Restoration and Reclamation Review
Student On-Line Journal
Vol.7, No.1, Fall 2001
Department of Horticultural Science
University of Minnesota, St.Paul, MN

The Apalachicola Bluffs and Ravines Preserve in Northern Florida:

a longleaf pine and wiregrass restoration project

Elizabeth Vaughan

Introduction

Longleaf pine restoration projects range from the burning of fire-suppressed forests to the restoration of entire communities. Since 1985, the uplands of the Apalachicola Bluffs and Ravines Preserve have been the site of an ambitious, long-term project by The Nature Conservancy to restore this premier natural area's historical vegetation. This 2,540-hectare (6,300-acre) preserve lies along the Apalachicola River in the Florida panhandle 50 miles west of Tallahassee in Liberty County.[1] The preserve's uplands' deep, marine-deposited, porous sands historically supported an open canopy of *Pinus palustris* (longleaf pine), scattered oaks (*Quercus laevis*, *Q. geminata*, *Q. incana*, and *Q. minima*), *Aristida stricta* (wiregrass), and other grasses and forbs (Seamon 1998). However, prior to Conservancy ownership, the uplands were windrowed and converted to a *Pinus elliotti* (slash pine) plantation. Although slash pine grows near the preserve, it is not found naturally on the preserve's deep sands because it is much less fire resistant that longleaf pine (Hattenbach et al. 1998, Seamon 1998). This paper examines the longleaf pine ecosystem, the steps taken in a long-term longleaf pine restoration project, the lessons learned at 16 years into the project, and the unresolved questions regarding the preserve's future.

The Longleaf Pine Ecosystem

Longleaf pine communities like those found in the preserve are well documented to be largely the product of frequent fire (Noss 1989, Smith 1996, Kush et al. 2000). Prior to the arrival of the first European settlers, forests dominated by longleaf pine and maintained by periodic fire occurred throughout most of the southern coastal plain (Frost 1993). Fires ignited by a combination of lightning strikes from frequent thunderstorms or from aboriginal incendiarism swept across the presettlement longleaf savannas at intervals ranging from 1 to 10 years (Landers et al.1995, Kush and Meldahl 2000). These low-intensity fires and other usually small-scale disturbances resulted in open, patchy, park-like longleaf pine barrens. As today, these open areas were usually composed of even- or multi-aged mosaics of forests, woodlands, and savannas, with a diverse groundcover dominated by wiregrass and other bunch grasses, and usually free of understory brush and hardwoods (Landers et al.1995). Although relatively simple in structure, the longleaf pine ecosystem contains some of the most diverse communities known from the temperate zone. There have been over 40 species of plants per square meter documented in the xeric longleaf pine woodlands such as those in the preserve (Peet and Allard 1993). Longleaf pine and wiregrass, a keystone component in xeric longleaf pine woodlands, possess traits that help the ignition and spread of fire. Both species exhibit pronounced fire tolerance, longevity, and nutrient-water retention that reinforce their dominance and restrict the scale of vegetation change following disturbance (Peet and Allard 1993, Landers et al. 1995).

Fire suppression prevents longleaf pine from regenerating by allowing more aggressive hardwoods and pines, such as slash pine, to dominate. Longleaf pine is an intolerant pioneer species, and it only produces large seed crops every 3 to 8 years on average. Its heavy, large seeds are wind dispersed but most fall only within 100 feet (30 m) of the parent tree. Seeds generally require contact with bare mineral soil to sprout. Once established, seedlings grow slowly into a many-needled young sapling that looks like a grass. Where competition is present, it may remain in the stemless grass stage for years (Voigt 1986, Landers et al. 1995, Smith 1996).

At the time of presettlement, longleaf pine forests may have dominated as many as 36 million ha (90 million acres) throughout the southeastern United States. Today, however, the remaining longleaf pine forests are estimated at less than 1.2 million ha (3 million acres) mainly due to land clearing for human occupation and agriculture and the suppression of fire (Johnson and Gjerstad 1998, Landers et al. 1995).

History of the Preserve

The demise of the longleaf pine on the area that is now the Apalachicola Bluffs and Ravines Preserve is similar to what occurred in the southeast over the last 200 years. It was selectively logged through the 1940s, and vigorous fire suppression allowed gaps to close and litter to accumulate. Fire suppression resulted in the elimination of the patches of bare soil needed for longleaf regeneration. Open range laws at that time also allowed domestic hogs to roam free, and hogs fed on young trees throughout the longleaf sandhill areas. Clear cutting began in the mid-1950s and was followed by clearing of all remaining vegetation into windrows. The wiregrass population was greatly reduced and was replaced with fire-intolerant species such as *Rubus cuneifolius* (blackberry) and *Eupatorium compositifolium* (dog fennel) and other species that do not carry fire well. The windrows provided refuges for any remaining wiregrass, but they also provided sites for the establishment of hardwoods. The hardwoods created firebreaks across the landscape and stopped fires from creeping downslope. The firebreaks also allowed hardwoods from the slope forest to invade the sandhills (Seamon 1998). By 1958, the majority of the preserve's sandhills were cut and cleared and subsequently planted in slash pine. With the absence of fire, the dominant vegetation became slash pine, *Quercus laevis* (turkey oak), and other hardwoods. (Seamon 1998).

Restoration of the Preserve

In the preserve, the tops and the slopes of the gently rolling hills of the sandhill community drop off into steep ravines. These ravines were the original conservation targets of the first parcels purchased by The Nature Conservancy in 1982. The cool, moist ravines are home to a high proportion of northern species such as *Hydrangea quercifolia* (oak-leaf hydrangea), *Epigea repens* (trailing arbutus), *Kalmia latifolia* (mountain laurel), and *Agkistrodon contortix* (southern copperhead), all of which reach their southern limits on the preserve. The slopes are also the refuge to a number of endemics including the rare *Torreya taxifolia* (Florida torreya), *Taxus floridana* (Florida yew), and *Desmognanthes apalachicoli* (Apalachicola dusky salamander) (Seamon 1990; Seamon 1998).

After purchasing the preserve, The Nature Conservancy realized that the sustainability of the slope community may be dependent on processes in the preserve's uplands, such as fire (Hattenbach et al. 1998). One indication in this relationship is the decline of the *Torreya taxifolia* (Florida torreya). This species has suffered from a fungal infection that eventually leads to its death. The onset of the fungal blight in the early 1960s coincided with the harvest of longleaf pine. Historic fires in the uplands burned over the edges of the ravines, removing leaf litter and causing smoke to settle into the slope forest. This smoke may have acted as a fungicide that controlled the fungal disease (Seamon 1990). Thus, in 1985, The Nature Conservancy expanded its original conservation goal of preserving the slope forest community to include restoring the longleaf pine/wiregrass sandhill community on 1,200 ha (3,000 acres) of disturbed uplands. Most of this area was covered by slash pine although some had been clearcut immediately prior to purchase by the Conservancy. At the time of purchase, there were 77 ha (192 acres) of intact sandhill on the preserve (Seamon 1998).

Canopy restoration

The restoration effort began in the winter of 1985-1986. Slash pine was clearcut in certain areas to open up the canopy, and 300,000 bareroot longleaf pine seedlings were planted by hand (Hattenbach et al.

1998). Due to the size of the site, no supplemental watering was done. The year following the first planting was extremely dry, and only 10 percent of the seedlings survived (Seamon 1998). Since that failure, only containerized longleaf pine seedling have been planted. Barnett et al. (1996) note that failure of bareroot longleaf pine seedlings is common, so most silviculturists prefer to plant containerized longleaf seedlings. The cost of containerized seedlings in 1998 was $150 per 1,000 seedlings, twice the cost of bareroot seedlings. However, each year's containerized planting has fared much better with a survival rate between 70 and 85 percent (Seamon 1998). The container-grown longleaf pine seedlings are between 15.2 and 20.3 cm long (6 and 8 inches) and are bought already pulled from their containers. The seedlings are planted in mid-October and November if rainfall is adequate and again in January and February (G. Seamon, personal communication). As of April 1997, 929,000 longleaf pine seedlings have been planted by hand on 920 ha (2,300 acres) at a density of 500 to 1,250 per ha (200 to 500 trees per acre) (Seamon 1998).

Ground plane restoration

The Nature Conservancy's goals for the preserve of restoring the longleaf pine/wiregrass sandhill community and enhancing the biological diversity within the community mandated a prescribed fire program. Since the low-intensity fires necessary for a longleaf pine community will not carry unless the herbaceous groundcover is reestablished, the next step in the restoration project was to reestablish wiregrass, the historical dominant fuel source (Seamon 1998). Wiregrass seedbank studies were done in some areas in the preserve, and virtually no seeds were found (G. Seamon, personal communication). Therefore, the preserve's site managers looked to establish an annual wiregrass seed collection from the preserve's existing wiregrass sites. They began by investigating the most favorable time of year to burn in order to encourage groundcover seed production as well as to restore the historical role of fire necessary for the longleaf pine ecosystem. There is contradictory evidence on the evaluation of effects of season of burn on trees and on groundcover vegetation. In presettlement times, most fires occurred in spring and early summer. Foresters and range managers have traditionally burned Southeastern pine forests in the winter, partly due to the thought that burning in the growing season was considered harmful to pine silviculture (Streng et al. 1993). But what about a restoration project in a longleaf/wiregrass community?

In 1993, Streng, Glitzenstein, and Platt published a report from a long-term study of season of burn in longleaf pine sandhills in north Florida. They found, similar to other studies, that early growing season burns result in high rates of death of midstory oaks. They also found little effect of burning season on longleaf pine dynamics. Until the late 1980s, it was believed that wiregrass rarely flowered or produced viable seed, and it was known to have a low reproductive capacity (Clewell 1989). However, they reported a large positive effect of growing season burning versus dormant season burning on flowering and presumably seed production of dominant grasses (including wiregrass) and some forbs. Conversely, there was little effect of burning season on the abundance of species in the groundcover, even after ten years of study. Why would wiregrass and some of the other species increase seed production but not increase in abundance? The authors hypothesize that opportunities for seedling establishment in wiregrass occur, but only rarely, since the groundcover in sandhill sites is dominated by long-lived perennial plants which fires rarely kill. When adult plants are killed by local fire hot spots or in small-scale disturbances caused by animals, opportunities for seed establishment open up.

Considering this evidence, one may conclude that it is necessary to establish the groundcover vegetation by either planting plugs or by direct seeding and implementing the growing season burns that once occurred naturally to help increase the wiregrass flowering and seed production. The Conservancy site managers of the Apalachicola preserve made this conclusion after they completed their own studies. Two trials on burning and wiregrass seed germination conducted by The Nature Conservancy's Fire Management and Research Program and the Northwest Florida Stewardship on other north Florida preserves from 1989 and 1991 verified that early summer burning induced flowering and maximum seed production in wiregrass (Seamon 1998). Based on these studies, a program began in 1989 on the Apalachicola preserve of burning the approximately 77 ha (192 acres) of surviving intact longleaf pine and wiregrass sites in early summer on a three-year rotation. Seeds of wiregrass and other groundcover species from these sites are harvested each fall and planted on the preserve. Annual germination rates of the collected wiregrass seed have ranged from 6 to 44%. Seamon (1998) speculates that low rates occurred because of early collection or in summers of high humidity and a resulting increase of infectious smut growth. Wiregrass seeds harvested annually from the preserve are sown in an on-site nursery and are grown into plugs. From 1989-1996, over 210,000 wiregrass plugs covering 8 ha (20 acres) were planted on the preserve. Volunteers collect and sow seeds, care for the plants in the nursery, and plant the plugs. However, planting is slow (only 8 ha of 1,200 have been planted after 7 years), and the cost averages about $7,400 per ha ($3,000 per acre). Although wiregrass plugs are still being grown and planted today to create nursery sites for collecting seeds in the future (G. Seamon, personal communication), it was decided in 1993 to investigate methods of mechanically harvesting and direct-seeding the wiregrass and other groundcover species (Seamon 1998).

After a number of trial and error experiments, the mangers found that a machine called a Woodward Flail-Vac Seed Stripper that attaches to the front of an all-terrain vehicle was the best for collecting groundcover seed suitable for direct seeding. It can collect a 125-liter (33-gallon) bag of seed and other material in less than 20 minutes. It was determined that between 10 and 21 percent of the weight of a full bag contained wiregrass seed. Other native groundcover species collected include *Haplopappus divaricatus*, *Pityopsis graminifolia*, *Solidago odora*, *Petalostemon pinnatum*, *Liatris chapmanii*. *Liatris graminifolia*, and *Liatris tenuifolia* (Seamon 1998). As for a method of direct seeding groundcover, the cheapest and most effective method was eventually found to be a hay blower with a flexible hose carried in the back of a pickup truck (Seamon 1998). Before seeding, the ground is cleared of any woody debris via a bulldozer or through burning (G. Seamon, personal communication).

To determine the most successful method of wiregrass and other groundcover establishment, Seamon (1998) conducted two direct-seeding trials in 1995 and 1996 in the preserve. The results showed that direct seeding can be an effective method of establishing wiregrass, and rolling the seed in after sowing increases wiregrass seedling establishment and survival. In addition, Hattenbach et al. (1998) also performed a similar scientific study in 1997 in the preserve. The seven treatments in this study consisted of the following:

1. unsown control plots;
2. sowing native seed (wiregrass and other understory species) alone or
3. sowing native seed with a winter rye cover crop;
4. rolling the seed in or not following sowing or
5. not rolling the seed in following sowing;
6. adding supplemental water for the first four months after sowing or
7. not adding supplemental water after sowing.

Seeds were sown on bare soil. Monitoring showed high species richness in all study plots, but no wiregrass emerged in the unsown control plots even though an equal number of the other native species naturally dispersed into the unsown plots. In all other plots, wiregrass density was within the range reported for healthy sandhill communities (Clewell 1989). Neither supplemental water nor sowing an annual cover crop increased understory species richness or density. Similar to Seamon's (1998) studies, wiregrass density was highest in plots that were rolled (Hattenbach et al. 1998). This study showed that direct seeding of wiregrass can be successful and that establishment of wiregrass, either through direct seeding or plugs, is a necessary step in wiregrass restoration. However, the success of other groundcover species in this study shows that direct seeding of these species may not be necessary since adjacent refugial populations and surface soils were present. Additional direct-seeding trials of wiregrass and other species are ongoing.

Evaluation of Success

Lessons learned

In the beginning of the restoration, the site managers first considered the vertical structure of the longleaf pine community. Since longleaf pine is a poor competitor, one can surmise that establishing the canopy by first planting longleaf pine seedlings rather than the groundcover (wiregrass and forbs) allows the pines to become established and reach the point where the root collar is about 4/5 cm (1/3 inch) in diameter (about 1.5 years of age). At this stage, the seedlings are resistant to fire (Smith 1996). The relatively large size of the preserve allows for annual planting of longleaf pine in different areas that could be followed in a few years by the establishment of the groundcover. However, the site managers found that establishing the longleaf pine was extremely easy (the return of fire has either killed or prevented the spread of any remaining slash pine), but establishing the wiregrass proved more of a challenge. At best, the site managers have been able to restore only 40 ha (100 acres) of wiregrass in a year with significant rainfall. Today, the managers establish the wiregrass first before planting the longleaf pine. In fact, Greg Seamon, the preserve's land steward, notes that if he could go back to 1985 and have unlimited funding, he would not worry about establishing the longleaf pine but instead concentrate more on removing the barriers to fire to establish the groundcover faster: bulldoze all windrows, clearcut all slash pine, scarify the ground in preparation for seeding, and collect and plant wiregrass and other groundcover seed as much as possible. Seamon points out that having a site planted only in longleaf pine doesn't make it a functioning sandhill ecosystem, it simply makes it a longleaf plantation: the diversity is in the groundcover (G. Seamon, personal communication).

The site managers determined that the upper end of their original longleaf planting density, 1,250 trees per ha (500 trees per acre), was probably too high. By reviewing old aerial photos and interviewing area landowners (there are no sandhill reference sites in the area), they estimated a more historic density at 28-60 trees per ha (70-150 trees per acre) with the higher densities closer to the moisture and nutrient rich ravines. However, the land that is now the preserve had been altered by the time the aerial photos were taken and before the remembrances of the people who were interviewed, so the planting density estimate is truly a guess at presettlement conditions (G. Seamon, personal communication). Interestingly, this density is relatively close to what was found in a study of forty old-growth longleaf pine forests in Florida, Alabama, and Mississippi. These forests were documented to have an average of 16 trees per ha (40 trees per acre) greater or equal to 10 cm (4 inches) diameter at breast height (Landers and Boyer 1999). The density of trees per ha planted in recent years on the preserve is within the lower range of 500-1,250 to compensate for seedling death, natural attrition rate, and death due to weather disturbances such as wind. In addition, it also helps control unwanted vegetation and closes the canopy quickly and allows for self-thinning and for thinning by the site managers in the future.

In his project report, Seamon (1998) notes that the seeds for the bareroot and containerized seedlings were not collected from the preserve or even from north Florida. They have no origin for most of the pines planted on the preserve. In hindsight, Seamon (1998) noted that they should have paid greater attention to the provenance of the planting stock.

Measures of success

The site's land steward says that he will consider the entire site a success when the wiregrass carries fire and reproduces on its own, and when the site contains suitable animal habitat that allows for the movement of animals and plants within neighboring pine plantations. Progress has been made towards these goals. New wiregrass seedlings were found in 2000 on a site that was seeded in 1995 and burned in 1999 (G. Seamon, personal communication). Historically, the open patchy habitat preserved by frequent ground fires in longleaf pine forests promoted an abundance of wildlife. *Gopherus polyphemus* (gopher tortoise), *Scirurs niger* (southern fox squirrel), and *Picoides borealis* (red-cockaded woodpecker) are keystone animal species of longleaf pine-wiregrass sandhills (Landers et al.1985, Noss 1989). Since one of the restoration goals is to increase biodiversity, in 1992 the site managers set out permanent transects to begin long-term monitoring of two of these species, the gopher tortoise and *Sciurus niger shermani* (Sherman's fox squirrel, a subspecies of the southern fox squirrel). 50 by 50 meter plots (164 by 164 feet) were measured, and monitoring was done in 1995, 1998, and 2001. Where the managers once found only larger gopher tortoise burrows, they have since documented increases in the diversity of burrow sizes. This indicates that there are both young and adult tortoises. Sherman's fox squirrel was found on the site in 2001; however, the land steward notes that since there are no large longleaf pines on the site, the squirrels do not have a reliable food source at this point. Red cockaded woodpeckers need an even higher quality longleaf pine habitat, and there are no woodpeckers in the preserve. The nearest red cockaded woodpecker population is approximately 72 km (45 miles) south in the Apalachicola National Forest. In order to establish a population, these birds would have to be brought in at a much later date when habitat quality is adequate (G. Seamon, personal communication).

Another point of evaluation and research opportunity could be the study of small-scale disturbances present such as animal-created soil disturbances and downed trees. Research on small-scale disturbances has been extensive in grasslands, temperate hardwood forests, and tropical rain forests, but there is little published information on disturbance in longleaf pine-wiregrass forests. Hermann (1993) suggests that small-scale disturbances were important components of the presettlement landscape in the southeastern United States. Study of these could help to determine spatial patterns in groundcover species and help to re-create a full range of components in a restored longleaf pine landscape.

Since the restoration of the uplands actually began to help preserve and restore the slope forest communities, it is interesting to note that the Florida torreya has experienced a 3 percent annual mortality rate in recent years. The species may have suffered irreparable damage from the lack of fire in the uplands, but study is ongoing. However, another rare species, *Matelea alabamensis*, (Alabama spiny-pod), has responded positively by producing more flowers and seed (G. Seamon, personal communication).

The project seems to have been relatively well funded through donations, private foundations, and grants including some through the Department of the Interior and the U.S. Fish and Wildlife Service (Seamon 1998). However, virtually any restoration project, especially a long-term project like a forest restoration, could use additional funding. Additional funding would allow the site managers to achieve some of their ideal goals by speeding up the land clearing and groundcover planting process. Lack of funding has also limited the size of the animal monitoring transects which are quite small, covering only 5 percent of the uplands (G. Seamon, personal communication).

Summary

The site managers have made an excellent effort in the first stages of restoring the Apalachicola Bluffs and Ravines Preserve. After 16 years of work, the basic structure of 30% of the disturbed uplands has been restored (Table 1). The most important part of the longleaf pine ecosystem, fire, has been established. In the preserve, fire kills the competing slash pine and understory woody vegetation, reduces the floor litter, exposes bare mineral soil necessary for longleaf regeneration, and stimulates the wiregrass and other groundcover. Fire also allows for groundcover diversity that is found in sandhill communities. The site managers have certainly recognized the importance of fire in this ecosystem, and they have considered the life history strategies of longleaf pine and wiregrass, the two keystone species, and have established the basic structure of the forest. They have been active in experimenting to find the most efficient and economical methods of seeding and planting, and using the most up-to-date research to establish groundcover. They are measuring the project's success by the quality of animal habitat, an important indicator of site quality.

At this point in the restoration project, the answers to some questions remain. Can the fire-suppressed uplands be restored to support a fully functioning longleaf pine ecosystem and provide quality habitat to keystone animal species? Will the rare plant species in the slope forest recover, or is the damage from lack of fire in previous years irreversible? The Apalachicola Bluffs and Ravines Preserve will obviously need continued research-based management including regular burning, and The Nature Conservancy will need to plan for the site's future management and financial support. With the preserve's proper management and support, later generations will know the answers to our current questions, and those answers will improve the success of future sandhill restoration projects.

Table 1

Apalachicola Bluffs and Ravines Preserve: progress summary.

Date	Action	Outcome
Winter 1985-1986	300,000 *Pinus palustris* (longleaf pine) bareroot seedlings planted.	Only 10% survived.
1987 to 1998	Over 929,000 containerized longleaf pine seedlings planted by staff and volunteers.	920 ha (2,300 acres) have been planted at a density of 500-1,250 trees per ha (200-500 per acre). On average each year, 70-85% survive at one year after planting. Containerized seedlings have been planted each year since as conditions permit. Seedlings planted in the 1980s are now between 1 and 3 meters (3.2-9.8 feet) in height.
1987 to present	Burning of surviving intact *Aristida stricta* (wiregrass) sites in early summer on a three-year rotation. Seeds of those and other groundcover species harvested in late fall and seeded on-site.	Wiregrass germination tests since 1989 show a low of 6% in 1990 to a high of 44% in 1996.
1989 to present	Wiregrass plugs grown from seed collected on site or from adjacent state-owned lands. Volunteers collect and sow seed, care for the nursery, and plant plugs.	Planting is slow and costly. Costs average $7,400/ha ($3,000/acre). As of November 1996, 210,000 plugs covering 8 of 1,200 ha (20 of 3,000 acres) have been planted. Led to investigation of methods to mechanically harvest and direct seed wiregrass and other groundcover species.
1989 to present	Fire is used as a primary management tool. Burning is done every 3-5 years as conditions permit.	As of 1998, 231 of 1,200 ha (572 of 3,000 acres) restored.

Information from Seamon, 1998.

Literature Cited

Barnett, J.P., J.D. Haywood, and M.A. Sword. 1996. Artificial regeneration of longleaf pine: reevaluation of technique. Pages 53-54 in J.S. Kush, Editor. Longleaf Alliance Report. The Longleaf Alliance, Auburn, AL.

Clewell, A. 1989. Natural history of wiregrass (*Aristida stricta* Michx., Gramineae). Natural Areas Journal 9: 223-232.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. Pages 17-44 in S. Hermann, Editor. Proceedings of the Tall Timbers Fire Ecology Conference, No. 18, The Longleaf Pine Ecosystem: ecology, restoration, and management. Tallahassee, FL: Tall Timbers Research Station.

Hattenbach, M.J., D.R. Gordon, G.S. Seamon, and R.G. Studenmund. 1998. Development of direct-seeding techniques to restore native groundcover in a sandhill ecosystem. Pages 64-66 in J.S. Kush, Editor. Longleaf Alliance Report. The Longleaf Alliance, Auburn, AL.

Hermann, S.M. 1993. Small-scale disturbances in longleaf pine forests. Pages 265-274 in S. Hermann, Editor. Proceedings of the Tall Timbers Fire Ecology Conference, No. 18, The Longleaf Pine Ecosystem: ecology, restoration, and management. Tallahassee, FL: Tall Timbers Research Station.

Johnson, R. and D. Gjerstad. 1998. Landscape-scale restoration of the longleaf pine ecosystem. Restoration and Management Notes 16: 41-45.

Kush, J.S., R.S. Meldahl, and W.D. Boyer. 2000. Understory plant community response to season of burn in natural longleaf pine forests. Pages 32-39 in W.K. Moser and C.F. Moser, Editors. Proceedings of the Tall Timbers Fire Ecology Conference, No. 21, Fire and forest ecology: innovative silviculture and vegetation management. Tallahassee, FL: Tall Timbers Research Station.

Landers, J.L and W.D. Boyer. 1999. An old-growth definition for upland longleaf and South Florida slash pine forests, woodlands, and savannas. General Technical Report SRS-29. U.S. Department of Agriculture, Forest Service, Southern Research Station.

Landers, J. L., D. H. Van Lear, and W. D. Boyer. 1995. The longleaf pine forests in the Southeast: requiem or renaissance? Journal of Forestry 93: 39-44.

Noss, R. F. 1989. Longleaf pine and wiregrass: Keystone components of an endangered ecosystem. Natural Areas Journal 9: 234-235.

Peet, R.K. and D.J. Allard. 1993. Longleaf pine vegetation of the Southern Atlantic and Gulf Coast regions: a preliminary classification. Pages 45-81 in S. Hermann, Editor. Proceedings of the Tall Timbers Fire Ecology Conference, No. 18, The Longleaf Pine Ecosystem: ecology, restoration, and management. Tallahassee, FL: Tall Timbers Research Station.

Seamon, G. 1998. A longleaf pine sandhill restoration in northwest Florida. Restoration and Management Notes 16: 46-50.

Seamon, P. Summer 1990. Fire Ecology Report. The Nature Conservancy Fire Management and Research Program, Tallahassee, FL.

Smith, L.M. 1996. How longleaf develops, grows, and reproduces in relationship to various habits and environmental conditions. Pages 6-8 in J.S. Kush, Editor. Longleaf Alliance Report. The Longleaf Alliance, Auburn, AL.

Streng, D.R., Glitzenstein, J.S., and Platt, W.J. 1993. Evaluating effects of season of burn in longleaf pine forests: a critical literature review and some results from an ongoing long-term study. Pages 227-264 in S. Hermann, Editor. Proceedings of the Tall Timbers Fire Ecology Conference, No. 18, The Longleaf Pine Ecosystem: ecology, restoration, and management. Tallahassee, FL: Tall Timbers Research Station.

Voigt, W. 1986. Report on the longleaf pine. American Forests: May 43-46.

[1]The preserve is located in Township 1 North, Range 7 West, Sections 7, 8, 9, 16-21, 30 and Range 8 West, Sections 12, 24, 25.