SILVICULTURAL STRATEGIES FOR PROMOTING LONGLEAF PINE RECRUITMENT IN MULTIAGED STANDS

Joshua J. Puhlick, Benjamin O. Knapp, Ian Goldberg, Brandon T. Rutledge, R. Scott Taylor, and John L. Willis

ABSTRACT

In longleaf pine (*Pinus palustris*) ecosystems, an objective of some landowners is to develop multiaged stands with a component of large longleaf pine trees. A potential strategy to accelerate recruitment of trees to larger size classes is to purposefully release saplings within dense patches of longleaf pine. At The Jones Center at Ichauway, we thinned patches of sapling-sized trees within mature stands. We thinned from below with the modification that some dominant and codominant trees were also cut. Before thinning, average densities within patches of two harvest areas were 712 and 1,145 trees per acre. Many patches had stand density index values close to those associated with the onset of competition-induced mortality. Thinning was done with a feller-buncher and there was minimal damage to residual saplings. Precommercial thinning in multiaged stands of open pine systems is an investment but may accomplish objectives such as enhanced carbon accumulation and groundcover productivity.

INTRODUCTION

Reducing tree densities within sapling thickets that occur as a component of multiaged stands is often necessary to increase tree vigor (fig. 1). In open pine (*Pinus* spp.) systems with frequent, low-intensity fires, burning can sometimes reduce tree densities within dense patches of pine saplings (Cooper 1960, Weaver 1943). Similar to heavy snow loads causing tree mortality within sapling thickets of ponderosa pine (*P. ponderosa*) (Pearson 1950), we have observed a thinning effect in dense patches of longleaf pine (*P. palustris*) due to wind disturbance (fig. 2).

Emulating these natural processes in open pine systems using precommercial thinning has been underutilized in multiaged stands because of the cost and a lack of knowledge of the potential benefits. For example, thinning dense patches of pine saplings could potentially enhance carbon accumulation, increase native groundcover, and benefit wildlife species associated with open pine systems. Increased tree vigor through reduced competition for resources could also decrease

Figure 1— A thicket of longleaf pine saplings that developed in a canopy gap of a multiaged stand at The Jones Center at Ichauway. (Photo by Joshua Puhlick)

Joshua J. Puhlick, Assistant Scientist, The Jones Center at Ichauway, Newton, GA 39870

Benjamin O. Knapp, Associate Professor, University of Missouri, School of Natural Resources, Columbia, MO 65211

Ian Goldberg, Graduate Student, University of Missouri, School of Natural Resources, Columbia, MO 65211

Brandon T. Rutledge, Conservation Coordinator, The Jones Center at Ichauway, Newton, GA 39870

R. Scott Taylor, Research Associate, The Jones Center at Ichauway, Newton, GA 39870

John L. Willis, Research Forester, U.S. Department of Agriculture, Forest Service, Southern Research Station, Auburn, AL 36849

Figure 2—Excessive bending and snapping of stems within a dense patch of longleaf pine due to Hurricane Michael, which occurred in October 2018. This photo was taken in September 2021 at The Jones Center at Ichauway. (Photo by Joshua Puhlick)

the vulnerability of residual saplings to drought (D'Amato and others 2013). On poor sites and for tree species with poor height differentiation, saplings in dense thickets may reach the point of stagnation (Smith and others 1997). Releasing some individuals within patches, especially before stagnation occurs, could enhance carbon accumulation in these stands. Recruiting trees with large diameters and crowns faster than without thinning could also be desirable for wildlife species such as the red-cockaded woodpecker (*Leuconotopicus borealis*) (Shaw and Long 2007).

In even-aged stands, density management diagrams (DMDs) are often used to inform thinning schedules and estimate stand trajectories. However, DMDs can also be used for one-age cohorts within multiaged stands (Shaw and Long 2007). First, the stand density index (SDI) is calculated for a group (or patch) of similar-sized trees within a multiaged stand. This is done by using the density and mean tree size (or volume) based on trees within the patch and the patch size. Briefly, SDI is an index of relative density that is independent of stand age and site quality and is useful for evaluating the degree of competitive interaction among trees. The patch's SDI is then compared to various relative density thresholds such as values that correspond to the onset of competition among trees and the onset of competition-induced mortality.

The overall goal of this study was to evaluate the use of precommercial thinning to reduce tree densities within dense sapling patches that are a component of multiaged longleaf pine stands. Specific objectives were to 1) quantify attributes of sapling patches (e.g., tree density and mean tree size) before and after precommercial thinning, and 2) evaluate patch trajectories using a DMD developed for longleaf pine by Shaw and Long (2007).

MATERIALS AND METHODS

Study Area

The study was located at The Jones Center at Ichauway, in the Gulf Coastal Plain of southwestern Georgia. Soils are predominately well-drained loamy sands over sandy loams. The climate features long, hot summers and cool, short winters. The study was conducted in two harvest areas of approximately 300 acres each. The harvest areas were named Whitehead and Malone-Bud Walker and were classified as upland longleaf pine-hardwood woodlands. Groundcover was diverse but dominated by wiregrass (*Aristida beyrichiana*). Aerial photography from 1938 shows that these locations contained sparse tree cover and agricultural fields. No timber harvesting has occurred in these areas since 1989, and no records of previous harvesting within these locations exist. Starting around 1991, the frequency of prescribed burning was changed from annual to biennial to establish new cohorts of longleaf pine. The Whitehead harvest area was cut in April 2022, and the Malone-Bud Walker harvest area was cut in February and March 2023. Both locations contained multiaged stands, and the prescription for both was single-tree selection cutting.

Plot Selection and Tree Measurements

In both harvest areas, we recorded the locations of all sapling patches before timber harvesting. Circular, 0.5-acre plots for measuring trees were installed so that they completely contained one or more patches. This plot size was chosen to evaluate the influence of competition on sapling-sized trees. Trees were measured on two plots within the Whitehead harvest area to determine if the precommercial thinning of saplings within patches could be reasonably accomplished using a feller-buncher. We also identified 12 potential plot locations within the Malone-Bud Walker harvest area. These locations were classified as having patches with small-, mid-, or large-sized saplings. We randomly chose two plots from each size category for a total of six plots in the Malone-Bud Walker harvest area (table 1). Then, we randomly selected one plot from each size category to be treated (i.e., saplings within patches were to be thinned) and the other plot was not to be treated (i.e., saplings within patches were not to be thinned).

We used data from eight plots across the two harvest areas to quantify the attributes of patches before and after timber harvest and precommercial thinning of trees within patches. Single-tree selection cutting and precommercial thinning of trees within patches was conducted while logging equipment was on site in the winter of 2022 and again in 2023. In this study, postharvest results were based on saplings that were marked to be retained. For control plots in the Malone-Bud Walker harvest area, saplings were identified within patches that would be retained if thinning were to occur. For future studies, the growth and mortality of these individuals will be compared to that of individuals in treated patches.

Table 1—Grand mean height of residual longleaf pine saplings within dense sapling patches of the Malone-Bud Walker harvest area by research plot

Plot	Total height (feet)	Number of patches	Patch size classification
8	30	2	Small
12	35	1	Small
1	49	2	Mid
18	50	4	Mid
14	52	2	Large
16	53	3	Large

Patch size classification was based on sapling height.

For each plot, species, diameter at breast height (d.b.h.), and azimuth and distance from plot center were recorded for trees at least 1 inch d.b.h. This size threshold was used by Shaw and Long (2007) to construct their DMD. For each tree, we also noted if it was to be retained or cut based on tree marking by the silviculturist (see Prescription section). To spatially display trees in ArcMap (ESRI, Redlands, CA), the x- and y-coordinates of each tree were derived using azimuth and distance from plot center, and the location of plot center. The boundaries of sapling patches within plots were hand sketched on field sheets to aid in delineating polygons around patches in ArcMap (fig. 3). Information for trees within these polygons was exported to Excel (Microsoft, Redmond, WA) so that descriptive statistics could be calculated for each patch. These statistics were calculated using only longleaf pines. Larger hardwoods generally occurred outside of patches and across all plots there were only 15 hardwoods ≥5.0 inches d.b.h. and 140 hardwoods <5.0 inches d.b.h.

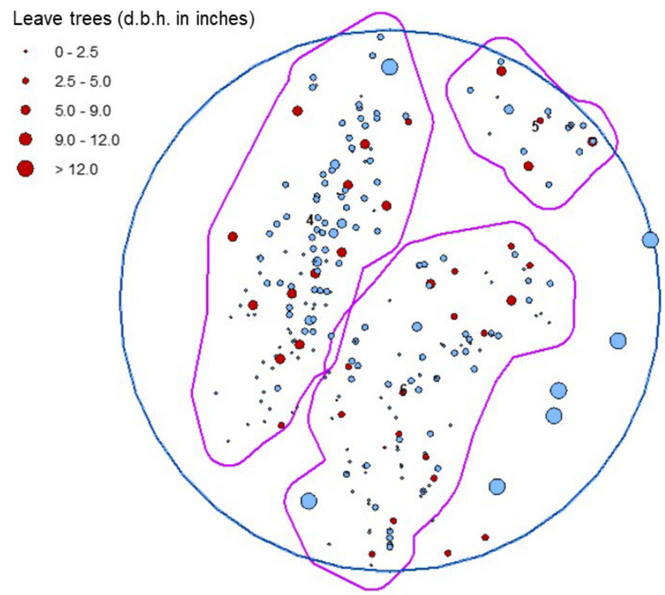

Figure 3—Three distinct patches of trees delineated within a 0.5-acre research plot in the Whitehead harvest area. Blue circles indicate trees to be cut. The size of the blue (light) circles represents the same diameter-at-breast-height range as for the red (dark) circles (trees to be retained).

Prescription

The treatment was a thinning from below with the modification that some dominant and codominant trees were also cut (fig. 4). We retained dominant and codominant trees of good form and with robust crowns. During marking, we also considered the spacing of residual trees based on the average height of dominant trees within patches. We followed recommendations by Wilson (1946), who suggested a spacing of one-fourth to one-fifth of the height for shade-intolerant species. For precommercial thinning, Wilson (1946) indicated that trees could be spaced according to the height they would obtain at the time of the first commercial thinning. Alternatively, he noted that spacing according to heights at the time of precommercial thinning is appropriate when the silviculturist is concerned about a thinning being too severe (e.g., concerns about windthrow). We used the conservative approach to spacing which was based on the average height of dominant trees within patches at the time of precommercial thinning. This decision was also based on the current belief that longleaf pine is more tolerant of shade than once thought (Samuelson and Stokes 2012). This suggests that a narrower spacing between trees may be appropriate. Most hardwood trees were cut so that they would not influence growth of residual pines.

RESULTS

For the two plots in the Whitehead harvest area, there were a total of six sapling patches. For these patches, mean tree densities were 712 trees per acre before thinning and 82 trees per acre after thinning (table 2). Thinning shifted the quadratic mean diameter (QMD) from 3.6 to 5.7 inches. For the six plots in the Malone-Bud Walker harvest area, there were a total of 14 sapling patches. For these patches, mean tree densities were 1,145 trees per acre before thinning and 112 trees per acre after thinning. Thinning shifted the QMD from 2.8 to 4.5 inches. For patches in the Malone-Bud Walker harvest area, patch size was 0.12 ± 0.05 acre (mean ± standard deviation).

Figure 4—Repeat photography of stand conditions (left) before and (right) after thinning a dense patch of longleaf pine in the Malone-Bud Walker harvest area. (Photos by Joshua Puhlick)

Table 2—Mean (standard deviation) and range of patch attributes by harvest area and time period for longleaf pine trees with a diameter at breast height ≥1.0 and <8.0 inches

	Whitehead		Malone-Bud Walker	
Patch attribute	**Prethinning**	**Postthinning**	**Prethinning**	**Postthinning**
Basal area	48 (16)	14 (5)	48 (19)	12 (5)
	26–69	4–19	23–77	5–19
Density	712 (236)	82 (37)	1,145 (322)	112 (40)
	331–935	23–126	693–1587	43–191
QMD	3.6 (0.4)	5.7 (0.7)	2.8 (0.6)	4.5 (1.1)
	2.8–4.0	4.3–6.3	2.0–3.8	2.7–6.4
SDI	133 (44)	31 (12)	145 (50)	30 (10)
	70–189	10–42	73–220	13–45
SDI_{sum}	125 (40)	31 (12)	137 (47)	29 (10)
	66–175	10–42	69–206	12–44
SDI_{sum}:SDI	0.94 (0.01)	0.99 (0.01)	0.94 (0.01)	0.98 (0.01)
	0.93–0.95	0.98–1.00	0.91–0.97	0.95–1.00

Basal area is in square feet per acre, density is trees per acre.
QMD = quadratic mean diameter (inches); SDI = stand density index; SDI_{sum} = sum of contributions of individual trees to overall stand density (equation 3 in Shaw and Long 2007).

Before thinning patches, 16 of 20 patches had SDI values >100, but none had SDI values >250. An SDI of 100 generally represents a transition from open-grown to competing tree populations, and we expected to see competition-induced mortality at values >250 to a maximum SDI of 400 (Shaw and Long 2007). Several patches in the Malone-Bud Walker harvest area had SDIs approaching the self-thinning line (fig. 5). For both harvest areas, mean SDI_{sum}:SDI was 0.94 before thinning (table 2), which indicates that the size distribution of trees within patches was similar to that of even-aged stands (Ducey 2009, Ducey and Larson 2003). After thinning, SDI_{sum}:SDI ranged from 0.95 to 1.00.

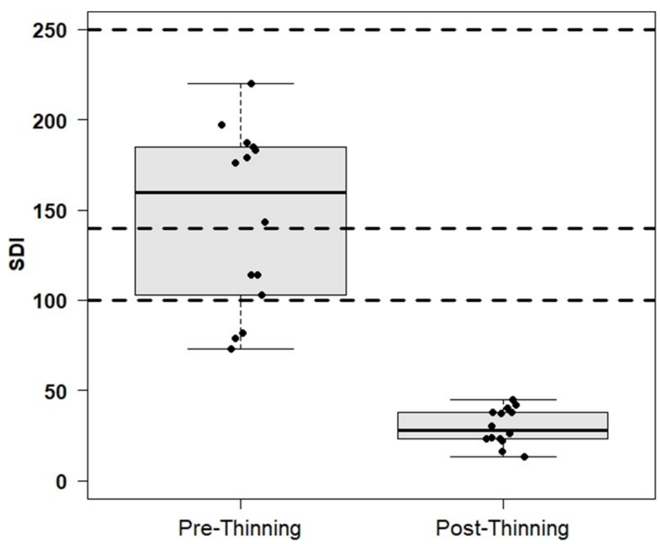

Figure 5—Stand density indices (SDIs) before and after thinning in the Malone-Bud Walker harvest area. The boxes define the interquartile range (IQR, 25–75 percent quartile). The vertical line below the boxes extends to a horizontal line that is the 25th percentile minus 1.5 times the IQR, and the vertical line above the boxes extends to a horizontal line that is the 75th percentile minus 1.5 times the IQR. The horizontal line in each box is the median. Dots represent individual patches. SDIs of 250, 140, and 100 represent the threshold for the self-thinning zone, the lower limit of full site occupancy for longleaf pine, and a transition from open-grown to competing tree populations, respectively (Shaw and Long 2007).

DISCUSSION

Thinning dense patches of longleaf pine saplings that are a component of multiaged stands may be an appropriate treatment for accelerating recruitment of trees to larger size classes and reducing competition-induced mortality. However, the influence of thinning on residual tree growth and mortality needs to be monitored and compared among trees within treated and nontreated patches. Pretreatment SDI_{sum}:SDI values suggested that using the DMD to make decisions about thinning was appropriate. For other multiaged stands with sapling patches, it is important to remember that the distribution of tree diameters within patches could influence values of SDI_{sum}:SDI and proper use of the DMD. Although pretreatment SDI values were below the self-thinning line, we observed tree mortality in some patches. If the primary cause of death was competition-induced (we cannot rule out that some trees were killed in prescribed fires), then earlier intervention may have been appropriate.

Residual saplings had desired characteristics for wood quality, and we observed no mortality from windthrow or other disturbance agents since thinning. Most residuals were of good form and had branch-free boles for at least the first 16 feet starting from the base of the tree. Residuals also had low height-to-diameter ratios, which are important to maintain wind firmness. Though thinning may accelerate recruitment of saplings to larger diameter classes relative to natural gap dynamics, saplings within patches tended to display good height differentiation. For this reason, choosing not to thin some patches within a stand may be appropriate. Additionally, more research is needed to evaluate growth and mortality of residual trees in thinned patches.

Managers at Ichauway feel that the immediate and future benefits of precommercial thinning justify the costs. The cost of thinning patches was slightly over $100 per acre. In the Malone-Bud Walker harvest area, there were 12 total 0.5-acre plots with sapling patches available for research purposes. Assuming half of those plots were thinned, it would amount to a total cost of approximately $300. Such a cost may be justified in woodlands managed for multiple values such as aesthetics, recreation, or to improve the ability to see through the stand. Another long-term benefit of recruiting trees to larger size classes more quickly at Ichauway was improved wildlife habitat. Overall, our findings indicate this may be a practical treatment for landowners with multiaged longleaf pine stands.

LITERATURE CITED

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs. 30(2): 129–164. https://doi.org/10.2307/1948549.

D'Amato, A.W.; Bradford, J.B.; Fraver, S.; Palik, B.J. 2013. Effects of thinning on drought vulnerability and climate response in north temperate forest ecosystems. Ecological Applications. 23(8): 1735–1742. https://doi.org/10.1890/13-0677.1.

Ducey, M.J. 2009. The ratio of additive and traditional stand density indices. Western Journal of Applied Forestry. 24(1): 5–10. https://doi.org/10.1093/wjaf/24.1.5.

Ducey, M.J.; Larson, B.C. 2003. Is there a correct stand density index? An alternate interpretation. Western Journal of Applied Forestry. 18(3): 179–184. https://doi.org/10.1093/wjaf/18.3.179.

Pearson, G.A. 1950. Management of ponderosa pine in the Southwest as developed by research and experimental practice. Agric. Monogr. 6. Washington, DC: U.S. Department of Agriculture Forest Service. 218 p.

Samuelson, L.J.; Stokes, T.A. 2012. Leaf physiological and morphological responses to shade in grass-stage seedlings and young trees of longleaf pine. Forests. 3(3): 684–699. https://doi.org/10.3390/f3030684.

Shaw, J.D.; Long, J.N. 2007. A density management diagram for longleaf pine stands with application to red-cockaded woodpecker habitat. Southern Journal of Applied Forestry. 31(1): 28–38. https://doi.org/10.1093/sjaf/31.1.28.

Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997. The practice of silviculture: Applied forest ecology. 9th ed. New York: John Wiley & Sons, Inc. 537 p.

Weaver, H. 1943. Fire as an ecological and silvicultural factor in the ponderosa-pine region of the Pacific Slope. Journal of Forestry. 41(1): 7–15. https://doi.org/10.1093/jof/41.1.7.

Wilson, F.G. 1946. Numerical expression of stocking in terms of height. Journal of Forestry. 44(10): 758–761. https://doi.org/10.1093/jof/44.10.758.