Remnant Bottomland Forests near the Terminus of the Mississippi River in Southeastern Louisiana

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ABSTRACT

The woody communities of seven of the most intact bottomland hardwood forests of southeastern Louisiana are described. The seven forests are on old levee ridges associated with past distributaries of the Mississippi River. The communities were divided by diameter size class into overstory (≥10.0 cm dbh) and understory (3.0 cm ≥ 10.0 cm dbh). The overstory (27 species) and understory (24 species) shared 18 species out of a total of 33. The understory stratum in these forests was not as uniform as the overstory across the forests in both dominants and subdominants. The forests were divided into two groups based upon size and abundance of two dominant overstory trees, live oak (*Quercus virginiana*) and sugarberry (*Celtis laevigata*). Other important overstory taxa were water oak (*Quercus nigra*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and elm (*Ulmus* spp.). The average total overstory density for the forests was 358.5 stems/ha and the average total overstory basal area was 30.5 m^2/ha. The effect of microtopography, with its impact on hydroperiod, along and across the levee ridges was likely the principal variable impacting species dominance and diversity across the forests. These forests are under severe threat and conservation of those still remaining is a priority.

INTRODUCTION

Fifty years ago, Penfound (1952) wrote of the many human activities impacting "southern swamps." Bottomland hardwood forests have been disappearing largely because of human demands for agricultural or municipal land, while some are still cut for timber. Loss of bottomland hardwoods in the Mississippi River drainage is particularly severe due to agricultural conversion (Mitsch and Gosselink 1993, Gosselink et al. 19901, with less than one third of the original forested lands in some stage of regrowth. More than half of the alluvial-forested lands within the Mississippi River drainage occurred in Louisiana, but more than 62% of the state's forested wetlands had been cleared by 1991 (Vissage et al. 1992).

The earliest quantitative study on Mississippi alluvial lands was conducted in a "southern floodplain forest," sensu Braun (1950), near the terminus of the Mississippi River (Penfound and Howard 1940). Their "evergreen oak" forest grew on an old natural levee along one of the distributaries of a former delta complex located 10 km east of New Orleans. The forest has since been cut and the land on which it grew now supports homes and shopping centers. Recently, Devall (1990) documented the relatively intact woody community growing in an active floodplain still contiguous with the main channel of the Mississippi River about 280 km by river upstream from New Orleans.

A growing conservation interest in both forested and herbaceous wetlands, brought about by threats from development in the 1970's–80's, resulted in the largest two tracts of undeveloped land around New Orleans being protected through federal purchase creating Bayou Sauvage National Wildlife Refuge and Jean Lafitte National Historical Park. Portions of these protected lands still support forests on remnant natural levees, similar to those studied by Penfound and Howard (1940). The idea for the current study developed while conducting a plant inventory of the communities in Jean Lafitte National Historical Park White et al. 1983). The principal objective of this study was to describe the primary structure and species composition of the area's oldest forest vegetation before more of it is destroyed by human activity.

Study Area and Sites

The general study area is located in southeastern Louisiana where the southernmost Mississippi River bottomland forests grow. Over the past 6,000 years the Mississippi River has changed course several times building a succession of deltas that created the east to central coastal lands of the State (Neil1 and Deegan 1986). The region of this study, around and south of New Orleans, is a complicated mosaic of vegetated lands of elevations ranging from about 2 m to below mean sea level. The elevated lands of the region are natural levees of different vintages created by the once-changing meanders of the Mississippi River. It is on the highest of these levees that the forests of this study grow.

To select the sites for study, aerial infrared photography, covering all forested lands from New Orleans south to the mouth of the Mississippi River, was studied then ground-truthed for the oldest and least disturbed forests. Knowledgeable local people were consulted, when necessary, to corroborate the locations of the least disturbed forests of a particular area. Only seven forest sites were found, that in whole or part, could be labeled older-growth-Sauvage, Airline, Lafitte, Oak, Verret, Hermit, and Jackson (Figure 1). From the size of trees, forest structure, and local knowledge, it seems likely that these forests became established by the turn of the last century on abandoned plantation land or on variously disturbed land near plantations.

Five of the forests (Lafitte, Oak, Verret, Hermit, and Sauvage) are located on the original levees along former distributaries (Bayou des Familles, River aux Chenes, Bayou Terre aux Beouf, Bayou Grand Chenier, and Bayou Sauvage, respectively) of the past river deltas. The remaining two forests (Jackson and Airline) are on lands built by the river while in its present position but before construction of flood-protection levees during the first half of this century.

The Oak, Verret, Hermit, and Sauvage forests are strips from 0.5 to several km long (depending on disturbances) and from about 100-300 m wide on or near the original narrow crowns of the levees adjacent to the associated abandoned distributaries. The Jackson and Lafitte forests grow on wider levees (up to about 1 km). The Jackson forest site is a remnant intact strip about 300 m by 800 m, while the Lafitte forest is part of a larger more extensive bottomland hardwood region within Jean Lafitte National Historical Park near the forests described by White et al. (1983). The Airline forest (since cut) was a remnant patch, about 300 m $\times$ 500 m, within the greater New Orleans metropolitan area and it was growing on relatively elevated ground originally $<$ 2 m above mean sea level.

The Jackson forest, located 80 km south of New Orleans and 10 km upstream from the marshlands at river mile 0.0, is the southmost intact bottomland levee forest remaining within the Mississippi River drainage. The Sauvage forest is located within Bayou Sauvage National Wildlife Refuge and the vegetational gradients in the region recently have been described (Wall and Darwin 1999). The Jackson forest is under some protection by the local government. Since they were surveyed, the Verret and Airline forests have been cut because of development.

Three of the forests (Oak, Hermit, and Sauvage) lack the shallow furrows dug to drain the extensive sugarcane fields of the 1800's, suggesting less hydrologic disturbance. In addition, unlike the other forests, the Oak and Hermit sites have always been outside the flood-protection levee system of the region. Therefore, they are the last regional forest sites that can receive natural flooding from storm tides.

The seven forests grow on either levee or swamp soils of southern Mississippi Valley alluvium (Garofolo 1982). Levee soils of the Commerce-Sharkey Association support five of the forests-Lafitte, Oak, Verret, Jackson, and Hermit. These soils are level to nearly level, poorly to somewhat poorly drained, and range from higher and more loamy (Commerce) to lower and more clayey (Sharkey). According to detailed soil maps (Garofolo 1982), the Airline and Sauvage forests are down-gradient from these Commerce-Sharkey soils near the boundary with the more

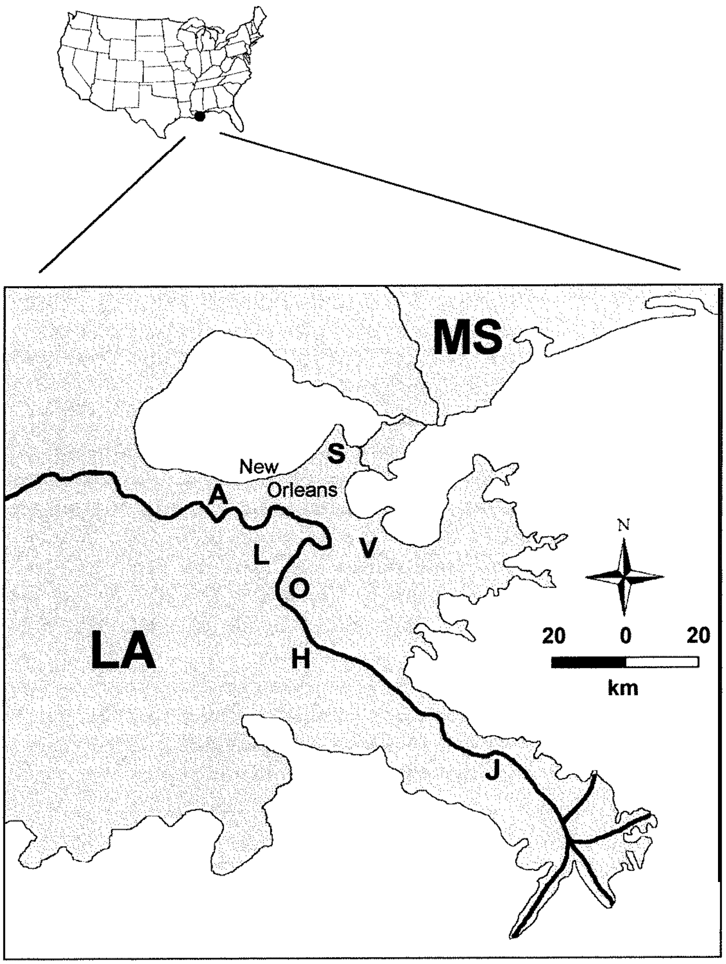

Figure 1. Study region and location of seven bottomland hardwood forests on natural levees along the Mississippi River in southeastern Louisiana. Forest site abbreviations: A = Airline; H = Hermit; J = Jackson; L = Lafitte; 0 = Oak; S = Sauvage; V = Verret.

hydric swamp soils that typically can support forests of *Taxodium distichum* (L.) Richard (baldcypress) and *Nyssa aquatica* L. (water tupelo). The Airline forest site has more clayey mineral soils of the Haplaquepts Drained Association, whereas the Sauvage forest site contains more organic mineral soils of the Maurepas-Hydraquents Association.

The climate of the region is strongly influenced by moist semi-tropical air from the Gulf of Mexico, especially during the summer. This influence is particularly striking during the winter months when periods of semi-tropical air alternate with northern cold continental air. Regionally, the mean annual precipitation (rain) is approximately 150 cm; July is the wettest month (about 20 cm) and October is the driest month (about 8 cm). In New Orleans the mean annual temperature is 19.9°C, ranging from a January mean of 12.2°C to a July mean of 27.3°C (Ruffner 1980). There are slight annual climate differences across the 40 km latitudinal range of the study sites. Due primarily to the maritime influence of the Gulf of Mexico, mean annual precipitation differs over this range by up to 10 cm (Garofolo 1982), being, on average, wetter towards the south. The average number of days of freezing temperature or below is 4 per year for the forests in the immediate New Orleans area to about 2 days in 7 years for the region of the Jackson forest near the mouth of the Mississippi River (adapted from Ruffncr 1980).

METHODS

Vegetation

During the period 1983-96, the quadrat sampling technique (Cox 1996) was used to sample the woody vegetation in the seven forests. A total of 86-20 m X 30 m quadrats was delineated with rope and compass. The number of quadrats sampled in each forest was usually 12, although 10 quadrats were used at the Jackson forest because of its shape and small size and 16 quadrats were used at the Verret forest because of its larger size. Quadrats were established long-axis parallel to the original levee's long axis and separated by 50 paces (about 50 m) along transects aligned perpendicular to the original levee's long-axis. Transects were separated by 50 paces and most transects extended entirely over the attenuated crown of the natural levee of each forest avoiding any noticeable elevation gradient. Each transect consisted of four quadrats except at the Jackson forest where two transects of five quadrats each were sampled. Within each quadrat, woody stems greater than or equal to 3.0 cm diameter at breast height (dbh) were recorded by species and diameter. From these data two size classes were separated: "understory" (stems 3.0-9.9 cm dbh) and overstory (dbh $\geq$ 10.0 cm). Importance values for each species in each of the size classes were calculated based upon the sum of relative density and relative basal area.

For each forest, a Shannon Diversity (H′) value was determined for the overstory component using the formula; $H' = \log N - 1/N\ \Sigma n_i \log n_i$, where n_i = the number of individuals of each species and N = total stems of all species for the site (Cox 1996). Some valuable comparative information could be obtained using the Shannon index even though the total areas sampled in two of the forests (Verret, Jackson) were not the same as those in the other five forests. The total number of species encountered in all the quadrats at a forest was used as a comparative index of species richness (sensu Cox 1996). Nomenclature follows Radford et al. (1968). Three taxa [*Ulmus, Fraxinus,* and Carya other than *C. illinoensis* (Wang.) K. Koch] were particularly difficult to distinguish to the level of species when immature or sterile and, therefore, were recorded at the genus level. It is worth noting that for two of these taxa, one species appears to be more common (*Ulmus americana* L., American elm, and *Fraxinus americana* L., white ash) in these forests even though *U. rubra* Muhl. and *F. pennsylvanica* Marshall were also found.

Soils

All the forests but Airline were on prominent natural levee crowns (ridges). There was no evidence of the ridge and swale topography so impacting on stands of vegetation common to many southern bottomland forests. Because of this uncomplicated topography it seemed worthwhile to obtain minimal information on the soils in these alluvial forests. Two soil samples were taken from the middle of each forest site on a single day in May 1997 and in January 1998. Each sample was tested for moisture content, amount of organic material, pH and grain-sizes. The amount of water was determined by percent weight loss upon air-drying and the amount of organic material was determined by percent weight loss on ignition (LOI). The pH was read from a digital bench-top meter in a half-soil and half-water by weight solution. The grain-size analysis was run on a 25 g sample using a standard sedimentation procedure (Barnes 1959).

RESULTS

Overstory

Twenty-seven taxa were identified in the overstory of the forests in the seven bottomland hardwood swamp sites. The forests had a range in richness of 8-14 overstory species (Table 1). *Quercus virginiana* Miller (live oak), *Celtis laevigata* Willd. (sugarberry), *Quercus nigra* L. (water oak), *Liyuidambar styraciflua* L. (sweetgum), *Ulmus* spp. (elm), *Acer rubrum* L. (red maple), and *Fraxinus* spp. (ash) were the seven taxa with the highest average importance value in the forests (Table 2). These ubiquitous taxa were found in all but two forests (live oak was not found in the Airline forest, ash was not found in the Verret forest) and they contributed a total

Table 1. Diversity and soil variable means (n = 2) at seven bottomland hardwood forests in southeastern Louisiana. LO1 = loss on ignition. Soil association types (see text for details): AC = Commerce-Sharkey; AP = Maurepas-Hydraquents; AR = Haplaquepts, Drained

	Forests						
	Lafitte	Oak	Verret	Jackson	Airline	Hermit	Sauvage
Diversity							
Quadrat (.06 ha) number	12	12	16	10	12	12	72
Shannon Overstory Diversity	1.173	0.587	0.834	0.802	0.919	0.789	0.650
Overstory Richness	12	8	12	11	14	11	11
Understory Richness	12	10	72	10	19	9	13
Soils							
Association Type							
pH	AC	AC	AC	AC	AR/AC	AC	AP/AC
Moisture (%)	5.79	6.55	7.31	6.12	7.40	6.11	6.16
Organic Material (LOI; %)	21.0	27.0	26.0	25.5	22.5	21.0	25.5
Clay (<0.002 mm; %)	7.5	12.5	14.5	13.0	15.0	12.0	13.0
Silt (0.02-0.002 mm; %)	25.0	35.0	35.0	30.2	40.7	32.0	27.5
Fine Sand (0.2–0.02 mm; %)	18.0	39.0	34.0	38.8	24.5	30.0	37.0
Coarse Sand (2.0–0.2 mm;	48.1	18.7	15.3	18.1	21.2	25.8	23.4
%)	0.3	0.9	1.0	0.4	1.4	0.2	0.7

Table 2. Importance values (IV) for overstory (dbh ≥ 10.0 cm) taxa in seven bottomland hardwood forests in southeastern Louisiana. To be included, each taxon had a combined importance value across all forests of ≥ 5.0. Importance value = relative density + relative dominance. Bold face numbers (vertically) indicate the three taxa in each forest with the highest importance values; superscripts indicate their ranking. "Other includes 10 minor taxa; see text

	Forests							
	Quercus virginiana (Live Oak)-Dominated				*Celtis laevigata* (Sugarberry)-Dominated			
Taxa	Lafitte	Oak	Verret	Jackson	Airline	Hermit	Sauvage	Mean IV
Quercus virginiana Miller	**43.0**[1]	58.7'	67.0'	88.1'	—	17.6	46.0"	45.7
Celtis laevigata Willd.	20.5	10.6	24.1:'	19.7	56.8'	58.9'	107.4'	42.6
Ulmus spp.	21.9	28.9:'	17.5	29.9:'	24.9:'	44.1'	14.2"	25.9
Quercus nigra L.	**33.7**[2]	3.0	3.6	39.72	30.1"	22.5	10.7	20.5
Acer rubrum L.	**25.0**[3]	72.6'	10.0	3.7	21.5	3.8	0.4	19.6
Liquidambar styraciflua L.	10.9	21.2	56.9'	1.6	0.6	33.5"	6.1	18.7
Fraxinus spp.	5.8	3.5	—	5.8	24.2	15.5	1.2	8.0
Acer negundo L.	17.0		—	—	17.6	0.6	—	5.0
Quercus laurifolia Michx.	—	—	9.5	—	11.8	—	—	3.0
Persea palustris (Raf.) Sarg.	—	—	—	8.6	—	2.3	—	1.6
Sapium sebiferum (L.) Roxb.	—	—			3.7	—	4.6	1.2
Gleditsia triacanthos L.	—	—		—	—	—	5.8	0.8
Carya illinoensis (Wang.) K. Koch	—	—	5.9	—	—	—	—	0.8
Carya spp.	—	—	3.9	—	1.7	—	—	0.8
Taxodium distichum (L.) Richard	1.3	—	—	—	3.7	—	—	0.7
Carpinus caroliniana Walter	19.7	—			—	—	—	0.4
Quercus lyrata Walter	0.7	1.7		—	—	—	—	0.3
*Other	0.5	—	1.6	3.0	3.2	1.1	3.6	2.4

181.1 importance value (IV) out of the possible 200.0 total (90.6%). The forests were grouped into those dominated by live oak (Lafitte, Oak, Verret, Jackson; live oak mean IV = 64.2) or sugarberry (Airline, Hermit, Sauvage; sugarberry mean IV = 74.4). Four of these seven taxa (elm, water oak, red maple, sweetgum) can be called secondarily important species (mean IVs = 25.9, 20.5, 19.6, 18.7, respectively) and they appear to be equally associated with both the live oak and sugarberry-dominated forests. Another tree species, *Acer negundo* L. (boxelder), had relatively high importance values in two of the seven forests (Airline and Verret).

In addition to the taxa in Table 2, ten overstory species with low importance values were found in one or two forests and, therefore, were considered to be scarce overstory components. These ten species were, *Diospyros virginiana* L. (persimmon), *Myrica cerifera* L. (wax myrtle), *Cornus drummondii* C.A. Meyer (swamp dogwood), *Morus rubra* L. (red mulberry), *Nyssa aquatica* (water tupelo), *Populus deltoides* Marshall (cottonwood), *Cinnamomum camphora* (L.) Presl. (the introduced camphor tree), *Magnolia virginiana* L. (sweetbay), *Crataegus viridis* L. (green hawthorn), and C. *marshallii* Eggl. (parsley hawthorn). Three of these ten species were important in the understory (*D. uirginiana, C. uiridis, C. drummondii).* It is also worth noting that *Sapium sebiferum* (L.) Roxb., Chinese tallowtree, an extremely invasive non-native species in the local forests, was found in two of the sugarberry-dominated forests. The species was also common near most of the other forests.

Six of the seven ubiquitous and important overstory taxa (live oak, sugarberry, water oak, sweetgum, elm, red maple) contributed a combined 84% to the average of the total density (358.5 stems/ha) in the seven forests (Table 3). The Hermit forest had the lowest density in the overstory (275.0 stems/ha). The Oak and Sauvage forests had densities considerably above the values for the other forests (449.6 and 425.2 stems/ha, respectively). In each of these two forests, small diameter stems of a single species (red maple in the Oak forest; sugarberry in the Sauvage forest) contributed to more than half of the total density. On average, sugarberry was the most commonly occurring tree in the seven forests (79.0 stems/ha), with elms (60.2 stems/ha), red maple (57.9 stems/ha), and live oak (41.2 stems/ha) common. Water oak (30.9 stems/ha) and sweetgum (30.7 stems/ha) were also relatively abundant. Ashes were prevalent in most forests, too, but they were not as commonly encountered (13.8 stems/ha) as the other six species.

The seven ubiquitous taxa had a total 28.4 m^2/ha basal area or 93% of the average total (30.5 m^2/ha) in the forests (Table 3). Live oak contributed 35.1% (10.7 m^2/ha average) to this total forest basal area. Its large average size (56.7 cm dbh), high density, and characteristic low sprawling shape were striking, even in those forests in which it did not dominate. Its size was particularly noticeable compared to the much smaller average stem size (29.1 cm dbh) of the other six ubiquitous taxa. Sugarberry had the second largest average basal area (6.4 m^2/ha) in the forests, followed by water oak (3.5 m^2/ha), sweetgum (2.9 m^2/ha), and the elms (2.5 m^2/ha).

Understory

Twenty-four taxa were identified in the forests as understory components (3.0–9.9 cm dbh); 18 of these were also found in the overstory. In contrast to the classification by overstory, the seven forests were not divisible into groups using the understory taxa. Table 4 presents the Importance Values for the 16 most important taxa. Seven of these taxa (red maple, sugarberry, elm, water oak, sweet gum, green hawthorn, and ash) were found in all but two forests and made up 74.8% of the total IV. Six of these seven important understory taxa were also the most important taxa in the overstory. Live oak was missing from the understory in three (Oak, Airline, Hermit) of the seven forests, and yet it was found in the overstory of two of these forests (Oak and Hermit). Green hawthorn, an important understory species, is a small tree that seldom reaches the canopy. The eight species recorded as “Other” in the understory (Table 4) were *Quercus lyrata* Walter (overcup oak), red mulberry, wax myrtle, *Prunus serotina* Ehrhart (black cherry), *Viburnum dentatum* L. (arrowwood), the introduced *Poncirus trifoliata* (L.) Raf. (trifoliate orange), *Ilex decidua* Walter (deciduous holly), and *Bumelia Zycoides* (L.) Persoon (buckthorn).

The total density of the understory at the sites ranged from 61.1 stems/ha (Hermit forest)

Table 3. Density (stems/ha) and basal area (m^2/ha) of the major overstory taxa (dbh $\geq$10 cm) in seven bottomland hardwood forests in southeastern Louisiana. *See Table 2 and text

	Density								Basal Area							
Taxa	Lafitte	Oak	Verret	Jackson	Airline	Hermit	Sauvage	X	Lafitte	Oak	Verret	Jackson	Airline	Hermit	Sauvage	X
Quercus uirginiana Miller	**31.9**	26.3	59.4	**100.1**	—	**6.9**	**63.9**	41.2	10.0	12.0	**17.9**	20.2	—	**3.9**	10.7	10.7
Celtis laevigata Willd.	36.1	20.8	55.2	51.7	72.2	77.8	**238.9**	79.0	2.8	1.4	2.6	1.9	10.8	7.8	17.7	6.4
Ulmus spp.	45.8	84.7	41.7	78.3	54.2	73.6	43.1	60.2	2.3	2.3	1.7	2.8	2.8	4.4	1.4	2.5
Quercus nigra L.	23.6	8.3	6.3	75.0	52.8	33.3	16.7	30.9	7.9	0.3	0.6	6.4	4.5	2.7	2.3	3.5
Acer ruhrum L.	59.7	254.1	27.1	11.7	43.1	8.3	1.4	57.9	1.9	3.7	0.6	0.2	2.7	0.2	0.1	1.3
Liquidambar styraciflua L.	12.5	43.0	94.8	3.3	1.4	43.1	16.7	30.7	2.1	2.6	10.1	0.2	0.1	4.6	0.8	2.9
Fraxinus spp.	11.1	11.1	—	15.0	33.3	22.2	4.2	138	0.7	0.2	—	0.6	4.4	1.9	0.1	1.1
Acer negundo L.	44.4	—	—		48.6	1.4		13.5	0.9				1.1	0.2	—	0.3
Quercus laurifolia Michx.			21.9		23.6	—	—	6.5	—	—	1.0		1.5			0.4
Persea palustris (Raf.) Sarg.				26.7		5.6	—	4.6	—	—		0.4		0.1	—	0.1
Sapium sebiferum (L.) Roxb.	—	—	—	—	6.9	—	15.3	3.2	—	—	—		0.5	—	0.3	0.1
Gleditsia triacanthos L.	—	—	—	—			11.1	1.6	—	—	—				1.1	0.2
Carya illinoensis (Wang.1 K. Koch			5.2	—			—	0.7	—	—	1.6	—				0.2
Carya spp.	—		6.3	—	2.8	—	—	1.3	—	—	0.7	—	0.3	—		0.1
Taxodium distichum (L.) Richard	2.8			—	4.2		—	1.0	0.2	—	—		0.8			0.1
Carpinus caroliniuna Walter	50.0	—	—	—	—	—	—	7.1	1.3	—						0.1
Quercus lyrata Walter	1.4	1.3	—					0.4	0.2	0.3	—			—	—	0.1
Other*	1.4		4.2	6.7	5.6	2.8	**13.9**	4.9			0.1	0.4	0.5		0.2	0.2
Total	320.7	449.6	322.1	368.5	348.7	275.0	425.2	358.5	30.5	22.8	36.9	33.1	30.0	25.8	34.7	30.5

Table 4. Importance values (IV), total density and total basal area of the understory (dbh 3.9-9.99 cm) taxa in seven bottomland hardwood forests in southeastern Louisiana. To be included, each taxon had a combined importance value across all forests of ≥9.0. Boldface numbers (vertically) indicate the three taxa in each forest with the highest importance values; superscripts indicate their ranking. Other includes 8 minor taxa, see text. *Denotes taxa not represented in overstory in any forest

Taxa	Forests							X
	Lafitte	Oak	Verret	Jackson	Airline	Hermit	Sauvage	
Acer rubrum L.	47.82	**165.2**[1]	**40.8**[2]	17.3	78.2’	25.4	6.3	54..4
Ulmus spp.	14.0	5.2	28.5”	**36.5**[3]	48.02	48.5”	14.3	27.9
**Crataegus viridis* L.	58.5’	**6.5**[3]	22.8	15.0	—	2.7	62.5’	24.0
Liquidambar styraciflua L.	5.9	**11.8**[2]	51.6’	—	2.9	44.9”	2.6	17.1
Quercus nigra L.	17.2	1.6	13.7	56.4’	15.4	3.6	1.5	15.6
**Cornus drummondii* C.A. Meyer		0.5	—	5.8		50.8	29.0”	12.3
Acer negundo L.	11.8	—			42.2”	5.0	—	8.4
Celtis laevigata Willd.	3.9	1.1	9.9	13.4	0.4	10.4	19.6	8.4
Persea palustris (Raf.) Sarg.	1.2	—	3.6	**49.8**[2]	1.1			8.0
Diospyros virginiana L.			—	—	—	8.6	24.8	4.8
Carpinus caroliniana Walter	30.2”	—	—			—	—	4.3
Supium sebiferum (L.) Roxb.	—				0.4		**25.8**[3]	3.7
Quercus laurifolia Michx.	—	—	14.8		7.0		—	3.1
Quercus virginiana Miller	2.0		11.8	4.6	—		1.4	2.8
Fraxinus spp.	6.9	3.1	1.0	0.7	0.9	—	2.4	2.1
**Ilex uomitoria* Aiton			—	—	0.4		8.9	1.3
Other	0.5	5.0	1.4	0.6	3.2	—	0.9	1.7
Total Density (stems/ha)	356.9	338.3	349.0	338.3	445.8	61.1	359.8	321.3
Total Basal Area (m^2/ha)	1.03	0.89	0.99	1.06	1.37	0.22	0.94	0.93

to 445.8 stems/ha (Airline forest), with an adjusted mean of 364.7 stems/ha (Table 4) when the low outlier of the Hermit forest was removed. The total basal area of the understory within these forests averaged only 1.0 m^2/ha even after the low outlier of 0.221 m^2/ha was removed from the Hermit forest.

Soils

The measured soil parameters at the sites (Table 1) were within the normal range for bottomland hardwood soils of Mississippi River alluvium. The pH of the soils was circumneutral (mean = 6.6) and therefore higher than most published results from many wetland forests (Mitsch and Gosselink 1993). The soils were predominantly clay (mean = 32.2%) and silt (mean = 31.6%). They had a mean total sand content of 25.1%, which is low for floodplain soils (Wharton et al. 1982). Finally, these forests had a high soil organic content (mean = 12.5%) compared to most forested floodplains (Wharton et al. 1982).

DISCUSSION

The bottomland hardwood forests surveyed in this study were grouped into those dominated by live oak and those dominated by sugarberry. There were five other co-subdominant overstory taxa in the forests: water oak, sweet gum, red maple, elm, and ash. In the overstory, species dominance was rather homogeneous between sites. All species that were among the three most dominant in any one forest were also among the six species highest in mean importance value across all sites. And all of these species were present in virtually every stand (*Quercus uirginiana* was present in 6 out of 7). There were ten species that were among the three most dominant in at least one forest, and three of these species were present in three or fewer of the seven stands (Table 4). Furthermore, immature individuals of the two dominant overstory species (live oak and sugarberry) were somewhat poorly represented in the understory of these forests. The rarity of saplings of dominant overstory species does not appear to be unusual in bottomland forests in this region (Harcombe and Marks 1977, Devall 1990, Wall and Darwin 1999). Both Levy and Walker (1979) and Marks and Harcombe (1981) identified some incongruence of the different woody layers and the former suggested differences in site disturbance as a possible reason.

The woody plant communities of other regional forests appeared to be similar to those in this study. The principal species were the same, but the actual dominance ranking can be different among forests. The communities of this study were similar to those in the six chenier (relict ridge lands surrounded by marsh) forests of coastal western Louisiana studied by Neyland and Meyer (1997). They identified live oak, sugarberry, and American elm as the most important native species, but with the invasive Chinese tallow tree also important. In this study Chinese tallow tree was found to be common only in the Sauvage forest. The chenier forests were lower in richness and diversity than the levee-ridge forests of this study.

White et al. (1983) reported on two forests in close proximity to the Lafitte forest. Those forests were dominated by water oak, with sweetgum, sugarberry, and live oak as co-subdominants. Because live oak was not dominant and because it is a slow growing, late successional species, it may be that those two forests were successionally younger or located in an area with different soils not as favorable for growth of live oak.

The difference in species dominance between the Lafitte (live oak-dominated) and Airline forests (sugarberry-dominated) was likely related to hydroperiod. From the site location, the Lafitte forest became established on elevated land near Bayou des Familles, the historic distributary and source of sediment to the site. However, the Airline forest likely occurs on more flooded lands because its location is farther down slope from its source of sediment. Neither forest was located as close to marshland as were the other forests of the study. The differences in soil association type between the sites (Table 1) support the idea that the two forests experience different hydroperiods.

The forest studied by Penfound and Howard (1940), dominated by water oak, grew on the same natural levee as the sugarberry-dominated Sauvage forest, but approximately 5 km upstream along the present Bayou Sauvage (the abandoned distributary of the Mississippi

River). Live oak was also a large component of their forest, with sugarberry, elm, and ash also present. The upstream location of the site indicates that it was along a wider and likely higher levee of Bayou Sauvage suggesting the Sauvage forest had a wetter hydroperiod. The difference in the dominant trees between the two forests supports this contention. Sugarberry is slightly more tolerant of flooding than water oak (Wharton et al. 1982, Mitsch and Gosselink 1993, Wall and Darwin 1999).

The average basal trunk area of the overstory trees in this study was low compared to the basal trunk area reported by other studies from bottomland hardwood swamps (36.8 m^2/ha, Robertson et al. 1978; $\approx$29.0 m^2/ha, Marks and Harcombe 1981; +30.0 m^2/ha, Held and Winstead 1975; 32.1 & 41.1 m^2/ha, Brown and Peterson 1983). Likewise, the average total overstory density reported for these alluvial forests was low when compared to other published results (415.5 stems/ha, Robertson et al. 1978; 423 stems/ha and 459 stems/ha, Brown and Peterson 1983). It is not known why the understory of the Hermit forest had such uncharacteristically low total stem density and total basal area.

CONCLUSIONS

Levee Forests Landscape Relationships

The proximity of a bottomland forest to its source streambank has been well known to result in differences in hydroperiod and soil type. This in turn has been shown to affect species composition and abundance as in the case of ridge and swale topography or streamside versus back-levee woody communities (Mitsch and Gosselink 1993). This hydroperiod gradient is perpendicular to stream flow, but a similar change in community composition may well take place as elevation changes on a levee parallel to streamflow.

In extreme southeastern Louisiana, long low gradients of elevation change must occur in the direction of current flow where the event of land building from deposition of Mississippi River sediment creates gradually downward sloping wedges to fingers of elevated forested land projecting into the lower surrounding extensive marsh land. The width of these elevated lands varies from tens to hundreds of meters and, upstream, the higher lands are thousands of meters across becoming continuous with elevated lands from other fingers. The relative position of a forest along these lands must be as important to community composition as the well documented elevation gradients near and far from (perpendicular to) the stream sediment source. This appears to be the case for the forests of this study. The Hermit, Sauvage, and Oak forests were located at the more distal ends of three narrow forested levees only a couple of hundred meters wide. They had the lowest diversity of the forests studied. In contrast, the Lafitte and Airline forests were positioned most proximally upon more elevated forested lands that are expansive, not confined to a narrow levee. These forests have the highest richness and diversity. The Jackson and Verret forests, the last of the seven studied forests, were growing on levee-ridges of intermediate width and both had intermediate levels of diversity.

Local Forest Conservation,

This study sampled the very last of the most intact bottomland hardwood forests within extreme southeastern Louisiana. Currently, two of the seven forests have been partially or wholly developed. They include one from each group of forest, the live oak-dominated forests (Verret) and the sugarberry-dominated forests (Airline). The Sauvage and Lafitte forests, one from each group, are federally owned and managed; thus they should be more protected. From a conservation standpoint, the Oak and Hermit forests, also one from each group, are particularly important not only because of a scarcity in regional forests generally, but also because both are located outside the flood-protection levee system and so will continue to be exposed to natural weather patterns. The Jackson forest has been under semi-protection by the local government because of its very old trees and its cathedral-like canopy structure. It is of concern that Chinese tallowtree has been rapidly increasing in numbers within southern Louisiana (Neyland and Meyer 1997, Wall and Darwin 1999). The extent to which it will invade all the forests of this study is unknown.

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