

Influence of Fire and Hardwood Control on Forest Structure of Montane Longleaf Pine Communities

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Abstract:

Mountain longleaf pine (*Pinus palustris* Mill) forests are a diminishing component of the once vast longleaf pine forests of the Southeast maintained by fire. From what was perhaps the largest temperate forest type dominated by a single species of tree in the U.S. occupying about 3% of its former range, mature longleaf pine forests are now considered rare. The Mountain Longleaf National Wildlife Refuge (MLNWR) holds significant acreages of young and old growth mountain longleaf pine. Protection and restoration of longleaf pine communities are the primary missions of the MLNWR. Because of a lack of historical information, data are needed on forest structure and fuel loads on the MLNWR. Our objectives were to: (1) establish permanent monitoring plots on the MLNWR, (2) document herbaceous and woody vegetation, and (3) measure biodiversity, forest structure, and fuel loads in longleaf communities with varying fire and management histories. We established 48 plots, each 0.1 ha in area. Each plot was categorized by the year it was burned (2008, 2006, 2004, no burn) and by hardwood control (HC, no HC). Shannon Diversity indices, species richness, ground cover, and fuel loads were measured in the summer of 2008.

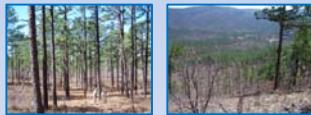
We identified 18, 19, and 22 different woody species in the overstory, mid-story, and understory, respectively. Longleaf pine basal area ranged from 5-10 m² ha⁻¹ with longleaf pine representing as much as 80% of total basal area. Mid-story basal area and woody species diversity in the forest stand were lower in plots receiving fire or hardwood control. Longleaf regeneration was found in only 17 plots and was highest in burned plots or plots receiving hardwood control. Burning increased grass and herbaceous ground cover. Fuel loads were high with an average humus layer of 35 Mg ha⁻¹. Regular fire intervals are needed to reduce fuels and mid-story density and aid in the regeneration of longleaf pine. This study highlights the importance of fire and hardwood control in maintaining existing longleaf pine and in longleaf pine regeneration in montane ecosystems.

Introduction:

- Prior to European settlement, the longleaf pine forest was perhaps the largest temperate forest type in the U.S. occupying between 24 and 36 million ha.
- Today, roughly 1.2 million ha, or 3 to 5% remains.
- A much smaller component of this diminished ecosystem is the montane longleaf pine ecosystem.
- Montane longleaf pine is found in northern Alabama and Georgia in the Blue Ridge, Ridge and Valley, and Cumberland Plateau mountain regions at elevations up to 600 m and is adapted to shallow rocky soils on mountain slopes and ridges. Montane longleaf pine represents a physiographically and climatically distinct region of longleaf pine's natural range.
- Montane longleaf pine forests have suffered the same decline as Coastal Plain longleaf pine forests caused by logging and long-term fire suppression.
- By 1995, only 40,000 ha of montane longleaf pine remained with only 20 ha identified as old growth.
- Previously part of Fort McChesin, the Mountain Longleaf National Wildlife Refuge (MLNWR) holds significant acreages of montane longleaf pine forest and at least 10 old growth tracts with high herbaceous communities on areas which experienced frequent fire.
- Wildfires were frequent in the past as a result of military training exercises. With military base closure and lack of fire, communities on the MLNWR face the possibility of being replaced by more aggressive fire sensitive species.
- To better manage existing stands and facilitate restoration, it is critical to acquire current information on forest structure and fuel loads on the MLNWR.

Objectives:

- Establish permanent monitoring plots on the MLNWR.
- Document herbaceous and woody vegetation.
- Measure biodiversity, forest structure, and fuel loads in longleaf communities with varying fire regimes and management histories.



Methods:

- The study was conducted at the Mountain Longleaf National Wildlife Refuge (MLNWR) which was established in 2006 and consists of 3,649 ha in the southern Appalachian mountains in Calhoun County, in northeast Alabama (Figure 1).

Measurements

- In the spring of 2008 we established 48 permanent plots on the MLNWR, 0.1 ha in area with a circular 0.04 ha measurement plot in the center.
 - Plots were categorized by whether or not hardwood control (HC) treatments were applied (no HC, HC) (Figure 1).
 - In HC plots, all vegetation <10.2 cm DBH was cut and removed from the plot in 2002 and in 2005; all hardwood stems ≥ 10.2 cm DBH were injected with Arsenal AC (Impruvy) using the "back and squirt" method.
- All stems ≥ 2.5 cm at DBH were measured and identified by species and defined as the forest stand. Overstory was defined as stems ≥ 10.2 cm DBH, mid-story was defined as stems 2.5 - 10.2 cm DBH, and understory was defined as stems < 2.5 cm DBH.
- 5 subplots, 0.3 m², were sampled by random azimuth and distances from plot center. Within each subplot, all woody species were identified by species and the number of stems counted and grass and herbaceous percent cover was visually estimated.
- Additional 30 x 30 cm subplots were sampled adjacent to 4 of 5 subplots for fuel loads. Within each of these subplots all litter layer, partially decomposing litter layer, and humus layer samples were collected then oven dried and weighed.
- Species diversity
 - Species richness (R) = number of species per plot.
 - Importance value (IV) based on relative density and dominance in overstory and mid-story and relative frequency and density in understory.
 - Shannon Diversity Index (H') = diversity based on richness and abundance.
- Burn year and hardwood control were not randomly assigned to plots and depended on MLNWR management activities which violates the main assumption of a completely randomized design. Therefore, we discuss trends in the data rather than significant differences detected from statistical tests.

Results:

Forest Stand Structure

- Longleaf pine density in the forest stand was 86 trees ha⁻¹ in plots with no HC and more than double at 195 trees ha⁻¹ in plots with HC (Figure 2).
- Forest stand basal area ranged from 11 to 18 m² ha⁻¹ and longleaf pine basal area ranged from 5.3 to 10.1 m² ha⁻¹ (Figure 3).
- The proportion of total basal area in longleaf was 45% in stands burned in 2008 and 70% in stands burned in 2004.
- Stands that received HC had 65% of basal area in longleaf pine versus 54% in stands with no HC.
- Because of hardwood invasion, R in the 2008 burn and no burn stands was approximately double that of stands burned in 2006 and 2004. H' ranged from 1.3 in 2008 and no burn plots to 0.9 in 2004 and 2006 burn years. Plots receiving HC had lower R and H' (Figure 4).

Overstory Composition

- A total of 18 woody species was found in the overstory (Table 1).
- IV₂₀₀ for longleaf pine in the overstory ranged from 81 in the 2008 burn stands and 85 in the no burn to 135 and 146 in stands burned in 2004 and 2006.
- Overstory longleaf pine IV₂₀₀ of HC stands was 121 versus 98 in stands with no HC.
- Other dominant species in the overstory include: *Quercus marilandica*, *Pinus echinata*, *Nyssa sylvatica*, *Quercus prinus*, and *Pinus taeda*.

Mid-Story Composition

- A total of 19 woody species was found in the mid-story (Table 2).
- Longleaf pine IV₂₀₀ in the mid-story was as low as 9 in the no burn stands and as high as 80 in the 2004 burn stands.
- Other dominant species in the mid-story include: *Quercus marilandica*, *Nyssa sylvatica*, *Acer rubrum*, *Vaccinium arboreum*, and *Ostrya virginiana*.

Understory

- Longleaf regeneration ranged from 0 to 24,104 trees ha⁻¹ and regeneration was highest in the 2004 and 2006 burns and in stands with HC (Figure 2).
- A total of 22 woody species was found in the understory with the most abundant being *Pinus palustris*, *Saxifraga alabamica*, *Quercus marilandica*, *Nyssa sylvatica*, *Quercus prinus*, and *Acer rubrum*. The IV₂₀₀ for longleaf regeneration was 38 in the 2004 burn and 70 in the 2006 burn year compared to 14 in the no burn and 0 in the 2008 burn year (Table 3).
- Herbaceous cover was low in all treatments. Herbaceous cover in stands burned in 2004 was 8% compared to 1% in stands burned in 2008 and 4% in stands with no burn. Grass cover was 18% in stands burned in 2004 and 3% with no burn. Hardwood control did not appear to have an influence on herbaceous or grass cover (Figure 5).

Fuels

- Burn year and hardwood control appeared to have minimal influence on fuel loads. Litter layer and partially decomposing litter layer averaged 12.0 and 7.0 Mg ha⁻¹, respectively. The humus layer was high in all treatments and was on average 35 Mg ha⁻¹. Average total fuel mass was 51 Mg ha⁻¹ (Figure 6).

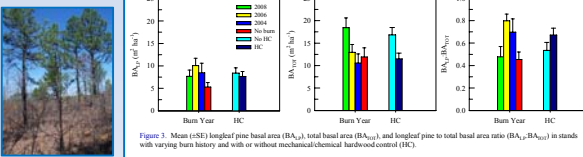


Figure 3. Mean (±SE) longleaf pine basal area (BA_{LP}), total basal area (BA_{TOT}), and longleaf pine to total basal area ratio (BA_{LP}/BA_{TOT}) in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

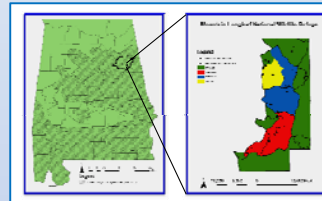


Figure 1. Map of the Mountain Longleaf National Wildlife Refuge with burn years and HC treatments indicated.

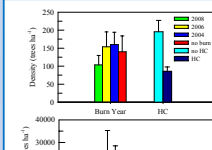


Figure 2. Mean (±SE) forest stand longleaf pine density and longleaf pine regeneration in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

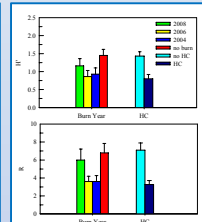


Figure 4. Mean (±SE) forest stand Shannon diversity index (H') and species richness (R) in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

Table 1. Mean importance values (IV₂₀₀) for overstory tree species in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

Species	Burn Year				Hardwood Control	
	2008	2006	2004	no burn	HC	no HC
<i>Pinus palustris</i>	81.2	145.7	134.7	85.1	98.0	121.3
<i>Quercus marilandica</i>	7.6	7.9	28.1	41.4	33.0	7.2
<i>Pinus echinata</i>	33.8	6.6	1.3	25.2	2.0	31.3
<i>Ostrya virginiana</i>	8.3	0.0	0.0	12.7	8.5	2.4
<i>Nyssa sylvatica</i>	5.7	4.3	1.5	12.1	9.9	2.3
<i>Quercus prinus</i>	21.1	7.1	2.0	8.6	15.3	6.8
<i>Quercus velutina</i>	4.2	1.7	3.0	4.4	4.9	2.2
<i>Carya pallida</i>	0.9	5.3	0.0	5.7	4.4	1.6
<i>Acer rubrum</i>	5.1	0.0	0.0	3.0	4.9	0.0
<i>Pinus taeda</i>	9.0	9.1	19.5	6.0	17.2	0.0
<i>Pinus serotina</i>	8.5	1.0	0.0	0.0	3.5	2.5
<i>Quercus coccinea</i>	4.7	0.0	0.0	3.2	0.0	0.0
<i>Carya glabra</i>	3.0	3.8	0.0	0.0	4.2	0.0
<i>Pinus virginiana</i>	1.7	4.3	0.0	0.0	3.7	0.0
<i>Carya tomentosa</i>	1.4	0.0	0.0	0.0	0.0	0.8
<i>Quercus coccinea</i>	1.3	0.8	0.0	0.0	1.3	0.0
<i>Liquidambar styraciflua</i>	0.7	0.0	0.0	0.0	0.5	1.5
<i>Quercus alata</i>	0.0	2.6	4.0	0.0	0.8	2.9

Table 2. Mean importance values (IV₂₀₀) for woody species found in the understorey in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

Species	Burn Year				Hardwood Control	
	2008	2006	2004	no burn	HC	no HC
<i>Pinus palustris</i>	0.0	79.2	38.7	14.0	26.9	32.6
<i>Acer rubrum</i>	75.1	21.2	0.0	27.3	31.8	45.3
<i>Saxifraga alabamica</i>	25.6	5.3	59.8	39.3	52.3	11.3
<i>Carya pallida</i>	0.0	19.7	4.8	21.3	10.4	11.9
<i>Quercus prinus</i>	12.9	9.1	0.0	15.8	8.8	10.7
<i>Carya glabra</i>	6.7	1.8	8.3	10.7	4.1	13.6
<i>Nyssa sylvatica</i>	6.0	14.3	2.5	10.0	9.4	7.5
<i>Rhus copallina</i>	25.6	5.3	59.8	9.3	52.3	11.3
<i>Diospyros virginiana</i>	0.0	0.0	41.4	9.3	5.3	15.0
<i>Quercus velutina</i>	0.0	2.2	0.0	2.7	1.3	1.0
<i>Quercus marilandica</i>	22.4	0.0	13.9	0.0	3.6	15.3
<i>Alnus incana</i>	14.3	4.4	0.0	0.0	0.0	10.5
<i>Quercus rubra</i>	8.1	0.0	0.0	0.0	5.5	0.0
<i>Quercus stellata</i>	6.7	0.0	5.8	0.0	0.0	4.1
<i>Carya tomentosa</i>	6.7	0.0	0.0	0.0	0.0	3.9
<i>Liquidambar styraciflua</i>	6.7	0.0	0.0	0.0	0.0	3.9
<i>Amelanchier canadensis</i>	4.0	0.0	0.0	0.0	0.0	2.3
<i>Amelanchier canadensis</i>	2.5	2.2	0.0	0.0	3.0	0.0
<i>Pinus echinata</i>	2.4	0.9	0.0	0.0	0.0	1.6
<i>Ostrya virginiana</i>	0.0	0.0	2.5	0.0	0.0	1.0
<i>Pinus taeda</i>	0.0	3.6	1.7	0.0	0.0	2.4
<i>Abies balsamea</i>	0.0	3.1	5.1	0.0	1.4	2.0

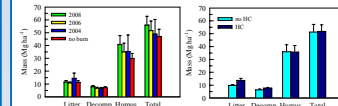


Figure 5. Mean (±SE) percent herbaceous and grass cover in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).

Conclusions:

- Stands receiving HC or fire had fewer hardwoods, lower mid-story basal area, greater longleaf density, and increased dominance and abundance of longleaf in the overstory.
- Fire and hardwood control aided in the regeneration of longleaf pine; however, longleaf regeneration is still scarce on the MLNWR.
- Without fire management, fire sensitive species such as *Vaccinium arboreum*, *Acer rubrum*, and *Ostrya virginiana* found in the mid-story will threaten longleaf communities on the MLNWR.
- At present, only one prescribed burn has been conducted at each stand with little impact on forest fuels. Regular fire intervals would further facilitate the reduction in fuels and mid-story density and aid in the regeneration of longleaf pine.

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Figure 6. Mean (±SE) dry mass of litter, partially decomposing litter and humus layers and total dry mass in stands with varying burn history and with or without mechanical/chemical hardwood control (HC).