[Journal of the Arkansas Academy of Science](https://scholarworks.uark.edu/jaas)

Volume 60 | Article 7

2006

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Abstract.—The Levi Wilcoxon Demonstration Forest near Hamburg, Arkansas is an industrially-owned remnant of old-growth pine and hardwoods. Some of the loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pine in this stand are over 200 years old, and numerous individuals exceed 90 cm in diameter and 30 m in height. A 2000 survey of a portion of this tract found that 27 tree species contributed an average of 387.5 live stems/ha and 31.8 m^2/ha of basal area. An inventory of the same plots in 2006 yielded noticeable declines in density (now down to 342.5 stems/ha) and basal area (now 28.2 m^2/ha). Much of this loss came in the aftermath of a windstorm in May 2003, which felled a number of overstory pines. Loblolly pine decreased from 49.6 stems/ha and 13.2 m^2/ha in 2000 to 42.1 trees/ha and 11.2 m^2/ha in 2006, while shortleaf pine declined from 21.7 trees/ha and 5.0 m^2/ha to 14.6 trees/ha and 3.5 m^2/ha. Further pine mortality came from smaller-scale windthrow, lightning, and bark beetle infestations. Some hardwoods were also toppled by storms or crushed by falling trees, but most appear to have succumbed to drought, competition, and salvage logging. However, hardwood basal area remained virtually unchanged over this period, signifying adequate diameter growth and midstory recruitment. In particular, shade-tolerant hardwood species showed notable gains. Even though most overstory pines currently appear healthy, natural catastrophes and the lack of new canopy recruits may eradicate virtually all pines from this stand within 30 to 50 years.

Key words:—Levi Wilcoxon Demonstration Forest, loblolly pine, natural disturbance, shortleaf pine, windthrow.

Introduction

Very few stands of pine-dominated old-growth remain in the Upper West Gulf Coastal Plain of Arkansas. Extensive lumbering and agricultural clearing, coupled with other large-scale catastrophic disturbances, have converted millions of hectares of virgin forest into stands of young timber, pastureland, row crops, and commercial and residential developments. The remaining old-growth is found in a few small tracts that escaped conversion. Most prominent of the south Arkansas pine-hardwood old-growth sites are the "Lost Forty" in Calhoun County (Heitzman et al. 2004) and the Levi Wilcoxon Demonstration Forest (LWDF) in Ashley County (Georgia-Pacific, n.d., Allen 1985, Bragg 2004a), both of which are currently owned by large companies (Potlatch Corporation and Plum Creek Timber Company, respectively).

Although these sites currently receive some degree of protection from perturbations, they are still subject to forest succession and certain disturbances. For example, the LWDF is periodically salvaged to remove dead and dying pines. These mechanisms of change, coupled with decades of fire exclusion, forest fragmentation, and invasion by exotic species, have noticeably altered the composition, structure, and dynamics of old forest remnants across the South (e.g., Jones et al. 1981, Shelton and Cain 1999, Harrington et al. 2000, Bragg 2002, Harcombe et al. 2002).

The LWDF was ecologically described using field data collected between 2000 and 2003 (Bragg 2004a). Since this initial measurement, the stand has been affected by both catastrophic (primarily from a single windstorm and the resultant salvage) and individualistic (e.g., lightning strikes, beetle kills, drought) mortality of the mid- and overstory trees. The preservation and long-term management of the LWDF depends on our ability to anticipate change, which in turn requires a better understanding of short-term stand dynamics.

Materials and Methods

Site Description.—The LWDF (Fig. 1) is located in Ashley County, approximately 6 km south of Hamburg, Arkansas (Fig. 2). Most of the LWDF is gently rolling (0 to 2% slopes) and dominated by Calloway and Grenada silt loams (Glossic Fragiudalfs) on the higher ground and Arkabutla silt loams (Aeric Fluvaquents) along minor stream drainages (Gill et al. 1979). The mean elevation of the LWDF is 45 m, and the stand is located on a landform identified by Saucier (1974) as the Prairie Terrace Formation. The abundantly distributed "pimple" or "prairie" mounds throughout the stand provide further evidence of its association with the Pleistocene-period Prairie Terrace. The study site averages 140 cm of precipitation and 200 to 225 frost-free days annually (Gill et al. 1979).

Historically, the presettlement upland vegetation of southern Arkansas was pine, pine-oak, and oak-hickory-gum forests, pine-oak-hickory woodlands, and scattered prairies (Vanatta et al. 1916, Turner 1937, Bragg 2002 2003). When first reserved by the Crossett Lumber Company, the LWDF was overwhelmingly pine-dominated (Anonymous 1948). Over the decades, mortality and salvage removed many of the large loblolly (*Pinus taeda* L.) and shortleaf (*Pinus echinata* Mill.) pines (Bragg 2004a).

Fig. 1. View of a portion of the Levi Wilcoxon Demonstration Forest (LWDF) looking north towards Hamburg, Arkansas, from the LWDF parking area near the corner of Highways 425 and 52. The stand is dominated by supercanopy pines with lower canopy levels comprised almost entirely of a variety of hardwood species.

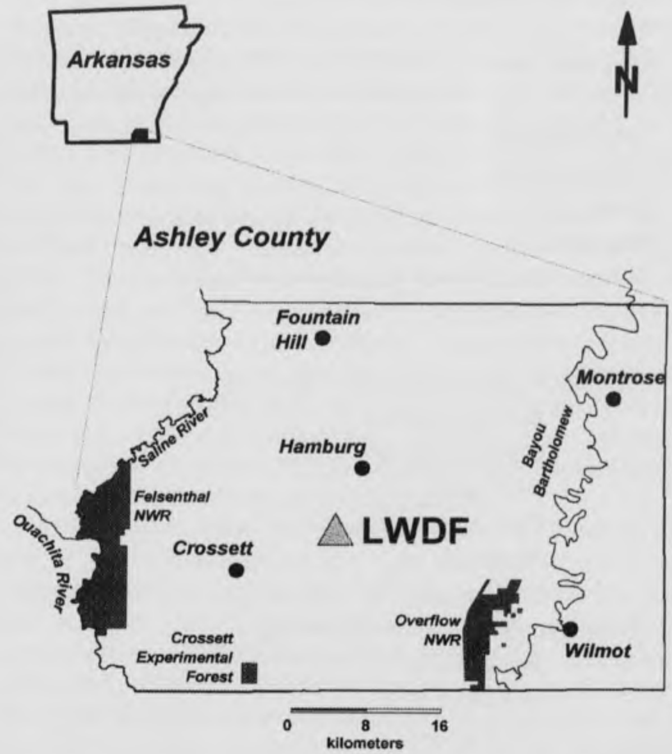

Fig. 2. Map of Ashley County, Arkansas, showing the location of the Levi Wilcoxon Demonstration Forest (LWDF) relative to other geographic features.

Hardwoods have grown increasingly numerous, although they do not yet constitute a majority of stand basal area.

Fire, glaze, and windthrow were the primary presettlement disturbances of the study area, with insect and disease outbreaks, lightning, and drought also impacting forested areas (Turner 1937, Bragg 2002). Frequent fires helped maintain relatively open understories in upland forests, conditions that changed as forestry and fire control were implemented by the 1930s. Logging and agriculture spread rapidly across the region beginning in the mid-1800s. However, most farming operations failed, and much of the cleared land in Ashley County quickly reverted back to forest (Vanatta et al. 1916). The post-fire control forests that seeded into the cut-over lands, abandoned farms, and neglected pastures were considerably denser, younger, and more even-aged than the original forests, with greater numbers of briars, vines, shrubs, and shade-tolerant tree species in the understory (Bragg 2002). Over time, stand composition of the old-growth LWDF remnant has also shifted toward a dense, woody, shade-tolerant understory.

Mid- and Overstory Remeasurement.—To ensure continuity, this paper will follow the same live tree sampling protocols of Bragg (2004a). Only the 6-ha reserved area of the LWDF was re-evaluated for overstory compositional and structural dynamics, using the same twenty-four 0.1-ha circular plots (17.84 m radius) established in the summer of 2000. In the original study, 8 plots were established on every transect, and transects were located 40 m from the next to avoid overlap. Plot centers were spaced 100 m apart along each transect, and every live tree > 9 cm in diameter at breast height (DBH) was tallied for species (Table 1) and DBH (measured to the nearest 0.25 cm using a diameter tape).

Species abundances and stand stocking (number of trees and basal area per hectare) were derived from the plot-level information. The analysis of species dynamics in this paper sometimes includes the use of functional groups rather than individual taxa. Occasionally, this aggregation was used to facilitate the graphical display of data. However, in the case of the red oak subgroup, the lumping of southern red oak (*Quercus falcata* Michx.), cherrybark oak (*Quercus pagoda* Raf.), and black oak (*Quercus velutina* Lam.) was done to avoid misidentification of these visually similar oaks in a less-than-ideal dormant leaf-off state.

Select individuals from the entire 20+ ha LWDF were incorporated in the sections of this paper that refer to tree size or age. Tree heights were originally measured using a cloth tape and percent-baseline clinometer using the tangent method. The 2006 heights were determined with a Laser Technology Impulse 200LR™ laser rangefinder and the sine method of height calculation (Blozan 2004, Bragg, in press). Age data for the LWDF were supplemented by ring counts made at stump height (approximately 45 to 60 cm above groundline) on four recently felled snags. In addition, Dr. Brian R. Lockhart of

Table 1. Scientific and common names of mid- and overstory tree species mentioned in this paper. Species are grouped according to the categories used in Table 2 and Fig. 3.

Common name	Scientific name[a]
Shortleaf pine	*Pinus echinata* Mill.
Loblolly pine	*Pinus taeda* L.
Sweetgum	*Liquidambar styraciflua* L.
Blackgum	*Nyssa sylvatica* L.
White oaks (grouped from the following)	*Quercus* spp.
White oak	*Quercus alba* L.
Post oak	*Quercus stellata* Wang.
Red oaks (grouped from the following)	*Quercus* spp.
Southern red oak	*Quercus falcata* Michx.
Cherrybark oak	*Quercus pagoda* Raf.
Black oak	*Quercus velutina* Lam.
Red oak subgroup	*Quercus falcata* + *Quercus pagoda* + *Quercus velutina*
Water oak	*Quercus nigra* L.
Willow oak	*Quercus phellos* L.
Elms (grouped from the following)	*Ulmus* spp.
Winged elm	*Ulmus alata* Michx.
American elm	*Ulmus americana* L.
Slippery elm	*Ulmus rubra* Muhl.
Other hardwoods (grouped from the following)	--
Red maple	*Acer rubrum* L.
American hornbeam	*Carpinus caroliniana* Walt.
Bitternut hickory	*Carya cordiformis* (Wang.) K. Koch
Mockernut hickory	*Carya tomentosa* Nutt.
Sugarberry	*Celtis laevigata* Willd.
Flowering dogwood	*Cornus florida* L.
Persimmon	*Diospyros virginiana* L.
Green ash	*Fraxinus pennsylvanica* Marsh.
American holly	*Ilex opaca* Ait.
Red mulberry	*Morus rubra* L.
Eastern hophornbeam	*Ostrya virginiana* (Mill.) Koch
Black cherry	*Prunus serotina* Ehrh.
Sassafras	*Sassafras albidum* (Nutt.) Nees.

[a]Species nomenclature from Harlow et al. (1979), Smith (1988), and Moore (1999).

the USDA Forest Service also contributed stump dimensions and ring counts for the LWDF collected by students from 36 pines salvaged following an insect outbreak and other mortality events in the latter half of the 1980s.

Results and Discussion

In the 5 years since the original forest survey of the LWDF was completed, a number of events affected stand structure and composition. A severe straight-line windstorm struck the area in May of 2003, felling many of the larger pines. The LWDF has been isolated in recent years as adjacent mature forests have been clearcut, accentuating storm loss-mediated structural changes. Thus, as the winds of this storm swept across the area from west-to-east, there were few obstructions to dissipate their energy before they struck the north-south oriented LWDF (Bragg 2004a). In addition to direct mortality from this particular windstorm, insects (primarily bark beetles (*Dendroctonus* spp.)) attracted to the fallen pines killed other nearby pines in the months following the storm. Other isolated storms produced further overstory losses via windthrow, lightning, and post-storm insect attack. Not surprisingly, overall tree density in the LWDF decreased from 387.5 stems/ha in the fall of 2000 to 342.5 trees/ha by February of 2006. Over this same time period, average basal area in the LWDF declined from the 31.8 m^2/ha initially reported to 28.2 m^2/ha in 2006, a reduction of 11%.

Species Composition Trends.—Table 2 provides a comparison of the species composition between the first inventory and this effort. Bragg (2004a) reported 27 tree species on the study plots in 2000, but the 2006 remeasurement yielded only 24. This discrepancy is not due to identification errors, but rather to the loss of a handful of tree-sized specimens on the plots. The three taxa absent from the 2006 inventory (persimmon (*Diospyros virginiana* L.), willow oak (*Quercus phellos* L.), and American elm (*Ulmus americana* L.)) were represented by 1, 4, and 1 individuals, respectively, in the original survey. Though specifically searched for, these individuals were not found and appear to have perished from drought, salvage logging, or as in the case of one willow oak, from being crushed by a falling tree. Another species, sugarberry (*Celtis laevigata* Willd.), appears poised to join the ranks of the missing taxa, as the single individual noted in 2000 was barely clinging to life after a large white oak (*Quercus alba* L.) fell onto it in 2005. Such is the ecological role of uncommon understory species—they are noticeably more volatile, and thus can have a dramatic impact on taxonomic richness. However, their disappearance from the study plots does not mean that these species vanished from the LWDF, as all of these species are still found in the forest encompassing the reserved area.

The absolute values and relative dominance of species fluctuated over the last 5 years (Table 2). The pines declined in prominence, especially following the windstorm. The most abundant taxon in the 2000 inventory, sweetgum (*Liquidambar styraciflua* L.), also decreased appreciably, losing over 16% of its number, primarily in the smallest diameter classes. Other taxa experiencing substantial (>10%) decreases included white oak (down 19%), post oak (*Quercus stellata* Wang., -17%), the red oak subgroup (-10%), slippery elm (*Ulmus rubra* Muhl., -36%), mockernut hickory (*Carya tomentosa* Nutt., -18%), flowering dogwood (*Cornus florida* L., -35%), red mulberry (*Morus rubra* L., -20%), and black cherry (*Prunus serotina* Ehrh., -22%). Most of these were in subordinate canopy positions and did not directly suffer from the severe winds or lightning faced by the emergent pines. Rather, falling trees, post-storm salvage operations, moisture extremes, light competition, and decay coupled with wind or glaze have killed hardwoods throughout the LWDF. Flowering dogwood, for instance, is particularly drought sensitive and died in large numbers during prolonged dryness in 2000 and 2001.

Some species increased their abundance over the last 5 years. Blackgum (*Nyssa sylvatica* L., up 7%), winged elm (*Ulmus alata* Michx., +15%), red maple (*Acer rubrum* L., +21%), bitternut hickory (*Carya cordiformis* (Wang.) K. Koch, +50%), and eastern hophornbeam (*Ostrya virginiana* (Mill.) Koch, +198%) all produced noticeable density increases. However, the large percentage growth for bitternut hickory and eastern hophornbeam does not translate to great numbers of new stems, as these were very uncommon species when inventoried in 2000. The increasers weathered the drought and storms of the last 5 years, and their higher shade tolerance allows for them to persist longer under a closed canopy. They are also capable of exploiting relatively small canopy gaps produced by disturbance events, so long as they can survive the proliferation of woody vines (e.g., *Vitis* spp., *Smilax* spp., *Lonicera* spp., *Gelsemium sempervirens* (L.) Jaume St.-Hil., *Lygodium japonicum* (Thunb. ex. Murr.) Sw.) following overstory removal.

Changes in Pine Dominance.—Pine dominance in the LWDF has varied considerably over the last 50 years and especially since the initial 2000 inventory. In 1948, a picture was taken of Levi Wilcoxon standing next to a sign at the entrance to the LWDF (Johnson et al. 1994, p. 58). Though not particularly detailed, the sign had basic statistics on the natural area, including that there were about 193 trees/ha on this site 15 cm DBH or greater, most (if not all) of which were loblolly or shortleaf pine. Although no longer the most common species, loblolly pine still dominates the stand, contributing 42.1 stems/ha and 11.2 m^2/ha to the stand totals (approximately 12% and 40%, respectively). The change in density and basal area for loblolly pine represent decreases of 15% and 16%, respectively, over the last 5 years. Shortleaf pine has declined even more precipitously since 2000, losing 33% and 30% of its density and basal area totals, respectively (Table 2). Pine mortality in some of the largest diameter classes was the primary cause of the declines in stand density and basal area (Fig. 3).

The rapid decline of the LWDF pine overstory parallels that of a nearby old forest. The tree component of the Reynolds Research Natural Area (RRNA) on the Crossett Experimental Forest south of Crossett, Arkansas has been monitored since the late 1930s (e.g., Cain and Shelton 1996, Shelton and Cain 1999). From 1935 to 1965 (Fig. 4), loblolly and shortleaf pine basal area increased from 13 m^2/ha to between 21 and 23 m^2/ha and was sustained at this level for the next 30 years (Cain and Shelton 1996, Shelton and Cain 1999). During this period, pine basal area was maintained by aggregate growth slightly higher or equal to mortality losses, not by the recruitment of new pines into the canopy. Pine abundance in the RRNA eventually dropped to the point that mortality losses could not be made up for by growth, and thus its basal area fell rapidly—by 2000, only 18.7 m^2/ha of live pines remained (Bragg 2002). Almost 6 years later, a follow-up cruise noted a further reduction in pine basal area on the RRNA to approximately 14 m^2/ha. This decline is also being experienced for most of the same reasons

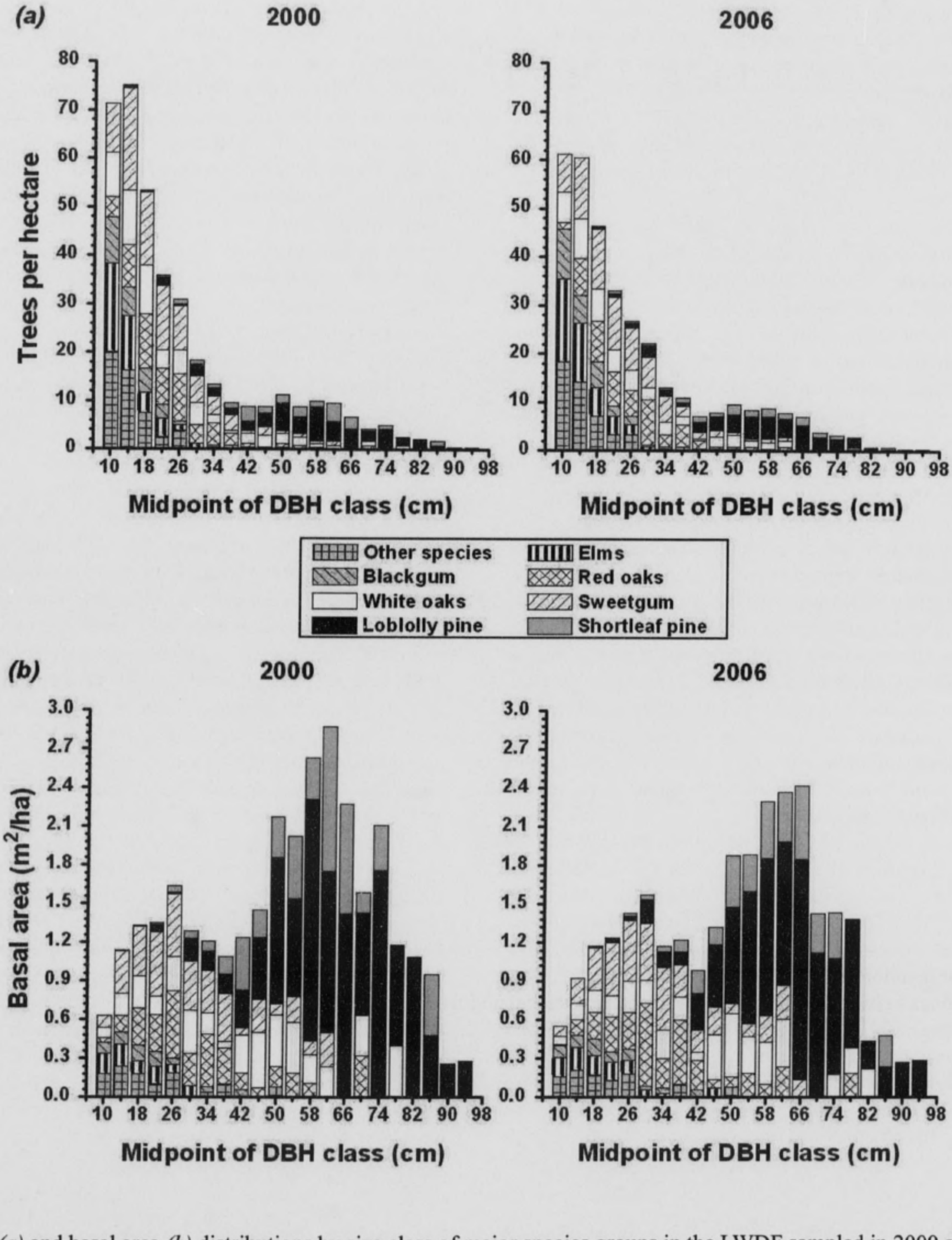

Fig. 3. Density *(a)* and basal area *(b)* distributions by size class of major species groups in the LWDF sampled in 2000 and 2006.

Table 2. Initial (Bragg 2004a) versus current mid- and overstory inventories of live trees in the reserved portion of the Levi Wilcoxon Demonstration Forest in Ashley County, Arkansas.

Species/species group [a]	Density (trees/ha) 2000	Density (trees/ha) 2006	Diff. [b] (%)	Basal area (m^2/ha) 2000	Basal area (m^2/ha) 2006	Diff. (%)	Mean DBH (cm) 2000	Mean DBH (cm) 2006	Diff. (%)
Shortleaf pine	21.67	14.58	-33	5.02	3.51	-30	52.4	53.5	2
Loblolly pine	49.58	42.08	-15	13.23	11.15	-16	55.9	56.0	0
Sweetgum	85.83	71.67	-16	3.83	3.82	0	21.5	23.6	9
Blackgum	25.00	26.67	7	0.55	0.61	11	15.5	15.7	1
White oaks									
White oak	55.00	44.58	-19	3.56	3.38	-5	24.6	26.8	9
Post oak	2.50	2.08	-17	0.59	0.43	-27	49.9	44.5	-11
Red oaks									
Red oak subgroup [c]	47.50	42.92	-10	2.41	2.47	2	22.2	23.5	6
Water oak	8.75	7.92	-9	0.75	0.91	21	28.8	34.2	19
Willow oak	1.67	0.00	-100	0.06	0.00	-100	20.1	--	n/a [d]
Elms									
Winged elm	33.75	38.75	15	0.64	0.83	30	14.7	15.3	4
American elm	0.42	0.00	-100	0.01	0.00	-100	10.9	--	n/a
Slippery elm	5.83	3.75	-36	0.08	0.06	-25	12.7	13.3	5
Other hardwoods									
Red maple	13.75	16.67	21	0.18	0.22	22	12.6	12.5	-1
American hornbeam	1.25	1.25	0	0.02	0.03	50	14.4	16.1	12
Bitternut hickory	1.67	2.50	50	0.11	0.15	36	23.8	22.7	-5
Mockernut hickory	4.58	3.75	-18	0.20	0.17	-15	21.6	22.4	4
Sugarberry	0.42	0.42	0	0.01	0.01	0	12.4	12.7	2
Flowering dogwood	10.83	7.08	-35	0.14	0.09	-36	12.5	12.7	2
Persimmon	0.42	0.00	-100	0.01	0.00	-100	9.4	--	n/a
Green ash	0.42	0.42	0	0.01	0.01	0	9.9	10.7	8
American holly	0.83	0.83	0	0.01	0.01	0	13.3	14.5	9
Red mulberry	2.08	1.67	-20	0.05	0.06	20	16.7	21.2	27
Eastern hophornbeam	0.42	1.25	198	0.01	0.01	0	9.9	11.4	15
Black cherry	7.50	5.83	-22	0.19	0.13	-32	17.3	15.9	-8
Sassafras	5.83	5.83	0	0.13	0.15	15	15.9	17.4	9
TOTALS:	387.50	342.50	-12	31.80	28.21	-11			

[a] See Table 1 for taxonomic grouping details.
[b] Percent difference between 2000 and 2006 inventories, calculated from: ([2006 – 2000] / 2000) * 100.
[c] Due to the difficulty in differentiating southern red oak, cherrybark oak, and black oak in the dormant (leaf-off) period, these species were grouped into the "Red oak subgroup".
[d] Diameter change is undefined, therefore there is no applicable (n/a) measure of percent change in this case.

as in the LWDF (Fig. 4). However, the RRNA is not regularly salvaged to remove dead and dying pines, so this preserve has considerably more large woody debris than the LWDF.

Stand Structural Change.—Diameter class distributions in the LWDF were comparable to those reported in 2000 (Fig. 3). Hardwood dominance increased in virtually all size classes, and this trend will continue into the foreseeable future unless an adequately severe and extensive disturbance opens the overstory and reduces the duff enough to permit large-scale pine regeneration and canopy recruitment. In particular, large pines and shade-intolerant hardwoods—such as sweetgum and the red oak subgroup—will continue to decrease, while more shade-tolerant hardwoods (e.g., flowering dogwood, winged elm, blackgum, and hickory) occupy an increasing proportion

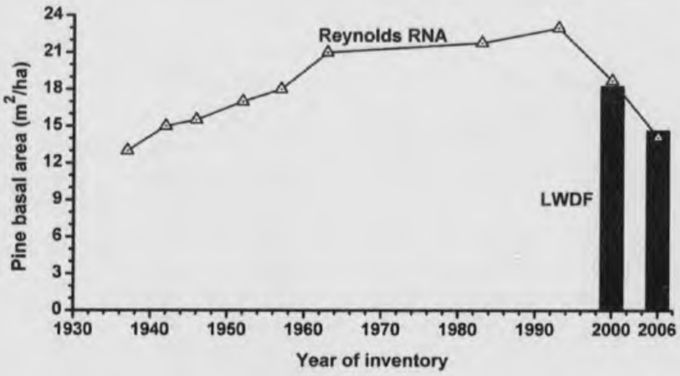

Fig. 4. Long-term trend of overstory pine basal area at the Reynolds RNA (line) and the LWDF (bars). Data compiled from Cain and Shelton (1996), Bragg (2002), and this study.

of the small- to medium-sized diameter classes.

Storm losses were not evenly distributed throughout the LWDF. A relatively large swath of damage perhaps a hectare in extent appeared in the middle of the reserved area. This, coupled with insect-related post-storm mortality, caused a considerable gap in the canopy to form. However, rather than providing an opportunity for the reestablishment of the current overstory species, the existing understory of American beauty berry (*Callicarpa americana* L.), woody vines (e.g., *Vitis* spp.), graminoids, and other exploiters of forest openings (e.g., *Rubus* spp.) quickly and almost completely occupied the larger openings. Shade-tolerant hardwood regeneration should gradually emerge from these thickets, but it is highly unlikely that pine seedlings will persist in the dense undergrowth long enough to ascend into the canopy. Few of the smaller gaps caused by individual trees being killed by storms or their aftermath provide adequate space to permit seedlings to reach the overstory, regardless of their shade tolerance. The limited amount of resources freed by these minor gaps will be appropriated by shrubs and vines in the understory and eventually lost to the lateral crown expansion of canopy trees.

Large Tree Attributes.—Bragg (2004a) also surveyed the entire LWDF for trees of exceptional dimensions. Though storms, lightning, and beetles have killed many large loblolly and shortleaf pines, including several >100 cm in DBH, the two most notable pines have survived to date. The Morris Pine, a 300+ year old loblolly named after a long-time Crossett Lumber Company employee (Anonymous 1950), was measured at almost 142 cm DBH in 2000. In 2006, this pine had not changed in diameter and was nearly 36 m tall (Table 3). The Morris Pine still appears healthy, although it is increasingly isolated as neighboring pines die.

The Walsh Pine, the current state and probable national champion shortleaf pine, measured 90.7 cm DBH and 43.3 m tall in 2001 and now scales 90.9 cm DBH and 41.5 m tall. The Walsh Pine has not become shorter over the years; rather, the 1.8 m height difference arose from the use of more accurate laser technology and a more dependable height determination technique (the sine method). The tangent method used in 2000 is prone to overestimate height, especially for large, wide-crowned individuals. As an example, the 120.7 cm DBH, 45.6 m tall loblolly pine reported in Bragg (2004a) was originally measured using the tangent method with a cloth tape and clinometer. This tree was blown over and partially salvaged in 2003. However, the base of the pine remains were it fell, and the top was also left in place, making it possible to measure its stem length along the ground. This tree turned out to be just over 40 m tall, or almost 6 m shorter than first thought.

Wind, decay, and drought also killed a number of large hardwoods, especially some hollow oaks, but in general these hardwoods were less impacted by the last 5 years of disturbances than the pines. White oak and post oak comprised the majority of the biggest hardwoods across the site, with a few sweetgum, southern red oak, and water oak (*Quercus nigra* L.) greater than 70 cm DBH scattered throughout the LWDF (Table 3). A relatively large (46.5 cm DBH and 27.6 m tall) winged elm was also located in 2006. Most hardwoods in the LWDF are noticeably shorter than the pines, which form a supercanopy above them. A few sweetgum exceed 35 m tall, but most overstory hardwoods are between 25 and 30 m.

Supplemental Pine Age Data.—In late 2005, four shortleaf pine snags were felled to minimize vehicular hazards along Highway 425 as it passes through the LWDF, and ring counts were made on the stumps left behind (Table 4). Due to pre-existing decay of the outer rings and heart rot, these ring counts are only approximate. Without more accurate cross-dating, we cannot specify exactly when these trees succumbed, except to say that they died from 2 to 4 years ago. These shortleaf pines ranged from 146 to 166 years old. Other sources have identified cohorts of similarly aged pines at a number of nearby sites (e.g., Jones 1971, Tompkins 2000, Heitzman et al. 2004, Bragg 2004b); the age of these pines coincide with the beginning of large-scale Euroamerican settlement in this portion of the Upper Gulf Coastal Plain.

Stump 4, though the hardest to age given its rotten heartwood, contained other important information. Two obvious fire scars dating to approximately 25 and 102 years ago were found on the cut face of the stump. It is possible other fire scars will be discovered on this tree once a section has been removed and sanded for more detailed observations. A number of fire scarred live pines can be found throughout the LWDF, including several within 50 m of this stump. Given this relative abundance, it should be possible to construct at least a partial fire chronology in this stand, which will prove helpful in understanding historic fire regimes.

Dr. Brian R. Lockhart of the USDA Forest Service provided additional data on 36 pine stumps from the LWDF, which were aged by students in 1988. Combined with the age records from Bragg (2004a) and those mentioned in this paper, a graph of

Table 3. Large tree dimensions across the entire LWDF measured in February-March 2006.

Species [a]	DBH (cm)	Height [b] (m)	Average [c] crown width (m)	Bigness Index [d]	Notes
Loblolly pine	141.7	35.6	17.4	306	Morris Pine
Loblolly pine	104.1	**42.2**	14.5	279	
Loblolly pine	109.0	37.2	16.4	270	
Loblolly pine	101.6	38.6	20.4	269	
White oak	114.8	**33.3**	20.9	268	
Shortleaf pine	111.5	35.4	16.9	--	double stem
Loblolly pine	106.9	35.6	16.8	263	
Shortleaf pine	90.9	**41.5**	15.2	261	Walsh Pine
Shortleaf pine	87.6	40.1	11.3	249	
White oak	92.7	33.5	23.4	244	
Southern red oak	97.8	**31.3**	24.4	244	
Shortleaf pine	83.8	36.9	13.8	236	
Shortleaf pine	74.9	39.5	11.4	232	
White oak	92.7	30.7	19.4	231	
Sweetgum	76.2	**36.8**	15.2	227	
White oak	81.5	32.0	22.5	224	
Shortleaf pine	78.2	34.3	11.9	219	
White oak	74.9	32.5	16.6	213	
Sweetgum	81.5	30.2	15.9	213	
Post oak	81.3	**30.4**	13.0	211	
Shortleaf pine	63.8	37.9	8.7	210	
Post oak	81.3	27.9	18.3	207	
Water oak	71.9	**31.2**	11.2	200	
Winged elm	46.5	**27.6**	14.2	160	

[a] Not every tree species present in the LWDF is represented in this table. The tallest example of each species is indicated by **bold-faced text**.
[b] The height reported in this table is calculated using the sine method, which is considerably more accurate for large dimension individuals, especially wide-crowned hardwoods (Blozan 2004, Bragg 2006).
[c] Average of the widest portion of the crown and the width perpendicular to this axis.
[d] Bigness Index (American Forests 2006) = circumference (in inches) + tree height (in feet) + ¼ average crown width (in feet)

establishment dates shows a long history of pine recruitment during the 19th Century and first half of the 20th Century (Fig. 5). There is a considerable range of pine ages in the LWDF, from an estimated 300+ years for the Morris Pine to approximately 50 years old (Fig. 5). The estimated age of the Morris Pine clearly isolates it temporally from the rest of the stand. However, this incomplete and non-random sample does not infer that there are no other pines in the stand that originated in the 18th Century—rather, it simply implies that we did not date any others to this period.

Even though precise dating was often complicated by extensive basal decay, most pines aged in the LWDF originated from 1840 to 1900. Since the LWDF was old-growth when established in 1948, the lack of old pines that would have dominated the canopy when the stand was reserved indicates that this cohort has almost completely succumbed. Pine recruitment

Table 4. Tree age dated from shortleaf pine stumps dated in March of 2006 on the LWDF.

Stump number	Stump diameter (cm)	Ring count	Comments
1	69.8	146	Ring count to pith; no obvious fire scars
2	77.5	150	Ring count to pith; no obvious fire scars
3	87.6	166	Ring count to pith; no obvious fire scars
4	86.4	151	Ring count to rotten core; fire scars from 25 and 102 years ago

has also been virtually non-existent since the 1950s, with the most recent canopy ascensions following the abandonment of the unpaved highway to Bastrop, Louisiana, decades ago. A few small pockets of young (<10 yr old) pine can be found along the edge of Highway 425, but regeneration conditions within the stand are too unfavorable to maintain pine dominance.

Using the pine stump ring counts from the 1988 data, the stump ages of Bragg (2004a), and the new data points collected in 2006, a linear regression model of pine age as a function of stump diameter was developed (Fig. 6). Loblolly and shortleaf pine were not distinguished from each other, partially because they both follow the same general allometric patterns and partially because a considerable number of the 1988 pines were not identified to species (shown as stars in Fig. 6). Although the slope of the equation is highly significant ($P < 0.0001$), the regression explained only a small portion of the overall variance in the data ($R^2 = 0.2355$). This is not surprising, given that 60 to 70 cm pine stumps in the LWDF ranged in age from less than 60 years to 160 years. Generally, there is a much stronger relationship between diameter and age in well-regulated loblolly/shortleaf pine forests, and the dispersed nature of the data in Fig. 6 is further evidence of the old-growth structure of the LWDF.

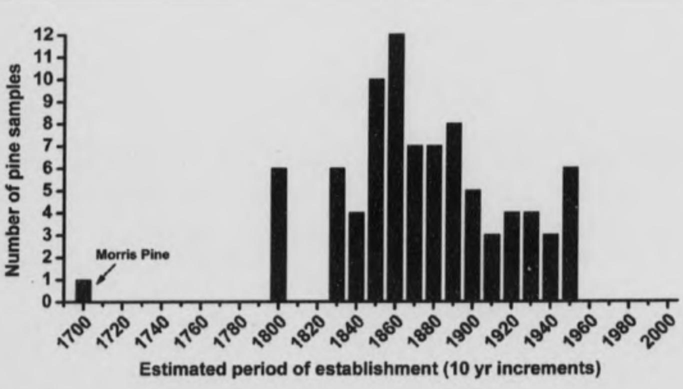

Fig. 5. Establishment pattern of selected pines in the LWDF taken from data in Bragg (2004a), the current study, and unpublished data collected by Dr. Brian Lockhart in 1988. Age of the Morris Pine and the individuals established in 1800 are estimates.

Conclusions

Five years, though a short period of time in the history of this old pine stand, has been a time of dramatic changes in species abundance and dominance. The strong windstorm that struck the LWDF, though not as devastating as a tornado or crown fire, had a disproportionate impact on the overstory pines and thus accelerated succession toward hardwoods. However,

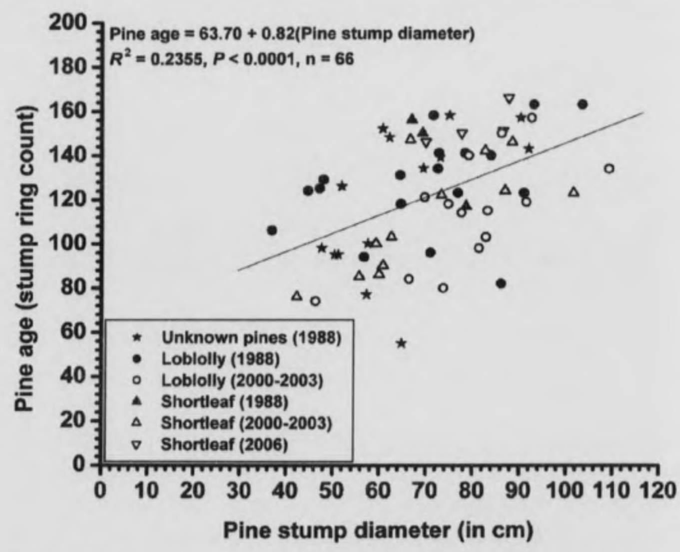

Fig. 6. Relationship between pine age and stump diameter at the LWDF using data from the present study, Bragg (2004a), and unpublished data from 1988.

even relatively brief periods of drought that occurred during the last few years were sufficient to at least temporarily impact many of the under- and midstory tree species, further altering the successional trajectory of this remnant old-growth stand. Under all of these pressures, long-term maintenance of a pine overstory will be virtually impossible in this preserve without deliberate human intervention to assure its recruitment.

ACKNOWLEDGMENTS.—I would like to recognize the contributions of the following: Mike Chain (USDA Forest Service), Conner Fristoe (Plum Creek Timber Company), Jim Guldin (USDA Forest Service), Brian Lockhart (USDA Forest Service), Mike Shelton (USDA Forest Service), Kirby Sneed (USDA Forest Service), and Bruce Walsh (USDA Forest Service, deceased). Brian Lockhart also graciously provided the previously unpublished pine stump ring counts for the LWDF.

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