Composition, Structure, and Dynamics of a Mature, Unmanaged, Pine-dominated Old-field Stand in Southeastern Arkansas

Don C. Bragg[1,*], and Eric Heitzman[2]

Abstract - This study describes the composition and structure of a mature, second-growth *Pinus taeda* (Loblolly Pine) and *Pinus echinata* (Shortleaf Pine)-dominated old-field stand. Now owned by the University of Arkansas, this 22.5-ha parcel just outside of the city of Monticello, AR, has been protected as a *de facto* natural area since the 1950s. Many of the overstory pines exceeded 75 cm in diameter at breast height (DBH) and some have reached 100 cm. Increment cores indicated that most of the pine overstory originated between 80 and 100 years ago, probably following agricultural abandonment. Pine recruitment occurred somewhat gradually until the canopy closed, after which tree species establishment became dominated by hardwoods. Of the nearly 6000 tree seedlings/saplings per hectare in the interior of this stand, just under 4% were pine—the under- and midstory were dominated by shade-tolerant hardwoods. No obvious evidence of past land-management practices remained, save the rare old stump or formerly open-grown pine or oak. Coarse woody debris is beginning to accumulate in some portions of the stand, primarily from the senescence of short-lived hardwoods. Comparisons with other tracts in southern Arkansas suggest that this stand differs from other contemporary examples of mature pine-dominated timber, with a richness in composition and structure not apparent in managed stands of natural or planted origin.

Introduction

As late as the early 20th century, many of the landscapes of the West Gulf Coastal Plain in the southern United States were covered in old-growth pine-dominated forests (Bragg 2002, Eldredge 1952). Some of these pine systems were open, verging on savanna, and contained large trees 200–400 years old (Platt 1999), while others were more closed canopy, with a mixture of large *Pinus palustris* Mill. (Longleaf Pine), *Pinus taeda* L. (Loblolly Pine), and/or *Pinus echinata* (Shortleaf Pine) rising above and under midstory of hardwoods (Eldredge 1952). Even the extensive hardwood-dominated forests of the region often had a prominent if passing pine component (Quarterman and Keever 1962). However, their commercial viability, the exhaustion of other eastern forests, and improved logging and milling techniques destined the southern pinery for exploitation (Schultz 1997).

Decades of logging, agriculture, and other intensive land practices have dramatically reshaped the vegetation patterns of the southern United States. Typically, the virgin forest was cleared and then the land was converted to some form of agriculture. Over much of this region, marginal farms were

[1]Southern Research Station, USDA Forest Service, PO Box 3516 UAM, Monticello, AR 71656. [2]Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV 26506. [*]Corresponding author - dbragg@fs.fed.us.

soon abandoned, and many quickly reforested into relatively dense stands of pure pine, pure hardwood, or gradations in between (e.g., Bragg 2004a, Quarterman and Keever 1962, Schultz 1999). During the 20th century, these natural-origin stands matured and most were logged again (often repeatedly), producing a landscape dominated by modified forests. Lately, forest management has significantly intensified across most of the South, with pine plantations replacing many stands of natural origin (Conner and Hartsell 2002). These most recent trends are not likely to slow—if anything, the pressure to further intensify management on a stable to declining timber base is increasing (e.g., Fox et al. 2007, Schultz 1999).

Very few mature second-growth southern pine-dominated stands have escaped silvicultural manipulation. One such example is the Reynolds Research Natural Area (RRNA) on the Crossett Experimental Forest (CEF) near Crossett, AR. The overstory dynamics of the RRNA have been well-documented (e.g., Cain and Shelton 1994, 1995, 1996; Guldin and Baker 1984; Shelton and Cain 1999). This 32-ha stand, which had been heavily cutover and high-graded before 1920, was reserved as an unharvested control during the 1930s to demonstrate decreases in pine productivity when compared to well-managed stands (Shelton and Cain 1999). Aside from decades of fire protection and some minor salvage following limited *Dendroctonus frontalis* Zimm. (Southern Pine Beetle) outbreaks in the early 1970s, this stand has been allowed to develop virtually untouched.

However, the RRNA is far more the exception than the rule—very little research has been done in mature, unmanaged second-growth pine stands in the Upper West Gulf Coastal Plain (UWGCP) and few examples of this covertype now remain. The extensive loss of older, natural-origin pine-dominated forests across the UWGCP, coupled with the rapid conversion of whole landscapes to short-rotation, intensively managed pine plantations will likely have important ramifications for system characteristics, including carbon storage, community and landscape diversity patterns, endangered species management, ecosystem services, and even local socioeconomic well-being. For instance, changes to avian guilds have been repeatedly documented as a function of recent silvicultural changes across the UWGCP (e.g., Aquilani 2006, Thill and Koerth 2005).

This study documents the composition and structure of a mature, natural-origin Loblolly and Shortleaf Pine-dominated stand in the absence of silvicultural manipulation. This particular stand, arising from an "old-field" (former agricultural/pastoral land) condition, is a typical example of the second-growth pine-dominated forest that once covered much of the UWGCP. We compare the traits of this stand with published information from nearby managed and unmanaged pine forests to assess the ecological implications of large-scale conversion of forested landscapes in this region.

Field-site Description

The study site (Fig. 1) is located in the UWGCP geographic province on property owned by the University of Arkansas near Monticello, AR

(33º37'17.75"N, 91º43'31.33"W). Figure 2 shows the position of the study area and includes a coarse-resolution covertype map with major geographic points of reference. Only scattered records exist on the history of this particular tract, but evidence of at least 1 old homesite, some overgrown traces, and a few well-decayed stumps suggest the events leading to the stand seen today. Prior to World War II, this tract was privately owned, but the area came under federal control by 1942, with the property serving as a Women's Army Auxiliary Corps (WAAC) training facility before being converted to a prisoner of war (POW) camp for Italian soldiers from 1943 until 1946 (Pomeroy 1976). The land developed for the prisoners was located to the west of the study area (Fig. 2). After World War II, the property was deeded to the University of Arkansas for forestry research and demonstration projects. Since this time, much of the former Monticello POW Camp has received various harvesting and planting treatments, with the exception of the *de facto* natural area reported in this work. This 22.5-ha stand, hereafter referred to as the POW Camp Natural Area (POWCNA), appears to have been protected from natural and anthropogenic disturbance for most of the last 60+ years.

Elevations for most of the POWCNA range between 58 and 63 m above mean sea level. The study area is largely comprised of Pleistocene-era terraces, upon which are found low-gradient Calloway silt loams and gently to steeply sloped Grenada silt loams (Haley et al. 1993, Larance et al. 1976). The POWCNA receives an average of about 130 cm of precipitation annually, and is dissected by an unnamed semi-permanent stream and numerous small drains that flow only during the wettest times of the year (typically in winter and spring). The ephemeral stream has carved a small, steep, relatively incised (often ≥2 m deep) channel, flanked by terraces comprised of a narrow band of Holocene alluvium (primarily Amy silt loam). Widely scattered tip-up mounds can be found, especially along the active stream terraces.

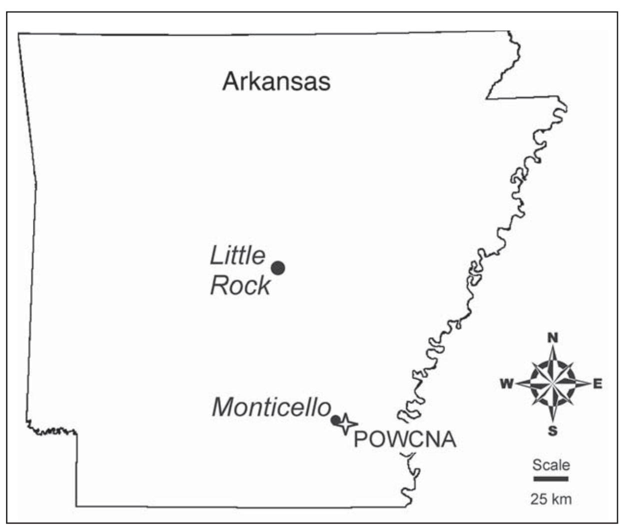

Figure 1. Location of the POW Camp Natural Area (POWCNA) in southeastern Arkansas.

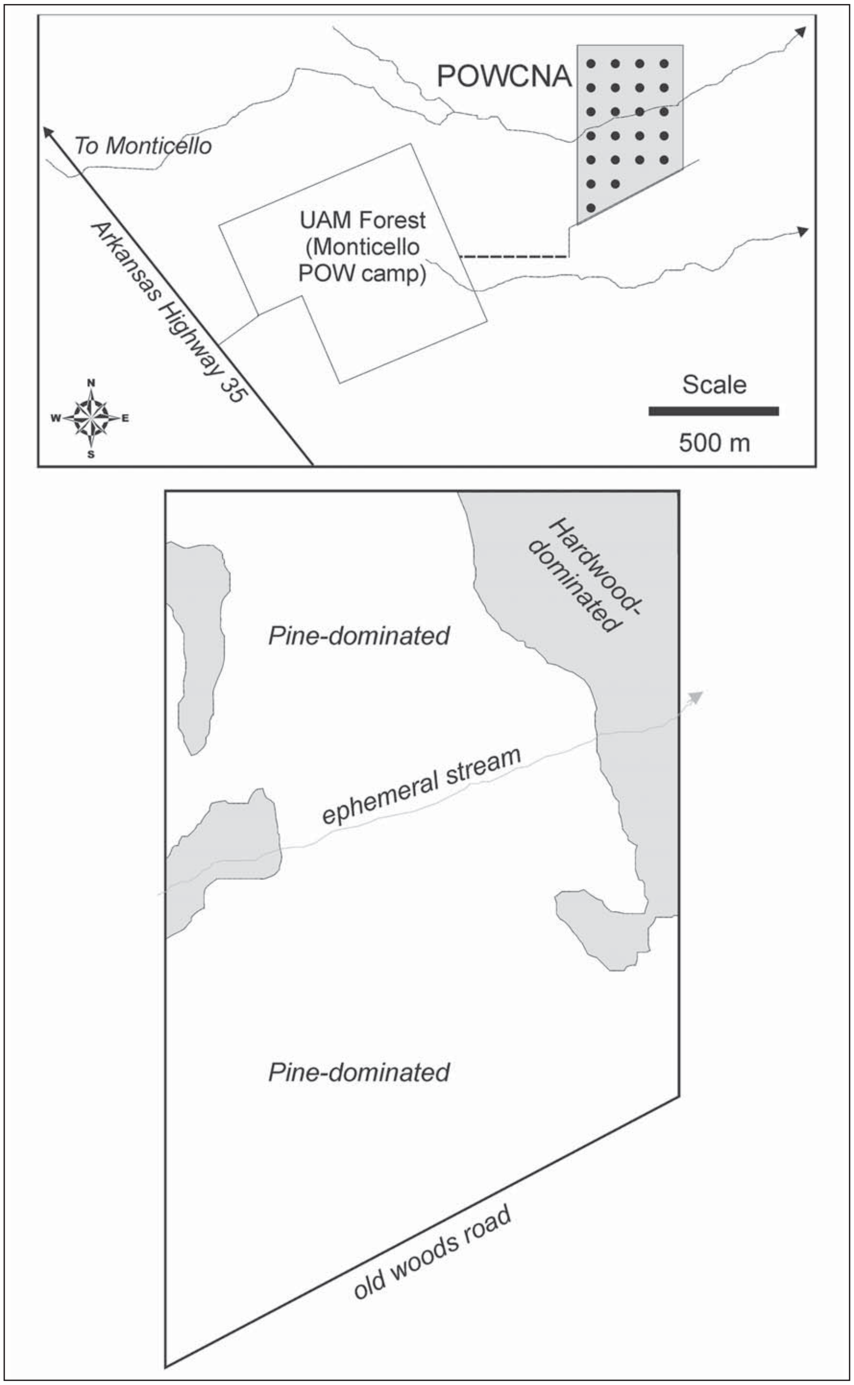

Figure 2. Configuration of the sample plot layout in the POWCNA (top) coupled with a broad covertype distribution and geographic feature outline (bottom).

Before Euroamerican settlement, this region was covered by a mixture of Loblolly and Shortleaf Pine intermingled with hardwood species, especially along riparian corridors (Bragg 2002, 2008). The study area likely followed a land-developmental trajectory that included being cleared 100–150 years ago, farmed (either with row crops or pastured, or both) for years, then abandoned and allowed to revert back to forest. Much of this historic landscape became poorly timbered and was frequently burned until reforestation efforts and fire control were implemented after 1930 (Bruner 1930, Reynolds 1980, Schultz 1999).

Methods

Overstory sampling

Using a series of fixed-radius plots, data on tree species composition, stocking, and density were gathered on the POWCNA between December 2004 and May 2005. Four parallel transects spaced 80.5 m apart were established in the POWCNA (Fig. 2). Starting along an overgrown woods road, each transect extended due north to the northernmost edge of the university's property. Between five and seven 0.081-ha circular plots were established along each transect (for a grand total of 23 overstory plots), with 80.5 m between plot centers (Fig. 2). Each plot was at least 30 m from the boundaries of the POWCNA to avoid edge effects caused by adjacent clearcuts. Plot centers were marked with a piece of steel rebar and flagged to assist in their relocation. On these overstory plots, every live tree at least 9.0 cm diameter at breast height (DBH) was tallied by species and DBH (to the nearest 0.1 cm) recorded. Ring counts at DBH for a subsample of 44 Loblolly and 15 Shortleaf Pines were taken with an increment corer. Because we did not cross-date the cores, these age estimates are approximate. However, they are a reasonable proxy for age given their broad interpretation in this paper.

Importance values (IVs) for all tree species in the mid- and overstory were calculated using the number of stems of species *i* divided by the total number of stems of all species (relative number, or RN_i), the basal area of species *i* divided by the total basal area of all species (relative basal area, RB_i), and the number of plots with *i* divided by the total possible number of plots with all species (relative frequency, RF_i). These three values were then averaged and scaled between 0 and 100:

$$IV_i = 100 \times ([RN_i + RB_i + RF_i] / 3) \qquad [1]$$

Equation 1 adjusts for the abundance and distribution of species—taxa that are common but spatially limited will have a lower IV than those that are as common but more evenly distributed. This approach also constrains the influence of numbers or density by standardizing their quantity relative to the whole.

In addition to the plot information on tree abundance, a number of supplementary measurements on diameter, height, age, and species occurrence were taken on individual trees off the plots (but still on the POWCNA) to better help describe tree and stand attributes. For instance, additional Loblolly and Shortleaf Pines were sampled for age from outside of these plots after the initial sample was drawn to help determine if apparent gaps in the size or age structure were real or due to a limited sample size.

Understory sampling

Woody understory plants were sampled using 0.0004-ha subplots nested within each overstory plot and located at each of the 4 cardinal directions, for a total of 92 subplots. Each plant had to be rooted within the plot to be tallied. The woody understory was separated into 6 size classes by species. The first 3 classes were based on height, with stems placed into individuals 15–76 cm tall, 77–137 cm tall, and >137 cm tall, but with stem <1.5 cm DBH. Stems >1.5 cm DBH were divided into 3 DBH classes: >1.5–3.8 cm, >3.8–6.4 cm, and >6.4–8.9 cm. These data were recorded as counts of plants, so specific diameters within size classes are not known.

Understory IV were calculated in a similar fashion to the overstory (equation [1]) using their relative number (number stems of species *i* divided by the total number stems from all species), relative basal area (density, in terms of stem basal area of species *i* divided by the total basal area of all species) and relative frequency (number of subplots with species *i* divided by the total number of subplots for all species). Because we only had stem counts and no cover measure for relative basal area (density) with the three smallest size classes (A, B, and C), a diameter was assigned to each class (A = 0.004 cm, B = 0.008 cm, C = 0.025 cm) and these values were then multiplied by the number of stems per size class to determine their contribution to density.

We were concerned that the small size of these subplots would not fully capture the abundance of woody vines in this stand. Lianas comprised much of the leaf cover in the midstory, yet their stems were typically tightly clustered. Rather than using the small understory subplots, we nested a single liana-only plot 6.22 m in radius (0.012 ha) based on the overstory plot center. All woody vines ≥1.37 m tall rooted within this liana subplot were identified to genus or species and its DBH measured. No IVs were calculated for the woody vines as this measure is inadequate to account for their extensive foliar coverage in the midstory of this stand.

Coarse woody debris inventory

All coarse woody debris (CWD) falling within the 0.081-ha plots were recorded following methodology reported in Bragg (2004b). Three classes of CWD were tallied: logs (downed wood ≥1 m long and 10 cm minimum diameter), snags (standing dead tree ≥2 m tall and with a minimum diameter of 10 cm), and stumps (standing dead tree <2 m tall and a minimum of 10 cm diameter, with a minimum solid wood volume of 0.01 m^3). CWD pieces were identified as either pine or hardwood, and the following attributes were measured: length (to the nearest 0.03 m, if measured with a cloth tape, or 0.3 m, if estimated with a tape and clinometer), large- and small-end diameters (to the nearest 0.25 cm if measured with a caliper or diameter tape, or to the nearest

2.5 cm, if estimated for a standing snag), and decay class. Three decay classes were distinguished: decay class 1 = freshly dead wood; decay class 2 = some bark loss and wood decay, but piece is still sound; and decay class 3 = most or all bark missing, wood structural integrity largely or completely absent.

CWD volume (*V*, in m^3) for every piece of large dead wood that fell within the overstory plot margins was determined with Smalian's formula (Fonseca 2005):

$$V = (\pi[D + d] \times L) / 8, \quad [2]$$

where *D* represents the large-end diameter (in m), *d* is the small-end diameter (in m), and *L* is piece length (in m). CWD frequency and volume per hectare were extrapolated from summing each plot's total and averaging over all plots. Estimates of ranges and variance were determined by calculating per hectare totals or volumes for each plot.

Results

The POWCNA is a pine-dominated stand with emergent Loblolly and Shortleaf rising above a dense mid- and overstory occupied largely by hardwoods. The understory is relatively open and populated with increasingly shade-tolerant hardwood tree species, woody shrubs, and lianas. Some small gaps in the overstory have been opened over the years, and these are typically rapidly occupied by dense thickets of new plant growth.

Understory woody vegetation

There were dozens of woody understory taxa, primarily the advanced regeneration of tree species. Understory trees of prominence (Table 1) included *Sassafras albidum* (Sassafras), *Quercus alba* (White Oak), *Ostrya virginiana* (Eastern Hophornbeam), *Acer rubrum* (Red Maple), *Nyssa sylvatica* (Blackgum), *Ulmus alata* (Winged Elm), *Carpinus caroliniana* (American Hornbeam), *Quercus falcata* (Southern Red Oak), *Symplocos tinctoria* (Sweet-leaf), and even a few Loblolly Pine seedlings, especially north of the ephemeral stream. Moderate to very shade-tolerant hardwood tree species (e.g., White Oak, Eastern Hophornbeam, Red Maple, American Hornbeam, *Cornus florida* [Flowering Dogwood]) dominate this strata largely because of their ability to reach larger understory size classes under this low-light environment (Table 1). *Ilex opaca* (American Holly) was present in a number of locations across the POWCNA, but only as advanced regeneration off the measurement plots.

There were relatively few woody understory species beyond the tree component (Table 1). The most common shrub species found on the study area plots included *Vaccinium* spp., *Corylus americana* (American Hazelnut), *Callicarpa americana* (American Beauty Berry), and *Ilex decidua* (Deciduous Holly). *Vaccinium* spp. dominated the IV of the understory and were clearly the most important of the woody shrubs, with an IV (10.0) 2.5 times greater than then next highest shrub (Table 1). A number of other shrub species were found off of the plots in other parts of the stand, including

Table 1. Average species abundance, basal area, subplot frequency, and importance values (IV) for understory woody plants (excluding lianas) in the POWCNA near Monticello, AR.

Taxonomic group / Species or genus [A]	Total stems per ha	Stems/ha by size class code[B]						RN [c] (%)	RB[C] (%)	RF[C] (%)	IV[C] score
		A	B	C	1	2	3				
Shrubs	2551.5	2121.8	322.4	107.5	0	0	0	-	-	-	-
Vaccinium spp.[D]	1611.5	1504.1	26.9	80.6	0	0	0	20.27	0.46	9.3	10.0
American Hazelnut (*Corylus americana* Walt.)	537.2	322.3	188.0	26.9	0	0	0	6.76	0.21	4.9	4.0
American Beauty Berry (*Callicarpa americana* L.)	161.1	107.4	53.7	0	0	0	0	2.03	0.03	3.7	1.9
Deciduous Holly (*Ilex decidua* Walter)	107.4	80.6	26.9	0	0	0	0	1.35	0.02	0.6	0.7
Red Buckeye (*Aesculus pavia* L.)	53.7	53.7	0	0	0	0	0	0.68	0.01	1.2	0.6
Rubus spp.	53.7	53.7	0	0	0	0	0	0.68	0.01	1.2	0.6
Serviceberry (*Amelanchier arborea* (Michx. F.) Fern.)	26.9	0	26.9	0	0	0	0	0.34	0.01	0.6	0.3
Trees	5398.8	4243.8	215.0	188.2	376.1	268.8	107.6	-	-	-	-
Sassafras (*Sassafras albidum* (Nutt.) Nees.)	725.2	671.5	53.7	0	0	0	0	9.12	0.09	5.6	4.9
White Oak (*Quercus alba* L.)	698.3	617.7	0	26.9	26.9	0	26.9	8.78	11.05	9.9	9.9
Eastern Hophornbeam (*Ostrya virginiana* (Mill.) Koch.)	644.6	456.6	26.9	80.6	53.7	26.9	0	8.11	6.89	9.9	8.3
Red Maple (*Acer rubrum* L.)	590.9	537.2	0	0	0	26.9	26.9	7.43	14.22	5.6	9.1
Blackgum (*Nyssa sylvatica* Marsh.)	564.0	564.0	0	0	0	0	0	7.09	0.06	8.0	5.1
Winged Elm (*Ulmus alata* Michx.)	456.6	322.3	26.9	26.9	53.7	26.9	0	5.74	6.68	7.4	6.6
American Hornbeam (*Carpinus caroliniana* Walt.)	349.2	134.3	26.9	26.9	107.4	26.9	26.9	4.39	18.64	4.9	9.3
Southern Red Oak (*Quercus falcata* Michx.)	241.7	241.7	0	0	0	0	0	3.04	0.03	4.3	2.5

Table 1, continued.

Taxonomic group Species or genus[A]	Total stems per ha	Stems/ha by size class code[B] A	B	C	1	2	3	RN[C] (%)	RB[C] (%)	RF[C] (%)	IV[C] score
Trees, continued											
Loblolly Pine (*Pinus taeda* L.)	214.9	214.9	0	0	0	0	0	2.70	0.02	4.3	2.3
Sweetgum (*Liquidambar styraciflua* L.)	188.0	26.9	53.7	26.9	0	80.6	0	2.36	13.20	4.3	6.6
Sweet-leaf (*Symplocos tinctoria* (L.) L'Hér.)	188.0	161.1	26.9	0	0	0	0	2.36	0.03	2.5	1.6
Flowering Dogwood (*Cornus florida* L.)	134.3	26.9	0	0	26.9	53.7	26.9	1.69	19.61	3.1	8.1
Mockernut Hickory (*Carya tomentosa* Nutt.)	134.3	53.7	0	0	80.6	0	0	1.69	3.27	3.1	2.7
Water Oak (*Quercus nigra* L.)	80.6	53.7	0	0	0	26.9	0	1.01	4.36	1.2	2.2
Black Cherry (*Prunus serotina* Ehrh.)	53.7	53.7	0	0	0	0	0	0.68	0.01	1.2	0.6
Cherrybark Oak (*Quercus pagoda* Raf.)	26.9	26.9	0	0	0	0	0	0.34	0	0.6	0.3
Hickory (*Carya* spp.)	26.9	26.9	0	0	0	0	0	0.34	0	0.6	0.3
Redbud (*Cercis canadensis* L.)	26.9	26.9	0	0	0	0	0	0.34	0	0.6	0.3
White Ash (*Fraxinus americana* L.)	26.9	0	0	0	26.9	0	0	0.34	1.09	0.6	0.7
Willow Oak (*Quercus phellos* L.)	26.9	26.9	0	0	0	0	0	0.34	0	0.6	0.3

[A]All species nomenclature from Smith (1988) and Moore (1999). Totals may not add due to rounding errors.

[B]Size codes—for all stems <1.5 cm DBH: A = 15 to 74 cm tall, B = 75 to 136 cm tall, C = ≥137 cm tall; for all stems ≥1.5cm DBH: 1 = 1.5 to 3.8 cm DBH, 2 = 3.9 to 6.3 cm DBH, 3 = 6.4 to 9.0 cm DBH.

[C]RN (relative number) = 100 x (number of stems of species / total number of stems); RB (relative basal area) = 100 x (basal area of species / total understory basal area); RF (relative frequency) = 100 x (number of subplots with species / total number of subplots for all species); IV (importance value) score = (RN + RB + RF) / 3.

[D]Probably includes (in order of likelihood): *Vaccinium arboreum* Marsh. (Farkleberry) and *Vaccinium stamineum* L. (Deerberry).

Hamamelis virginiana (Witch-hazel), *Aesculus pavia* (Red Buckeye), and *Prunus* spp. The vast majority of woody shrubs were 1 m or less in height (Table 1).

Woody vines were abundant in the study area, with >1000 stems/ha that reached at least 1.37 m in height (Table 2). *Vitis rotundifolia* (Muscadine) and *Toxicodendron radicans* Kuntze (Poison Ivy) dominated the lianas, comprising nearly two-thirds of all stems. Greenbriers, grapes other than Muscadine, *Lonicera* spp. (Honeysuckle), and *Berchemia scandens* (Rattan) composed the remaining third. In the POWCNA, these lianas can grow to considerable size—we found Muscadine and *Vitis aestivalis* (Summer Grape) vines >10 cm in diameter. In addition to large girth, it was not unusual for some species of lianas (e.g., grapes and poison ivy) to grow into the highest layers of the forest canopy, sometimes exceeding 30 m in height.

Overstory richness, abundance, and importance

The POWCNA has considerable overstory richness, with 26 tree species >8.9 cm DBH found in the established study plots (Table 3). In addition to these taxa, several other tree species were found in the POWCNA that never occurred in the study plots, including native species such as American Holly, *Quercus pagoda* (Cherrybark Oak), *Fraxinus pennsylvanica* (Green Ash), *Carya cordiformis* (Bitternut Hickory), and *Diospyros virginiana* (Persimmon), and taxa that were probably introduced such as *Liriodendron tulipifera* (Tulip-poplar). Thus, at least 32 tree species were found in this 22.5-ha parcel.

Loblolly Pine dominated all measures of stocking, constituting 21.1% of the 489.9 stems/ha and 56.3% of the 34.4 m^2/ha of total live tree basal area found in the POWCNA. Loblolly Pine was the sole species found on all 23 plots, with only *Liquidambar styraciflua* (Sweetgum) and Red Maple also found on >90% of the plots (Table 3). Loblolly was over twice as important

Table 2. Woody vine abundance, basal area, and DBH distribution in the POWCNA.

Common name	Scientific name	Stems per ha	Basal area (m^2/ha)	Min. DBH (cm)	Max. DBH (cm)	Avg. DBH (cm)	Std. dev. (cm)
Muscadine	*Vitis rotundifolia* Michx.	374.2	0.078	0.1	5.0	1.4	0.88
Poison Ivy	*Toxicodendron radicans* (L.) Kuntze	263.7	0.032	0.1	5.1	0.7	1.06
Greenbrier[A]	*Smilax* spp.	114.0	0.002	0.1	1.0	0.4	0.19
Honeysuckle[B]	*Lonicera* spp.	110.5	0.009	0.2	2.0	0.9	0.44
Grape[C]	*Vitis* spp.	103.3	0.099	0.3	14.0	2.4	2.58
Rattan	*Berchemia scandens* (Hill) K. Koch	39.2	0.015	0.6	3.4	2.1	0.89
Totals (per hectare):		1005.0	0.236				

[A]Probably includes (in order of likelihood): *Smilax rotundifolia* L. (Roundleaf Greenbrier), *Smilax bona-nox* L. (Saw Greenbrier), *Smilax glauca* Walt. (Cat Greenbrier), and/or *Smilax smallii* Morong. (Lanceleaf Greenbrier).

[B]Probably includes (in order of likelihood): *Lonicera japonica* Thunb. (Japanese Honeysuckle) and/or *Lonicera sempervirens* Ait. (Trumpet Honeysuckle).

[C]Probably includes (in order of likelihood): *Vitis aestivalis* Michx. (Summer Grape), *Vitis cinerea* Englem. ex Millard (Graybark Grape), *Vitis vulpina* L. (Frost Grape), and/or *Vitis palmata* Vahl. (Catbird Grape).

as the next highest species, Sweetgum (IV = 28.9 versus 12.9). The other pine species in the stand, Shortleaf, was noticeably less common, contributing only about 2.4% of the total number of live stems per hectare and <7.5% of stand basal area. Shortleaf Pine's relatively high basal area helped inflate its IV compared to species with similar numbers—there were 7 hardwood species with more trees per hectare than Shortleaf Pine, yet all had lower IVs than Shortleaf's 4.8 (Table 3).

Non-pine species contributed the majority of live stems to the tallies. Sweetgum alone provided 20.6%, followed by Red Maple (12.2%), White Oak (7.3%), and Southern Red Oak (5.2%). No other single species exceeded 5% of the relative abundance, and 4 species (*Juniperus virginiana* [Eastern Redcedar], *Amelanchier arborea* [Serviceberry], *Castanea pumila* [Chinkapin], and Sweet-leaf) were represented by a single individual on the

Table 3. Species abundance, basal area, plot frequency, and importance values (IV) of mid- and overstory trees (those ≥9 cm DBH) from the plot samples in the POWCNA.

Common name	Scientific name[A]	Trees per ha	Basal area (m^2/ha)	Plots with sp. (%)	IV[B]
Loblolly Pine		103.7	19.36	23	28.9
Sweetgum		101.0	3.14	22	12.9
Red Maple		59.6	0.88	21	7.7
White Oak		36.0	1.00	16	5.6
Southern Red Oak		25.3	3.39	14	6.9
American Hornbeam		21.0	0.24	15	3.7
Flowering Dogwood		17.2	0.21	14	3.2
Winged Elm		15.6	0.21	14	3.1
Sassafras		15.0	0.24	8	2.3
Eastern Hophornbeam		14.0	0.16	14	3.0
Blackgum		12.4	0.29	17	3.4
Post Oak	*Quercus stellata* Wang.	12.4	1.21	4	2.6
Shortleaf Pine	*Pinus echinata* Mill.	11.8	2.56	11	4.8
Water Oak		10.7	0.49	11	2.7
Black Oak	*Quercus velutina* Lam.	7.5	0.23	9	1.9
Mockernut Hickory		6.5	0.17	5	1.3
White Ash		6.5	0.22	9	1.9
Black Cherry		5.4	0.22	8	1.7
Willow Oak		2.2	0.09	4	0.8
Redbud		1.6	0.01	1	0.3
Red Mulberry	*Morus rubra* L.	1.6	0.03	3	0.5
American Elm	*Ulmus americana* L.	1.1	0.03	2	0.4
Eastern Redcedar	*Juniperus virginiana* L.	0.5	<0.01	1	0.2
Serviceberry		0.5	<0.01	1	0.2
Chinkapin	*Castanea pumila* (L.) Mill.	0.5	0.01	1	0.2
Sweet-leaf		0.5	0.01	1	0.2
Totals		489.9	34.4	249	100.0

[A]Scientific names presented in Table 1 were not repeated here.

[B]Importance value (IV) = (relative number + relative basal area + relative frequency) / 3, where relative number = (species number / total number) × 100; relative basal area = (species basal area / total basal area) × 100; and relative frequency = (number of plots with species/sum of plots over all species) × 100.

overstory sample plots. As a group, hardwoods easily were more numerous than the conifers in this stand, comprising over 75% of all live stems per hectare in the POWCNA, yet there impact on overall importance was noticeably less, with just under 2/3 of the total (Table 3). Sweetgum was the only hardwood to contribute more than 10% of the total stand IV, as most were 5% or less.

Overstory basal-area and size-class distributions

Even with the relatively high abundance of hardwoods, the basal area and importance value measures reflect the dominance of the stand by the pines. Sweetgum, for example, though >20% of total live stems, contributed <10% of total stand basal area, compared to Loblolly Pine's 56.3% of stand basal area from roughly the same number of stems. Even Shortleaf Pine managed to contribute 7.4% of stand basal area from only 2.4% of total stems. The large size of the pines in the POWCNA ensured that their basal area was substantially higher than most hardwoods, and resulted in their dominance of the IV measured for this stand (Table 3).

Many of the overstory pines on the plots exceeded 75 cm DBH, and some approached or exceeded 100 cm (Table 4). The largest Loblolly Pine encountered in the entire POWCNA was located off of the plots and measured 104.1 cm DBH. The largest observed Shortleaf Pine was considerably smaller, measuring 72.4 cm DBH, but on average the Shortleaf in the POWCNA study plots were larger in diameter than the Loblolly Pine (51.6 cm versus 45.3 cm DBH). Loblolly and Shortleaf Pine were the only species with average diameters >45 cm, and amongst the non-pine taxa, only Southern Red Oak (37.8 cm DBH) and *Quercus stellata* (Post Oak; 33.8 cm DBH) averaged >30 cm.

The POWCNA overstory stocking was dominated by hardwoods, although these made up a minority of the basal area. Overstory hardwoods were concentrated in the 2 smallest sets of size classes (Fig. 3b, c), and only dominated the smallest of these (Fig. 3b). Few hardwoods were found on these plots in the co-dominant and dominant size categories, and the largest of these was a 72-cm DBH Southern Red Oak. However, within the POWCNA as a whole (including areas off-plot), a considerable number of hardwood specimens >75 cm DBH can be found, including White Oaks, Southern Red Oaks, Water Oaks, Cherrybark Oaks, and Sweetgums (Table 4). Most of the biggest pines in the POWCNA are the 30 to 35 m tall individuals that emerge well above the 20 to 30 m tall hardwood canopy.

Pine age structure

Increment cores indicated that most of the pine component originated between 60 and 100 years ago (Fig. 4). Of the original 59 pines sampled, the oldest Loblolly and Shortleaf Pines were between 100 and 110 years old. Ages ranged considerably, with some pines as young as 22 years old, and the majority of stems ranging between 30 and 90 years old. The supplemental pine age sample noticeably extended the age range of the pines. A number of these additional trees fell in a small gap that formed approximately 50 years ago. Several others were collected north of the ephemeral stream in part of the hardwood-dominated section on the east side of the POWCNA. In this section of hardwoods, scattered overstory pines are found. However, the under- and midstories are thoroughly dominated by hardwoods, and the few small pines growing in this strata have been long suppressed—one Loblolly Pine 12.4 cm in diameter had 31 annual rings at DBH and another nearby Loblolly 18.0 cm in diameter had 37 rings. In the western section of hardwoods just north of the intermittent stream, an 85.3-cm-DBH Loblolly Pine was cored that had at least 120 rings, and may have exceeded 130 years old (the rings near the pith were decayed and did not extract from the tree).

Table 4. Diameter at breast height (DBH) distribution by species of mid- and overstory trees (≥9 cm DBH), including a selection of off-plot individuals, in the POWCNA.

	Diameter at breast height (cm)			Standard	Off-plot[A] large DBH
Common name	Minimum	Maximum	Average	deviation	trees (cm)
Loblolly Pine	12.7	97.5	45.3	18.03	104.1
Sweetgum	9.4	61.0	17.7	9.14	78.0
Red Maple	9.4	30.7	13.2	3.71	40.9
White Oak	9.4	56.9	16.8	8.47	111.8
Southern Red Oak	9.9	71.6	37.8	16.85	93.7
American Hornbeam	9.7	16.3	11.8	1.85	21.1
Flowering Dogwood	9.7	16.5	12.2	2.02	21.3
Winged Elm	9.4	22.6	12.9	3.05	48.3
Sassafras	9.7	23.6	13.9	3.79	29.7
Eastern Hophornbeam	9.7	16.0	12.0	1.87	24.1
Blackgum	9.7	32.5	16.0	6.33	55.6
Post Oak	12.7	61.2	33.8	10.48	70.4
Shortleaf Pine	30.0	68.6	51.6	10.07	72.4
Water Oak	9.4	44.2	21.8	10.44	93.5
Black Oak	9.4	33.8	18.2	7.87	-[B]
Mockernut Hickory	9.4	24.6	17.0	6.35	42.9
White Ash	9.4	36.8	18.8	9.57	-
Black Cherry	9.7	46.2	20.7	10.86	48.0
Willow Oak	13.0	38.1	21.0	11.62	70.4
Redbud	9.9	12.2	10.8	1.21	18.0
Red Mulberry	10.9	20.6	14.9	5.07	24.4
American Elm	10.9	22.9	16.9	8.49	-
Eastern Redcedar	9.9	9.9	9.9	-[C]	48.3
Serviceberry	10.2	10.2	10.2	-	-
Chinkapin	17.8	17.8	17.8	-	24.1
Sweet-leaf	10.9	10.9	10.9	-	19.0
Off-plot only species					
Cherrybark Oak					92.5
Green Ash (*Fraxinus pennsylvanica* Marsh.)					65.5
Witch-hazel (*Hamamelis virginiana* L.)					9.1
Bitternut Hickory (*Carya cordiformis* (Wang.) K. Koch)					69.1
Persimmon (*Diospyros virginiana* L.)					19.8

[A]DBH measurements for very large individuals found outside of the 23 established study plots, but within the general boundaries of the POWCNA.
[B]No larger tree observed than on study plots.
[C]Standard deviations are not applicable to species with only one measured tree in the entire study.

A considerable range in pine ages for a given size class is also apparent (Fig. 4). At the greatest extreme, our sample found several pines between 30 and 35 cm in DBH that varied from about 40 rings to as many as 105 rings—over 60 years difference. Most of the pines of similar diameter were not as different

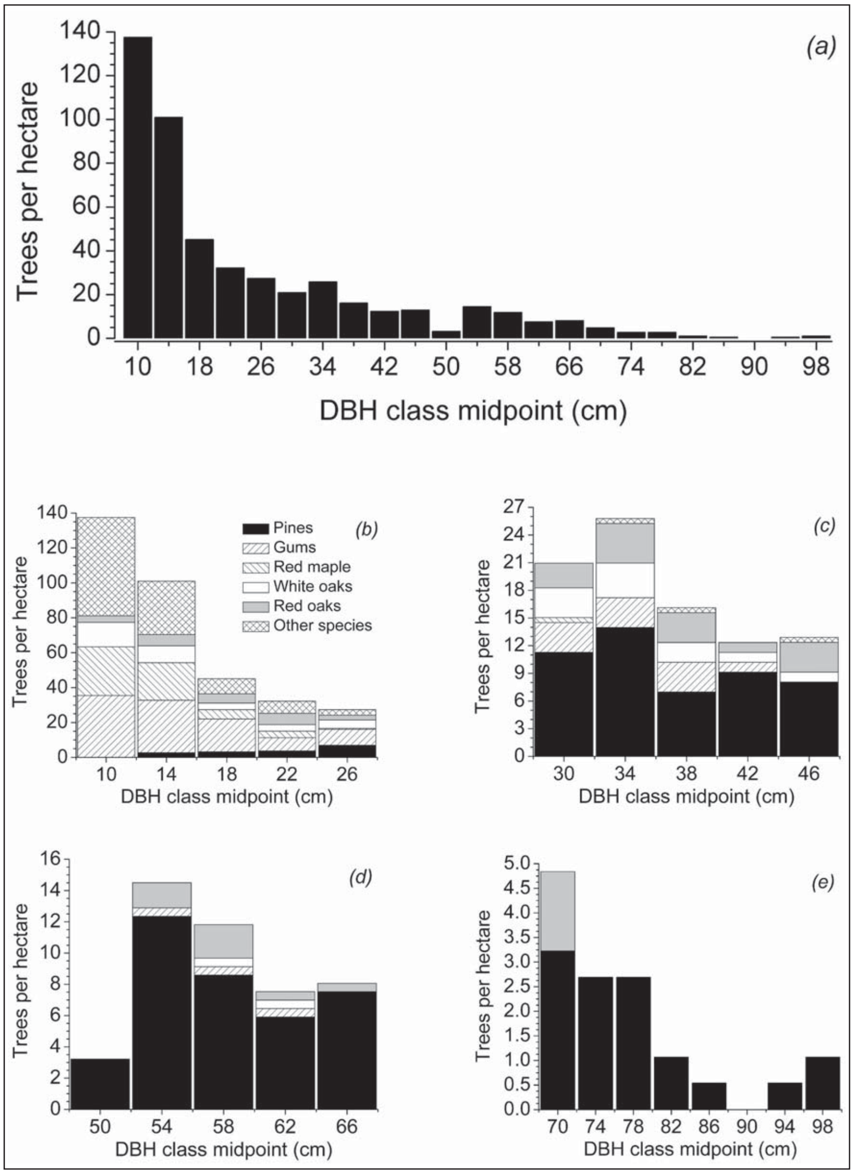

Figure 3. Aggregate size class distribution of the trees >9.0 cm DBH (*a*) in the POWCNA. This distribution can be broken down by species into suppressed (*b*), intermediate (*c*), co-dominant (*d*), and dominant (*e*) size classes (note the different scales for *b*–*e*).

in age, but 2–3 decades of age range were not unusual (Fig. 4). Furthermore, though the data suggest a positive linear trend between DBH and pine age, this relationship becomes less reliable with increasingly large stems. In fact, the largest known (104.1 cm DBH) Loblolly Pine on this site produced only 81 rings when cored at DBH—considerably younger than some pines that were much smaller in diameter (Fig. 4). The presence of low, large branch stubs and a broad spreading crown are good indicators (Marks and Gardescu 2001) that this particular pine was probably open-grown for most of its early years.

Coarse woody debris

Of the approximately 213 pieces of CWD per hectare in the POWCNA, a decided majority (91%) were classified as logs, with 4.5% of the pieces being snags and 4.5% called stumps (Table 5). Combined, these pieces of CWD averaged 28.9 m^3/ha in volume. Logs were found on all sample plots, but not every location had a snag or stump. Logs contributed just over 92% of the CWD volume in this stand, followed by snags (4.1%) and stumps (3.8%).

On average, most (73.4% of the 213.2 pieces/ha) of the CWD was assigned to decay class 2 (Table 5). Very little freshly dead (decay class 1; 3.8%) or long-dead (decay class 3; 22.8%) material was encountered. These abundance patterns were also roughly mirrored with their corresponding

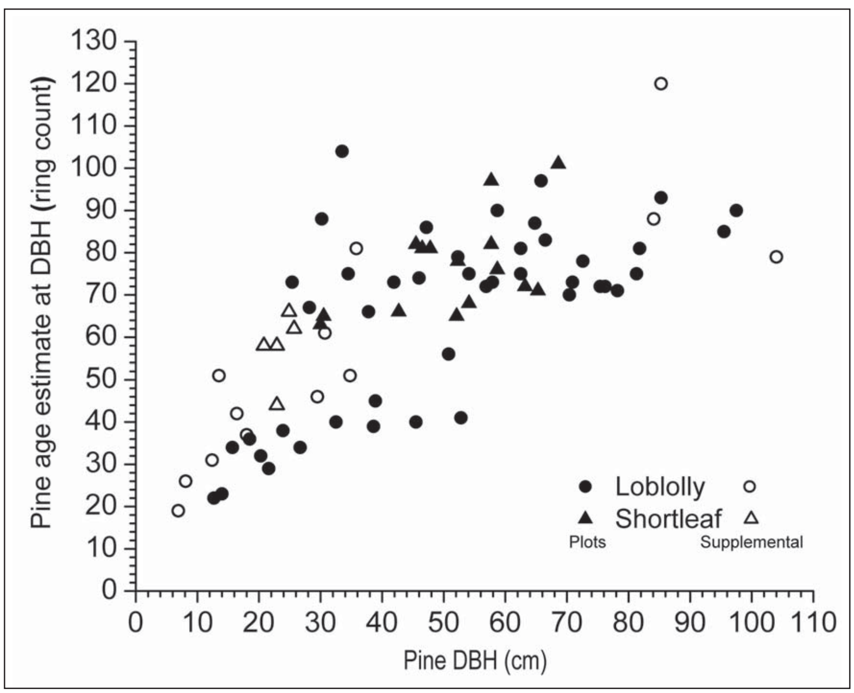

Figure 4. Age-class structure of the pine component of the POWCNA. Filled symbols are from the plot-based random sample, while the open symbols are from supplemental pines chosen to fill data gaps.

volumes: decay class 2 had the most (79.9% of the total volume), followed by decay class 3 (15.9%) and decay class 1 (3.8%).

The dead wood was more equitably divided between functional groups than either abundance or volume. There was slightly more pine CWD than hardwood (54.1% versus 45.9%, respectively; Table 5). In terms of volume, pines were somewhat more dominant, comprising 64.4% of the 28.9 m^3/ha of CWD measured in the POWCNA. This discrepancy is due to the larger average size of pine CWD compared to hardwoods. For instance, the biggest individual piece of CWD was a 4.4-m^3 pine log (decay class 2) that was 22.2 m long. In terms of volume, this single pine log contributed just over 8% of all of the CWD sampled in this study. Given that an average piece of CWD totaled only 0.14 m^3, this particular piece was highly influential in determining the volume statistics found in the data in Table 5.

Discussion

The POWCNA shares some attributes with other mature pine-hardwood stands in the UWGCP of southern Arkansas. One of these common features is the shift away from a fire-dominated disturbance regime towards one dictated by wind, ice, and insects. Though fires periodically still burn through the area, their frequency has undoubtedly diminished during the last century. These changes to disturbance regimes have produced a cascade of interrelated biological legacies that shape the stands seen today (e.g., Brewer 2001).

Understory woody vegetation patterns

Unlike many managed mature pine stands of natural origin in the UWGCP, the POWCNA understory is dominated by hardwood tree seedlings and saplings. In intensively managed pine forests, decades of herbicide use have typically produced a pine- and shrub-dominated understory. This pattern is seen, for example, in the Good and Poor Forestry Farm Forties on the Crossett

Table 5. Stand-level coarse woody debris attributes by the type of coarse woody debris (CWD) found in the POWCNA. V = volume, D = diameter, and L = length. SD = standard deviation.

CWD	Pieces (number per ha)			Volumes (m^3 per ha)			Largest piece by		
type	Average[A]	SD	Range	Average[A]	SD	Range	V (m^3)	D (m)	L (m)
Log	193.8	91.4	61.7–395.1	26.6	18.4	4.9–77.9	4.4	0.7	22.2
Snag	9.7	9.8	0.0–37.0	1.2	2.5	0.0–11.9	1.0	0.4	15.2
Stump	9.7	11.1	0.0–37.0	1.1	1.8	0.0–7.7	0.6	0.6	2.7
DC1[B]	8.1	11.5	0.0–37.0	1.1	2.6	0.0–11.9			
DC2	156.7	74.2	49.4–296.3	23.1	16.5	6.0–77.9			
DC3	48.3	33.3	0.0–111.1	4.6	4.6	0.0–20.2			
Hardwood	97.7	62.9	0.0–222.2	10.2	9.1	0.0–35.6			
Pine	115.4	108.4	0.0–370.4	18.6	18.9	0.0–72.2			
Totals	213.2			28.9					

[A]Due to rounding, totals of average values may not be exact between CWD types.
[B]DC1 = decay class 1; DC2 = decay class 2; DC3 = decay class 3. See text for definitions.

Experimental Forest, while the adjacent untreated RRNA has experienced a decades-long dominance of a hardwood understory to the almost complete exclusion of pines (Cain and Shelton 1995, 1996). Most of these hardwoods are of greater shade tolerance than pines or early successional hardwood species, further reinforcing the RRNA's transition (barring severe catastrophic disturbance) to closed-canopy hardwood forest.

Lianas are abundant in many managed and unmanaged forests of the UWGCP (e.g., Blair and Brunett 1976), especially when not treated to limit their competition with trees. Presumably, lianas have increased during the decades since canopy closure in the unmanaged POWCNA. Unfortunately, we lack longitudinal data on the dynamics of lianas in this particular stand. However, this trend has been noted by Allen et al. (2007) in bottomland forests in other parts of the southeastern United States. It is apparent when crossing the POWCNA that the spreading crowns of woody vines occupy much of the midstory canopy, and hence intercept a considerable portion of the light that otherwise would have reached the understory. This, in turn, produces an increasingly shaded environment for shade-intolerant tree species already struggling to survive under a partial tree overstory. Whether the result of long-term fire suppression (Bragg 2004b) or changing climatic conditions (Allen et al. 2007), the increase in lianas in unmanaged southern forests and their interception of a large portion of the light available has serious implications for the regeneration of many different tree species, especially the shade-intolerant pines.

Overstory recruitment dynamics

At the POWCNA, early tree establishment was primarily pine. Following canopy closure, tree regeneration shifted to increasingly shade-tolerant hardwoods including *Quercus*, *Carya*, *Acer*, *Cornus*, *Ulmus*, *Nyssa*, and *Ostrya*. Only a few small pine seedlings can be found in the present-day stand (Table 1). This shift in recruitment is certainly not due to a dearth of pine propagules but rather a function of shading, the long-term absence of surface fires, and the lack of suitable pine seed germination conditions (Blair and Brunett 1976, Schultz 1997).

Unlike some studies that have repeated measures of species composition to show the long-term trends of mature pine-dominated forests in the Gulf Coastal Plain (e.g., Blair and Brunett 1976, Bragg 2006, Fail 1991, Shelton and Cain 1999, Switzer et al. 1979), our interpretation of the future trajectory of the POWCNA is based solely on the current picture of the stand. However, barring a catastrophic disturbance severe enough to open the stand and provide favorable germination sites, the Loblolly and Shortleaf Pine-dominated overstory will inevitably die, and the lack of advanced pine regeneration implies that only hardwoods will remain to exploit the gaps formed (Quarterman and Keever 1962; Schultz 1997, 1999). Halls and Homesley (1966) came to the same conclusion in a second-growth, unmanaged, pine-hardwood stand in southeastern Texas, even though this stand had experienced surface fires often during its first 50 years; 25 years of fire suppression resulted in hardwood occupation and dominance of the lower crown levels.

Over time, researchers have gradually learned more about the role of natural disturbances in healthy forest ecosystems (e.g., Crow 1978, Glitzenstein et al. 1986, Oosting 1944). For example, barring stand-replacing disturbances such as fire, Switzer et al. (1979) noted that comparable unmanaged pine-hardwood stands transition into hardwood-dominated forests at 100–130 years after old-field abandonment. This change, though dramatic, was not abrupt—they defined a middle successional stage in which pine composition declined from 80% of total stand basal area to 65% between years 45 and 100. Pine dominance continued to fall during the next 150 years, until it comprised <10% of the density at 250 years (Switzer et al. 1979). In the POWCNA, pine constituted just under 64% of the basal area (Table 3), suggesting that the stand most closely resembles a 100-year-old pine forest just beginning its transition to hardwood dominance—even though most of the pines are between 60 and 85 years old.

Unmanaged multi-aged pine stands (such as the POWCNA) are likely to transition differently than the even-aged stands assumed in the original Switzer et al. (1979) study. Both the RRNA on the Crossett Experimental Forest (Shelton and Cain 1999) and the Levi Wilcoxon Demonstration Forest (Bragg 2004b) had higher pine basal areas (61% and 57%, respectively) than expected for their pine overstory ages (between 70 and 140 years and 100 to 300 years, respectively). Some of these discrepancies probably arose from differences in the management and environmental history of these stands, while others are associated with the dilution of cohort-based mortality in older, uneven-aged stands of pine prior to the suppression of fire and extensive invasion by hardwoods. Regardless of age structure, most unmanaged older pine-dominated forests are rapidly losing their pine overstory without replacement (Bragg 2006). Attempts to restore fire to these locations to suppress hardwoods and promote pine regeneration have been complicated by the establishment of persistent hardwood rootstocks capable of resprouting after top-killing fires (Garren 1943, Hodgkins 1958, Reynolds 1956).

Pine age distribution

Data from the POWCNA indicates that the pine component of the overstory recruited to the canopy over multiple decades. This distribution (Fig. 4) indicates that this particular second-growth pine-dominated stand is uneven-aged and implies gradual canopy closure, rather than a pulse of recruitment following a specific disturbance. In contrast, Turner (1937) provided examples of second-growth Loblolly and/or Shortleaf Pine stands in southern Arkansas with much narrower ranges of pine ages (80–95 years, 78–91 years, 109–116 years, and 104–119 years). Their relatively pure, pine-dominated species composition, coupled with narrow age ranges, was thought to result from old-field recolonization or recovery following a catastrophic natural disturbance, specifically severe winds (Turner 1937). Bragg (2004a) also described a 1930s-era second-growth pine-dominated Loblolly stand in Ashley County, AR, as even-aged. This age structure was inferred from some unpublished correspondence cited in Bragg (2004a) of a different old-field stand of Loblolly Pine witnessed by Ike Rawls, former superintendent of the Crossett Experimental Forest. In his letter, Rawls reported a visit with Professor H.H. Chapman of Yale University and remarked that these old-field pines were about 76 years old, and ≤71 cm in DBH (with an average of 51 cm DBH), not including smaller suppressed pines. It was logical, Bragg (2004a) concluded, that the 1930s-era stand was similarly aged—other examples of dated and similarly structured stands can be found in the literature (e.g., Glitzenstein et al. 1986).

The results of the POWCNA study offer a different possibility—the pines in the 1930s-era stand may actually have much more variation in age than first thought. Both stands display a range of pine size classes, though the largest pines (and hardwoods) in the POWCNA are noticeably bigger (Table 4) than those in the 1930s-era stand (Table 2 in Bragg [2004a]). Otherwise, both stands exhibit a comparable, broadly unimodal pattern, with Loblolly primarily occupying the larger classes (Fig. 3, and Fig. 3 in Bragg [2004a]) and smaller hardwoods dominating the smallest classes. Regrettably, there is no way to document the actual age structure of the 1930s-era stand, as these data were not collected in the original sampling (Bragg 2004a). Conventional wisdom has often labeled the mature, second-growth pine forests of the region as even-aged, and the variation in pine size resulting from differences attributable to local site conditions, competition/suppression, or genetic variation. Undoubtedly, these factors have come into play, as the extensive logging, land clearing, and agricultural abandonment of the UWGCP has produced myriads of even-aged, second-growth pine stands. However, it is also obvious that exceptions to this overstory recruitment pattern can be found—stand history can be considerably more complicated than presently assumed.

As an example, the logging that started in the late 19th century and continues to the present has not completely eliminated old pines in the UWGCP, even though it greatly diminished their abundance across the landscape. Rather, early logging operations typically "high-graded" standing timber, with the choicest and most merchantable trees and species removed and the remainder left behind (e.g., Hall 1945, Reynolds 1980). Hence, in addition to the gradual recruitment and occupation of cleared former agricultural lands, the inefficiency of this lumbering often produced stands with scattered large cull stems, now-released intermediate and suppressed stems, and an abundance of new seedlings. Over time, these stands often developed into what was sometimes thought of as even-aged second-growth, even though they may be better identified as multi-aged stands with scattered old-growth individuals. The RRNA, as an example, was cut prior to 1920 using a diameter-limit cut, with pines >38 cm or larger at the stump felled and all other "submerchantable" stems left (Cain and Shelton 1994). Thus, given the eventual protection of this stand in the RRNA, a few trees 130–150 years old can still be found (Cain and Shelton 1994). Hence, it was not surprising to find an isolated individual on the POWCNA that appears to be ≥120 years old—it would have been too small and isolated when major logging occurred to have been cut at that time, and decades of protection have allowed it to emerge over a stand of younger hardwoods.

Historical and ecological legacies

Very little obvious evidence of the historical logging or agricultural practices remains. Only a handful of stumps with signs of cutting still survive, and these are well-decayed and weathered, indicating that they are decades old (these are not remnants of the virgin forest, but rather pines felled in the mid-20th century). In fact, most of what remains of this particular legacy is the resin-soaked pine heartwood. No specific evidence (e.g., furrows) of historical row cropping is apparent, although a handful of old trails or roads are visible, especially where they eroded some of the steeper slopes on the site. There may also be indications of an old fire break along a portion of the stand, although there is no way to confirm this feature. A handful of old stumps have some charring from past fires, but there is no fire scarring ("catfaces") on any of the standing timber, indicating that if fire had occurred in the forest following agricultural abandonment, it was either too low in intensity to damage the trees, or it happened long enough ago to have been completely encapsulated by the trees.

Beyond available written records, the best biological evidence of the open-grown origins of this stand can be found in the morphology of some of the trees scattered throughout the stand. Marks and Gardescu (2001) provided a blueprint for the examination of modern stands for historical land use. Features such as well-defined edges in the age-and size-class structure of the overstory, remnant species of old-field conditions, "wolfy" tree forms, and other evidence of the presence or absence of human activities (e.g., the lack of tip-up mounds in plowed fields) are example indicators of past treatments. The POWCNA displays several of these characteristics. The largest Loblolly Pine found in the entire stand, for example, still shows the remnants of branches within 3 m of the ground and many large, stout branches in its crown, indicating that this tree grew most of its early life under open conditions. A high rate of *Phellinus pini* Ames (Red Heart) infection is also suggestive of old-field stand development. Pines that grow in more open conditions tend to develop larger, more persistent branches, which better serve as avenues for heart rot fungi to enter than branches that form under closed canopy conditions (Hepting and Chapman 1938). Similar wolfy branch patterns and widely spreading crowns are also evident with the biggest oaks found on the site.

While past farming practices are known to produce long-term impacts on forest recovery (e.g., Flinn and Vellend 2005, Hedman et al. 2000), given the estimated 80–100 years of relatively undisturbed reforestation that has occurred in the POWCNA, little remains to suggest agriculturally based human influences. Because most of the upland agricultural efforts in southern Arkansas were abandoned before they depleted the land in the late 19th and early 20th centuries, site conditions have not been drastically changed in most locations. After about 60 years, Switzer et al. (1979) reported that most soil properties, including litter composition and depth, organic matter content, and soil chemistry, had largely recovered to "undisturbed" levels in a chronosequence of pine-hardwood forests in eastern Mississippi. If historical disturbance regimes had also been imposed on the POWCNA following agricultural abandonment, at least the stand overstory may have also returned to what may have been expected in a comparably aged pine-hardwood virgin forest. However, continued fire protection, coupled with the presence of invasive species, will ensure that some departure from presettlement forest structure, composition, and function will persist.

One such biotic legacy can be seen in the tree composition of the POWCNA. Eastern Redcedar, for instance, was not used as a witness tree in the General Land Office (GLO) public land survey notes from Ashley County, AR, just south of the study area (Bragg 2003) or near Warren, AR, just to the west (D.C. Bragg, unpubl. data). Although not abundant in the POWCNA, Eastern Redcedar is present in places on the natural area. Most of these individuals are fairly large, with many dead low branches, and probably are 70 or more years old (the only Eastern Redcedar cored had at least 70 obvious annual rings). In this part of Arkansas, our personal experience has found that Eastern Redcedar is comparatively uncommon and usually associated with old homesites, fields, pastures, and fencerows. Indeed, a number of dead and fallen large Eastern Redcedars were found surrounding the historic homesite on the POWCNA.

Coarse woody debris

Dead trees have long been recognized as important substrates for southern forests (e.g., Lemon 1945, McMinn and Crossley 1996). A history of agricultural use, followed by reforestation, has been shown to depress CWD for decades (e.g., Lõhmus and Lõhmus 2005). CWD is not a prominent part of the current biophysical structure of the POWCNA, even though it is accumulating in some portions of the stand. Much of the CWD is in small-sized pieces, often of easily decayed hardwoods, and hence has a fairly short residency. Large pine logs, snags, and stumps are usually the most persistent pool of CWD in stands such as the POWCNA. Given that few truly decay-resistant species are found in these stands, most dead wood disappears quickly in the warm, humid, termite-filled environment of southern Arkansas. This is true for the dead pine—their long-term persistence is more a matter of sheer size and their tendency to develop a core of resin-soaked, decay-resistant heartwood (also called "rich pine"). Unless consumed by fire, these resinous cores can last for decades, even when in contact with moist ground.

Only a few of the overstory pines have recently died. However, because of the relatively short lifespan of Loblolly and Shortleaf on mesic sites in this region, pine mortality is expected to increase significantly over the next few decades. Observations on dead-wood abundance and volume show that the POWCNA has roughly the same volume of CWD as a comparably aged, managed Loblolly-Shortleaf Pine stand on the Crossett Experimental Forest and dramatically less than 2 older, unmanaged pine-hardwood stands (Table 6). However, the POWCNA is rapidly approaching a stage in its developmental history likely to be marked by significant pine mortality, with each dead pine contributing a large quantity of CWD. The dense stand that has developed over the last century has slowed the growth of the pine overstory appreciably. The emergent pines are more susceptible to events such as lightning strikes or wind gusts that may kill or injure them. Wounded pines can serve as the focal point for insects, including bark beetles such as *Dendroctonus* and/or *Ips* spp., and this can lead to larger outbreaks. Cain and Shelton (1996) reported such a sequence of events in the RRNA that quickly killed about 10% of the pine overstory. Severe windstorms have also disproportionately affected exposed pine timber in other mature pine remnants near the POWCNA (e.g., Bragg 2006). These exogenous factors will progressively reduce the pine dominance to a fraction of its past total, and almost all pines will die before they reach 300 years of age (Switzer et al. 1979).

The relatively small stature of most hardwoods in the POWCNA limits their contribution to the stand CWD totals—on average, their volumes are appreciably less than the much larger overstory pines. However, for a stand of the age of the POWCNA, this is probably not the only reason why hardwood CWD totals are limited. Spetich et al. (1999) found that 50 - to 120-year-old hardwood-dominated forests tend to have lower CWD volumes than either younger or older stands. Hardwood stands of intermediate age typically have less CWD largely because they lack the dead wood legacies from the previous stand and decay-prone hardwood snags are also short-lived across most of the region. Cain (1996) noted that hardwood snags had changed from 56.3% "hard" (i.e., relatively sound) and 43.7% "soft" (i.e., decayed) 2 years after being injected with herbicides to 8.7% hard and 91.3% soft by 6 years after treatment.

Conclusions

The POWCNA's prominence of pine (and to a lesser extent, certain shade-intolerant species of hardwood) is consistent with the dominant

Table 6. Coarse woody debris abundance and volume in some mature pine-hardwood stands of southern Arkansas.

Stand	Arkansas county	Management regime	Count (#/ha)	Volume (m^3/ha)	Source
POWCNA	Drew	Unmanaged second-growth	213.2	28.9	This study
Good Forty[A]	Ashley	Managed second-growth	-[B]	35.5	Zhang (2000)
Reynolds RNA[A]	Ashley	Unmanaged second-growth (with some old-growth culls)	-[B]	93.7–309.7	Zhang (2000)
Levi Wilcoxon DF[C]	Ashley	Old-growth (some salvage of dead pine)	33.0	191.0	Bragg (2004b)

[A]The Good Forty and Reynolds Research Natural Area are found on the Crossett Experimental Forest of the USDA Forest Service.
[B]No count data for all types of CWD.
[C]The Levi Wilcoxon Demonstration Forest is owned by Plum Creek Lumber Company.

vegetation patterns this particular site would have had prior to Euroamerican settlement of the region. The multiple age classes currently found in the pine component also probably reflect the often complex nature of stand origin in this region, with numerous cohorts periodically recruited as the landscape responded to geological and edaphic controls, natural disturbances, and human influences (Bragg 2006, Peacock et al. 2008).

However, the recovery of the arboreal component of forests is but one of many indicators of ecological restoration following agricultural abandonment and reforestation. This study considered only the woody plant components of the POWCNA—forest herbs, non-vascular taxa, fauna, fungi, etc. were not studied. These components can take decades longer to recover pre-disturbance levels, especially if propagule dispersal limitations are present (Flinn and Vellend 2005). The presence of invasive woody species such as *Ligustrum sinenese* Lour. (Chinese Privet) and *Lonicera japonica* Thunb. (Japanese Honeysuckle) in the area, coupled with the absence of regular surface fires, decades of native hardwood expansion, and alterations to historic disturbance regimes further complicate the return of historical forest cover. Hence, additional study is needed to examine the full suite of environmental conditions presented in the POWCNA to determine if this stand should be considered a viable example of mature southern pine-dominated forest, or if it still suffers from a legacy of past land-use practices.

Over 60 years ago, H.H. Chapman advocated for natural-area establishment to be driven by more than just the desire to protect unique environmental attributes. Rather, he envisioned a wide range of stand conditions being protected from human intervention but still under the full influence of natural disturbance regimes, even if they occasionally obliterate the original feature for which the stand was preserved (Chapman 1947). In doing so, the full range of ecosystem functionality would be preserved. Decades of practice, however, have proved antithetical to this vision, as resource managers have diligently worked to keep certain natural disturbances (e.g., fire) from protected remnants, or to minimize the impacts of other events (e.g., insect outbreaks, ice or wind storms) through salvage harvests. The fact that most natural areas are small and imbedded within intensively manipulated landscapes has not helped, as liability issues pressure managers to stem events propagating from their properties. Perhaps the best conservation value of this protected parcel is that the POWCNA represents a rapidly vanishing example of a mesic, mature, unmanaged pine-hardwood forest on the UWGCP in southern Arkansas. Given the South-wide conversion of structurally and compositionally diverse natural-origin pine-dominated forests to pine plantation monocultures, agricultural lands, and commercial/residential areas (Conner and Hartsell 2002), this loss may become a key conservation issue in the 21st century.

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