Effects of Rock and Shrub Coverage on the Longleaf Pine (*Pinus palustris*) at Oak Mountain State Park, Pelham, Alabama

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Abstract

This study was designed to achieve a better understanding of the relationship between rock and shrub cover and longleaf pine (*Pinus palustris*) communities. Longleaf pine once covered much of the southeastern United States, but widespread harvesting, land development and fire suppression have led to a major decrease in the extent of this ecosystem. The longleaf community has declined to less than 3% of its former range, now covering less than 1.2 million hectares. Longleaf pine communities are dependent upon fire to promote regeneration of longleaf seedlings by reducing competition. In our study, both rock and shrub cover are important ecological factors to understand in the longleaf community because of how they relate to fire. Due to the suppression of fire, longleaf pine communities are met with increasing competition from shrubs in the seedling and adult stages. Rock coverage could possibly act as a fire surrogate because there is less soil for trees to root, lower soil moisture, and lower nutrient levels, which may help to reduce competition. To study these relationships, 26 plots were surveyed in Oak Mountain State Park, Pelham, Alabama, which contains a very important type of longleaf community: the mountain longleaf pine. We set up the plots in two distinct areas of the park: 13 plots in the foothills (the low hills or mountains at the bottom of Double Oak Mountain), and 13 plots in the ridge (south-east facing slope of Double Oak Mountain). We used a line transect method to determine rock and shrub cover for each zone and compare it to small (height < 1.3 m) and large (height > 1.3 m) longleaf pine growth using Mann-Whitney tests and regressions. Shrub cover was divided into highbush blueberry (*Vaccinium arboretum*) and lowbush blueberry *(Vaccinium*

pallidum). We found a significant positive correlation in the ridge between lowbush blueberry coverage and large longleaf pine stems, and between rock coverage and basal diameter for small longleaf pine stems. All lowbush blueberry regressions in the ridge were positively correlated while all regressions involving highbush blueberry in the ridge were found to have negative correlations. There were no significant regressions in the foothills and no clear pattern with regard to the directionality of the relationships. We concluded that lowbush blueberry may be positively correlated with longleaf pine in the ridge because they are both dependent on fire and the ridge community has been burned more recently. Highbush blueberry may be negatively correlated with longleaf pine in the ridge because it is significantly larger than lowbush and may be competing with longleaf pine for light and nutrients. We concluded that increasing rock coverage in the ridge results in increasing basal diameter for small longleaf stems possibly due to a lack of nutrients and water in the ridge, which may cause small longleaf stems to grow in girth before growing in height to adapt in the harsh conditions. However, none of these relationships were found in the foothill community. Therefore, our main conclusion was the difference between the ridge and foothill communities and how these communities have very different ecological relationships.

Introduction

The longleaf pine community is one of the most species-rich communities outside the tropics (Smith *et al.*, 2000). Longleaf pine forests (*Pinus palustris*) once covered much of the southeastern United States, but widespread harvesting, land development and fire suppression have led to a major decrease in the extent of this ecosystem (Maceina *et al*., 2000). According to Glitzenstein et al. (1996), the longleaf community has declined to less than 3% of its former range, now covering less than 1.2 million hectares. Because of the this decline, a large number of the endemic species to the longleaf pine forest are appearing as candidates on federal and state threatened and endangered species list (Smith *et al.*, 2000).

The interruption in the natural fire cycle is one of the most important causes of the decline of longleaf pine forests. Frequent fires promote the regeneration and growth of fire-tolerant longleaf seedlings by reducing competition. Since the 1930's, fire suppression efforts have helped to transform the open longleaf pine forests to dense stands of overstory pines (usually loblolly (*Pinus taeda*) due to its shade tolerance), midstory hardwoods, and understory shrubs (Harrington *et al.*, 2003).

Longleaf pine forests tend to favor an open canopy, well-drained soils, and minimal competition. Their natural range extended along the Coastal Plain from Texas to Virginia and from central Florida to the Piedmont and mountains of northern Alabama and Georgia (Varner *et al.*, 2003). Longleaf pine grows in a host of sites ranging from poorly-drained flatwoods to sandhills to mountain ridges resulting in a range of community types including forests, woodlands, and savannas (Brockway *et al.*, 1999).

Most of the regions where longleaf pine is known to be found have been well-researched and documented. However, little information exists on the mountainous communities found in the Blue Ridge, Ridge and Valley, Cumberland Plateau, and Piedmont physiographic regions of Georgia and Alabama (Maceina *et al.,* 2000). In these communities, often called the mountain longleaf pine forests (Varner *et al.,* 2003), longleaf can be found in different areas ranging from dry, rocky ridges to rocky outcrops on the sides of mountains to low hills coming off the slope of a larger mountain (Garren, 1941). The soils in these areas can be very dry and nutrient-poor, which may help to reduce the competition (Meilleur *et al.,* 1997). Mountain longleaf pine stands may also allow for a more open canopy and more light to reach the understory due to rock cover and slope steepness, which could make it difficult for other trees to compete for soil. According to Varner et al. (2003), historic fires in mountain longleaf pine forests were frequent and necessary to preserve this ecosystem in the contemporary southeastern landscape.

Two factors which could be very important to the longleaf pine's ecology in these mountainous areas are rock and shrub cover. According to Varner et al. (2003), the longleaf forests found in the Piedmont and Valley and Ridge regions of Alabama do well in rocky areas. In these rocky areas, the more competitive species of other ecosystems are not able to colonize because of the harsh conditions (McVaugh, 1943). With increasing rock cover, there is less soil for trees to root, lower soil moisture, and lower nutrient levels. Therefore, these rocky areas could be considered as fire surrogates because they may help to reduce competition. Both rock outcroppings and fire usually

result in an acidic soil, which favors nutrient-poor adapted plants such as the longleaf pine (Meilleur *et al.,* 1997). However, these effects are not well understood (Williams, 1998).

Shrubs may also play an important role in the processes, structure, and composition of forests. According to Lambers and Clark (2003), forest community structure and composition may be largely determined at the seedling stage. Seeds represent the principal manner in which woody species colonize new habitats (Lambers and Clark, 2003). Shrub coverage may play an important role in the establishment of seedlings because of competition for soil nutrients (e.g., belowground) and light (e.g., aboveground). Shrubs have been shown to decrease seedling densities as early as the first-year seedling stages, suggesting the effects were the result of either low light or low moisture (Lambers and Clark, 2003). Longleaf pine is intolerant to shade and regenerates most successfully with minimal competition from woody vegetation (Harrington *et al.,* 2003). However, shrubs may also buffer harsh conditions and facilitate tree recruitment of degraded lands (Duncan and Chapman, 2003).

In the mountain longleaf pine ecosystem, two common shrub species are highbush blueberry (*Vaccimium arboretum*) and lowbush blueberry (*Vaccinium pallidum*). Highbush blueberry is a large, many-branched, upright shrub that grows to 2 – 3 meters tall and is common throughout the Coastal Plain and Piedmont regions. It flourishes on sand dunes, granitic outcrops, dry hillsides, rocky woods, and meadows, and is commonly found in longleaf-slash pine, loblolly-shortleaf pine, oak-pine, and oak-hickory ecosystems (USFS, 2004). In longleaf pine-shortleaf communities, highbush

blueberry reaches its greatest abundance in sites that are burned less frequently, but may be protected from the effects of fire in moist areas or on rocky sites lacking fuel (USFS, 2004).

Lowbush blueberry is an erect, deciduous shrub that usually reaches heights of 23 - 53 centimeters. It is common throughout the Coastal Plain and Piedmont regions and is found on disturbed sites, abandoned farmland, roadsides, upland ridges, and shale barrens (USFS, 2004). It grows well on dry and acidic soils. Lowbush blueberry is well-adapted to frequent fires and readily resprouts in post-fire communities from rhizomes or surviving portions of aerial stems (USFS, 2004). These differences in the small and large shrubs may be important because they could have different effects on the community due to the scale at which they require and use resources.

The goal of our research was to better understand the relationships and interactions between rock and shrub cover and *P. palustris* in the mountain longleaf pine community of north-central Alabama. Because the presence of rocks may reduce competition with longleaf, we hypothesized that rock cover should have a positive effect on the number and size of longleaf pine stems. Due to the competition of shrub cover with longleaf pine, we hypothesized that amount of shrub cover would have a negative effect on the number and size of longleaf pine stems. We considered these relationships between rock and shrub cover and longleaf pine in two distinct communities within Oak Mountain State Park, Pelham, AL: the foothills and the ridge. The foothill community was the low hills and mountains coming off the slope of Double Oak Mountain, while the ridge community was the south-east facing slope of Double Oak Mountain. The foothills

and ridge were compared to determine if rock and shrub cover play different roles in these longleaf pine communities.

<u>Methods</u>

This study took place at Oak Mountain State Park in Pelham, Alabama. The park consists of two different community types: the foothills and the ridge. The foothills were characterized as the low hills or mountains at the bottom of Double Oak Mountain. In the foothills, longleaf pine is found most intact on or just below hilltops. The ridge was defined as the southeast-facing slopes of Double Oak Mountain. Data was collected on twenty-six plots throughout the park.

The plots were established and surveyed during the summer of 2003. The diameter at breast height (DBH) was recorded for all trees $\geq$ 1.3 m tall and the basal diameter (BD) was recorded for all trees $<$ 1.3 m tall. Plots were 50 X 20 m, and divided into 10 X 10 m blocks. The twenty-six plots consisted of thirteen foothill plots and thirteen ridge plots. Six plots were selectively-placed (three in both the foothills and ridge communities) and located where the longleaf pine community was generally assessed to be the most intact.

Foothill plots were established on randomly selected hilltops. No greater than one plot was placed on the same hilltop. The center of the plot was placed at the highest point of the hilltop and the long-axis of the plot ran from North to South. The ten ridge plots were placed at randomly selected locations (minimum of 200m apart) along North-South transects crossing the south ridge and south-facing slopes of Double Oak Mountain. The selectively-placed plots were non-randomly placed in both the ridge and

foothill categories where longleaf communities were least disturbed and most similar to what we expect the original longleaf forests were like. These plots were not always aligned in the North-South direction.

All plots were sampled for rock and shrub cover using a line-transect method. For each block within the plots, we surveyed two transects: one running North-South and the other running East-West, each running through the center of the block. The two transects intersected in the middle of the block. The linear distance of rock that intersected the transect line was recorded. Only rock that was visible or covered by leaf litter was sampled; rock buried by soil was not included. In addition, only rock ≥ 5 cm along its greatest axis was recorded. Rock distances for the entire plot were summed and divided by 200 m to obtain the proportion of rock cover per plot.

The total linear distance of shrub canopy (leaves or stems) intersecting the transect lines was also measured from canopy to canopy of shrub cover (excluding gaps within the canopy of ≥ 5 cm) and similarly calculated to provide the proportion of the plot covered by shrubs. Shrubs were defined as a woody plant, often with multiple stems growing from the base and usually not growing over 3 m in height. The majority of the shrubs recorded were lowbush blueberry (*Vaccinium pallidum*) or highbush blueberry (*Vaccimium arboretum*). In addition, a few individuals of downy service berry (*Amelanchier arborea*) and a yet unidentified shrub (species A) was recorded during the surveys (n < 5 per species). These shrubs were combined with highbush blueberry into the large shrub category because there were so few of them relative to highbush blueberry.

The proportion of rock cover and shrub cover for each plot was then compared to the total number of longleaf, small longleaf (height < 1.3 m), and large longleaf (height ≥ 1.3 m) for the same plot. Statistical analyses were performed on the data using Microsoft

Excel. The descriptive statistics were first calculated for shrub and rock cover and longleaf pine variables in both the ridge and foothill plots. Next, Mann-Whitney tests were performed to determine if there was any significant difference in the foothills and ridge plots. Finally, regressions were computed for rock and shrub cover vs. longleaf pine variables in the foothills and ridge plots.

Results

The surveys indicate that the foothill and ridge communities are similar for some variables but greatly differ for other variables. Table 1 shows that the number of large longleaf pine stems was similar in both the foothill and ridge communities; however, there was a greater number of small longleaf stems in the ridge than the foothills (Mann-Whitney test, P = 0.05). Although there was a marginally insignificant difference between the ridge and foothill communities in mean longleaf DBH (Mann-Whitney test, P = 0.0643), no significant difference was found in the foothill and ridge communities concerning mean DBH of large stems and mean BD of small stems (Table 1). There was a greater density of lowbush blueberry in the foothill plots than in the ridge (Mann-Whitney test, P = <0.001). However, there was a greater density of large shrubs in the ridge compared to the foothills (Mann-Whitney test, P = 0.002). Furthermore, the proportion of rock was much higher on the ridge than in the foothills (Mann-Whitney test, P = <0.001).

Table 1: Variables describing the forest in survey plots (n = 26) in the foothill and ridge areas of Oak Mountain State Park, Pelham, AL**.** The small longleaf pine stems were < 1.3 m in height and large stems were ≥ 1.3 m in height.

Longleaf Community	Mean	SD	Median	Range

Foothill Variables				
# large LLP stems	35.8	44.3	22.0	2 – 156.0
# small LLP stems	3.4	7.9	0.0	0.0 – 29.0
Mean DBH large LLP stems	20.9	7.3	21.1	6.9 – 35.0
Mean BD small LLP stems	1.2	1.6	0.0	0.0 - 3.6
Total lowbush coverage (m)	17.4	22.3	12.1	0.2 - 82.7
Total large shrub coverage (m)	11.5	12.4	6.3	0.0 - 37.4
Total rock coverage (m)	0.9	1.3	0.6	0.0 - 4.7
Ridge Variables				
# large LLP stems	30.9	47.3	18.0	0.0 – 172.0
# small LLP stems	67.3	160.4	8.0	0.0 – 593.0
Mean DBH large LLP stems	14.7	8.9	17.7	0.0 - 28.5
Mean BD small LLP stems	1.6	1.4	1.4	0.0 - 3.9
Total lowbush coverage (m)	0.8	1.1	0.0	0.0 - 3.4
Total large shrub coverage (m)	46.0	28.5	48.8	2.4 - 85.6
Total rock coverage (m)	38.2	20.1	33.5	16.9 - 76.1

The regressions in Table 2 comparing the rock and shrub cover with longleaf pine variables show the significant relationships in the ridge community. There was a significant positive correlation between the average lowbush coverage and large longleaf stems, and a marginally insignificant relationship between lowbush coverage and mean BD for small longleaf stems (Table 2). All other lowbush regressions were not significant (Table 2). The regressions comparing mean large shrub coverage with mean basal diameter of small longleaf stems, and mean large shrub coverage with the number of small longleaf stems were found to be marginally insignificant (Table 2). All other large shrub regressions were not significant (Table 2). All regressions involving lowbush blueberry were found to have positive correlations while all regressions involving large shrubs were found to have negative correlations. There was a significant positive correlation comparing mean rock coverage with mean basal diameter for small longleaf stems (Table 2). All other regressions with rock coverage were not significant (Table 2).

Table 2: Regressions of rock and shrub cover against variables of longleaf pine forests in the ridge community of Oak Mountain State Park, Pelham, AL. The small longleaf pine stems were < 1.3 m in height and large stems were ≥ 1.3 m in height. The degree of freedom for all regressions was 11.

Regressions	r	r^2	P – value
Mean lowbush coverage			
# large LLP stems	0.9	0.7	< 0.001
# small LLP stems	0.4	0.2	0.2
Mean DBH for large LLP stems	0.2	0.03	0.6
Mean BD for small LLP stems	0.5	0.2	0.1
Mean large shrub coverage			
# large LLP stems	-0.5	0.3	0.08
# small LLP stems	-0.07	0.01	0.8
Mean DBH for large LLP stems	-0.2	0.03	0.6
Mean BD for small LLP stems	-0.5	0.3	0.07
Mean rock coverage			
# large LLP stems	0.07	0.01	0.8
# small LLP stems	-0.2	0.04	0.5
Mean DBH for large LLP stems	0.2	0.04	0.5
Mean BD for small LLP stems	0.6	0.4	0.02

The regressions in Table 3 comparing the rock and shrub cover with longleaf pine variables do not show any significant relationships in the foothill community. There was also no clear pattern with regard to the directionality of the relationships between rock and shrub cover and longleaf pine variables.

Table 3. Regressions of rock and shrub cover against variables of longleaf pine forests in the foothills community of Oak Mountain State Park, Pelham, AL. The small longleaf pine stems were $<$ 1.3 m in height and large stems were $\geq$ 1.3 m in height. The degree of freedom for all regressions was 11.

Regressions	r	r^2	P – value
Mean lowbush coverage			
# large LLP stems	-0.3	0.1	0.3
# small LLP stems	-0.3	0.07	0.4
Mean DBH for large LLP stems	0.5	0.2	0.1
Mean BD for small LLP stems	-0.4	0.2	0.2
Mean large shrub coverage			
# large LLP stems	-0.04	0.001	0.9
# small LLP stems	-0.203	0.041	0.5
Mean DBH for large LLP stems	0.1	0.009	0.8
Mean BD for small LLP stems	0.4	0.1	0.2
Mean rock coverage			
# large LLP stems	-0.2	0.02	0.6
# small LLP stems	-0.2	0.06	0.4
Mean DBH for large LLP stems	-0.4	0.2	0.2
Mean BD for small LLP stems	-0.3	0.07	0.4

Discussion

The highlight from our results would be the difference found between the foothill community and the ridge community. The number of large longleaf pine stems, mean DBH for large stems, and mean BD for small stems were all similar in both the foothill and ridge communities. There was a significantly greater amount of lowbush blueberry found in the foothills than in the ridge, and a significantly greater amount of highbush blueberry found in the ridge than in the foothills. Rock cover was significantly greater in the ridge community than the foothill community. These differences could be suggestive of different ecological relationships between shrub and rock cover and longleaf pine occurring in the two community types.

Fire frequency, rock cover, canopy cover, soil moisture, and soil acidity all possibly affect the longleaf pine. The ridge community at Oak Mountain State Park has been burned in the 1980s, but the foothills have not been burned as recently. Consequently, the ridge community consists of relatively harsh conditions consistent with more frequent fires, while the foothill community has more moist soil and other favorable conditions for hardwood species. The longleaf pine in the foothills may have more competition with other hardwood species, possibly due to the moist soils and increased shade present because of a lack of fire. Another factor that may contribute to the different community types at Oak Mountain State Park is the harvesting of longleaf pine trees. There was logging at the park in the 1930's and again in the 1950's. The foothill community may have been targeted earlier and more heavily than the ridge community due to better accessibility to the longleaf trees. This could have resulted in earlier successional species moving into the foothills more rapidly than the ridge.

The ridge community had more small longleaf pine stems than the foothills community. This may be explained by several reasons. The fact that there has been a fire more recently in the ridge than the foothills could possibly be one explanation for this difference. The longleaf pine seedling cannot thrive in competition with other tree species, brush, or grass without repeated fires preceding and during its period of establishment (Means and Grow, 1985). Therefore, the ridge may have more small longleaf pine stems because of reduced competition resulting from the more recent fire. Longleaf may be better equipped to survive the shallow and rocky soils that are present on the ridge. According to Means and Grow (1985), young (small) longleaf stems grow a long, heavy taproot that probably allows the tree to reach far down into the soil for moisture. This could explain the greater number of small longleaf in the ridge because they have an adaptation to survive the harsh soils, whereas in the moist soil found in the foothills, the small longleaf might be out-competed by other hardwood species. In addition, lowbush blueberry tends to grow in dense thickets in the foothills which may prevent the establishment of other hardwood species, and lowbush may not be found in the ridge because it is being out-competed by the highbush blueberry.

In the ridge, there was a significantly positive correlation between lowbush coverage and large longleaf stems. This data suggests that the more large longleaf pine a community has, the more lowbush blueberry the community will have. However, it must also be considered that there is almost an insignificant amount of lowbush found in the ridge community. Longleaf pine is probably driving the system because the small size of lowbush blueberry provides minimal above and below ground competition to a large longleaf pine. This positive relationship between lowbush coverage and large longleaf stems could possibly be explained because of lowbush blueberry's dependence on fire. Lowbush blueberry is well-adapted to a fire ecosystem because it readily resprouts from rhizomes or surviving portions of aerial stems in post-fire communities (USFS, 2004). Therefore, since the longleaf pine community is also dependent on fire, lowbush blueberry may follow the prosperity of the longleaf in the ridge community because it has been burned more recently. However, this trend does not hold true for the regression comparing lowbush coverage with large longleaf stems in the foothills. The average number of large longleaf stems is similar in the ridge and foothill communities, but the average lowbush coverage in the foothills is significantly greater than the lowbush coverage in the ridge. With these data, a significant positive regression between lowbush coverage and large longleaf stems, similar to the one found in the ridge, would be expected in the foothills. However, no relationship was found in the foothills community. This seems to support a difference in the ecology present in the foothill and ridge communities.

It was expected that lowbush blueberry competes with small longleaf pine for nutrients and light. The data from our surveys show lowbush blueberry to be weakly positively correlated to basal diameter for small longleaf pine in the ridge community. Again it must also be considered that there is almost an insignificant amount of lowbush found in the ridge community. However, this relationship could possibly be related to the ridge community's harsh climate, including low precipitation levels. Longleaf pine and lowbush blueberry grow well on dry and acidic soils (Meilleur *et al.*, 1997; USFS, 2004), which may contribute to their ability to survive together in the harsh soils found in the ridge. In addition, Mulligan et al. (2002) found evidence to suggest longleaf pine seedlings may respond favorably to shade conditions for an initial period of time in areas of low precipitation as the shade preserves moisture for the seedlings, which could be another possible explanation for this relationship.

There were no significant regressions between highbush coverage and any longleaf pine variables in the ridge or foothill community. Interestingly, all of the regressions involving lowbush blueberry in the ridge are positively correlated, while all the highbush blueberry regressions in the ridge are negatively correlated. This may be due to the fact that highbush blueberry is significantly larger than lowbush blueberry (2 – 3 meters taller), and therefore might compete with longleaf pine at a greater level than the lowbush blueberry. In addition, highbush blueberry reaches its greatest abundance in sites that are burned less frequently (USFS, 2004), while longleaf communities rely on frequent fires. Consequently, in areas where fires have been more recent, longleaf pine growth would increase while highbush blueberry coverage would decrease, which the negatively correlated regressions suggest.

There was a significant positive regression between rock coverage and basal diameter for small longleaf stems in the ridge community. The conditions on the ridge are probably consistent with the conditions in similar rocky areas, which usually result in an acidic, nutrient-poor soil (Meilleur *et al.*, 1997). These soil conditions could possibly explain the relationship between rock coverage and basal diameter for small stems. Due to a lack of nutrients and water, the small longleaf stems may grow in girth before growing in height to adapt to these harsh conditions. None of the other longleaf variables were found to have a significant regression with mean rock coverage in the ridge. There were no significant regressions found between rock coverage and all longleaf variables in the foothill community.

In our survey, rock may also be acting as a fire surrogate. One important way fire promotes the establishment of longleaf pine is by removing vegetation that surrounds the slow-growing longleaf seedlings (Garren, 1941). Fire burns back young hardwoods that compete with longleaf pine and would otherwise take over (Means and Grow, 1985). There is also evidence that suggests burning almost inevitably results in a less fertile soil (Haig, 1938). The more rock cover in a plot, the more likely the plot could resemble a fire-dependent community. The abundance of rock would make it hard for hardwoods to grow but more favorable for longleaf stems to survive due to the acidic soils and reduced area to grow (Meilleur *et al.*, 1997). The more rock cover, the less soil there is for trees to grow, which could lead to lower levels of nutrients. Meilleur et al. (1997) also found that pitch pine (*Pinus rigida*), a similar system to the longleaf pine, may colonize a wide range of soil conditions including rocky areas because they provide a favorable microclimate, such as south-facing slopes. This supports the findings from our survey that show longleaf pine to colonize different communities such as the foothills and the ridge where there may be favorable ecological conditions.

This survey must continue to research the relationship between rock and shrub cover and longleaf pine to determine the best methods for understanding longleaf pine communities. In future experiments, research could focus on the interaction of shrub cover with other species of trees. Research of different factors in the longleaf community such as leaf litter, canopy cover, soil moisture, and soil acidity would also contribute to the understanding of the community. Future rock studies could be performed using different techniques such as aerial topography maps which indicate rock cover to give a more precise measurement of the rock cover proportion by plot.

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References

Brockway, D., and K. Outcalt (1999) Restoring longleaf pine wiregrass ecosystems: Hexazinone application enhances effects of prescribed fire. *Forest Ecology and Management* 137: 121-138.

Duncan. R. S., and C.A. Chapman (2003) Tree-shrub interactions during early secondary forest succession in Uganda. *Restoration Ecology* 11: 198-207.

Lambers, J., and J. Clark (2003) Effects of dispersal, shrubs, and density-dependent mortality on seed and seedling distributions in temperate forests. *Canadian Journal of Forest Research* 33: 783-795.

Garren, K. (1941) Effects of fire on vegetation of the southeastern United States. *Botanical Review* 98: 617-654.

Glitzenstein, J., D. Streng, D. Wade (2003) Fire frequency effects on longleaf pine (*Pinus palustris* P. Miller) vegetation in South Carolina and northeast Florida, USA. *Natural Areas Journal* 23: 22-37.

Haig, I. (1938) Fire in modern forest management. *Journal of Forestry* p. 1045-1051.

Harrington, T., C. Dagley, and M. Edwards (2003) Above- and below-ground competition from longleaf pine plantations limits performance of reintroduced herbaceous species. *Forest Science* 5: 681-695.

Maceina, E., J. Kush, and R. Meldahl (2000) Vegetation Survey of montane longleaf pine community at Fort McClellan, Alabama. *Castanea* 65: 147-154.

Means, D. and G. Grow (1985) The Endangered Longleaf Pine Community. *ENFO* 1-11.

Meilleur, A., J. Brisson, A. Bouchard (1997) Ecological analyses of the northernmost population of pitch pine (*Pinus rigida*). *Canadian Journal of Forest Research* 27: 1342-1350.

McVaugh, R. (1943) The vegetation of the granitic flat-rocks of the southeastern United States. *Ecological Monographs* 13: 120-165.

Peet, R. and D. Allard (1993) Longleaf pine vegetation of the southern Atlantic and eastern Gulf Coast regions: A preliminary classification. P. 46-80.

Smith, G., M. Patterson, and H. Trendell (2000) The demise of the longleaf pine ecosystem. *Southeastern Geographer* 40: 75-92.

Varner, J., J. Kush, and R. Meldahl (2003) Vegetation of frequently burned old-growth longleaf pine (*Pinus palustris* Mill.) savannas on Choccolocco Mountain, Alabama, USA. *Natural Areas Journal* 23: 43-52.

Williams, C. (1998) History and status of table mountain pitch pine forests of the southern Appalachian Mountains (USA). *Natural Areas Journal* 18: 81-30.

Vaccinium arboretum (2004). Retrieved November 28, 2004, from http://www.fs.fed.us/database/feis/plants/shrub/vacarb/

Vaccinium pallidum (2003). Retrieved November 28, 2004, from http://www.fs.fed.us/database/feis/plants/shrub/vacpal/