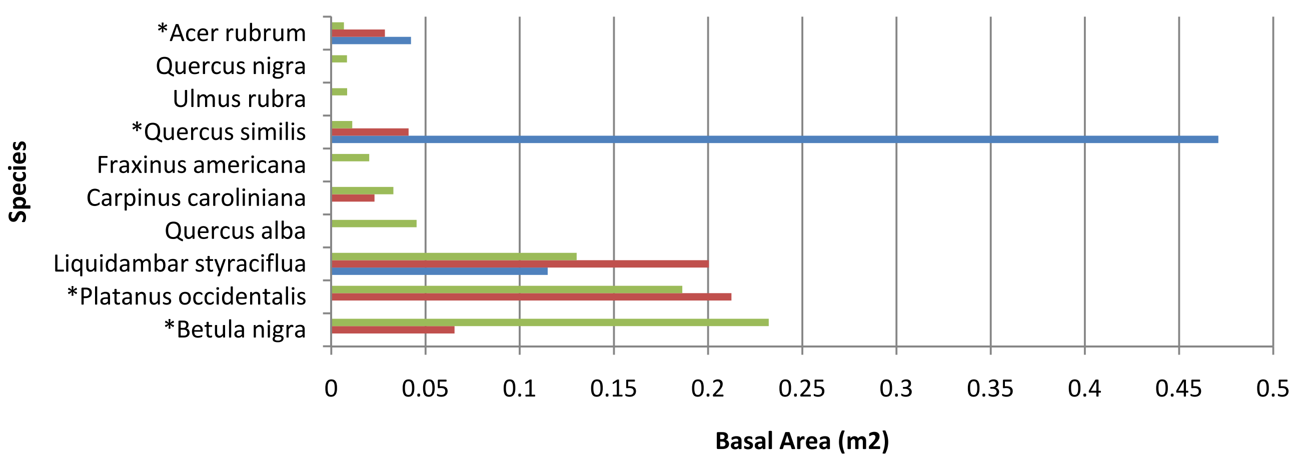


Figure 11. At Big Cow Creek site, dominance of all tree species found in the (top) slough and (bottom) levee plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the total basal area (m^2) in all plots combined.

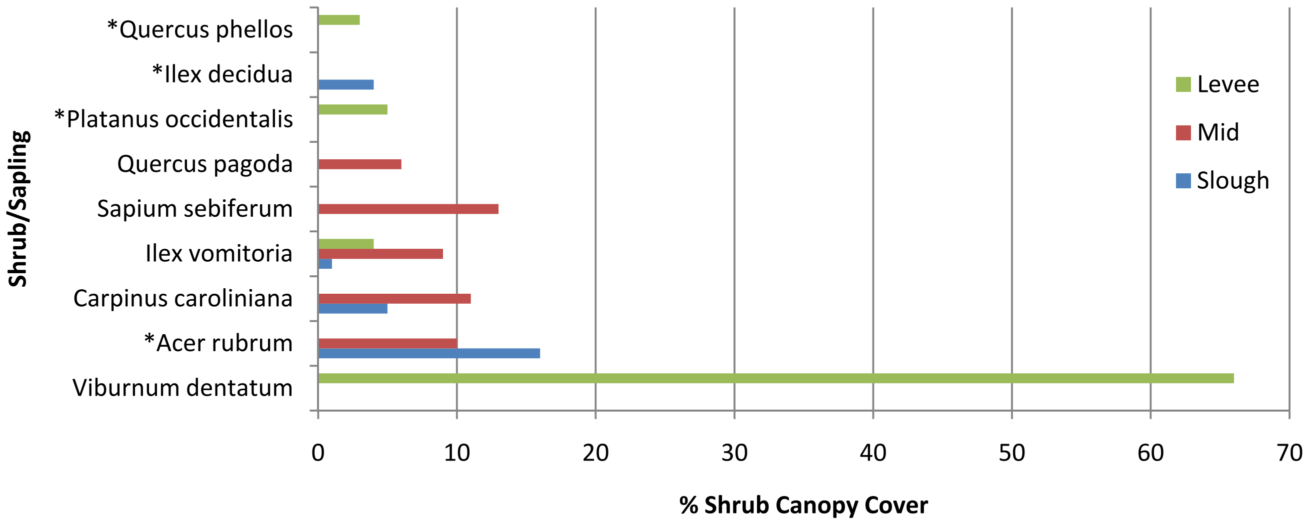


Figure 12. At Big Cow Creek site, dominance of all shrub/sapling species found in all topographic plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the % shrub canopy cover in all plots combined.

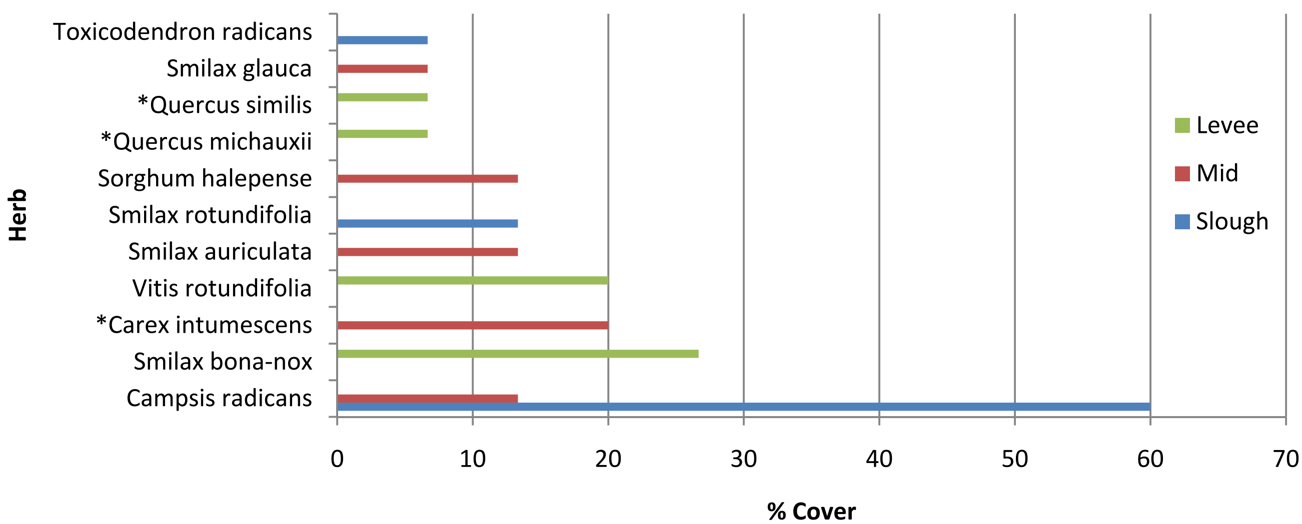


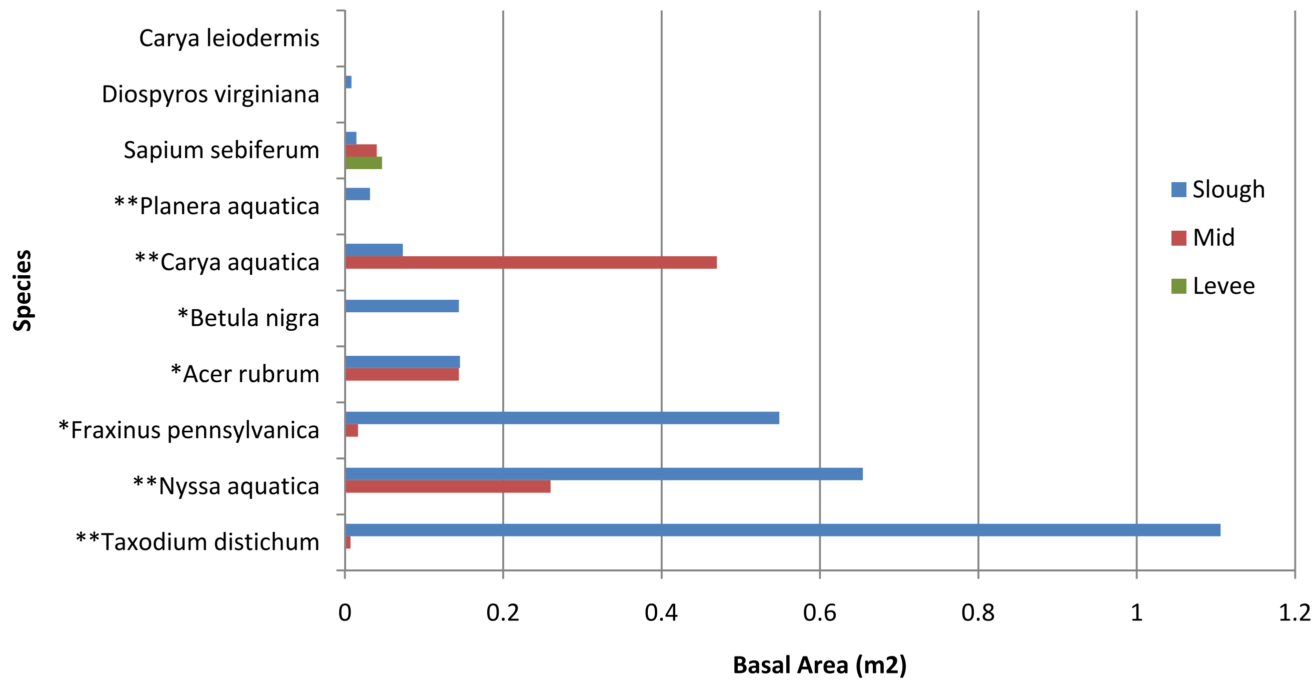
Figure 13. At Big Cow Creek site, dominance of all herbaceous species found in all topographic plots. FACW species are indicated by "*". Dominance is measured as the % cover in all plots combined.

Sabine Island

Sabine Island had much higher plant diversity than the other two sites, much of which can be accounted for by wetland species. Even though there was only two feet of elevation difference between the lowest plot and the highest plot, there is a dramatic difference in the species composition between plots. Of the ten tree species present in the sloughs, seven were wetland (4 OBL, 3 FACW) species (Figure 14). These wetland species exhibited considerable dominance over the non-wetland species present in both the sloughs and the mid-floodplain plots, but not on the levees. On the levees, only three tree species were wetland types (1 OBL, 2 FACW – See Figure 14, bottom). None of the non-wetland species, except Chinese Tallow (*Sapium sebiferum*), were present in the sloughs.

Of the eleven species found in our shrub/sapling survey at Sabine Island, five are wetland species (2 OBL, 3 FACW) (Figure 15). Surprisingly, we saw very few saplings or seedlings of bald cypress (*Taxodium distichum*) and water elm (*Planera aquatica*), both highly desirable OBL tree species that are very common as large trees in this area. Only one sapling of each occurred in our plots and was only found in the sloughs. In addition, River birch (*Betula nigra*) saplings were found in the sloughs and red maple (*Acer rubrum*) was found mostly in midfloodplain plots. However, Chinese tallow (*Sapium sebiferum*), a FAC species, and Carolina buckthorn (*Frangula caroliniana*), a FACU species, were more common in the sloughs than the OBL species mentioned above. More research should be conducted to address why regeneration is limited even in this area where all three slough plots were completely saturated or inundated, creating conditions that favor wetland plants. Perhaps this area has experienced prolonged flooding (Figure 3, right), which would result in unfavorable conditions as bald cypress requires saturated soils that are not flooded for 1-3 months in order to germinate (Burns and Honkala, 1990).

At Sabine Island, of the nine herbaceous species that occurred, four were wetland (3 OBL, 1 FACW) and were mostly restricted to the slough areas with minor occurrence on the mid-floodplain areas (Figure 16). Although poison ivy (*Toxicodendron radicans*) and greenbriar (*Smilax bona-nox*) were common in the sloughs, the three OBL species had the greatest dominance within the sloughs.



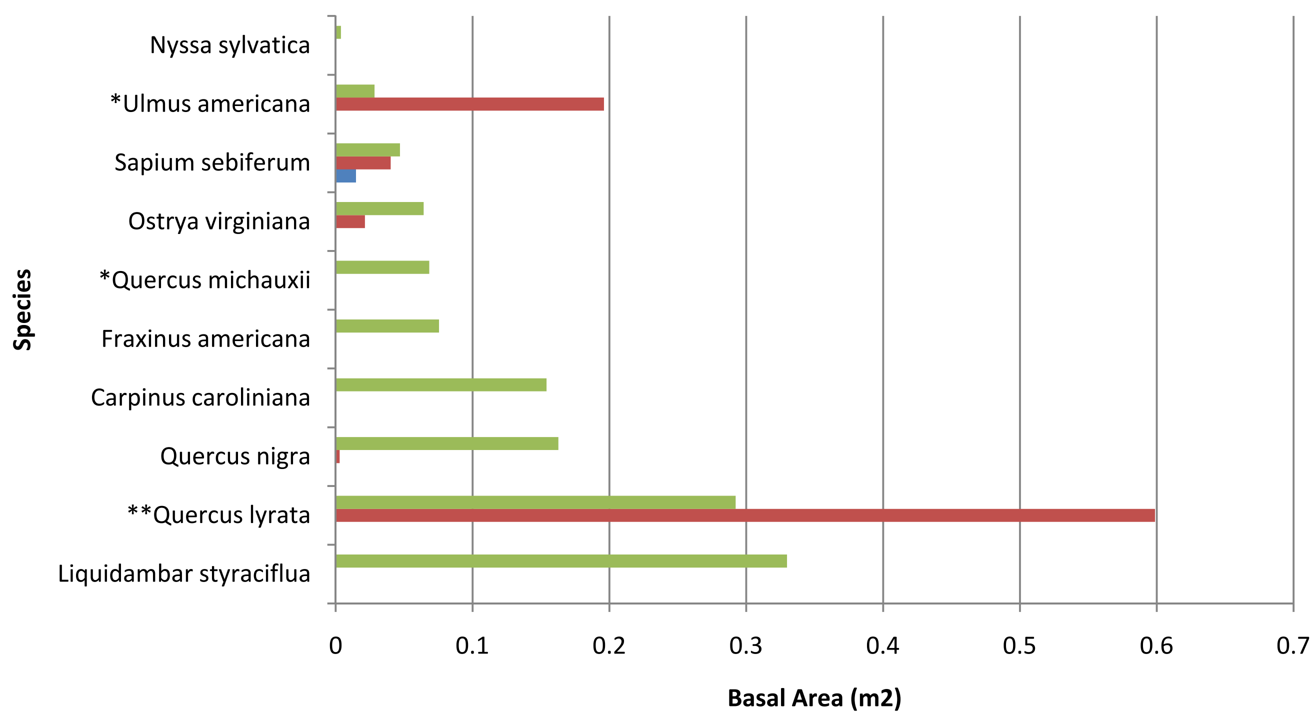


Figure 14. At Sabine Island site, dominance of all tree species found in the (top) slough and (bottom) levee plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the total basal area (m^2) in all plots combined.

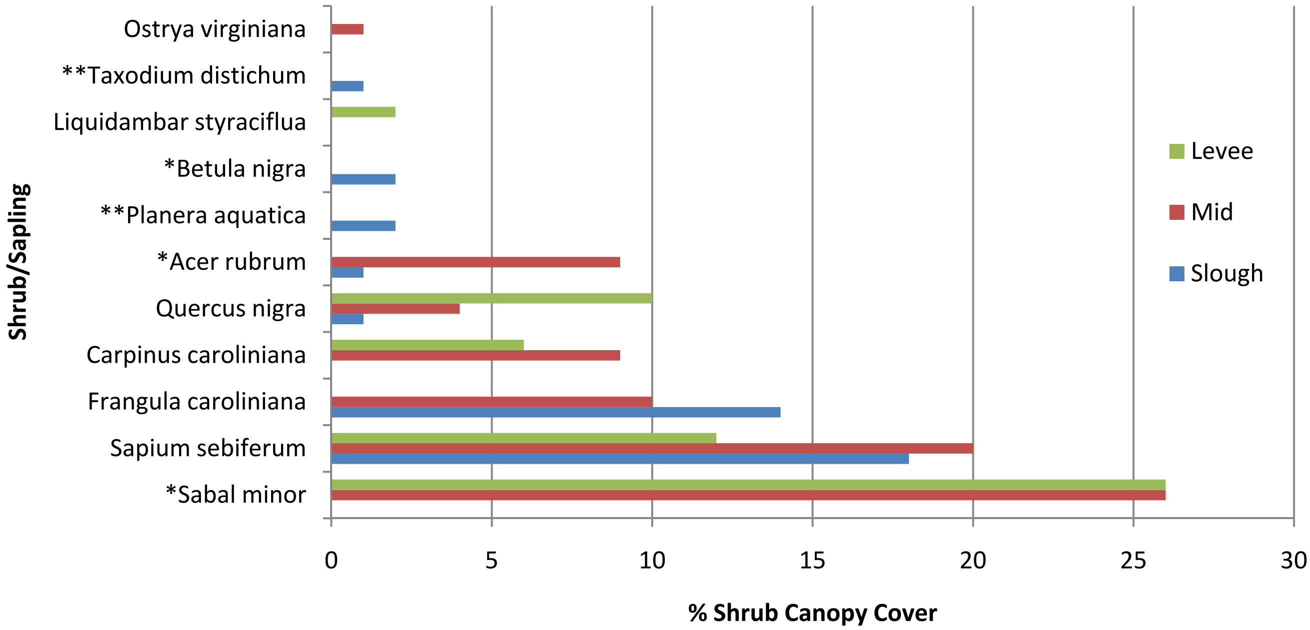


Figure 15. At Sabine Island site, dominance of all shrub/sapling species found in all topographic plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the % shrub canopy cover in all plots combined.

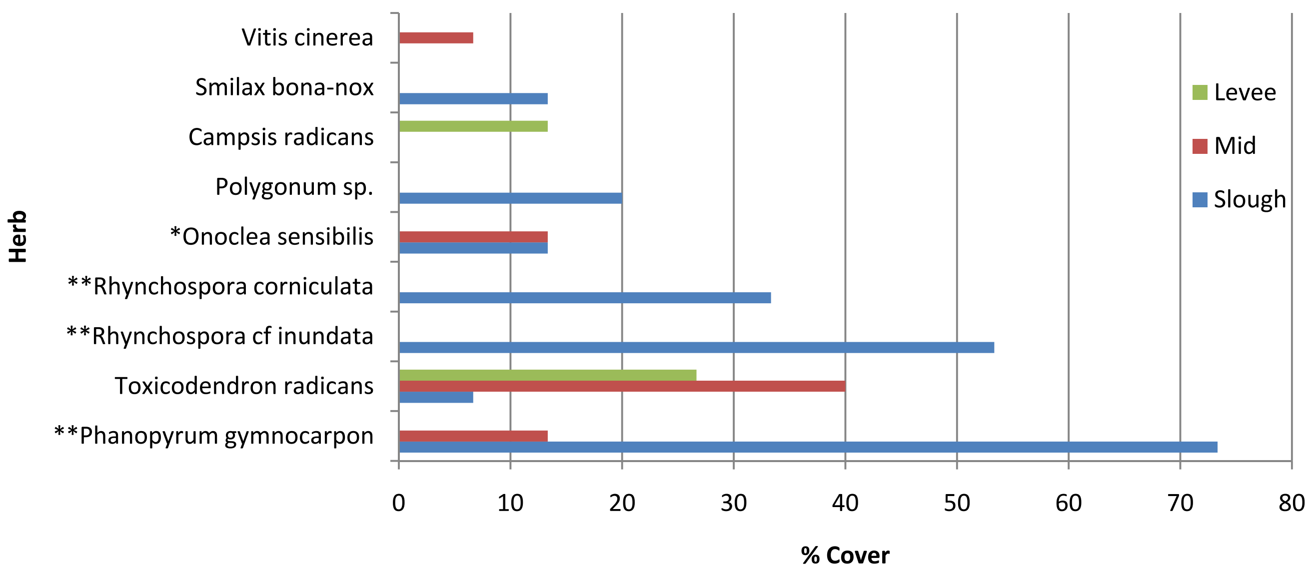


Figure 16. At Sabine Island site, dominance of all herbaceous species found in all topographic plots. OBL species are indicated by "**". FACW species are indicated by "*". Dominance is measured as the % cover in all plots combined.

Conclusion

It is widely acknowledged that dams across America have altered the hydrology and sediment regimes of rivers downstream (Williams and Wolman, 1984; Brandt, 2000; Graf, 2006). The effects that these altered regimes have on riparian ecosystems varies and additional factors, such as channel planform, climate, and land use, influence the changes experienced by river systems (Scott and others, 1996; Friedman and others, 1998; Johnson, 1998; Steiger and others, 2005).

Analysis of the hydrological regime before and after Toledo Bend Dam was constructed on the Sabine River revealed interesting conclusions. The Bon Wier gauge (RM 91) experienced no change in peak discharge, while total discharge and duration were reduced, and frequency increased after the dam was built. More research needs to be done to evaluate why flooding at this gauge is more frequent, reduced in magnitude, shorter in duration, and of the same intensity after the dam was built than before.

At the Ruliff gauge (RM 35), there was no difference among any of the four variables (peak discharge, total discharge, duration, frequency) after the dam was built than before. This is likely due to the greater tributary inputs, minimal influence from the dam, and extremely low elevation setting (Phillips, 2008).

It appears there has been little change in the hydrological regime since the dam was built. Although total discharge and duration were reduced at Bon Wier, peak discharge stayed the same and flooding was more frequent. More research should be conducted to determine if floodplain area that is inundated during flooding has been reduced since dam construction.

Historical vegetation data is unavailable for the Sabine River floodplain; therefore, results from this study convey the vegetation composition at the present time. The vegetation analysis displayed broad conclusions. Among the tree, shrub, and herbaceous surveys, OBL species were largely restricted from the levee and mid-floodplain areas, while FACU and FAC species were mostly excluded from slough areas. FACW species had similar occurrences among all topographic plots.

Future research could be focused on two objectives: inundation mapping and vegetation-flow response guilds. Inundation mapping would reveal what areas of the floodplain are flooded at certain river discharges which could be linked back to elevation differences and vegetation composition within the floodplain.

Vegetation-flow response guilds have been proposed by Merritt and others (2010) as a framework for predicting vegetation response to changing environmental conditions. Riparian species can be grouped by shared traits, such as life history, reproductive strategy, morphology, and adaptations to flooding and soil anoxia, which relate to the various components of the hydrological regime (Merritt and others, 2010). By placing these species into guilds, evaluations can be conducted at the community level, which respond to long-term flow regimes (Merritt and others, 2010). Probabilistic models can be developed that will predict changes in vegetation composition based on changes in flow, as well as aid in the establishment of instream flow recommendations (Merritt and others, 2010).

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Appendix A

Species expected to be found in Sabine River basin based on Hayes (2009).

Tree Species							
Scientific name	**Common name**	**Native or invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or evergreen**	**Wildlife value**	**Drought Tolerance**
Acer barbatum	Southern sugar maple	Native	FAC [1]	3	Deciduous		Low [1]
Acer rubrum	Red maple	Native	FACW [4]	4	Deciduous	Deer browse [3]	Medium [1,3]
Betula nigra	River birch	Native	FACW [4]	4	Deciduous	Bird seed and deer browse [3]	Low [1]
Carpinus caroliniana	American hornbeam	Native	FAC [1,4]	3	Deciduous	Seeds eaten by birds and mammals as well as browse for deer [3]	Low [1]
Carya aquatica	Water hickory	Native	OBL [1,4]	5	Deciduous	Nuts of limited use to squirrels and hogs [3]	Medium [1]
Carya cordiformis	Bitternut hickory	Native	FAC [4]	3	Deciduous	Birds and mammals eat nuts [3]	High [1]
Carya glabra	Pignut hickory	Native	FACU [1,4]	2	Deciduous	Seeds, nuts, barks and leaves eaten by birds, and various mammals [3]	High [1]
Carya illinoinensis	Pecan	Native	FAC+ [4]	3.5	Deciduous	Pecan nuts eaten by birds, squirrels, opossums, raccoons and hogs [3]	Low [1]
Celtis laevigata	Sugarberry	Native	FAC [4]	3	Deciduous	Fruit eaten by 10 species of birds and others [3]	Low [1]
Celtis occidentalis	Hackberry	Native	FAC [4]	3	Deciduous	Fruit and seeds eaten by small mammals and birds [3]	High [1]
Diospyros virginiana	Persimmon	Native	FAC [4,5]	3	Deciduous	Fruit eaten by many mammals and birds [3]	Medium [1]
Fagus grandifolia	American beech	Native	FACU [4]	2	Deciduous	Nuts and mast palatable to birds, and mammals including black bear, squirrels and deer [3]	High [1]
Fraxinus caroliniana	Carolina ash	Native	OBL [4]	5	Deciduous		Low [1]
Fraxinus pennsylvanica	Green ash	Native	FACW [4]	4	Deciduous	Seeds eaten by birds and mammals [3]	Medium [1]
Gleditsia aquatica	Water locust	Native	OBL [4]	5	Deciduous		None [1]
Gleditsia triacanthos	Honey locust	Native	FAC [4,5]	3	Deciduous	Fruits eaten by deer, bobwhites, starlings, squirrels, crows, livestock and opossums [3]	High [1,3]
Juglans nigra	Black walnut	Native	FACU [4]	2	Deciduous	kernels from nuts eaten by wildlife [3]	Low [1,3]

Scientific name	Common name	Native or invasive	Wetland indicator	Wetland indicator ranking	Deciduous or evergreen	Wildlife value	Drought Tolerance
Juniperus virginiana	Eastern red cedar	Native	FAC [4]	3	Evergreen	food from fruits and good nesting and roosting for birds [3]	High [1,3]
Liquidambar styraciflua	Sweetgum	Native	FAC+ [4]	3.5	Deciduous	seeds eaten by wildlife [3]	Low [1]
Maclura pomifera	Osage orange	Native	FACU [4]	2	Deciduous	provides habitat for birds and animals [3]	Medium [1,3]
Magnolia virginiana	Sweetbay	Native	FACW+ [4]	4.5	Deciduous	good food for deer, cattle, seed eaten by squirrels, and birds [3]	None [1]
Nyssa aquatica	Water tupelo	Native	OBL [4]	5	Deciduous	many kinds of wildlife eat fruit [3]	None [1,3]
Nyssa sylvatica	Blackgum	Native	FAC [4]	3	Deciduous	fruit and sprouts important for birds and mammals and cavities make good den tree [3]	Low [1]
Persea borbonia	Redbay	Native	FACW [4]	4	Evergreen	fruit extremely valuable to songbirds, turkey, seeds for other birds, fruits and leaves browsed by deer and bear, withstands grazing very well [3]	Low [1]
Pinus echinata	Shortleaf pine	Native			Evergreen	seeds eaten by birds and small mammals, provides good nesting [3]	Medium
Pinus elliottii	Slash pine	Native	FACW [4]	4	Evergreen	seeds eaten by birds and small mammals, provides good nesting [3]	Low
Pinus palustris	Longleaf pine	Native	FACU+ [4]	2.5	Evergreen	seeds eaten by birds and small mammals, provides good nesting, especially for red cockaded woodpecker [3]	Medium [1]
Pinus taeda	Loblolly pine	Native	FAC [4]	3	Evergreen	provide habitat and nesting for birds and mammals [3]	Low [1,3]
Planera aquatica	Planar tree	Native	OBL [4]	5	Deciduous		Low [1]
Platanus occidentalis	Sycamore	Native	FACW [4]	4	Deciduous	seeds eaten by several bird species [3]	Low [1]
Populus deltoides	Eastern cottonwood	Native	FAC+ [4]	3.5	Deciduous	seedlings and young trees browsed by rabbits, deer and livestock [3]	Medium [1]
Quercus alba	White oak	Native	FACU [4]	2	Deciduous	acorns inconsistent source of food for squirrels and many birds, browse for deer [3]	Medium [1]
Quercus falcata	Southern red oak	Native	FACU- [4]	1.5	Deciduous	acorns valuable food for wildlife [3]	High [1]
Quercus laurifolia	Laurel oak	Native	FACW [4]	4	Deciduous	several birds, deer, squirrels, raccoons eat	Low [1]

						acorns [3]	
Scientific name	**Common name**	**Native or invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or evergreen**	**Wildlife value**	**Drought Tolerance**
Quercus lyrata	Overcup oak	Native	OBL [4]	5	Deciduous	provide habitat and acorns for wildlife [3]	None [1,3]
Quercus michauxii	Swamp chestnut oak	Native	FACW- [4]	3.5	Deciduous	acorns food for birds and mammals [3]	Low [1]
Quercus nigra	Water oak	Native	FAC [4]	3	Deciduous	good wildlife habitat [3]	Low [1]
Quercus pagoda	Cherrybark oak	Native	FAC+ [4]	3.5	Deciduous	several birds, deer, squirrels, raccoons eat acorns [3]	Low [1]
Quercus phellos	Willow oak	Native	FACW- [4]	3.5	Deciduous	Large acorn production for wildlife [3]	None [1]
Quercus shumardii	Shumard oak	Native	FACW- [4]	3.5	Deciduous	produces acorns every 2 to 4 years [3]	High [1,3]
Quercus similis	Bottomland post oak	Native	FACW [4]	4	Deciduous		
Quercus stellata	Post oak	Native	FACU [4]	2	Deciduous	highly valuable acorns for food and provides excellent wildlife cover and nesting sites [3]	High [1,3]
Salix nigra	Black willow	Native	OBL [4]	5	Deciduous		Low [1]
Sapium sebiferum	Chinese tallow	Invasive	FAC [4]	3	Deciduous	seeds eaten by birds [3]	High [8]
Sassafras albidum	Sassfras	Native	FACU [4]	2	Deciduous	bark, twigs, and leaves good food for wildlife [3]	High [1]
Taxodium distichum	Bald cypress	Native	OBL [4]	5	Deciduous	seeds eaten by turkeys, squirrels, grosbeaks, wood ducks and other waterfowl and wading birds, provide excellent nesting for birds [3]	Low [1,3]
Tilia americana	American basswood	Native	FAC [4]	3	Deciduous	seeds and twigs eaten by wildlife [3]	Low [1]
Ulmus alata	Winged elm	Native	FACU+ [4]	2.5	Deciduous	mast eaten by birds and animals, twigs and leaves by deer [3]	Low [1]
Ulmus americana	American elm	Native	FACW [4]	4	Deciduous	squirrels and birds eat seeds [3]	Medium [1,3]
Ulmus crassifolia	Cedar elm	Native	FAC [4]	3	Deciduous	seeds are eaten by birds [3]	Medium [1]
Ulmus rubra	Slippery elm	Native	FAC [4]	3	Deciduous	seeds minor source of food [3]	Medium [1]
			Shrub/Sapling Species				
Scientific name	**Common name**	**Native or invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or evergreen**	**Wildlife value**	**Drought Tolerance**
Acer negundo	Boxelder	Native	FACW [4]	4	Deciduous	seeds eaten by mammals and birds [3]	

Scientific name	Common name	Native or invasive	Wetland indicator	Wetland indicator ranking	Deciduous or evergreen	Wildlife value	Drought Tolerance
Alnus serrulata	Hazel alder	Native	FACW [4]	4	Deciduous		Low [1]
Callicarpa americana	American beautyberry	Native	FACU- [4]	1.5	Deciduous	Fruit eaten by 40 species of birds, as well as deer and small mammals. Medium preference browse for deer [6]	High [1]
Cephalanthus occidentalis	Common buttonbush	Native	OBL [4]	5	Deciduous	low browse preference for deer, many bird and butterfly species feed on seeds and nectar [6]	Medium [1]
Forestiera acuminata	Eastern swamp privet	Native	OBL [4]	5	Deciduous		Low [1]
Frangula caroliniana	Carolina buckthorn	Native	FACU [4]	2	Deciduous	very little wildlife use [6]	Low [1]
Hibiscus moscheutos	Crimsoneyed rosemallow	Native	OBL [4]	5	Deciduous	poor quality food plant [6]	None [1]
Ilex decidua	Possumhaw Holly	Native	FACW- [4]	3.5	Deciduous		Medium [1]
Ilex opaca	American holly	Native	FAC- [4]	2.5	Evergreen	deer, squirrels, and other mammals, as well as 18 species of birds eat the fruit [3]	High [1]
Ilex vomitoria	Yaupon	Native	FAC [4]	3	Evergreen	fruits eaten by several bird and mammal species and foliage is important browse for deer [6]	High [1]
Ilex verticillata	Winterberry	Native	FACW [4,5]	4	Deciduous		Low [1]
Ligustrum sinense	Chinese privet	Invasive	FAC [4,7]	3	Evergreen	dense thickets provide cover and nesting habitats, high quality browse for deer [6]	Medium [1]
Myrica cerifera	Wax myrtle	Native	FAC+ [4]	3.5	Evergreen	seeds eaten by songbirds, waterfowl, turkey and northern bobwhite [6]	None [1]
Morus rubra	Red mulberry	Native	FAC [4]	3	Deciduous	large, sweet fruits eaten by deer and numerous small mammals, as well as birds [3]	Medium [1]
Ostrya virginiana	Hophornbeam	Native	FACU- [4]	1.5	Deciduous	preferred food for bobwhite, grouse, turkey, and other bird species, as well as squirrels and deer [3]	Medium [1]
Sabal minor	Dwarf palmetto	Native	FACW [4]	4	Evergreen	fruits eaten by several songbirds	None [1]

						and small mammals [6]	
Styrax americanus	American snowbell	Native	FACW [4]	4	Deciduous		

Herbaceous Species

Scientific name	Common name	Native or invasive	Wetland indicator	Wetland indicator ranking	Growth Habit	Duration	Drought Tolerance
Ambrosia psilostachya	Cuman ragweed	Native	FAC [4]	3	Forb/herb	Annual	
Ambrosia trifida	Great ragweed	Native	FAC [4]	3	Subshrub, Forb/herb	Annual	
Ampelopsis arborea	Peppervine	Native	FAC+ [4]	3.5	Vine, Shrub	Perennial	
Andropogon ternarius	Splitbeard bluestem	Native	FACU [4]	2	Graminoid	Perennial	None [1]
Aristida oligantha	Prairie three awn	Native					Medium [1]
Arundinaria gigantea	Giant cane	Native	FACW [4]	4	Subshrub, Shrub, Graminoid	Perennial	Yes
Aster ericoides		Native	UPL [4]	1			
Aster subulatus		Native	OBL [4]	5			Medium [1]
Berchemia scandens	Alabama supplejack	Native	FACW [4]	4	Vine	Perennial	
Brunnichia ovata	American buckwheat vine	Native	FACW [4]	4	Vine	Perennial	
Campsis radicans	Trumpet creeper	Native	FAC [4]	3	Vine	Perennial	
Carex amphibola	Eastern narrowleaf sedge	Native	FACW [4]	4	Graminoid	Perennial	
Carex cherokeensis	Cherokee sedge	Native	FACW- [4]	3.5	Graminoid	Perennial	High [1]
Carex hyalinolepis	Shoreline sedge	Native	OBL [4]	5	Graminoid	Perennial	Low [1]
Chasmanthium latifolium	Indian woodoats	Native	FAC- [4]	2.5	Graminoid	Perennial	
Chasmanthium laxum	Slender woodoats	Native	FACW- [4]	3.5	Graminoid	Perennial	Low [1]
Commelina virginica	Virginia Dayflower	Native	FACW [4,5]	4	Forb/herb	Perennial	Medium [1]
Cucurbita foetidissima	Missouri gourd	Native			Vine, Forb/herb	Perennial	Medium [1]
Cynodon dactylon	Bemudagrass	Invasive	FACU [4]	2	Graminoid	Perennial	Low [1]
Dichanthelium dichotomum var. ensifolium	Cypress panicgrass	Native	FAC [4]	3	Graminoid	Perennial	High [1]
Impatiens capensis	Spotted Jewelweed	Native	FACW [4,5]	4	Forb/herb	Annual	Medium [1]
Juncus effusus	Common rush	Native	FACW+ [4,5]	4.5	Graminoid	Perennial	
Lemna minor	Common duckweed	Native	OBL [4]	5	Forb/herb	Perennial	Low [1]

Scientific name	Common name	Native or invasive	Wetland indicator	Wetland indicator ranking	Growth Habit	Duration	Drought Tolerance
Lolium perenne	Perennial ryegrass	Invasive	FACU [4]	2	Graminoid	Perennial, Annual	Medium [1]
Lonicera japonica	Japanese honeysuckle	Invasive	FAC- [4]	2.5	Vine	Perennial	
Onoclea sensibilis	Sensitive fern	Native	FACW [4]	4	Forb/herb	Perennial	Low [1]
Packera glabella	Butterweed	Native	FACW+ [1]	4.5	Forb/herb	Annual	Medium [1]
Panicum anceps	Beaked panicgrass	Native	FAC- [4]	2.5	Graminoid	Perennial	
Panicum hemitomon	Maidencane	Native	OBL [4]	5	Graminoid	Perennial	Medium [1]
Paspalum floridanum	Florida paspalum	Native	FACW [4]	4	Graminoid	Perennial	
Paspalum notatum	Bahiagrass	Native	FACU+ [4]	2.5	Graminoid	Perennial	None [1]
Polygonum hydropiperoides	Swamp smartweed	Native	OBL [4]	5	Forb/herb	Perennial	
Potamogeton nodosus	Longleaf pondweed	Native	OBL [4]	5	Forb/herb	Perennial	
Rubus arvensis	Field blackberry	Native	FAC- [4]	2.5	Subshrub	Perennial	Low [1]
Saccharum baldwinii	Narrow plumegrass	Native	OBL [4]	5	Graminoid	Perennial	None [1]
Saururus cernuus	Lizard's tail	Native	OBL [4]	5	Forb/herb	Perennial	
Schizachyrium scoparium	Little bluestem	Native	FACU [4]	2	Graminoid	Perennial	
Smilax bona-nox	Saw greenbriar	Native	FAC [4]	3	Shrub, Vine	Perennial	
Smilax rotundifolia	Roundleaf greenbriar	Native	FAC [4]	3	Shrub, Vine	Perennial	High [1]
Solidago gigantea	Giant goldenrod	Native	FACW [4]	4	Forb/herb	Perennial	Medium [1]
Sorghastrum nutans	Indiangrass	Native	FACU [4]	2	Graminoid	Perennial	Medium [1]
Sorghum halepense	Johnsongrass	Invasive	FACU [4]	2	Graminoid	Perennial	Medium [1]
Tillandsia usneoides	Spanish moss	Native			Forb/herb, Vine	Perennial	Medium [1]
Toxicodendron radicans	Eastern poison ivy	Native	FAC [4]	3	Shrub, Subshrub, Forb/herb, Vine	Perennial	Low [1]
Tradescantia virginiana	Virginia spiderwort	Native	FAC+ [4,5]	3.5	Forb/herb	Perennial	
Tripsacum dactyloides	Eastern gamagrass	Native	FAC+ [4]	3.5	Graminoid	Perennial	
Vicia ludoviciana	Louisiana vetch	Native	FACU [4]	2	Forb/herb, Vine	Annual	Medium [1]
Woodwardia virginica	Virginia chainfern	Native	OBL [4]	5	Forb/herb	Perennial	Low [1]

[1] (USDA & NRCS, 2010)
[2] (Hook, 1984)

[3] (Burns and Honkala, 1990)
[4] (US Fish and Wildlife Service, 1996)
[5] (Ortego, 1986)
[6] (Miller and Miller, 1999)
[7] (Brown and Pezeshki, 2000)
[8] (Barrilleaux and Grace, 2000)

Appendix B

Species observed within the study plots.

Trees							
Scientific name	**Common name**	**Native or Invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or Evergreen**	**Wildlife value**	**Drought Tolerance**
Acer rubrum	Red maple	Native	FACW [4]	4	Deciduous	Deer browse [3]	Medium [1,3]
Betula nigra	River birch	Native	FACW [4]	4	Deciduous	Bird seed and deer browse [3]	Low [1]
Carpinus caroliniana	American hornbeam	Native	FAC [1,4]	3	Deciduous	Seeds eaten by birds and mammals as well as browse for deer [3]	Low [1]
Carya aquatica	Water hickory	Native	OBL [1,4]	5	Deciduous	Nuts of limited use to squirrels and hogs [3]	Medium [1]
Carya cordiformis	Bitternut hickory	Native	FAC [4]	3	Deciduous	Birds and mammals eat nuts [3]	High [1]
Carya illinoinensis	Pecan	Native	FAC+ [4]	3.5	Deciduous	Pecan nuts eaten by birds, squirrels, opossums, raccoons and hogs [3]	Low [1]
Carya leiodermis	Swamp Hickory	Native					
Carya sp							
Carya texana	Black Hickory	Native					
Celtis laevigata	Sugarberry	Native	FAC [4]	3	Deciduous	Fruit eaten by 10 species of birds and others [3]	Low [1]
Celtis occidentalis	Hackberry	Native	FAC [4]	3	Deciduous	Fruit and seeds eaten by small mammals and birds [3]	High [1]
Cornus foemina	Stiff Dogwood	Native	FACW-		Deciduous		Low [1]
Crataegus mollis	Downy Hawthorn	Native	FAC		Deciduous	Medium preference browse for deer, fruit not eaten extensively. Hawthorn thickets can provide excellent nesting habitats [6]	
Diospyros virginiana	Persimmon	Native	FAC [4,5]	3	Deciduous	Fruit eaten by many mammals and birds [3]	Medium [1]
Fagus grandifolia	American beech	Native	FACU [4]	2	Deciduous	Nuts and mast palatable to birds, and mammals including black bear, squirrels and deer [3]	High [1]

Scientific name	Common name	Native or Invasive	Wetland indicator	Wetland indicator ranking	Deciduous or Evergreen	Wildlife value	Drought Tolerance
Frangula caroliniana	Carolina buckthorn	Native	FACU [4]	2	Deciduous	very little wildlife use [6]	Low [1]
Fraxinus americana	White Ash		FACU		Deciduous	seeds eaten by many bird species [3]	Low [1]
Fraxinus caroliniana	Carolina ash	Native	OBL [4]	5	Deciduous		Low [1]
Fraxinus pennsylvanica	Green ash	Native	FACW [4]	4	Deciduous	Seeds eaten by birds and mammals [3]	Medium [1]
Ilex decidua	Possumhaw Holly	Native	FACW-		Deciduous		Medium [1]
Ilex opaca	American Holly	Native	FAC-		Evergreen	deer, squirrels, and other mammals, as well as 18 species of birds eat the fruit [3]	High [1]
Ilex vomitoria	Yaupon	Native	FAC		Evergreen	fruits eaten by several bird and mammal species and foliage is important browse for deer [6]	High [1]
Liquidambar styraciflua	Sweetgum	Native	FAC+ [4]	3.5	Deciduous	seeds eaten by wildlife [3]	Low [1]
Melia azedarach	China Berry	Invasive			Evergreen	seeds are a minor portion of bird diets [1]	High [1]
Nyssa aquatica	Water tupelo	Native	OBL [4]	5	Deciduous	many kinds of wildlife eat fruit [3]	None [1,3]
Nyssa biflora	Swamp Black Tupelo	Native	OBL [4]		Deciduous		None [1]
Nyssa sylvatica	Blackgum	Native	FAC [4]	3	Deciduous	fruit and sprouts important for birds and mammals and cavities make good den tree [3]	Low [1]
Ostrya virginiana	Hop-hornbeam	Native	FACU-		Deciduous	preferred food for bobwhite, grouse, turkey, and other bird species, as well as squirrels and deer [3]	Medium [1]
Planera aquatica	Planar tree	Native	OBL [4]	5	Deciduous		Low [1]
Platanus occidentalis	Sycamore	Native	FACW [4]	4	Deciduous	seeds eaten by several bird species [3]	Low [1]
Quercus alba	White oak	Native	FACU [4]	2	Deciduous	acorns inconsistent source of food for squirrels and many birds, browse for deer [3]	Medium [1]
Quercus laurifolia	Laurel oak	Native	FACW [4]	4	Deciduous	several birds, deer, squirrels, raccoons eat acorns [3]	Low [1]

Scientific name	Common name	Native or Invasive	Wetland indicator	Wetland indicator ranking	Deciduous or Evergreen	Wildlife value	Drought Tolerance
Quercus lyrata	Overcup oak	Native	OBL [4]	5	Deciduous	provide habitat and acorns for wildlife [3]	None [1,3]
Quercus michauxii	Swamp chestnut oak	Native	FACW- [4]	3.5	Deciduous	acorns food for birds and mammals [3]	Low [1]
Quercus nigra	Water oak	Native	FAC [4]	3	Deciduous	good wildlife habitat [3]	Low [1]
Quercus phellos	Willow oak	Native	FACW- [4]	3.5	Deciduous	Large acorn production for wildlife [3]	None [1]
Quercus similis	Bottomland post oak	Native	FACW [4]	4	Deciduous		
Sapium sebiferum	Chinese tallow	Invasive	FAC [4]	3	Deciduous	seeds eaten by birds	High [8]
Sassafras albidum	Sassfras	Native	FACU [4]	2	Deciduous	bark, twigs, and leaves good food for wildlife [3]	High [1]
Taxodium distichum	Bald cypress	Native	OBL [4]	5	Deciduous	seeds eaten by turkeys, squirrels, grosbeaks, wood ducks and other waterfowl and wading birds, provide excellent nesting for birds [3]	Low [1,3]
Ulmus americana	American elm	Native	FACW [4]	4	Deciduous	squirrels and birds eat seeds [3]	Medium [1,3]
Ulmus crassifolia	Cedar elm	Native	FAC [4]	3	Deciduous	seeds are eaten by birds [3]	Medium [1]
Ulmus rubra	Slippery elm	Native	FAC [4]	3	Deciduous	seeds minor source of food [3]	Medium [1]
Shrub/Sapling Species							
Scientific name	**Common name**	**Native or Invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or Evergreen**	**Wildlife value**	**Drought Tolerance**
Acer rubrum	Red maple	Native	FACW [4]	4	Deciduous	Deer browse [3]	Medium [1,3]
Betula nigra	River birch	Native	FACW [4]	4	Deciduous	Bird seed and deer browse [3]	Low [1]
Callicarpa americana	American beautyberry	Native	FACU- [4]	1.5	Deciduous	Fruit eaten by 40 species of birds, as well as deer and small mammals. Medium preference browse for deer [6]	High [1]
Carpinus caroliniana	American hornbeam	Native	FAC [1,4]	3	Deciduous	Seeds eaten by birds and mammals as well as browse for deer [3]	Low [1]
Carya sp							
Cephalanthus occidentalis	Common buttonbush	Native	OBL [4]	5	Deciduous	low browse preference for deer, many bird and butterfly species	Medium [1]

						feed on seeds and nectar [6]	
Scientific name	**Common name**	**Native or Invasive**	**Wetland indicator**	**Wetland indicator ranking**	**Deciduous or Evergreen**	**Wildlife value**	**Drought Tolerance**
Diospyros virginiana	Persimmon	Native	FAC [4,5]	3	Deciduous	Fruit eaten by many mammals and birds [3]	Medium [1]
Frangula caroliniana	Carolina Buckthorn	Native	FACU			very little wildlife use [6]	Low [1]
Ilex decidua	Possumhaw holly	Native	FACW- [4]	3.5	Deciduous		Medium [1]
Ilex opaca	American holly	Native	FAC- [4]	2.5	Evergreen	deer, squirrels, and other mammals, as well as 18 species of birds eat the fruit [3]	High [1]
Ilex vomitoria	Yaupon	Native	FAC [4]	3	Evergreen	fruits eaten by several bird and mammal species and foliage is important browse for deer [6]	High [1]
Liquidambar styraciflua	Sweetgum	Native	FAC+ [4]	3.5	Deciduous	seeds eaten by wildlife [3]	Low [1]
Ostrya virginiana	Hophornbeam	Native	FACU- [4]	1.5	Deciduous	preferred food for bobwhite, grouse, turkey, and other bird species, as well as squirrels and deer [3]	Medium [1]
Planera aquatica	Planar tree	Native	OBL [4]	5	Deciduous		Low [1]
Platanus occidentalis	Sycamore	Native	FACW [4]	4	Deciduous	seeds eaten by several bird species [3]	Low [1]
Quercus nigra	Water oak	Native	FAC [4]	3	Deciduous	good wildlife habitat [3]	Low [1]
Quercus pagoda	Cherrybark oak	Native	FAC+ [4]	3.5	Deciduous	several birds, deer, squirrels, raccoons eat acorns [3]	Low [1]
Quercus phellos	Willow oak	Native	FACW- [4]	3.5	Deciduous	Large acorn production for wildlife [3]	None [1]
Sabal minor	Dwarf palmetto	Native	FACW [4]	4	Evergreen	fruits eaten by several songbirds and small mammals [6]	None [1]
Sapium sebiferum	Chinese tallow	Invasive	FAC [4]	3	Deciduous	seeds eaten by birds	High [8]
Taxodium distichum	Bald cypress	Native	OBL [4]	5	Deciduous	seeds eaten by turkeys, squirrels, grosbeaks, wood ducks and other waterfowl and wading birds, provide excellent nesting for birds [3]	Low [1,3]
Ulmus crassifolia	Cedar elm	Native	FAC [4]	3	Deciduous	seeds are eaten by birds [3]	Medium [1]

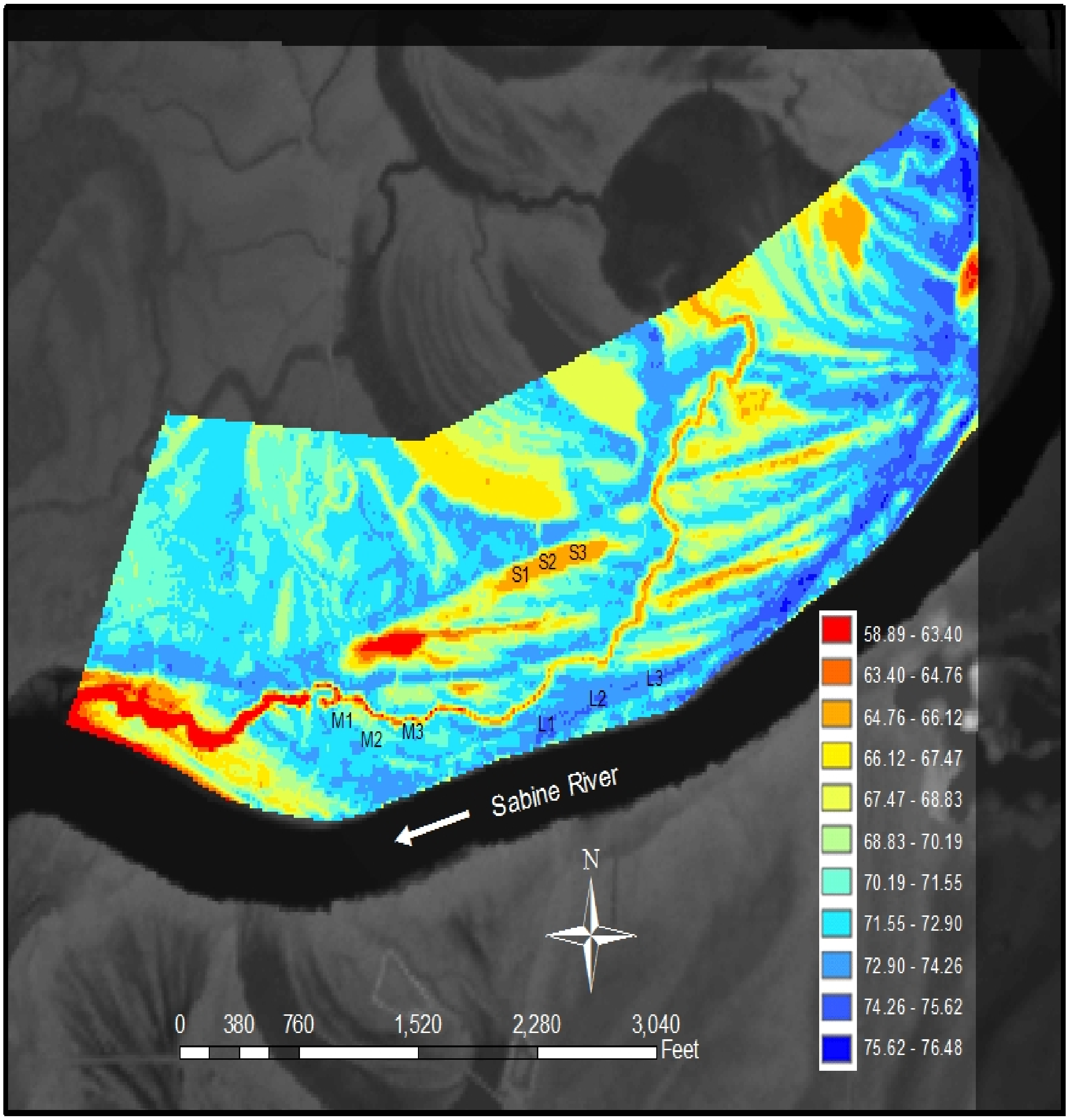
Scientific name	Common name	Native or Invasive	Wetland indicator	Wetland indicator ranking	Deciduous or Evergreen	Wildlife value	Drought Tolerance
Viburnum dentatum	Southern arrowwood	Native	FAC [4]	3	Deciduous	minor portion of diet for birds and mammals [1,6]	

Herbaceous Species

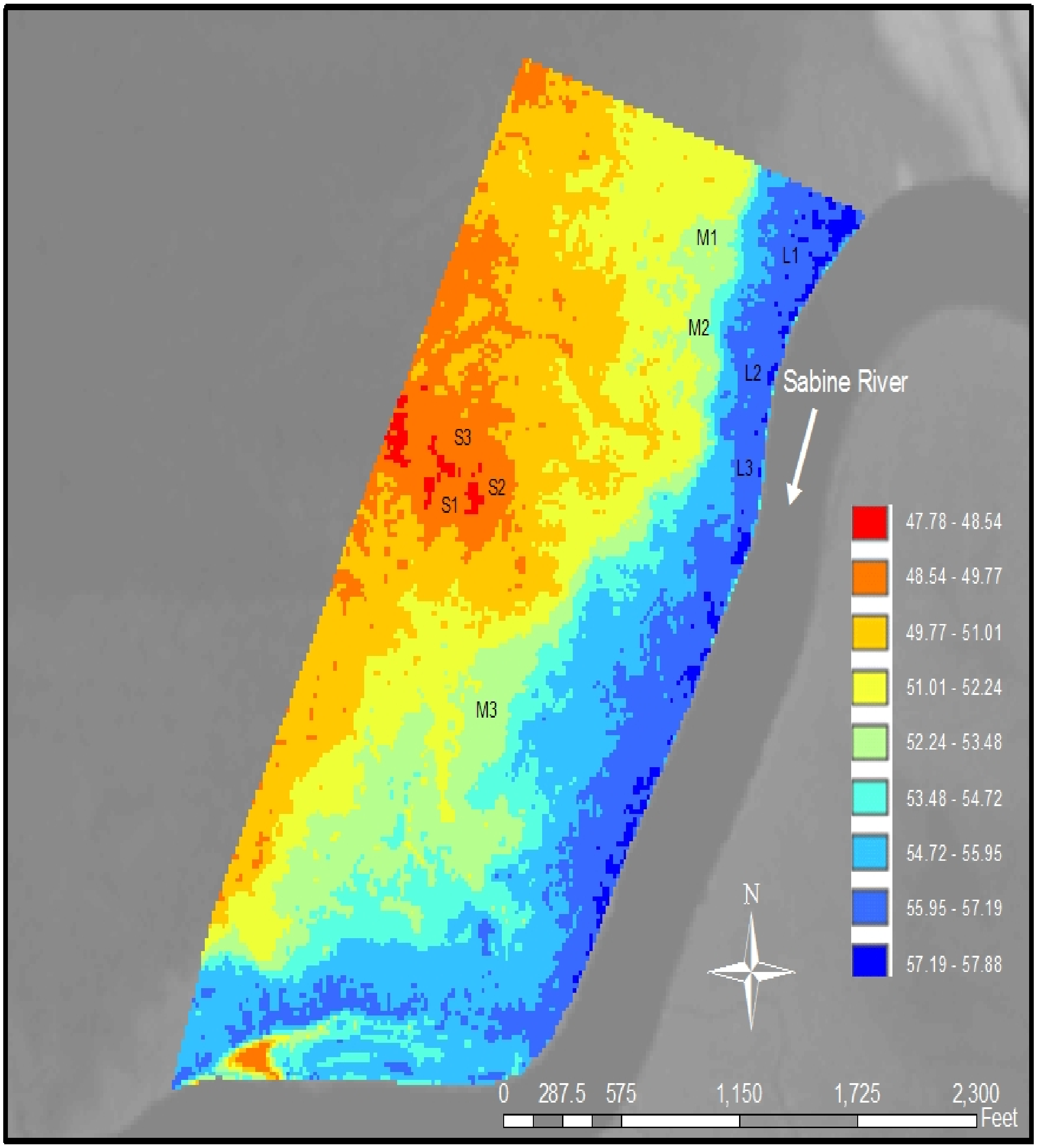
Scientific name	Common name	Native or invasive	Wetland indicator	Wetland indicator ranking	Growth Habit	Duration	Drought Tolerance
Brunnichia ovata	American buckwheat vine	Native	FACW [4]	4	Vine	Perennial	
Campsis radicans	Trumpet creeper	Native	FAC [4]	3	Vine	Perennial	High [1]
Carex intumescens	Greater Bladder Sedge	Native	FACW [4]	4	Graminoid	Perennial	None [1]
Onoclea sensibilis	Sensitive fern	Native	FACW [4]	4	Forb/herb	Perennial	
Phanopyrum gymnocarpon	Savannah Panic-grass	Native	OBL [4]	5	Graminoid	Perennial	
Polygonum sp.							
Quercus michauxii	Swamp chestnut oak	Native	FACW- [4]	3.5	Tree	Perennial	Low [1]
Quercus similis	Bottomland post oak	Native	FACW [4]	4	Tree	Perennial	
Rhynchospora cf inundata	Narrow-fruit Horned Beaksedge	Native	OBL [4]	5	Graminoid	Perennial	
Rhynchospora corniculata	Shortbristle Horned Beaksedge	Native	OBL [4]	5	Graminoid	Perennial	Medium [1]
Sapium sebiferum	Chinese tallow	Invasive	FAC [4]	3	Tree	Perennial	High [8]
Smilax auriculata	Earleaf Greenbriar	Native	FACU [4]	2	Shrub, Vine	Perennial	
Smilax bona-nox	Saw greenbriar	Native	FAC [4]	3	Shrub, Vine	Perennial	Medium [1]
Smilax glauca	Cat Greenbriar	Native	FAC [4]	3	Shrub, Vine	Perennial	Medium [1]
Smilax rotundifolia	Roundleaf greenbriar	Native	FAC [4]	3	Shrub, Vine	Perennial	Medium [1]
Sorghum halepense	Johnsongrass	Invasive	FACU [4]	2	Graminoid	Perennial	Low [1]
Toxicodendron radicans	Eastern poison ivy	Native	FAC [4]	3	Shrub, Forb/herb, Vine	Perennial	
Vitis cinerea	Graybark Grape	Native	FAC+ [4]	3.5	Vine	Perennial	High [1]
Vitis rotundifolia	Muscadine	Native	FAC [4]	3	Vine	Perennial	Medium [1]

[1] (USDA & NRCS, 2010)
[2] (Hook, 1984)
[3] (Burns and Honkala, 1990)
[4] (US Fish and Wildlife Service, 1996)
[5] (Ortego, 1986)
[6] (Miller and Miller, 1999)
[8] (Barrilleaux and Grace, 2000)

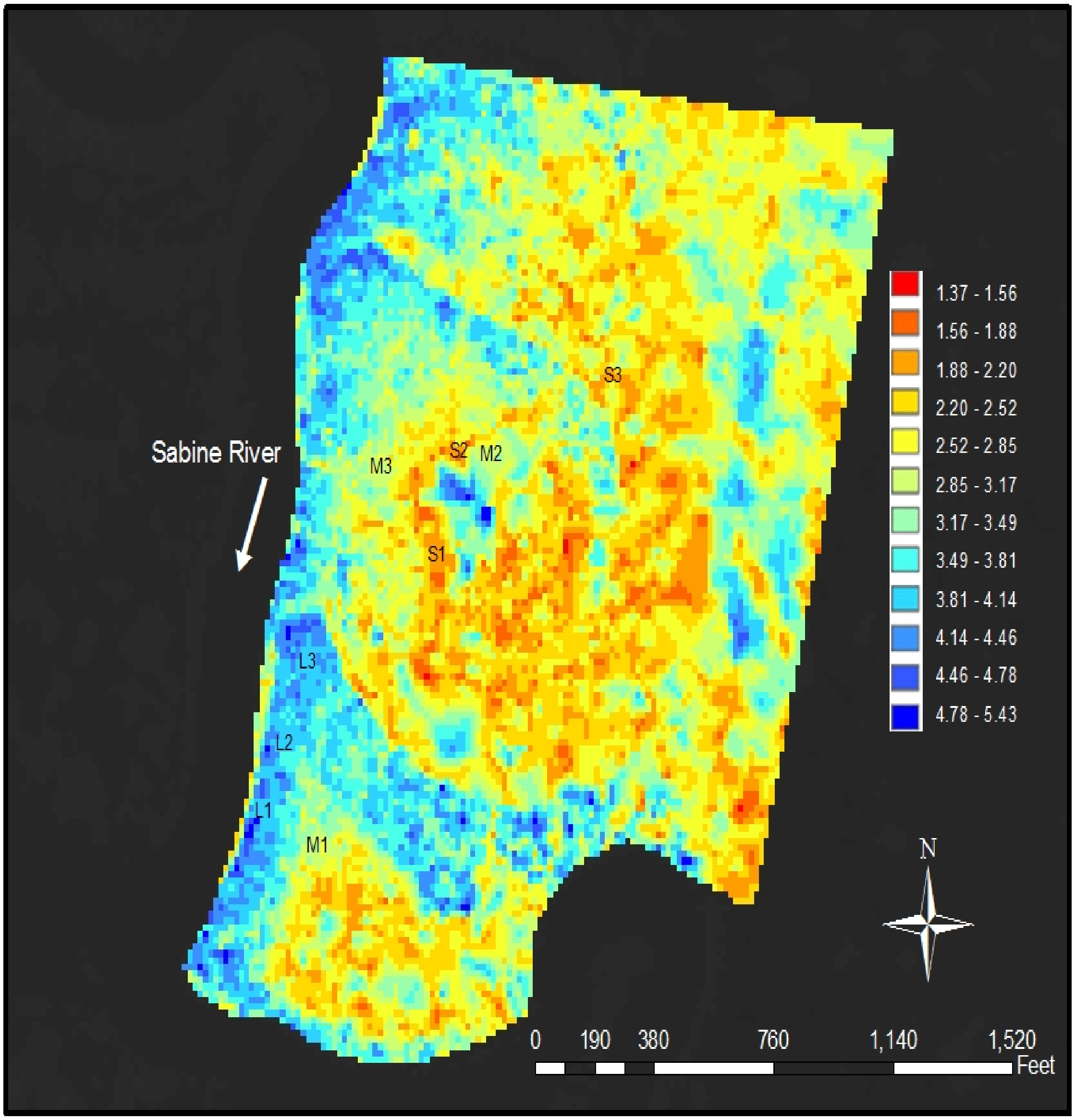
Appendix C



Anacoco Bayou site elevation map. Red indicates areas of lowest elevation. Blue indicates areas of highest elevation. Scale is in feet above sea level.



Big Cow Creek site elevation map. Red indicates areas of lowest elevation. Blue indicates areas of highest elevation. Scale is in feet above sea level.



Sabine Island site elevation map. Red indicates areas of lowest elevation. Blue indicates areas of highest elevation. Scale is in feet above sea level.

Appendix D

Elevations (in feet above sea level) and relative elevations (in feet) for each plot.

Site	Plot	Plot #	Elevation (ft)	Relative Elevation (ft)
Big Cow Creek	Levee	1	57.12	8.46
Big Cow Creek	Levee	2	56.6	7.94
Big Cow Creek	Levee	3	56.22	7.56
Big Cow Creek	Mid-Floodplain	1	52.45	3.79
Big Cow Creek	Mid-Floodplain	2	53.16	4.5
Big Cow Creek	Mid-Floodplain	3	52.5	3.84
Big Cow Creek	Slough	1	49.57	0.91
Big Cow Creek	Slough	2	48.94	0.28
Big Cow Creek	Slough	3	48.66	0
Sabine Island	Levee	1	4.12	2.07
Sabine Island	Levee	2	3.83	1.78
Sabine Island	Levee	3	4.09	2.04
Sabine Island	Mid-Floodplain	1	3.16	1.11
Sabine Island	Mid-Floodplain	2	2.77	0.72
Sabine Island	Mid-Floodplain	3	3	0.95
Sabine Island	Slough	1	2.1	0.05
Sabine Island	Slough	2	2.05	0
Sabine Island	Slough	3	2.49	0.44
Anacoco Bayou	Levee	1	74.33	8.78
Anacoco Bayou	Levee	2	74.88	9.33
Anacoco Bayou	Levee	3	74.36	8.81
Anacoco Bayou	Mid-Floodplain	1	70.31	4.76
Anacoco Bayou	Mid-Floodplain	2	71.09	5.54
Anacoco Bayou	Mid-Floodplain	3	71.07	5.52
Anacoco Bayou	Slough	1	65.77	0.22
Anacoco Bayou	Slough	2	65.56	0.01
Anacoco Bayou	Slough	3	65.55	0