RECONSTRUCTING STAND DYNAMICS OF A SHORTLEAF PINE-OAK WOODLAND IN EAST TEXAS: A CASE STUDY

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ABSTRACT

Upland forests of east Texas were historically composed of varying mixtures of pine and hardwood species, with local structure and composition driven by site characteristics and fire regimes. The restoration of natural communities, including upland woodlands with mixtures of shortleaf pine (*Pinus echinata*) and oaks (*Quercus* spp.), provides conservation benefit, but we lack information on optimal silvicultural practices to meet restoration objectives. We examined contemporary and past stand structure and composition and stand dynamics of a shortleaf pine-post oak woodland at Boggy Slough Conservation Area (BSCA) near Lufkin, TX, using dendrochronological stand reconstruction approaches. The stand was dominated by loblolly pine (*P. taeda*) and post oak (*Q. stellata*), as well as shortleaf pine in lower abundance. Post oaks were relatively small and not part of the upper canopy. The age distributions strongly differed among these species, with loblolly pine in the younger age classes (mostly 40- to 50-year-old age classes), post oak in the older age classes (mostly 100- to 110-year-old age classes), and shortleaf pine in between (mostly 80-year-old age class). These results suggest the shortleaf pine-oak woodland is in the process of transitioning to loblolly pine, with management intervention needed to regenerate and recruit shortleaf pine and post oak.

INTRODUCTION

Open forest ecosystems are characterized by open structure, in both horizontal and vertical dimensions, and an abundance of herbaceous vegetation in the understory (Hanberry and others 2018). Tree stocking can vary across a structural gradient, with savanna ecosystems having the lowest stocking and woodlands having greater stocking (Bragg and others 2020, Dey and others 2017). Consistent for all open forest ecosystems, however, is a lack of midstory stems, resulting in greater availability of light reaching the understory. Across most of the central and Eastern United States, frequent surface fires are important for maintaining these natural communities by reducing the development of a midstory and favoring fire-adapted species (Hanberry and others 2018). Evidence suggests that open forest ecosystems were historically more prevalent across the region, with the period of widespread fire exclusion during the 20th century contributing to their loss (Hanberry and others 2020, Nowacki and Abrams 2008). Given their unique conservation benefits, recent interest in restoring and maintaining open forest ecosystems has increased.

In addition to the conservation benefits provided from their open habitat structure, mixtures of softwood-hardwood tree species (termed ‘mixedwoods’) provide other benefits, such as diversification of forest products, heterogeneity in wildlife habitat, resilience to future uncertainty with climate change or forest health risks, and the potential for greater carbon productivity relative to similar structures of single species (Kabrick and others 2017, Kenefic and others 2021). However, managing for a mixture of tree species is challenging due to the different silvics of the species (Kenefic and others 2021). Mixtures of shortleaf pine (*Pinus echinata*) and oaks (*Quercus* spp.) occur commonly as open forest ecosystems in portions of the central and Southern United States. While often a restoration target, management of shortleaf pine-oak

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woodlands is challenged by differences in the fire adaptions of the constituent species (Arthur and others 2012, Stambaugh and others 2007) that result in difficulties regenerating the desired species together.

In the Pineywoods region of east Texas, upland sites include mixed composition of pines [shortleaf pine, loblolly pine (*P. taeda*), longleaf pine (*P. palustris*)] and oaks [southern red oak (*Q. falcata*), post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), white oak (*Q. alba*)]. Historically, mixtures of shortleaf pine and post oak were common, with longleaf pine dominant on sandier soils and loblolly pine dominant in low-lying areas and drainages (Bray 1904). Expansion of the timber industry resulted in widespread conversion of upland sites to loblolly pine plantations, and fire exclusion policies of the 20th century facilitated the increase in dominance of loblolly pine. With current interest in restoring shortleaf pine-oak woodlands, managers require information on regeneration patterns and stand dynamics that occur within these forest types.

The Boggy Slough Conservation Area (BSCA), owned by the T.L.L. Temple Foundation and located in Houston and Trinity Counties, TX, is approximately 19,000 acres and includes a mixture of bottomland hardwood and upland forest areas. With a history of ownership connected to the Southern Pine Lumber Company and the family of company founder T.L.L. Temple, BSCA is currently managed under a conservation easement for wildlife, timber, and conservation objectives. While portions of the BSCA had been converted to planted loblolly pine for timber production, approximately 10,600 acres are classified as naturally regenerated upland pine or pine-hardwood stands. In recent years, management objectives have included restoration of the open forest structure and maintaining canopy mixtures of shortleaf pine and oaks. Existing stands with this canopy mixture provide examples of compositional targets for management, but unknown stand histories obscure our understanding of the stand dynamics that resulted in these stands. In this study, we reconstruct stand dynamics by aging canopy trees within a shortleaf pine-oak woodland at BSCA. Our objectives were to describe 1) current structure and composition; 2) the age structure of the dominant pines and oaks; and 3) relationships between tree size and age for the major species (shortleaf pine, loblolly pine, and post oak). Results from this study will inform current management practices to restore and sustain shortleaf pine-oak woodlands.

METHODS

Study Site

At BSCA, we selected an approximately 100-acre, naturally regenerated upland pine-hardwood stand (31°18’20” N, 94°58’00” W), with no record of recent harvest activity. Soils in the study stand were mapped to the Kellison-Keltys-Lovelady map unit, with the Kellison soil series contributing 90 percent of the map unit (USDA NRCS 2022). Kellison loam (fine, smectitic, thermic Vertic Hapludalf) is well drained, with slopes of 5 to 15 percent. Site index (base age 50) of Kellison loam is 65 for shortleaf pine and 75 for loblolly pine (Coile and Schumacher 1953). The stand was mapped as a loamy claypan upland, supporting a shortleaf pine-post oak natural community.

Data Collection

We randomly located ten 0.20-acre, fixed-area circular plots throughout the selected stand. Within each plot, we marked each tree with diameter at breast height (d.b.h., 4.5 feet above the ground) ≥5 inches with a numbered aluminum tag and recorded species and d.b.h. Using an increment borer, we extracted one core at breast height from a subsample of trees on each plot. The subsample of cored trees was designed to systematically sample from the smallest and the largest trees from both oak and pine species groups, with interest in representation of mature canopy trees as well as potentially younger, recruiting trees. To achieve this, we used the tree list from each plot to determine the 3 smallest (in d.b.h.) oak trees and pine trees and the 3 largest (in d.b.h.) oak trees and pine trees, resulting in a total of 12 possible trees cored on each plot. If a plot did not have at least six oaks or pines, the sample size was reduced to the number of trees present. Cores were stored in straws and returned to the laboratory for processing. Each core was mounted to a wooden rail and sanded with progressively finer grit to allow determination of cellular anatomy.

Data Analysis

Each tree core was scanned with an Epson Expression 11000XL (Epson America, Inc., Los Alamitos, CA) scanner to create a digital image for analyses. Images were imported into CooRecorder/CDendro (Cybis Elektronik & Data AB, Saltsjobaden, Sweden) to determine boundaries of annual rings. If the pith was not reached with the core, the distance to the pith was estimated using default parameters in CooRecorder. The cores were crossdated using CDendro by creating a reference chronology for the stand, iteratively adding samples to the reference chronology as they were measured.

Descriptive statistics of forest structure (stocking, basal area, trees per acre, quadratic mean diameter) were calculated for each species of interest, including post oak, shortleaf pine, loblolly pine, other species, and total. We used Gingrich-style stocking as a measure of growing space occupancy, with stocking for hardwood species calculated based on upland hardwood equations of Gingrich (1967), and stocking for pine species calculated based on shortleaf pine equations of Rogers (1983). Frequency distributions were created for tree size, using 2-inch d.b.h. classes, using all trees sampled in the fixed-area plots and for tree age, using 10-year age classes, for the cored trees only. Because trees were cored at breast height, age represents an age of release (effective age) rather than true chronological age. For each cored tree, scatterplots were created for tree size (d.b.h.) by age for species of interest (post oak, shortleaf pine, and loblolly pine). We fit each scatterplot with a quadratic regression line to characterize the strength and form of the relationships.

RESULTS

The stand was dominated by loblolly pine and post oak, each contributing approximately equally to total stand stocking, followed by shortleaf pine. Total stand stocking was 68 percent, and basal area was 93 square feet per acre. Shortleaf pine had the largest quadratic mean diameter, with the other species group having the lowest (table 1). The small-diameter classes were dominated by loblolly pine and post oak, with very few post oaks occurring in diameter classes >12 inches. While loblolly pine was abundant in small-size classes, it was also the dominant species in large-diameter classes (fig. 1). Shortleaf pine was represented in similar abundance across all size classes.

The age distribution showed separation by species (fig. 2). The loblolly pines were in the younger age classes, with the greatest representation in the 40- and 50-year-old age classes. There was little overlap between loblolly pine and post oak, with the greatest representation of post oak in the 100- and 110-year-old age classes. Shortleaf pine occurred in the central portion of the age distribution, with the greatest representation in the 80-year-old age class. In contrast to loblolly pine, there were no shortleaf pines or post oaks younger than the 50-year-old age class.

Table 1—Stand structure characteristics for a pine-hardwood stand at Boggy Slough Conservation Area by species groups

Species group	Stocking	Basal area	Trees per acre	Quadratic mean diameter
	percent	*square feet per acre*	*n*	*inches*
Post oak	27.5	31.0	62.5	9.5
Other oaks	1.7	2.0	3.0	11.1
Shortleaf pine	7.5	12.3	14.5	12.5
Loblolly pine	26.8	42.6	69.0	10.6
Other species	4.9	5.3	13.5	8.5
Total	68.3	93.2	162.5	10.3

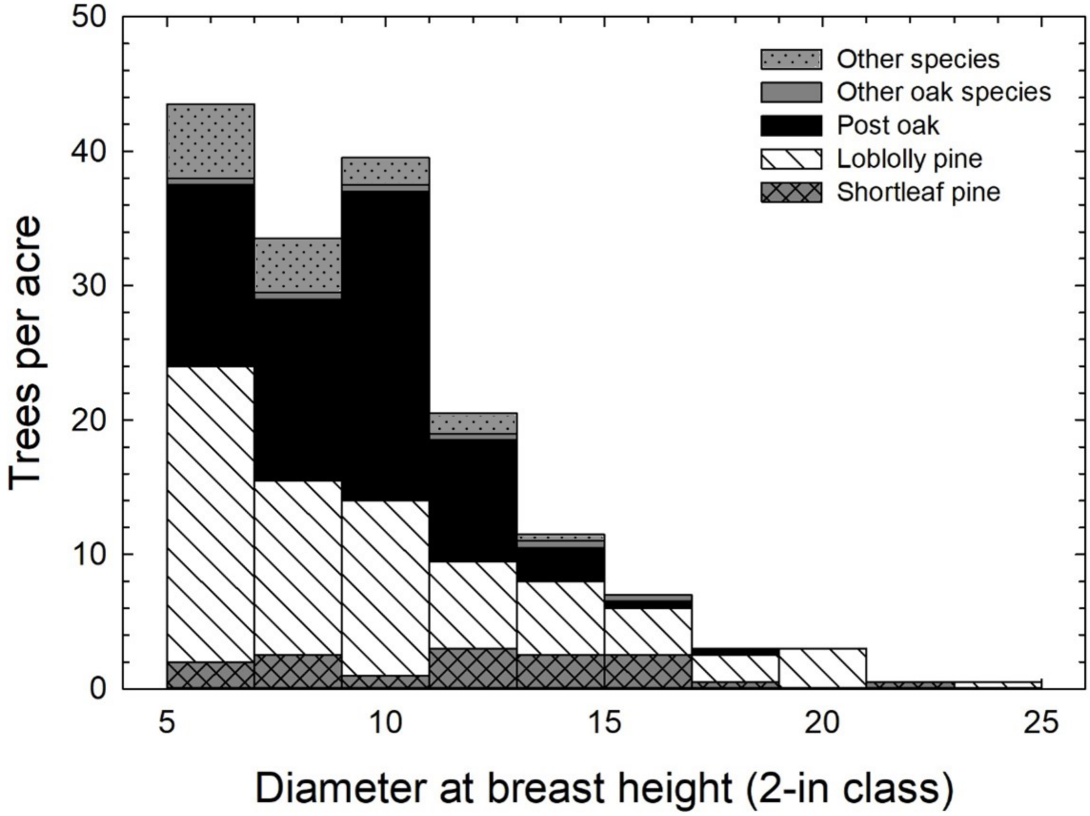

Figure 1—Diameter distribution (2-inch d.b.h. classes) by selected species groups of interest for the pine-hardwood stand at Boggy Slough Conservation Area.

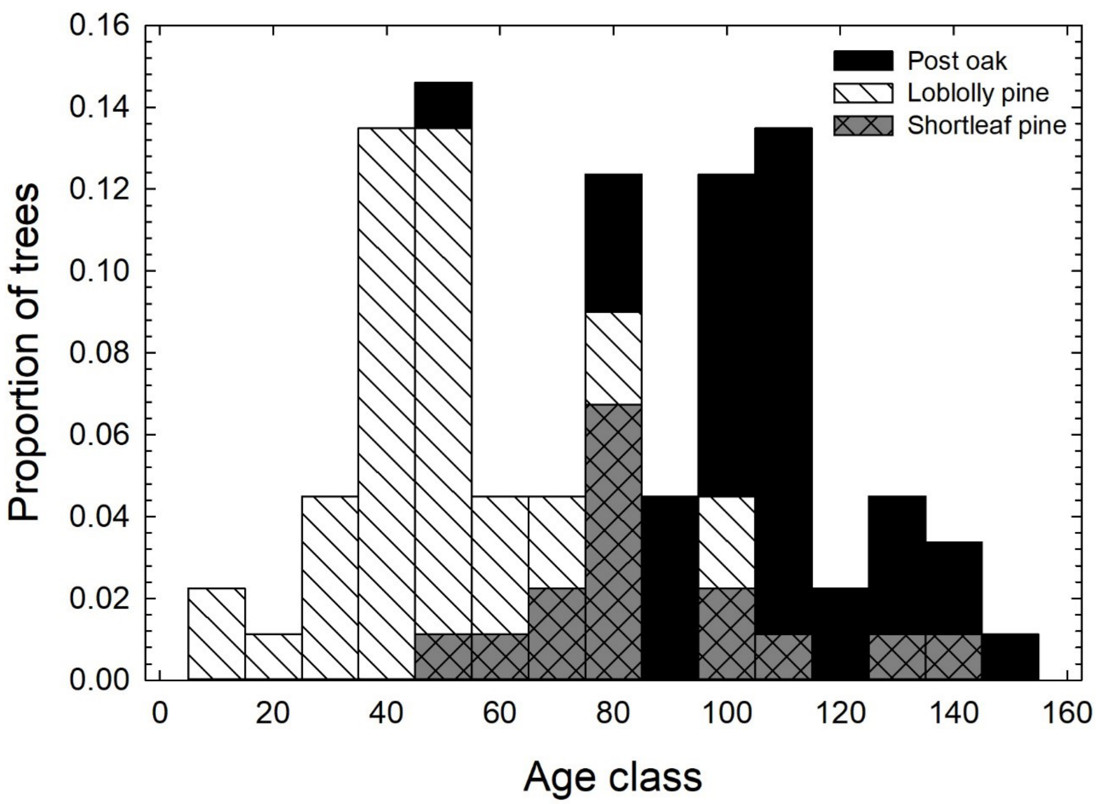

Figure 2—Age distribution (10-year age classes) by species for all cored trees from the pine-hardwood stand at Boggy Slough Conservation Area.

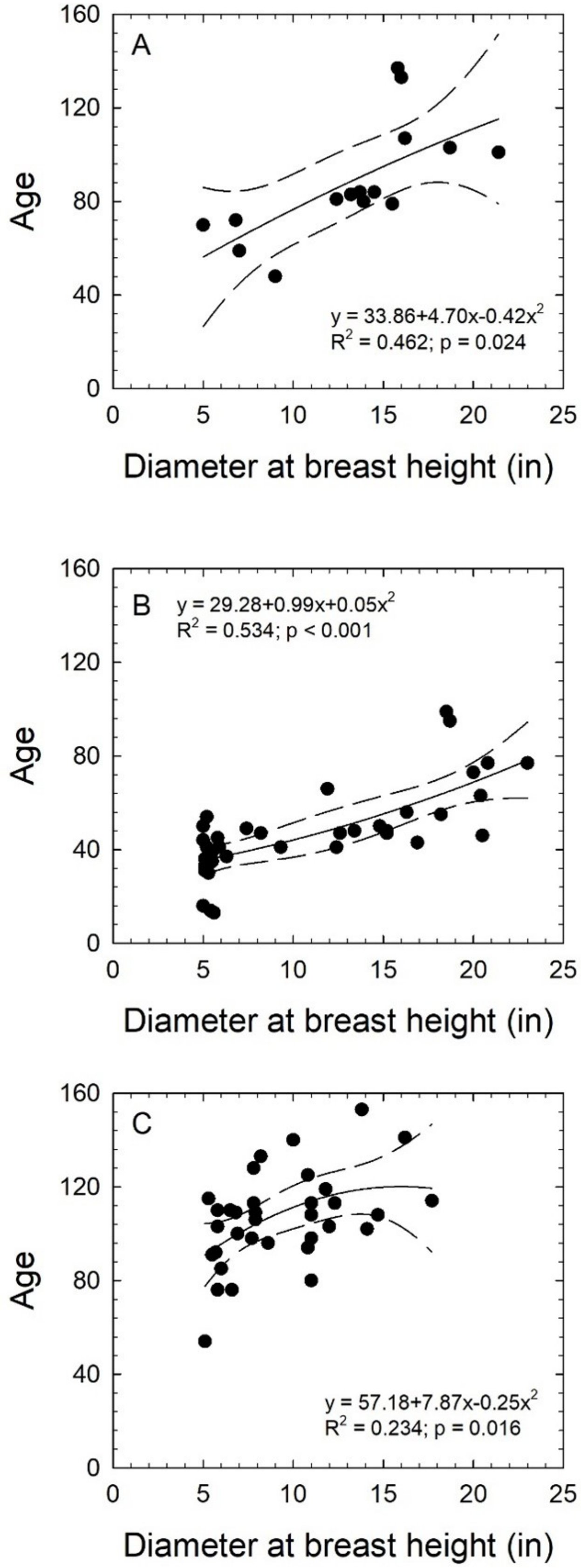

Figure 3—Relationship between diameter at breast height and tree age for (A) shortleaf pine, (B) loblolly pine, and (C) post oak.

The relationships between tree size and tree age also varied by species (fig. 3). Among the three species, tree size explained the greatest amount of variation in age for loblolly pine, with modeled estimates of age increasing more sharply for the largest trees. Across the range of tree sizes, shortleaf pines were older than loblolly pines at a given size, also showing a pattern of increased tree age associated with larger trees. Post oaks were the oldest across all tree sizes, with even the smallest trees (5 inches d.b.h.) being over 80 years old. Among the three species, tree size explained the least amount of variation in tree age for post oaks.

DISCUSSION

The stocking of the stand was generally consistent with a closed-canopy woodland. Recent studies and management guides have identified stocking levels associated with different types of open forest ecosystems, with <30 percent stocking associated with savannas, 30 to 55 percent stocking associated with open canopy woodlands, and 55 to 75 percent stocking associated with closed canopy woodlands (Dey and others 2017, Hanberry and others 2014). In general, at stocking levels in closed canopy woodlands, the trees fully occupy the growing space and maintain a closed canopy, but light levels beneath the canopy are greater than what would occur in a dense forest. Closed canopy woodlands can support abundant herbaceous vegetation in the understory, often dominated by forbs rather than graminoids due to the greater shading relative to open canopy woodlands or savannas (Knapp and others 2015, Peterson and others 2007).

The diameter distribution of the canopy trees in our study approximated a negative exponential, or reverse-J, form, showing greater abundance of small-diameter trees than large-diameter trees. In uneven-aged silvicultural systems, this structure is desirable, provided that the smaller trees are younger and represent the recruitment of new trees to the overstory to sustain the forest type through time (Guldin and Baker 1998). In our study, we observed a different pattern; the largest trees in the stand comprised older loblolly and shortleaf pines, and the smallest trees were dominated by older post oak and younger loblolly pines. The lack of young post oak or shortleaf pine shows that recruitment of these species has not occurred in recent decades, suggesting the stand may be in the process of transitioning away from the shortleaf pine-post oak woodland community.

Taken together, our results suggest a few key areas in which stand dynamics of the site may be related to management history. First, post oak and shortleaf pine are absent from young age classes, suggesting that conditions for regeneration or recruitment to the overstory size class have been unfavorable for these species. In contrast, the abundance of loblolly pine in the younger and smaller size classes suggests that conditions for regeneration and recruitment have been favorable for it. It is likely that periods of fire exclusion over the past several decades have favored loblolly pine regeneration and reduced success of shortleaf pine and post oak. Second, the differences in age distributions among the species suggest past disturbance events may be associated with regeneration pulses of each species. For example, the effective age of most of the post oaks was 100 to 110 years old, aligning with early ownership by Southern Pine Lumber Company, a period in which initial timber harvesting was widespread and focused on pine species in the uplands. Finally, the differences in size among the species, particularly given the size-age relationships, suggests that edaphic factors may contribute to the growth rates and stand structure. Despite their age, post oaks were relatively small throughout the stand. However, the history of timber harvest is not known for the area, so it is unclear if the post oaks were previously suppressed trees that were left after a past timber harvest and remained small. Future analyses of radial growth will be used to identify potential release events and quantify growth rates.

CONCLUSIONS

We characterized the structure and age demographics of a shortleaf pine-post oak woodland in east Texas. During the past 50 years, loblolly pines have established to become the dominant species, contributing most of the existing basal area and occurring across all size classes. While stand stocking is within the range associated with closed canopy woodlands, our results suggest that the stand is transitioning away from shortleaf pine-post oak composition and towards greater loblolly pine dominance. Maintaining a shortleaf pine-post oak woodland into the future would require management actions to reduce loblolly pine ingrowth and increase the establishment and recruitment of shortleaf pine and post oak.

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