Proceedings of the **Fifth Longleaf Alliance Regional Conference**

Longleaf Alliance Report No. 8

May 2005

Longleaf Pine: *Making Dollar$ and Sense*

October 12 - 15, 2004
Hattiesburg Lake Terrace Convention Center
Hattiesburg, Mississippi

THE LONGLEAF ALLIANCE

www.longleafalliance.org

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This conference would not be possible without the financial support of the following organizations:

Auburn University School of Forestry & Wildlife Sciences
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Simmons Tree Farm
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FOREWORD

Rhett Johnson, Co-Director, The Longleaf Alliance

The theme of the Fifth Regional Longleaf Alliance Regional Conference was *Longleaf Pine: Making Dollar$ and Sense*. This theme emphasizes that longleaf makes both economic and ecological sense on public and private lands. This proceeding contains a compilation of papers and posters presented at the conference addressing specific subject matter topics involving the restoration and management of longleaf pine ecosystems to include silvicultural, ecological, social, political and economic challenges.

The Fifth Longleaf Alliance Regional Conference held at Lake Terrace Convention Center in Hattiesburg, Mississippi may have been our best yet. Attendance was good at 281 and the enthusiasm was contagious. The program covered a diverse array of topics while the facilities were excellent. As always, we enjoyed good food, drink, and fellowship. Our invited speakers were well prepared, delivering presentations that were both timely and interesting. The panels were particularly thought-provoking and the only complaint I heard was that, with concurrent sessions, participants had to choose between two sessions when they wanted to attend both. The field trips to the De Soto National Forest and the Tatum family property were excellent and a high point. Anytime you can take 281 people in the woods at 8:00 in the morning and bring them back out at 4:30 in the afternoon and they're still excited and having a good time, you've done something right! Upon our return from the field trip we enjoyed a delicious buffet dinner at the Lake Terrace Conference Center followed by a most impressive musical entertainment. The Blues Rangers, a group of USDA Forest Service professionals, entertained us with original material that far exceeded my expectations and kept us clapping and tapping our feet until late into the night. I still listen to my CD occasionally just to remind me of the conference and some new good friends. Added treats were readings by recently published authors; Larry Earley, Jim Miller, and Gil Hoffman. I would be remiss if I didn't mention that the main reason the conference enjoyed so much success was the assistance of the local planning team. A relatively large group of natural resource professionals and landowners helped with the planning and organization of the conference a full year before we actually came to Hattiesburg. The local planning team was involved in, or took the lead in organizing everything from field trip to portapotties. It is always unfair to name individuals because some are left out, but Glenn Hughes, Randy Browning, Jim Elledge, Randy Rice, Linda Stine, John Lambert, Jan Barlow, Wayne Stone, Mike Davis, Ray Aycock, Don Seay, and Mark Anderson come to mind immediately. There were many others. Perhaps the most important was Mary Ann Iverson of Southern Mississippi's Continuing Education Department. Mary Ann did a wonderful job coordinating the facilities, lodging, meals, registration, and virtually everything else.

The Fifth Longleaf Alliance Regional Conference
October 12-15, 2004
Hattiesburg, Mississippi

Conference Program

<u>Tuesday, October 12</u>	**Lake View Terrace Convention Center**
1:00 – 8:00 PM	**Registration**
6:00 - 8:00 PM	**Ice Breaker, Poster Session**

<u>Wednesday, October 13</u>	**Lake View Terrace Convention Center**
7:00 – 8:30 AM	**Registration**

8:30 AM ***Welcome & Introductions*** (Glenn Hughes, Mississippi State University (Moderator); Charles Lee, President of Mississippi State University; Jim Sledge, Mississippi State Forester; Graeme Lockaby, Assoc. Dean for Research, School of Forestry & Wildlife Sciences, Auburn University)

8:45 AM ***Steam Logging in Mississippi: A Glimpse into the Past*** – Rev. David Price, Hattiesburg District Superintendent of the United Methodist Church & Railroad Enthusiast

9:20 AM ***Ecology of Longleaf Forests in Mississippi*** – Julie Moore, US Fish & Wildlife

10:00 AM **Break**

10:30 AM ***Correct Planting Density for Longleaf Pine: It Depends on Your Objectives and Who You Ask*** – David South, Auburn University

11:10 AM ***Economics of Pine Straw*** – Bill Pickens, North Carolina, Div. of Forestry

11:35 AM ***State of the Longleaf Alliance*** – Rhett Johnson, Co-Director, The Longleaf Alliance

12:00 Noon **Lunch Provided**

<u>Wednesday, October 13</u> **Lake View Terrace Convention Center**

1:30 PM **Concurrent Session I -** ***State and Federal Agencies and Their Issues*** – Panel: Ray Aycock, USFWS (Moderator); Roberta Moltzen, USFS; Ronnie Haynes, USFWS; Alan Holditch, NRCS; Jim Copeland, DoD; Jim Sledge, MS State For.

1:30 PM **Concurrent Session II -** ***Stand Density and Its Effect on Growth, Wood Quality, Pole Production, Wildlife Habitat, and Understory Composition*** – Panel: Steve Jack, JW Jones Ecological Research Center (Moderator); Wayne Stone, USFS; Jim Elledge, MS Consulting Forester; Will McDearman, USFWS; David South, Auburn University

3:00 PM **Break**

3:30 PM **Concurrent Session III -** ***Private Landowners and their Issues*** **–** Panel: Keville Larson, Larson & McGowin (Moderator); Judd Brooks, Mississippi Landowner; Paul Padgett, Cedar Creek; Robert Bonnie, Environmental Defense; Chester Hunt, MS Dept. of Wildlife, Fisheries & Parks; Randy Rice, MS Consulting Forester

3:30 PM **Concurrent Session IV -** ***Burning Issues in Longleaf Stands*** – Panel: Sharon Hermann, Auburn University (Moderator); Jimmy Atkinson, JW Jones Ecological Research Center; Bill Boyer, USFS (Retired); Jerry Windham, Desoto National Forest; Sue Grace, USFWL; John Kush, Auburn University

5:00 PM **Adjourn**

<u>Wednesday, October 13</u> **Evening Events –** Lake View Terrace Convention Center

6:00 – 8:00 PM **Social & Poster Session including Readings & Book Signings with:**

Mr. Lawrence S. Earley author of ***Looking for Longleaf: The Fall and Rise of an American Forest***

Dr. James Miller, USDA Forest Service, author of 1) ***Forest Plants of the Southeast and Their Wildlife Uses*** **and 2)** ***Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control***

Dr. Gil Hoffman, Hattiesburg historian, author of 1) ***Dummy Lines Through the Longleaf*** **and 2)** ***Steam Whistles in the Piney Woods Vol. I & II.***

<u>Thursday, October 14</u> **Field Day**

8:00 AM **Depart from the Lake Terrace Convention Center; One-half day at each site with lunch provided.**

Camp Shelby/DeSoto National Forest (Public Land Issues)

Identifying and Controlling Cogon Grass, Lisa Yager and C.J. Sabette
Understory Plant Diversity, Mike Davis and Julie Moore
Single Tree/Group Selection/Forest Management, Steve Jack, Bob Franklin, & Bob Cooper
Native Groundcover Restoration, George Ramseur TNC [Seed Collector and ASV/Positrac Demonstration] & Dennis McDevitt, Truax Native Seeder
Critters, Carl Qualls and Ed Moody
Managing Endangered Species, Diane Tyrone & Chris Potin
Issues Facing Burning on Public Land/Prioritizing Burning, Tony Wilde and Kevin Hiers
Growth and Yield, John Kush & Ralph Meldahl

Tatum Family Property (Private Land Issues)

Timber Products, Jim Elledge & Kenneth Conway
Pine Straw, Bill Johnson
Consultant Burning/Alternatives to Burning, John Buckley & Ken Outcalt
Wildlife Management, Randy Browning & Chester Hunt
Midstory Control Using Herbicides, Vic Nickels
Scalping, Planting Techniques, Seedling Quality, Mark Hainds

5:00 PM **Return to the Lake Terrace Convention Center**

6:00 PM **Social & Dinner at the Hattiesburg Lake Terrace Convention with music provided by the Blues Rangers**

<u>Friday, October 15</u> **Lake View Terrace Convention Center**

8:00 AM	***Nonnative Invasive Plants of Southern Forests*** – Jim Miller, USFS
8:40 AM	***Fire – Use It Lose It*** – Kevin Robertson, Tall Timbers
9:10 AM	***Identifying Longleaf Ecosystems Using Remote Sensing and GIS: Management Implications*** – John Hogland, Auburn University
9:35 AM	***Alternative Income Sources in Longleaf Forests*** – Daryl Jones, Mississippi State University
10:00 AM	**Break**
10:30 AM	***Forecasting Market Trends for Longleaf Products*** - Eric Gee, South. Forest Prod. Assoc.
11:00 AM	***Longleaf Ecosystem Restoration: Long Rotation Economics*** - Larry Teeter, Auburn U.
11:30 AM	***Wrap Up*** – Dean Gjerstad, Co-Director, The Longleaf Alliance

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REMOTE SENSING OF PITCHER PLANT HABITAT QUALITY

Gabriel A. Blossom, Michael A. Davis and Greg Carter

Abstract: Pitcher plant bogs and wet pine savannas represent some of the most diverse ecosystems in the Southeastern United States. Successful management of species diversity within these ecosystems typically involves the use of prescribed burns to keep woody invasive species from colonizing and displacing herbaceous plant communities. Assessment of bog status with respect to invasion by woody species and verification of successful burn events can involve time consuming and labor intensive plant sampling techniques to verify the effects of fire management practices. Remote sensing (using Quickbird, IKONOS or ATLAS imagery) could allow the assessment of bog health with minimal human resources, allocation of resources to critical sites, and classification of community succession within these ecosystems. Our project is designed to explore the feasibility of using remote sensing to evaluate the degree of invasion of pitcher-plant bogs by contrasting the results with more traditional assessments of plant species composition. Nine pitcher plant bogs at three stages of invasion will be analyzed. Sites will include, three open bogs (slight invasion), three medium bogs (moderate invasion), and three closed bogs (severe invasion). Plants tend to reflect more light in the near infrared and adsorb more light in other regions of the visual and near visual spectrum. The reflectance of a plant species or plant community varies in intensity through the electromagnetic spectrum. This variance tends to be unique to the plant or community in question. By classifying reflectance values it is possible to determine the location plant populations within a remotely sensed image. As the species composition of a pitcher plant bog changes, the degree the invasion increases, resulting in a measurable change in reflectance values.

THE CONSERVATION MANAGEMENT APPRENTICESHIP PROGRAM AT THE JONES CENTER

Lynne Boyd, Cory Drennan, Steve Jack, Mark Melvin and Jimmy Atkinson

Abstract: Interest in restoration of longleaf pine ecosystems and conservation-oriented management of existing longleaf pine systems – for both forest and wildlife values – is increasing. There is, however, a scarcity of well-trained individuals to carry out such management goals, and experience is difficult to obtain. Most academic programs in natural resources focus on specific and often intensive aspects of resource management (e.g., timber or game management) and rarely integrate conservation objectives as a primary consideration in the management of natural resources. In addition, few academic programs provide practical, hands-on training in land management. The Jones Center is uniquely situated to provide such training given the experience and expertise of our land management staff, the Ichauway property, and collaborative relationships with a variety of other individuals and organizations with significant expertise, and in 2001 we began a conservation management apprenticeship training program. Our intent is to train professionals who will eventually work in conservation-oriented management of public and private lands in the Southeast. All interns are *actively* involved in land management at Ichauway with a focus on ecologically sound resource management. Those trained in the program become competent and experienced practitioners of numerous aspects of conservation-oriented land management, from forest, wildlife and wetland management, to supervision of employees and contractors, to equipment and road maintenance. To date four individuals have participated in the apprenticeship program (no more than two at any time). We will provide a description of the program and activities, and share perspectives of those who have participated in the training.

LONGLEAF PINE GROWTH AND YIELD COMPARISON: PLANTATIONS ON PREPARED SITES AND NATURALLY ESTABLISHED STANDS

William D. Boyer and John S. Kush

Abstract: Existing studies include periodic remeasurements of both longleaf pine plantations established on intensively prepared sites and also naturally established stands. For the purpose of comparison, the best three of five monitored plantations on the lands of the T.R. Miller Mill Company in Escambia County, AL and naturally established stands in a long-term burning study on the Escambia Experimental Forest also in Escambia County were selected.

One plantation was established in winter of 1970, and a three-year remeasurement regime initiated at age 5. The other two plantations were established in the winter of 1971 and remeasurement regime initiated at age 4. At initial measurement, dominant-codominant trees in these plantations ranged from 6 to 8 feet in height. The natural stands selected for this comparison were part of a burning study that included biennial burns in winter, spring, summer plus unburned check, each with supplemental hardwood control with single chemical treatment, periodic hand clearing, or no treatment. Each treatment combination had three replications. Study stands originated from the 1958 seed crop. The shelterwood overstory was removed at age two, and all stands burned at age three-the only burn preceding establishment of the study at age 14. The first remeasurement took place at age 21, at which time a three-year remeasurement regime was initiated. The three unburned-untreated check plots were selected for the comparison with plantations. Both plantations and natural stands were commercially thinned. The volume removed was included in total yields of all monitored stands.

At age 14 (from seed), the average height of dominant-codominant trees in the plantations exceeded that in natural stands by 15 feet. Merchantable volume in plantations was more than five times greater than that in natural stands. Since that time, the gap in both height and volume has steadily shrunk. By age 33 (most recent plantation measurement) tree heights in natural stands slightly exceeded that in plantations. Volume yield (including thinnings) of natural stands had reached 84 percent of that in plantations.

If the gap between plantations and natural stands in volume yield continues to close, there may be little difference in total yield at a rotation age for poles and logs based on origin and early development of the stand. The rapid early growth of pines on prepared site, resulting from the absence of competition, apparently does not give them any long-term advantage over the natural stand with slow early growth due to competition from parent trees, other seedlings, and all the other vegetation on the forest floor.

Based on this comparison, the expense of planting longleaf on intensively prepared sites may have little, if any, payoff at rotation end. If an adequate longleaf pine seed source is present, natural regeneration appears to be by far the most economical option.

ECONOMIC ANALYSIS OF AN UNEVEN-AGED MANAGED LONGLEAF PINE HUNTING PLANTATION

Rodney L. Busby and W. Keith Moser

This paper presents a case study of one owner's experience with uneven-aged management of longleaf pine. The study site is a privately-owned quail-hunting property in Thomas County, Georgia, referred to here as Millpond–Sedgwick Land Company. It has been owned by the same family since the early part of the century and managed under the locally-developed Stoddard-Neel system since the middle of the century.

Actual yearly timber removal volumes were tracked for 33 years, from 1961 through 1993 and standing inventory were estimated from a beginning and ending inventory of the property. In 1961, the 3,144 acres of merchantable pine generally ranged up to 60+ years in age although there were small patches of considerably older trees. Current costs and returns are used in the analysis, and are assumed to remain constant, in real, after inflation, terms through out the planning horizon. Inventories grew at almost 1.4%/year during the period, since additional standing inventory would detract from the quail management goals of the owners, increased future harvest would be necessary. Three alternatives were modeled: (1) average historical harvest, with future harvest at 4% of ending inventory; (2) harvest of 4% of beginning stand inventory; and (3) clearcut and plant loblolly pine.

Historical harvests would return a landowner a net cash flow from timber operations of approximately $13/acre/year. Additional stand inventory may adversely impact quail populations, so now the owners need to take at least 4% of final inventory to maintain inventory levels. So, after the initial 33 year period of increasing inventory, the land is now capable of producing $71/acre/year. The owners did have the option of freezing beginning inventory and removing 4 percent of volume per year in a sustainable basis. If they had done so, the property could have produced a net cash flow of $40/acre/year. These were just longleaf timber production figures, and they don't include the recreational or environmental values of keeping the land in longleaf status.

The value of longleaf pine inventory is critical to the economics of the uneven-aged pine production. Figure 1 shows that the inventory on the Millpond site started out at $1,069/acre over the course of the 33 years, the value of the inventory increased to $1,647/acre. Inventory levels increased at approximately 1.4% per year since harvests were not equal to growth on the site. All or part of this inventory is available to harvest or to be a strategic asset reserve. The inventory is the investment in capital that allows the production of the periodic income, the higher the investment the more return needed to offset the value tied up in inventory.

Another alternative would be to convert the uneven-aged longleaf stand management to even-aged loblolly pine management. The processes are quite different. Even-aged management requires large investments at the front end and a fairly long wait to achieve returns. Uneven-aged management involves a great deal of capital tied up in inventory but it has periodic income. The average Millpond-Sedgwick Land Company lands were estimated to be site index 80 feet (base age 50). The maximum land expectation value would be expected to be $306/acre or the equal annual equivalent of $15/acre/year.

Naturally, this isn't the complete comparison between the two alternatives; the inventory of longleaf pine has to be accounted for. The longleaf stand provides key values for owners. It provides recreational and hunting opportunities that are the key value of the land to the owners. It also provides a store of value to the owners that can be tapped at any time to generate cash. In the case of the conversion of the stand to even-aged loblolly management, the stand must be harvested first and the value of the stand be converted to cash. In the case of the longleaf stand, any part of the inventory can be converted to cash at any time, although such removals will decrease the ongoing cash flows from the uneven-aged stand management. If the liquidation of the longleaf inventory were to be added to the even-aged loblolly pine alternative the result would be a higher timber values than the uneven-aged alternative. Non-timber and recreational values would have to equal a minimum of $10/acre/year to bridge the gap, which could easily be done given the value placed upon the hunting property alone.

USE OF CORROBORATIVE TECHNIQUES TO EVALUATE GROWTH AND NITROGEN FIXATION RATES OF NATIVE LEGUMES

Sarah E. Cathey, Lindsay R. Boring, Thomas R. Sinclair and R. Scott Taylor

Abstract: Native herbaceous legumes constitute more than 10 percent of vascular plants in frequently-burned longleaf pine savannas (Hainds et al 1999). This sizable group of constituents has been shown to be a key element in the nitrogen cycling of longleaf pine woodlands. As a silvicultural tool, legumes are capable of producing nitrogen input over an extended period of time, they replace nitrogen that is lost from burning and are a source of soil organic matter. The goal of this study is to accumulate useful nitrogen fixation and growth rate data for several species of native legumes. This data can be used to estimate nitrogen inputs of existing groundcover or to make informed decisions regarding which species should be prioritized for reestablishment of native groundcover.

Greenhouse, garden plot and woodland survey methods are all employed in the assessment of several species of legumes. Additionally, corroborative methods of evaluating nitrogen fixation are used within each study: δ15N, nodule biomass, plant total N, acetylene reduction assays, and transport product analysis. Fixation is evaluated in varying light and water regimes in order to investigate factors that may be limiting to nitrogen fixation for each species.

INTRODUCTION AND BACKGROUND

Longleaf pine reforestation initiatives on private lands in the southeastern U.S. have resulted in the conversion of approximately 700,000 acres of former agricultural, pulpwood plantation and fire suppressed land back into longleaf pine stands since 1998. Recovering understory diversity is a key element of wildlife management, and is necessary for restoring a longleaf-wiregrass ecosystem on nitrogen depleted soils (Markewitz et al 2002). This study seeks to identify those legumes that are important for nitrogen replacement in young planted stands and that show promise in the design of restoration systems.

Historically, frequent fire disturbance due to lightning and Native American ignitions has continuously suppressed hardwood populations and maintained the structure of the system. However, fire causes nutrient losses due to the consumption of litter and volatilization (Carter 2004). The mineralization of phosphorus during periodic fires may serve an important role in the nutrition, growth and reproduction of phosphorus-demanding legumes, facilitating the eventual replacement of nitrogen lost during burning (Hendricks et al 1999, Sprent 1987). Conservative estimates of legume nitrogen inputs from biological N_2-fixation in the longleaf-wiregrass system range from 7 to 9 kg N ha^{-1} yr^{-1} (Hendricks and Boring 1999). Hiers et al (2003) determined two species, *Tephrosia virginiana* and *Centrosema virginianum* to contain 74-92 percent nitrogen derived from the atmosphere.

As a silvicultural tool, legumes are capable of producing nitrogen input over an extended period of time and are a source of soil organic matter. Fixed nitrogen is typically less subject to leaching and is less likely to raise public concern about chemical application (an "organic" source) (Gordon, 1983). However, the use of legumes as a replacement for applied nitrogen is limited by the scientific community's knowledge of their capabilities as a nitrogen input.

Thus, whether the goal of a land manager is to assess the nitrogen dynamics of an existing stand of longleaf pine with an intact understory or to establish native groundcover beneath planted pine, understanding the life history and nitrogen fixing capabilities of several species of native legumes is imperative. The goal of this study is to accumulate useful nitrogen fixation and growth rate data for several species of native legumes that can be used to estimate nitrogen inputs of existing groundcover or to make informed decisions regarding which species should be prioritized for reestablishment of native groundcover.

OBJECTIVES

The overarching objective of this study is to explore the impact of various degrees of shading on growth and nitrogen fixation rates of legume species found in longleaf-wiregrass savannas. Three approaches will be used to explore these environmental influences.

<u>Experiment 1: Potted Plants, Gainesville, FL</u>

The primary objective is to observe the effects of shading versus full sun over the course of a single growing season on the growth of roots and shoots, nodule development, and nitrogen fixation rates. Next, the experiment seeks to investigate shading effects on nitrogenase activity over time in an individual plant using serial acetylene reduction assays. The final objective is the corroborate ureide transport product analyses with nodule biomass and acetylene reductions assays.

Experiment 2: Plantation Garden Plots, Ichauway
The primary objective of this experiment is to observe the differences in growth rate and habit between plants grown under three light regimes created by canopy shading over the course of a single growing season. The second objective is to compare nitrogen fixation capabilities of the various species in three light environments using %N, total N, biomass, $\delta^{15}N$ and N derived from the atmosphere (Ndfa). Finally, retranslocation and soil flux of nitrogen will be studied in select plants by comparing N content and $\delta^{15}N$ values of live and senescent leaves and root contents.

Experiment 3: Native Longleaf Woodland, Ichauway
A series of surveys of native longleaf woodland, will compare the density, biomass, nitrogen accumulation, and species richness of legumes on wet-mesic versus xeric site types on Ichauway. A second objective of this experiment is to observe the species and treatment differences in $\delta^{15}N$, plant biomass, and nitrogen transport products in irrigated versus adjacent reference woodland plants in early and late season samples.

METHODS
There are abundant ways of estimating biological nitrogen fixation by legumes *in situ*. The most useful methods are those that approximate amounts or proportions of plant N derived from atmospheric N_2 fixation, distinct from N acquired from the soil. One such method compares the natural abundance of 15-nitrogen isotopes with reference plants and soil values (Table 1). Additional methods of comparing N_2-fixing and non-fixing plants include analysis of xylem sap constituents, assays of nodule nitrogenase activity and analysis of total nitrogen contents. This study uses each of these methods which together propose a useful depiction of the nitrogen fixing capability of a species.

Analysis of plant tissue for isotopic nitrogen composition has become a common integrator for understanding the nitrogen cycling of a system. The ^{14}N isotope represents 99.6337% of all nitrogen atoms on earth, and 100% of atmospheric nitrogen (N_2). Soil nitrogen usually has 9.2‰ higher ^{15}N content than the atmosphere. The ^{15}N content of a sample is expressed as $\delta^{15}N$, which represents the isotopic ratio of the sample compared to an atmospheric standard. Thus, those plants that are able to accumulate nitrogen that originated in the atmospheric pool should have $\delta^{15}N$ values nearer zero than those plants that acquire their nitrogen solely from the soil (Table 1).

Table 1. δ15N isotopic profile of burned and unburned xeric longleaf pine ecosystem.

Regime	Sample	$\delta^{15}N$
Burned	Non-Fixers (reference)	-3.62532
Unburned	Non-Fixers (reference)	-2.99349
Burned	Fixers	-0.95099
-	Atmospheric standard	0.00000
Unburned	Soil, 0-20cm, average	3.80065
Burned	Soil, 0-20cm, average	4.44864

Fixed nitrogen from nodules is transferred through the xylem in the form of transport molecules such as amides, ureides, and amino acids. Ureide is an especially efficient transport molecule that is utilized by warm season legumes. A relatively small amount of photosynthate is required to transfer several fixed nitrogen molecules as ureide due to its low carbon to nitrogen ratio. Ureide-producing plants, such a soybean (*Glycine max*) commonly display high rates of nitrogen fixation. Izaguirre-Mayoral et al (1992) observed significant differences between relative amounts of ureide present in nodulated versus non-nodulated plants, and concluded that the ureide technique can be useful for detecting and quantifying symbiotic N_2-fixation in native legumes.

The acetylene reduction assay is based on the fact that the nitrogenase enzyme, which reduces atmospheric nitrogen to plant available forms, is also able to catalyze the reduction of acetylene to ethylene. Sample tissue is exposed to acetylene for an incubation period and then a gas sample is analyzed for ethylene concentration. The amount of ethylene present is indicative of the amount of N_2 that would have been reduced by that tissue given the same exposure.

Experiment 1:

One half of the specimens for each species of potted plants was grown at one-half and full sun, respectively. Species included in this experiment are *Chamaecrista nictitans*, *Centrosema virginianum, Clitoria mariana, Crotalaria rotundifolia, Lespedeza hirta, Psoralea canescens, Orbexilum lupinellum, Rhyncosia renformis, Tephrosia virginiana,* and *Mimosa quadrivalvis*.

Samples from the first set of specimens, planted in one-gallon pots, will be harvested in spring, summer and fall. At each harvest, dried biomass from above- and belowground and nodules will be compared. A 2-3cm section removed from the base of each stem will be collected for transport product analysis. A second set of specimens was grown in root elongation tubes. Root growth and nodule development was monitored and recorded twice weekly. Once roots reached or exceeded 85cm, the leaf area was determined, and stem and leaves were harvested and dried for further analysis. This experiment was concluded in September, 2004. Finally, a set of specimens was potted for a flow-through acetylene reduction system. These plants have been assayed once monthly to determine their relative nitrogenase activity over time. All plants, from across each of the three potting situations has been measured weekly for leaf addition and stem elongation.

Experiment 2:

Ten by ten foot plots were selected and marked under an even-aged 15 year-old stand of longleaf pine. Four plots were located under each of three overstory coverage levels: open, intermediate, and closed. The light environment in each plot will be more specifically characterized by hemispherical photographs (Battaglia et al 2003). Forty legumes, five each of eight species, and *Solidago sp*. as a reference plant, were randomly planted in rows within the plots. TDR rods were placed one foot inside each of the four corners of each plot, alternating 30 and 90cm rod lengths. Bi-weekly soil moisture readings have been taken from these locations in order to further characterize the microclimate of each plot.

Planted species are *Centrosema virginianum, Desmodium ciliare, Lespedeza angustifolia, Lespedeza hirta, Mimosa quadrivalvis, Orbexilum lupinellum, Psoralea canescens* and *Tephrosia virginiana*.

Entire plants from each plot will be destructively harvested once each in May, September and November. Assessment of plant height and leaf, stem, and root biomass will be conducted. Stem sections will be collected and placed in phosphate buffer solution for transport product analysis. Biomass will be dried, ground, and analyzed for total N and $\delta^{15}N$.

Experiment 3:

Four irrigated plots located in a xeric site and four in a wet-mesic sight, were surveyed. Within each plot, three transects radiating from the center of the plot marked an equal distance within and adjacent to each irrigated area. Aboveground plant material was collected from legumes and *Rubus argutus*, *Vaccinium myrtifolia*, and *Ruelia sp*. (as reference) along these three transects using the line-intercept method. A 2-3 cm section from the base of each legume stem was harvested into a vial of phosphate buffer solution for transport product analysis. Plants from along each transect represent irrigated and non-irrigated specimens. Aboveground biomass has been dried to constant weight and will be ground for analysis. Total nitrogen and $\delta^{15}N$ contents of select species will be determined on a composited per-transect basis.

Concurrently, a strip-transect was delineated 25m x 0.5m within each of the eight plots and also extended an equal distance outside of each irrigated area. Species rooted within this strip-transect were counted in order to further describe the species distribution and density in each irrigated plot and adjacent area (Table 2). Using this data in coordination with the data gained from the clipped samples, total aboveground nitrogen in legumes can be described on a land-area basis for dominant each species. Both the line-intercept and strip-transect surveys will be conducted in June and October of 2004.

Table 2. Diversity Analysis of Irrigated vs. Non-irrigated Xeric Plots

	Number Per Hectare		Ranking	
Species	Non-irrigated	Irrigated	Non-irrigated	Irrigated
Tephrosia virginiana	7200	800	1	11
Mimosa quadrivalvis	7000	10400	2	7
Centrosema virginiana	5200	6000	3	6
Crotalaria rotundifolia	5000	16400	4	2
Dalea pinnata	4800	11000	4	4
Clitoria mariana	4400	8600	6	9
Tephrosia spicata	3600	3200	7	8
Psoralea lupinella	3200	-	8	-
Stylosanthes biflora	2800	13000	9	3
Galactia spp.	2600	22000	10	1
Desmodium ciliare	1800	8200	11	5
Lespedeza repens	1800	600	11	12
Cassia nictitans	1000	3000	13	10
Lespedeza angustifolia	800	-	14	-
Crotalaria purshii	-	-	15	-
Lespedeza hirta	-	-	15	-
Rhyncosia renformis	-	3600	15	12
Zornia bracteata	-	200	-	14
Total Legumes Per Hectare	51,200	107,000		

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USE OF HERBICIDES AND PRESCRIBED BURNING TO CONTROL HARDWOODS IN THE REGENERATION AND RESTORATION OF MOUNTAIN LONGLEAF PINE HABITATS

Martin Cipollini, Amy Gaskell and Christopher Worrell

Abstract: Hardwood control is a problem in the regeneration and restoration of Longleaf Pine (*Pinus palustris*) stands. Data concerning hardwood management techniques are generally lacking for Mountain Longleaf Pine habitats in NW Georgia and NE Alabama. In this study, three experiments were set up on the Berry College campus to evaluate the effects of herbicide and prescribed burning in hardwood control: 1) an evaluation of Garlon 3A in the control of hardwood re-sprouts in a clear-cut area planted with Mountain Longleaf Pine seedlings; 2) an evaluation Arsenal injection in the control of hardwoods in mature Mountain Longleaf Pine stands, and; 3) an examination of the effects of a spring prescribed fuel reduction burn in mature stands. In the first experiment, hardwoods were treated by foliar spray in June 2004, and effects measured four weeks later. In the second experiment, hardwoods in five mature stands were injected in March 2004 and effects measured in July 2004. In the third experiment, fuel analyses were taken before and after an April 2004 prescribed burn (two study stands), and from burned and unburned areas (three study stands). Hardwood re-sprouts reacted differently to Garlon 3A, with certain species (e.g., Sweet-gum) showing resistance to the herbicide. The Arsenal injection results were confounded by the prescribed burn, but Red Maple was significantly negatively affected by the herbicide treatment independent of the effects of burning. Finally, fuel analysis showed limited effects on the abundance of small hardwoods despite considerable reduction of litter, duff and downed woody fuels.

INTRODUCTION

Prescribed burns and herbicide treatments are two methods that can be used to address the general problem of hardwood control in the restoration and regeneration of longleaf pine ecosystems. This paper will examine both approaches as applied to the Mountain Longleaf ecosystem on the Berry College campus in NW Georgia. The management plan for this site has been previously described, and can be found at the website listed at the bottom of this page. Briefly, two main issues are being addressed: a) the re-introduction of fire into mature fire-suppressed stands and b) the artificial regeneration of longleaf using containerized seedlings in clear-cut sites. In both cases, competition from hardwoods presents a problem. In this study we determine the effectiveness of using an herbicide (Garlon 3A™; Dow AgroSciences LLC) in controlling hardwood re-growth in clear-cuts and another herbicide (Arsenal AC®; BASF Corporation) to control hardwood encroachment in mature longleaf stands.

It is well known that frequent fires are necessary for the successful establishment and maintenance of longleaf habitats. What is less well known is how to re-establish a fire regime in areas lacking recent fire that contain a build-up of fuels, including duff, litter, downed woody fuels, herbaceous plants, shrubs, and tree saplings. This fuel build-up can increase the likelihood of devastating wildfires (even longleaf can be damaged if a fire is to hot or it becomes a crown fire). Therefore, another goal of this paper is to examine the effects of both wildfire and prescribed fuel reduction burns on adult hardwoods, living shrubs, tree seedlings and saplings, and on fuel loads due to dead organic matter.

METHODS

2004 PRESCRIBED BURN

Two study stands (A and B) in the core Berry Longleaf Management Area (Fig. 1) were subjected to a prescribed fuel reduction burn in April 2003 and all five stands were burned in April 2004. Areas adjacent to four of the stands were left as unburned reference stands.

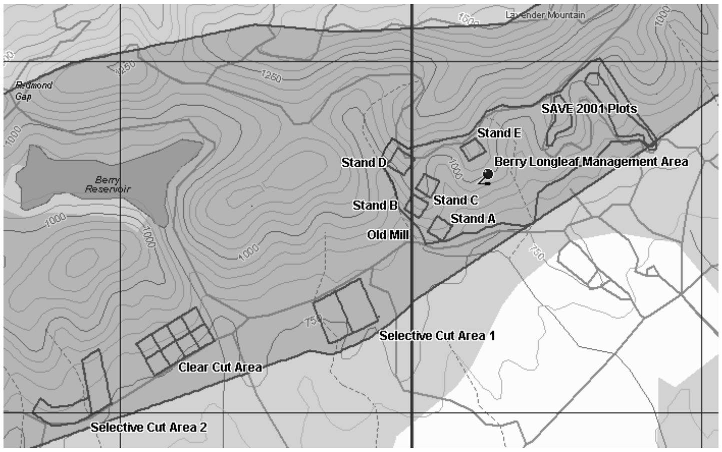

Figure 1. Map of study areas within the Lavendar Mountain area of the Berry College campus.

Project I: Using Herbicide in Clear-cut Areas with Re-growth
In a clear-cut area planted in 2003 with longleaf seedlings, we tagged, measured, and sprayed hardwood re-sprouts with Garlon 3A 1.5% + surfactant each week for four successive weeks starting in June 2004. One month and three months after treatment, we measured the proportion of canopy completely or partially damaged.

Project II: Analysis of Hardwoods Injected with Arsenal
Prior to leaf break in the spring of 2004, hardwood trees over 10 feet tall in the five study stands were injected with the herbicide 20% Arsenal AC (imazapyr) using the "hack and squirt" method (1 ml injection for every 3 inches DBH). We sampled hardwoods in the summer of 2004 (four months post-treatment) using the point-centered quarter method, simultaneously estimating proportion of canopy damaged and characterizing tree community composition.

Project III: Fuel, Herbaceous Plant, Shrub, and Tree Seedling/Sapling Analysis
We censused fuels in burned and unburned areas of contrasting study stands using Brown et al.'s (1982) method (Fig. 2). Data were analyzed via multiple analysis-of-variance (MANOVA). The independent variables were treatment (unburned vs. burned). The multiple dependent variables were the various fuel load parameters. Based upon earlier fuel models, we predicted a 1-2 ton/acre decrease in litter and significant hardwood mortality.

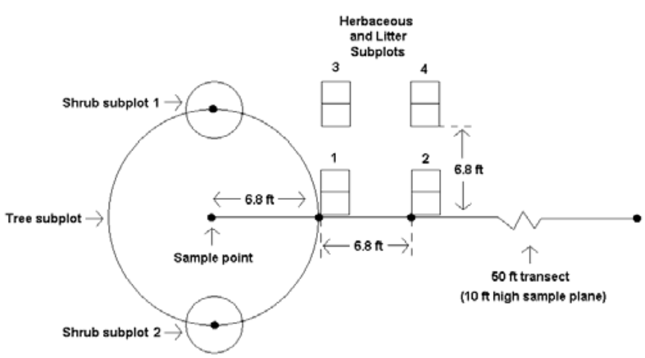

Figure 2. Sample point layout for fuel load sampling (adapted from Brown et al. 1982).

RESULTS AND DISCUSSION

Project I: Using Herbicide in Clear Cut Areas with Re-growth
Carya spp. (CARYA) and *Liquidambar styraciflua* (LIQSTY) were less affected after 1 month by the herbicide than were the other species (Fig. 3). *Prunus serotina* (PRUSER) and red (QUERED) and white (QUEWHT) *Quercus* species formed a group of species showing intermediate resistance. *Acer rubrum* (ACERUB), *Diosporos virginiana*

(DIOVIR), and *Liriodendron tulipifera* (LIRTUL) show the least resistance; each showed near total defoliation 1 month following treatment. After 3 months, nearly all individuals of all species were completely defoliated (results not shown). The primary conclusion is that foliar spraying with Garlon 3A is an effective way to kill small trees of most species in clear-cuts within this region.

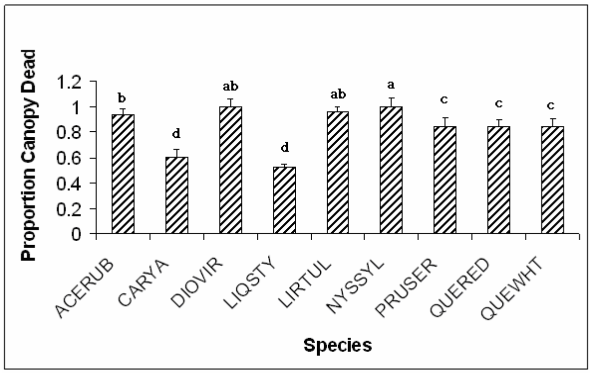

Figure 3. Proportion canopy dead for each species in weeks 2, 3, and 4 combined (with standard errors) at 1 month following foliar spraying with Garlon 3A. Identical letters denote means that do not differ significantly (P > 0.05) based upon Bonferroni tests.

Project II: Analysis of Hardwoods Injected with Arsenal

The tree community analysis provided evidence of the need for hardwood control in Berry College's longleaf stands (results not shown). All stands had significant presence of non-fire-tolerant hardwoods and pines. These results support the hypothesis that hardwood encroachment was taking place at the start of this study and support the need for management efforts directed at controlling hardwoods.

Within these stands, *Carya* spp. (CARYA) were the only species that showed a significant effect from the herbicide over and above effects of burning alone within the first season following injection (Fig. 4). *A. rubrum* (ACERUB) was more significantly damaged by the prescribed burn than the other species; this confounded effects of the herbicide treatment but provided evidence that control of this fire-intolerant species may result from burning alone. The oaks (*Q. stellata* [QUESTE] and *Q. montana* [QUEMON]) showed little effect of either the herbicide or the burning treatments. While full effects may not be realized until the second year following treatment, these data suggest that more aggressive techniques (e.g., higher doses of herbicide or girdling) may be required to control such species adequately.

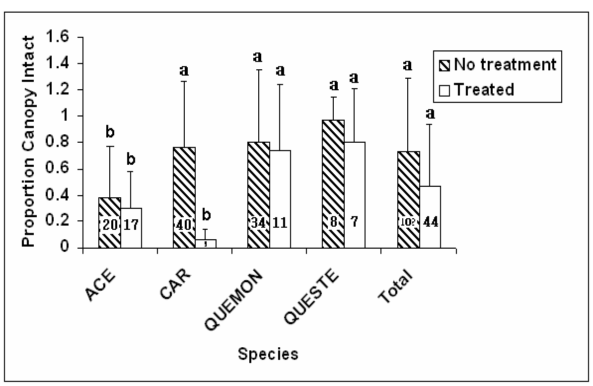

Figure 4. Proportion of canopy intact for Arsenal treated and untreated trees of each species (with standard errors and number of individuals of each species treated). Identical letters denote means that do not differ significantly (P > 0.05) based upon Bonferroni tests. ACE = *Acer* spp.; CAR = *Carya* spp.; QUEMON = *Q. montana*; QUESTE = *Q. stellata*.

Project III: Fuel, Herbaceous Plant, Shrub, and Tree Seedling/Sapling Analysis

The primary effect of the 2004 prescribed burn was to reduce litter and duff to a variable extent depending upon the history of the stand involved (Table 1) Reductions in litter in stands D and E (after only a single prescribed burn) far exceeded the expected 1-2 tons/acre. This may be attributed to the lack of significant rainfall in the period immediately prior to the burn coupled with higher than optimal temperatures and lower than optimal humidity. Significant damage to the duff layer was only seen in Stand B, which experienced three fires including a damaging wildfire. Of relevance to the issue of hardwood control via prescribed burning, results for stands A, D and E (where only prescribed burns were employed) showed no significant effects upon living tree fuel loads (trees < 10 ft tall). The results suggest that burning directed at reducing fuels without damaging longleaf pines is insufficient to control fire-tolerant hardwoods (esp. oaks). This further supports the need for some means of direct hardwood control.

Table 1. Means (lbs/acre) and MANOVA results for fuel load analyses in unburned and burned areas of stands A, B, D, and E.

Fuel Loads (lbs/acre)

Stand A	Unburned		Burned		
Fuel Class	Mean	Std. Error	Mean	Std. Error	
0-1/4"	142	22	257	26	*
1/4" - 1"	651	202	1016	243	
1" - 3"	325	222	2262	687	*
> 3" sound	0	0	1174	857	
> 3" rotten	910	763	4097	2086	
Litter	18993	2796	7375	1165	*
Herbs	1	1	21	9	*
Duff	41967	6638	27833	4149	
Live shrubs	74	29	59	16	
Dead shrubs	1	1	1	1	
Trees	569	331	65	8	
Total	63633	8708	44160	4174	

Stand C	Unburned		Burned		
Fuel Class	Mean	Std Error	Mean	Std Error	
0-1/4"	198	39	115	27	
¼" - 1"	1179	306	901	216	
1" – 3"	1132	400	2276	839	
> 3" sound	0	0	1336	569	*
> 3" rotten	1478	849	149	149	
Litter	22061	3261	6607	727	*
Herbs	105	82	0	0	
Duff	54578	8400	36531	8123	
Live shrubs	5658	2129	26	6	*
Dead shrubs	755	489	5	4	
Trees	144	89	448	247	
Total	87288	10467	48396	8214	

Stand B	Unburned		Burned		
Fuel Class	Mean	Std. Error	Mean	Std Error	
0-1/4"	142	22	256	39	*
1/4" - 1"	651	202	655	228	
1" - 3"	325	222	1977	937	
> 3" sound	0	0	6794	5584	
> 3" rotten	910	763	32367	15330	*
Litter	18993	2796	6452	2052	*
Herbs	1	1	49	41	
Duff	41967	6638	18700	4484	*
Live shrubs	74	29	96	36	
Dead shrubs	1	1	4	3	
Trees	569	331	80	18	
Total	63633	8708	67431	16229	

Stand D	Unburned		Burned		
Fuel Class	Mean	Std Error	Mean	Std Error	
0-1/4"	291	67	145	26	*
¼" - 1"	813	165	1346	261	
1" - 3"	2592	963	976	465	
> 3" sound	0	0	559	310	
> 3" rotten	4050	2429	873	759	
Litter	25774	3076	6812	775	*
Herbs	1	1	17	15	
Duff	66103	7114	48490	5903	
Live shrubs	212	113	324	100	
Dead shrubs	10	6	48	30	
Trees	40	11	248	128	
Total	99886	9969	59838	6060	

* denotes means that differ significantly ($P <= 0.05$) based upon tests of between-subjects (treatment) effects.
** hypothesis D.F. = 11; error D.F. = 18
N = 15 sample points per stand per treatment

Altogether, these results show that herbicide and prescribed burning treatments may be effective in the control of hardwoods in the regeneration and restoration of Mountain Longleaf habitats. Effects, however, are species dependent. As a result, managers should pay attention to the types of species present at a given site when preparing management plans. While herbicide foliar sprays seem to be very effective in controlling most species of re-sprouting hardwoods, fuel reduction burns and standard herbicide injection treatments may be insufficient to control developing and mature hardwoods.

ACKNOWLEDGEMENTS

We would like to acknowledge M. Belk and C. Donahue for assisting with the development of field methodology, S. Raper for donating the Garlon 3A, and N. Edmondson and the Interagency Burn Team for assistance with planning and implementing the prescribed burns. Funding was provided by the National Science Foundation Research Experiences for Undergraduates program (DBI-0354017) and Berry College Faculty Development and Development of Undergraduate Research Grants awarded to M.L.C. Field and laboratory work was facilitated by the Berry College Student Work Opportunity program.

CONTACT AND WEBSITE INFORMATION

Mailing address: 430 Berry College, Mount Berry, GA 30149; Email: mcipollini@berry.edu; Phone: 706-290-2149; Website: http://resource.berry.edu/longleaf

SOUTH CAROLINA LOWCOUNTRY FOREST CONSERVATION PROJECT

W. Conner, T. Williams, G. Kessler, R. Franklin, P. Layton, G. Wang, D. Van Lear, T. Straka, E. Cooper, C. LeShack, K. McIntyre, R. Mitchell, S. Jack, W. Haynie, A. Nygaard, L. Hay, D. Beach, J. Lareau, H. Lesesne, M. Robertson and P. Ferral

Abstract: Conservation of southeastern US coastal plain ecosystems is a global priority because of their high levels of biological diversity and rare and endemic species. Significant remnant longleaf pine forests, extensive riparian forests, and isolated wetlands support rich herbaceous floras, are essential habitat for neotropical migrants and rare herpetofauna. These ecosystems have been shaped by the interaction of two ecological processes: fire and hydrology. The 2.9 million-acre Lowcountry Forest Conservation Project on the coastal plain of South Carolina supports ecologically-viable examples of these communities and ecosystem, in a relatively intact forested landscape. The project area is at risk from a combination of threats: urban development, incompatible forestry practices, inappropriate fire regimes, altered hydrology in three rivers and climate change. While serious, these threats can be abated by a multi-faceted conservation approach. The project is a partnership of Clemson University, Ducks Unlimited, the Joseph W. Jones Ecological Research Center, Lowcountry Open Land Trust, South Carolina Coastal Conservation League, The Conservation Fund and The Nature Conservancy. One of the goals of this project is to create and disseminate economically and ecologically viable methods for conservation-based forest management on private lands, including restoration of degraded lands. The partnership was designed to provide a balanced approach that allocates funding and resources that can set into place longer-term actions that will succeed in sustaining this forested landscape and its biological diversity. Funding for the project is provided by the Doris Duke Charitable Foundation.

HANDLING UNFAMILIAR SEEDS OR HOW NOT TO DESTROY YOUR SEED SAMPLE

Kristina F. Connor and Nathan Schiff

Abstract: Beginning work on seeds of endangered and exotic species often means starting with little or no knowledge and working toward successful handling and storage. It is often found that, in the past, exotic or poisonous plants (such as poison ivy) have been regarded as high in nuisance value and low in usefulness. Thus little research has been done on the care and handling of their seeds. Alternatively, seeds from endangered plants are often regarded as too precious to waste on needless experimentation. We now realize that information on the germination characteristics and the biochemistry of seeds of exotic and invasive species can be used to devise means of controlling their spread; and the more we learn about endangered species, the better chance we have of either establishing new colonies or storing germplasm for future generations. In this paper, we present methods for handling seeds that are an unknown entity in order to gather the greatest amount of information, often from limited seed supplies, with minimal waste.

INTRODUCTION

When beginning work on seeds from species that are unfamiliar, approach as you would any scientific problem. Consult colleagues and initiate a thorough search for information in the library or on the internet. If information about other species in the same genus or family is found, use procedures to treat and store seeds of those species as a guideline. But proceed with caution. While appropriate in some cases, in others the destruction of the entire sample may result. For instance, seeds of *Acer saccharum* Marsh., sugar maple, are orthodox, meaning they can be dried to a moisture content (MC) of less than 12% (g/g fresh wt.) and stored under refrigeration for long periods of time. However, the seeds of *Acer saccharinum* L., silver maple, although similar in shape and size to those of sugar maple, are recalcitrant. If these recalcitrant seeds are dried below a critical MC, they lose viability. This susceptibility to moisture loss makes any period of storage for some recalcitrant seeds very short, while others, still classified as recalcitrant, can survive for 3 years under proper storage conditions.

You will also need to determine optimal germination conditions, dormancy requirements, best temperature for seed storage, and the length of time seeds can be stored and still retain high viability. We provide here some standard techniques and procedures that can be adapted, with caution, to establish a protocol for handling unfamiliar seeds.

METHODOLOGY: QUICK AND DIRTY

COLLECTION AND HANDLING

Have a clear plan of action before going into the field. Your objective is to collect seeds when they are fresh and fully ripe and the best way to do this is by tracking seed development. If possible, collect more seed than you think you will need. You'll rarely have 100% viability. Color change is the most common and easily identifiable indicator of maturity, although larger seeds are often collected from the ground after dissemination. Changes in MC and biochemical makeup are also common but less easy to test in the field. Cut open a few seeds to see if the seeds are filled and if the interior color is good.

It is vital that you maintain seed MC after collection. Remember that you know little if anything about these seeds. If you allow them to dry, you may kill them. Place seeds in a plastic bag and loosely seal for transport to the lab. It is important to keep the seeds cool but refrigeration is not necessarily recommended.

THE TIME LINE

In addition to a plan of action for the field trip, everything should be in place when you arrive back at the lab. Most temperate-zone seeds can be successfully stored under refrigeration (even when fully hydrated) for short periods of time but if you can begin work immediately, all the better.

TESTS

The following steps are proposed to minimize errors in the test process: Remember, don't assume the seeds are either orthodox or recalcitrant. If you have a large supply of seeds, we suggest you treat them as recalcitrant to avoid destruction of the seed sample.

Moisture Content (MC):
MC at time of shedding may be the first clue of whether a seed is orthodox or recalcitrant. A phase called maturation drying often occurs at the end of the ripening cycle of orthodox seeds. Their MC may drop slowly as seeds mature. In orthodox seeds with pulp, MC increases but mainly in the pulp. Recalcitrant seeds do not go through a maturation drying phase and have a high MC when shed (Bonner *et al*. 1994).

Dry seeds overnight in a 103^{o}C oven for 17 h to determine MC. Do this before undertaking any other tests. If you have some seeds to spare, weigh 21 of them in groups of 7 seeds. Then leave them on the lab bench to dry 12-24 h if small, 24-72 h if large. Put one group in the oven to determine dry weight, rehydrate the another group and put in the germination cabinet, and immerse the third group in liquid nitrogen (LN_2). Leave the seeds in the LN_2 for 1 h, then remove and allow towarm slowly at room temperature. Rehydrate the seeds before testing for germination. If seed MC has dropped below 12% (fresh weight basis) and the seeds survive immersion in LN_2 (or germinate in the cabinet), you're dealing with orthodox seeds.

The Thermogradient Table:
Test seeds on a thermogradient table to determine optimal germination temperatures. A two-way thermogradient table can be used to determine optimum temperature regimes for laboratory germination of the unfamiliar seeds. The thermogradient table can supply simultaneously a very large number of alternating temperature regimes which simulate natural seedbed conditions; circulating water baths pump hot and cold water through channels on opposite sides of the plate to create a very stable thermal gradient. At pre-selected times, solenoid valves automatically switch the flow to the other two sides, thus creating alternating temperature regimes at all spots on the plate except for the diagonal, which has constant temperatures. The grid size selected often depends on seed size. For larger seeds, such as those of *Lindera melissifolia* Walt. (pondberry, Fig. 1), we used an 8 x 8 cm grid - 100 different spots, four seeds per spot. If seeds are recalcitrant, they should germinate very quickly. If seeds are slower to germinate or do not germinate at all on the thermogradient table, odds are they are orthodox, and there may a dormancy requirement for these seeds.

Germination Tests:
The number of seeds used in the seed tests for germination may be limited by the number of seeds available. If you have an ample supply, 4 replications of 100 seeds is a good starting point. If seed supplies are limited, drop to 4 replications of 25 seeds. Use the temperature combination showing best results from the thermogradient table study to set the temperature program in the germination cabinet.

If you are limited by time and number of seeds, we suggest you eliminate the thermogradient study and take your best guess at setting the temperatures on the germination cabinets. For instance, when testing for germination of *Toxicodendron radicans* (L.) Kunst. (poison ivy, Fig. 2) seeds, which mature in the fall, we set the germinators on a 25/30 cycle. This means the germinator was set for 16 h of dark at 25^{o}C and for 8 h of light at 30^{o}C. If the seeds mature in spring, try setting the germinator for 8 h of dark at 20^{o}C and 16 h of light at 30^{o}C. The combination of 20/30^{o}C is prevalent in the literature for use on fall-maturing seeds from the temperate zone.

Storage Tests
If you determine that the seeds are orthodox before beginning the storage study, dry them to a MC between 5-12% and store at the temperature of your choice. If the seeds are recalcitrant, DO NOT under any circumstances dry before storage. Store the seeds fully hydrated at either 4^{o}C or -2^{o}C. Test at intervals for viability. If the seeds are very recalcitrant, such as those of *Quercus alba* L., they will germinate while in storage in as little as 2 months. If they are less recalcitrant, like *Quercus nigra* L., or sub-orthodox, they can be stored, with care, for a few years. If you are uncertain if the seeds are orthodox or recalcitrant, treat them as recalcitrant. Their storage lifespan will be shorter since they are stored fully hydrated, but you will not destroy your seed sample.

Overcoming Dormancy
This may be the most difficult problem you face. Dormancy is not an issue with recalcitrant seeds. Orthodox seeds, however, can have many types of dormancy requirements. If they are not overcome, your germination tests may give poor results despite the fact that the seeds are viable.

The best bet would be to check for information on other species or genera in the same family. For instance, while we found little or no information for poison ivy, we did find various treatments for *Rhus spp*. We set up a series of treatments and stratified the seeds for 0-90 days. The results, reported in Table 1, were encouraging (Schiff *et al*. 2004); we had success with very little first hand information.

SUMMARY

The following is a suggested protocol for handing unfamiliar seeds:

- Have a plan of action in mind before going to the field.
- Harvest fresh, fully ripe seeds. Perform a cutting test.
- Handle seeds as if they were recalcitrant.
- Determine MC of collected seeds using the oven-dry method.
- Use a thermogradient table to determine optimal germination temperatures. This step can be eliminated if seeds are in short supply.
- Germinate seeds to determine if they are viable. If you eliminate step 5, try a combination of 20/30 on temperate zone seeds.
- When in doubt, store seeds at 4^{o}C.
- Dormancy may be a serious problem for orthodox seeds. Check other plants in the same genus or family for information.

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Table 1. Mean percent germination of poison ivy seeds after 4 weeks and 12 weeks for 0, 30, 60, and 90 days of stratification.

Days Stratified Treatment[a]		0	30	60	90
After 4 weeks					
1 hr soak in water	0	32*	22*	40*	
Picked in February		1	40*	42*	72*
H_2SO4 30 min.	63	72	66	70	
H_2SO4 1 hr		34	62	50	52
H_2SO4 3 hr		16	2	0	0
H_2SO4 6 hr		3	0	0	0
After 12 weeks					
1 hr soak in water	0	82	60	70	
Picked in February		1	92	96	90

[a]Treatments marked with an asterisk are those that had viable seeds left after the 4 week test period and were tested for an additional 8 (12 total) weeks.

Figure 1. Pondberry drupes.

Figure 2. Poison ivy drupes

ACTIVELY MANAGING REAL & POTENTIAL LOBLOLLY PINE DECLINE STANDS TARGETED FOR LONGLEAF RESTORATION WITHIN RCW HABITAT

L.G. Eckhardt and R.D. Menard

Abstract: Loblolly pine is declining in the Southeast, and specific actions are required to reverse this trend. Pathogenic fungi (*Leptographium* species) vectored in by root feeding bark beetles and weevils are accelerating mortality of southern pine trees. Host symptoms include sparse crowns, reduces radial growth, deterioration of fine roots, decline, and mortality of loblolly pine by age 50. The endangered red-cockaded woodpecker (RCW) occurs in much of the loblolly pine range. Within loblolly stands, old- growth loblolly pines are the preferred habitat of the RCW. Restoration and prevention activities are essential to reduce the negative ecological impacts on RCW habitat associated with the change from healthy forests to declining trees. Assessment of decline risk within RCW habitat, prior to establishment of proposed management, can facilitate informed decisions regarding the desired future condition. A complex situation regarding long and short term foraging needs for RCW currently exists. The decline risk assessment can be utilized to identify declining habitat and sustainable loblolly stands, and prioritize active management strategies to achieve both old growth nesting and foraging RCW habitat.

THE USE OF GIS AND TOPOGRAPHICAL FEATURES TO DELINEATE SOUTHERN PINE DECLINE FOR IN THE SOUTHEASTERN UNITED STATES

L.G. Eckhardt and R.D. Menard

Abstract: Declining loblolly stands have been a management concern on the Talladega National Forest in Alabama since the 1960's. The symptoms include sparse crowns, reduced radial growth, deterioration of fine roots, decline and mortality by age 50. The purpose of this study was to analyze the geographic distribution of topographical features as they relate to the condition of loblolly pine trees on the Talladega National Forest and Gulf State Paper land in central Alabama. Slope was the variable best correlated with the intensity of decline, although aspect and convexity were also statistically linked to decline, which was more pronounced in convex, south/southwest oriented areas. The statistical data supports the geographical data in delineating loblolly pine decline. It was found in all cases that statistical and geographical data were in accordance with each other. These data appear to show an important topographical link that may influence the acceleration or severity of decline and indicates that the dominant determinants, or predictors, of loblolly decline are identifiable topographical features. The implication is that these factors could be developed into a model for similar geographic locations, which could be used for predicting sites which would be in decline or approaching decline, and would be a valuable tool for longleaf restoration prioritization, wildlife habitat management or other land management planning efforts.

LEPTOGRAPHIUM SPECIES AND THEIR VECTORS AS COMPONENTS OF LOBLOLLY PINE DECLINE: A GROWING CONCERN IN THE SOUTHEASTERN UNITED STATES

L.G. Eckhardt, R.D. Menard, J.P. Jones and N.J. Hess

Abstract: Loblolly pine (*Pinus taeda* L.) decline has been found on upland sites in central Alabama since the 1960's, but has become more prevalent and widespread since the 1990's (Hess *et al.*, 1999a, 1999b). Loblolly pine decline (LPD) is characterized by the deterioration of fine roots, sparse crowns and reduced radial growth followed by death. The onset of symptoms in LPD occurs when the trees reach the 40-50 yr age class, and affected trees decline slowly and die prematurely. Our data show a correlation of *Leptographium* spp. with symptoms of loblolly decline, insect and vegetation densities, and deteriorated roots. *Leptographium* species are associated with root-feeding insects that attack pine and are commonly present during pine decline and mortality in the United States. The relative importance of the beetles and stain fungi in the decline is still unclear. In the southeastern US, loblolly decline stands are more likely to contain *Leptographium* species in their root systems and be more vulnerable to southern pine beetle than symptomless stands. Decline plots in Alabama have *Leptographium* species associated with both roots and soil as well as root-feeding insects. Soil analysis shows that bulk density and total porosity are not growth limiting. Inoculation experiments indicate that *Leptographium* is capable of killing seedlings.

RAPID ASSESSMENT OF WOOD QUALITY PROPERTIES IN LONGLEAF PINE

Thomas Elder and Chi-Leung So

Abstract: Conventional wood quality measurements, such as mechanical, chemical or physical properties, are time consuming to perform, and as a consequence these data have either not been routinely collected or have been limited to relatively simple determinations, such as specific gravity. Advances in spectroscopy and multivariate statistical analyses, however, have made the determination of a wide array of properties feasible. Furthermore, these analyses are rapid to perform so that a large sample size can be evaluated in a relatively short period of time.

The current paper reports on the use of near infrared spectroscopy, multivariate statistical analyses, and the development of an automated sampling system to determine the wood quality of longleaf pine. The samples came from trees across a large geographic range, and grown under a variety of silvilcultural regimes, for which detailed growth and yield data have been collected. Quantitative relationships between wood quality and growth and yield results may be of utility in managing longleaf pine with the properties needed to achieve specific management objectives.

NORTHERN BOBWHITES AND PRESCRIBED FIRE IN LONGLEAF PINE

Travis Folk

Abstract: The importance of prescribed fire to maintenance of quality bobwhite habitat has been well known since the 1920's. However, prescribed fire was traditionally used during only the late winter months of February and March. This is in contrast to the natural timing of fire in the longleaf ecosystem, lightning ignited fires in late spring and early summer. Increasingly scientists are beginning to realize that the time of year fire occurs can have a significant impact on the post-fire plant community. To date, there has been little evaluation of how timing of prescribed fire and the resulting understory vegetation influence bobwhite survival, reproduction, and movement in the longleaf ecosystem. From February 2002 to September 2004, a radio telemetry study was conducted at Conecuh National Forest (south central Alabama) to begin to answer these questions. This project was conducted in predominantly longleaf pine stands managed with triennial prescribed burns which occurred at varying times in the annual cycle. While final analyses have not been completed, several interesting phenomenon were documented in the bobwhite population in Conecuh National Forest. Bobwhites have been considered a relatively sedentary game bird; however, bobwhites at Conecuh moved on average greater distances than other populations. Movement is greatest after covey breakup, April and May, but long distances can be moved throughout the summer. This is a novel behavior in the Southeast, and may bode well for establishment of populations in southern pinelands. Further work will need to be conducted to verify this hypothesis as well as evaluate movement between stands of that vary in time since last burn.

CHEMICAL CONTROL OF THE INVASIVE EXOTIC *LYGODIUM JAPONICUM*

J.L. Gagnon, S.B. Jack, B.D. Yahn and J.M. Stober

Abstract: Japanese climbing fern (JCF, *Lygodium japonicum*) is an exotic invasive which has the potential to completely infest localized areas through the formation of a thick frond mat and climbing upright vegetation. The dense mats can overtop native vegetation and change fire behavior by creating ladder fuels and smothering groundcover fuels. On Ichauway JCF is most prevalent in streamside hammocks, but is also found in upland areas which do not burn frequently. JCF is difficult to control because the spores are easily transported by wind and water, and potential herbicide treatments may damage non-target desirable species. We implemented a study to examine the effects of herbicide on JCF and non-target plants. Three blocks were chosen in three forest types: hardwood hammock, field edges, and moist depressions. Within each block, three 1 m x 1 m plots were surveyed for percent coverage of JCF and seven non-target understory species, and surrounding hardwoods documented. Each plot in a block was treated with either Arsenal (2.5 % a.i.), Glypro+ (2.0% a.i.) or Plateau (1.5% a.i.) which was broadcast applied in September 2003 using pump sprayers. Plots were surveyed two weeks and seven weeks after treatment and continue to be monitored in 2004. Early data indicate that all three herbicides effectively controlled JCF within 7 weeks of application in all three habitat types, with Glypro+ being the most effective (42 % control) followed by Arsenal (25% control). Glypro+ was also most effective at controlling non-target exotics (65 % control); Arsenal and Plateau had similar effectiveness on these species (32 % control). In September 2004 plots will be re-surveyed and any mortality of hardwoods surrounding the plots will be noted.

INTRODUCTION

Japanese climbing fern (*Lygodium japonicum* - JCF) is a category I invasive plant, native to both temperate and tropical Asia, which has naturalized across the Southeastern United States (Lott et al. 2003, Zeller and Leslie 2004). This species has the potential to completely infest localized areas through the formation of a thick frond mat and by climbing upright vegetation. The dense mats can overtop native vegetation and change fire behavior by creating ladder fuels and smothering groundcover fuels (Lott et al. 3003). JCF is difficult to control because the spores are easily transported by wind and water (Ferriter 2001). In areas of its range where frost occurs there is some dieback, but ferns growing up the stems of trees are insulated from much of the frost damage. Fire is also useful in controlling the species in areas which burn frequently. However, most occurrences are in hardwood depressions, hardwood hammocks or along field edges, areas which do not burn well or frequently because of inundation or fire-shadow effects. Herbicide treatments may be effective in controlling the spread of JCF, yet may also damage non-target desirable species. In central and south Florida, old-world climbing fern (*Lygodium mycrophyllum*), a closely related species, has become a major problem, with increases from 28,000 acres in 1993 to 110,000 acres in 1999 (Lott et al. 2003). A significant increase in JCF has been observed in parts of southwest Georgia as well. To develop management strategies to control the spread of JCF before it becomes a more serious problem, we implemented a pilot study to examine the possibility of reducing coverage using herbicides.

METHODS

Study Site

This project was located at the Joseph W. Jones Ecological Research Center at Ichauway. Ichauway is a 29,000 acre ecological reserve in the Coastal Plain of southwest Georgia, USA. Over 18,000 acres are in mature (70+), upland longleaf pine (*Pinus palustris*) forests. The climate for this area is classified as humid subtropical with an average annual precipitation of 52 inches distributed evenly throughout the year. Mean daily temperatures range from 69 to 93°F in summer and 41 to 63°F in the winter. Two major waterways pass through Ichauway: 13 miles of the Flint River form the eastern boundary of the property and 15 miles of the Ichawaynochaway Creek flow through the center of the property. These aquatic systems create many acres of streamside hammocks, which, in addition to numerous wetlands scattered across the property, provide ample areas subject to JCF invasion. On Ichauway, JCF is most prevalent in wet areas, but is also found in upland areas which do not burn well or frequently.

In fall, 2002, hammocks along the waterways and other areas of Ichauway were systematically surveyed to map the locations of JCF infestations. Three site types were selected for this study: field edges, hardwood hammocks and either depressional areas or areas dominated by pines other than longleaf [i.e., loblolly pine (*P. taeda*), slash pine (*P.*

elliottii var. *elliottii*) or shortleaf pine (*P. echinata*)]. Three plots were established in each site type (n = 9 plots total).

Field Measurements

In each of the nine plots, three 1 m x 1 m subplots were established. Each of the three subplots received one of the following treatments: Arsenal (2.5% imazapyr $acre^{-1}$) Glypro+ (2.0% glyphosate $acre^{-1}$) or Plateau (1.5% imazapic $acre^{-1}$). Sublots receiving the Arsenal treatment were located a minimum of 20 ft. from the other subplots to minimize transmittance through the soil. All herbicides were broadcast applied in September 2003 using backpack sprayers. Prior to herbicide application, percent cover of JCF and seven other non-target species were recorded and photos were taken at each subplot (n = 27) and site (n = 9). Non-target species included Canada goldenrod (*Solidago canadensis*), blackberry (*Rubus cuneifolius* and *R. trivialis*), Japanese honeysuckle (*Lonicera japonica*), greenbriar (*Smilax* spp.) winged elm (*Ulmus alata*) and wood oat (*Chasmanthium latifolium*). Additionally, hardwoods within 33 ft. of the center of the Arsenal subplots were mapped and diameters at breast height were measured to determine if the herbicide negatively affected growth and/or survival. Subplots were re-surveyed approximately two, seven and 52 weeks after treatment application.

RESULTS

At all three site types, each of the herbicide treatments effectively reduced JCF cover (Figure 1). There were no significant differences among the treatments or site types, with the exception of the Arsenal treatment 2 weeks after application. When JCF coverage was averaged across all sites, the Arsenal plots were significantly lower. This difference however, was not apparent 52 weeks after application. After 52 weeks, any JCF in the plots was a result of neighboring, untreated JCF growing into the plots. There did not appear to be any green-up of ferns rooted in the plots.

Cover of all non-target species was reduced by at least one of the herbicides (Figure 2). Eight weeks after application, the Glypro+ treatment resulted in mortality of all the non-target species except greenbriar, while Arsenal and Plateau both caused mortality of three of the non-target species. One year after treatment, many of the subplots were bare or were sparsely vegetated. Vegetative cover decreased from 83% to 22% in all plots. There were no significant differences in vegetative cover among treatments or site types.

The Arsenal treatment resulted in mortality of hardwoods surrounding the subplots in both field edge sites (33% mortality) and hardwood hammock sites (22% mortality). However, the number of hardwoods surrounding the plots varied by site type and subplot (from 0 to 24 trees). This variance and the small sample size prevent us from determining if there are significant differences in Arsenal's effects on hardwoods among the different site types. These subplots will be monitored for the next year to determine JCF re-colonization rates.

CONCLUSIONS

Though risky to generalize results from this small-scale pilot study, all three herbicides effectively reduced JCF cover in the three habitat types. There was a corresponding decrease in overall vegetative cover and some hardwood mortality was associated with the Arsenal treatment, indicating the need for a site by site prescription for areas with important non-target species. Another study (Zeller and Leslie 2004) showed that both Accord (a.i. glyphosate) and Escort (a.i. metsulfuron methyl) were effective in controlling old-world climbing fern in central Florida, but Escort resulted in the least amount of damage to non-target understory vegetation.

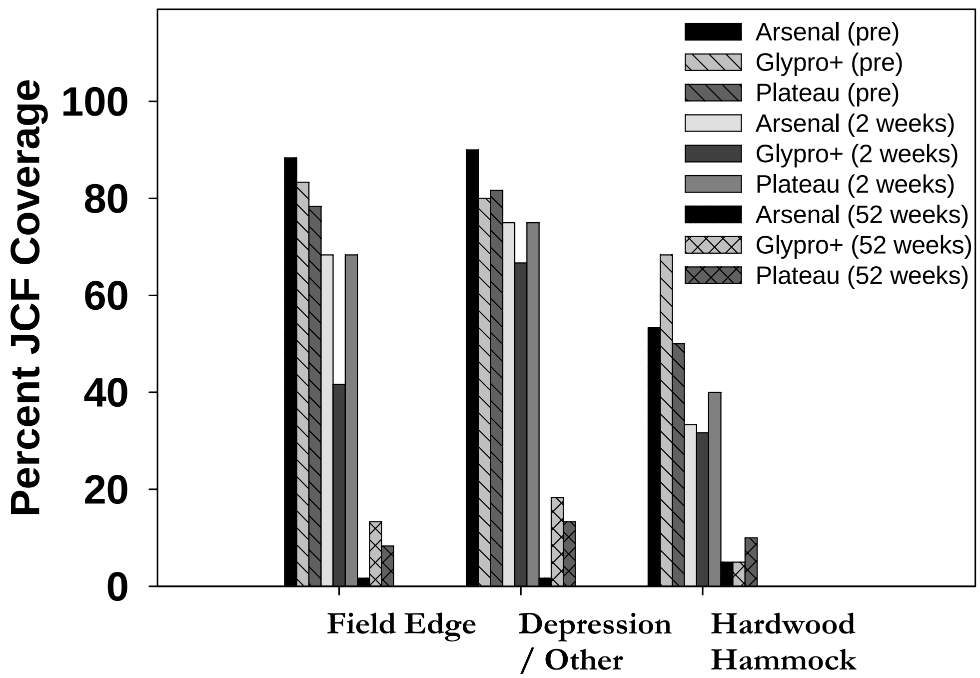

Figure 1. Effects of three different herbicides on JCF coverage over three sampling periods.

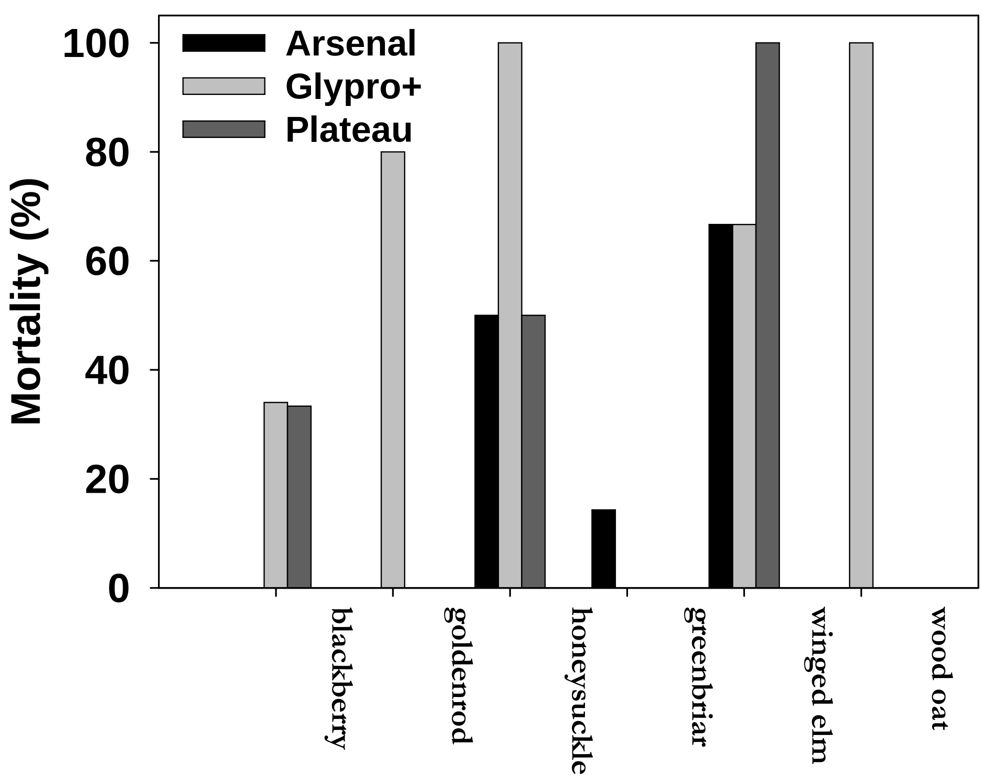

Figure 2. The effects of the different herbicides on non-target species eight weeks after application. These include both native and exotic species.

ACKNOWLEDGEMENTS
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CHOCCOLOCCO UPLAND INITIATIVE: RESTORING THE MONTANE LONGLEAF ECOSYSTEM FOR WILDLIFE

Jeff Gardner and Lesley Hodge

Abstract: The Shoal Creek Ranger District, in partnership with Alabama Wildlife and Freshwater Fisheries, Alabama Power, Quail Unlimited, and the National Fish and Wildlife Foundation are working to restore the imperiled montane longleaf ecosystem on the District. Historically, montane longleaf was the dominant forest type on the present-day Talladega National Forest; however, much of this forest was harvested to provide charcoal to fuel the local iron industry. Unfortunately, many of the remaining montane longleaf stands have been degraded due to fire suppression. Hardwood and off-site pine encroachment reduces the amount of sunlight reaching the forest floor and has resulted in decreased herbaceous layer diversity.

Many species of wildlife, and plants, associated with longleaf woodlands have declined because of the loss of this open habitat. Although longleaf woodlands may be lacking in the diversity of tree species, they more than make up for it with the presence of other plants and animals. The Shoal Creek Ranger District is home to one of the last remaining populations of the federally endangered red-cockaded woodpecker in the Appalachians. Many other species in decline, such as the Bachman's sparrow and bobwhite quail may be locally common in longleaf stands that closely mimic historical conditions.

To restore the open woodland structure associated with montane longleaf, the District is conducting the following activities: 1) wildlife stand improvement (midstory removal in mature pine stands), 2) increased prescribe burning, particularly during the growing season, in pine stands, and 3) monitoring vegetation and wildlife to assess responses associated with treatment activities.

MOUNTAIN LONGLEAF NATIONAL WILDLIFE REFUGE: MANAGEMENT PLANNING

B. William Garland

Abstract: Mountain Longleaf National Wildlife Refuge (Refuge) is located in Calhoun County in northeastern Alabama. It is contiguous to the City of Anniston, and lies approximately 65 miles east of Birmingham and 90 miles west of Atlanta. The 7,759 acre refuge was legislatively established on May 31, 2003 within the former military training base of Fort McClellan. On October 23, 2003, an additional 1,257 acres were contributed by the local community for a total acreage of 9016 acres. Fort McClellan was selected for closure by the Base Realignment and Closure Commission of 1995, and was effectively closed on September 30, 1999.

Refuge Vision: The Refuge Vision broadly reflects the reason for establishing the refuge, based on both legislated and planning purposes and objectives. The vision statement for Mountain Longleaf National Wildlife Refuge is as follows:

Mountain Longleaf National Wildlife Refuge will be managed to maintain and restore a naturally regenerating mountain longleaf pine ecosystem, along with providing educators, research scientists, and the public with a broad range of opportunities to appreciate and enjoy a rare and disappearing southern forest type.

The presence of the best remaining example of a fire maintained mountain longleaf pine ecosystem is recognized as the primary factor for selecting the area as a National Wildlife Refuge. With closure of the base in 1998, military related wildfires disappeared and longleaf pine forests no longer experienced recurring wildfires. Without implementation of an active management program, these forests were expected to slowly evolve into a hardwood dominated forest community. To meet the primary purpose of refuge establishment, priority was given to preserving and enhancing the longleaf pine ecosystem through an active management program.

LONGLEAF PINE MARKET TRENDS

Eric D. Gee

SOUTHERN PINE LUMBER PRODUCTION

Southern pine lumber production has consistently risen with demand. Since 2001, there has been a 2.5% increase. For 2004, production was up 3.7% over 2003. Southern pine production is projected to grow with strong market conditions over the next several years.

The 2004 southern pine lumber production equaled 18.1 billion board feet (bbf). The most desirable quality of southern pine is its strength. Eighty percent is manufactured as 2-inch thick dimension for structural markets, 9% for timbers that are 5-inches thick, and 10% as 1-inch boards.

In 2004, 1.5 bbf of boards were produced. Thirty percent was produced for the treated decking market, 40% dried to 19% moisture content (MC), 8% dried to 15% MC (for appearance grade), 6% for pattern stock such as moulding or millwork, and 17% was rough green (exported or resawn).

Looking at the various physical aspects of the four species that comprise the southern pine species category, and reclaimed heart pine, we see why southern pine is a durable and strong choice for interior flooring applications. Among the southern pines, longleaf and slash pine have a higher specific gravity and modulus of elasticity. As a group, the wood of southern pine is harder than walnut, cherry, and white oak.

WHY LONGLEAF IS PRIZED OVER OTHERS

When longleaf pine wood is compared to other species, it is prized because it generally has tighter growth rings and higher density making it more stable. The higher heartwood percentage gives it a unique amber tone. It also has a distinct grain pattern that is recognized world over. Much character is derived from knots and grain pattern.

Even the Southern Pine Inspection Board (SPIB) recognizes longleaf qualities for grading purposes. However, slash pine also exhibits many of the same hardness factors and can be classified as longleaf. "Longleaf lumber shall be produced only from southern pine tree species of *Pinus palustris* and *Pinus elliottii*...no less than 6 annual growth rings per inch..." (SPIB Grading Rule 111.5).

The lumber markets have many forces acting upon them. Housing starts and interest rates are directly related, as is the exchange rate – which can help spur exports/curb imports or vice versa. Natural disasters, within and outside of the region, and land use policy on federal forestlands all impact the production, product class, and where the final product will end up. It is a very complex system.

Because of southern yellow pine's strength qualities, dimension lumber drives the market. Boards are 'accidental' products because the majority of sawmills are set up to run high production, high yield products like 2-inch lumber. As margins tighten between 1-inch and 2-inch markets, the 2-inch market will win.

LONGLEAF MARKETS

Some typical longleaf appearance grade markets are furniture, windows and doors, cabinetry, paneling, and flooring. Why southern pine is prized for flooring material: "Southern pine always has been supreme in the softwood flooring field. It is not only resistant to heel and furniture marks, but possess a warmth and richness color all of its own." (SPIB Grading Rule 210).

Prices (per square foot) for antique heart pine are: Vertical Grain, 6"-$12.93; Prime Grade, 6"-$9.35; Select Grade, 6"-$7.39.

Current prices for solid sawn southern yellow pine flooring (per square foot): Vertical Grain, 6"-$3.75; Plainsawn, 6"-$2.90. To get a $/mbf conversion for 6" material, multiply the $/square foot price by 918.

Heartwood can begin to form in longleaf as early as 20 years. Prices for "new" heart pine flooring (per square foot) are: Vertical Grain, 6"-$6.90, Engineered, 6"-$7.75, Preferred, 6"-$4.90.

Some of the flooring trends in the domestic market industry today include: No.2 Grade for flooring (1x4 or 1x6), Vertical Grain flooring and No.2 1x6, while the export market prefers Clear Grades (No.1, saps, export prime).

MARKET COMPETITION

Turning our thoughts towards market competition: Year-to-date imports are up 37% from 2003. Brazil and Chile represent about 75% of softwood mouldings. Year-to-date exports are higher, with Asia creating a significant opportunity.

Despite these imports, Southern Pine is still the best for flooring. A study was conducted to compare various softwood species: southern yellow pine (SP), Chilean Radiata pine (CRP), Brazillian elliottii pine (BEP), New Zealand Radiata pine (NZRP), European redwood (ER), and European Whitewood (spruces) (EW).

Species	Radial Hardness	Tangential Hardness	Bending	Density
SP	3160	3264	.820	609
CRP	2821	3208	.719	505
BEP	2007	2464	.671	433
NZRP	3098	3173	.662	531
ER	2253	2549	.665	509
EW	1613	1805	.427	403

Export trends:

- Weak U.S. dollar spurring exports globally.
- Biggest challenge has been sourcing export material - with healthy markets for domestic grades, mills are producing less Saps, Export Prime, and particularly Flitches.
- Exports to weak European markets are rising - demand remains weak while competition from within Europe and, increasingly, Eastern Europe is growing.

Some examples of 2003/04 accomplishments in promoting southern yellow pine flooring: Michael Holigan's television show "Your New House," flooring and porch flooring DVDs, "Guide to Southern Pine Flooring" (in three languages), brochures, trade shows, and a technical report.

CONCLUSIONS

- Continue to plant longleaf
- Do not try to push the limits of growth
- Longleaf is desired for specialty products
- Consider uneven-aged management

UPROOTING THE WIREGRASS MYTH

John C. Gilbert, John S. Kush and John P. McGuire

Abstract: *Aristida beyrichiana* and *Aristida stricta*, commonly referred to as wiregrass, are both conditional understory species in the longleaf pine (*Pinus palustris* Mill.) ecosystem. A common but misleading association exists between longleaf pine and wiregrass. The longleaf pine-wiregrass ecosystem is often used synonymously with the entire longleaf pine ecosystem. Another common misconception is that the presence of wiregrass is necessary to maintain the structure and function of the longleaf pine ecosystem. In fact, the understory of the longleaf pine ecosystem is composed of an extensive variety of species which is not consistently dominated by a single species. Wiregrass is one of the more well known of the understory bunchgrasses. An often forgotten but prominent understory component of the longleaf pine ecosystem is bluestem (*Andropogon* spp.). Bluestem is also referred to as broomsedge, broomstraw, beardgrass, and a variety of other common names. At least nine species of bluestem have been identified in the longleaf pine ecosystem. The range of bluestem stretches from Texas to Florida, north to Maine, and west to North Dakota, which blankets the range of the longleaf pine ecosystem. The presence of bluestem provides many aesthetic, commercial, and ecological values to the understory of longleaf pine stands. With extensive restoration efforts of the longleaf pine ecosystem underway, bluestem is a valuable understory component across the longleaf pine ecosystem.

INTRODUCTION

A common misconception about the longleaf pine ecosystem is that wiregrass is a necessary component of the understory vegetation. Wiregrass is an integral understory component in the longleaf pine ecosystem, but it's not present throughout the range of longleaf pine. Even in the major range of wiregrass, it can be found as a codominant with a variety of other understory species (Outcalt 2000). In fact, the understory of the longleaf pine ecosystem is not dominated by any single species (Outcalt 2000). Another prominent understory component of the longleaf pine ecosystem is bluestem. The importance of bluestem in the understory of longleaf pine forests is often overlooked.

Ranges of Bluestem and Wiregrass

Pineland threeawn (*Aristida beyrichiana* Trin. & Rupr.) is commonly referred to as wiregrass. This type of wiregrass has a range from Mississippi to Florida and north into North and South Carolina. Another similar species of wiregrass that exists in North and South Carolina is *Aristida stricta* Michx. Both species are part of the longleaf pine-wiregrass range, but they have been classified as two different species (Miller and Miller 1999; Peet 1993). However, Kesler et al. (2003) argued that on the species level, the two were not distinctly different.

Bluestem is also referred to as broomstraw, beardgrass, and a variety of other common names. The range of bluestem stretches from Texas to Florida, north to Maine, and west to North Dakota, which blankets the range of the longleaf pine ecosystem (Miller and Miller 1999). Several bluestem species are present in this range. Table 1. displays nine separate species of bluestem that exist in the longleaf pine-bluestem range (Grelen and Duvall 1966).

Both wiregrass and bluestem have extensive ranges in the southeastern United States. Range maps vary from different sources because natural and mechanical disturbances continually affect the composition of stands. There is also a great deal of overlap between the extensive ranges of the species of interest. Endozoochory with white-tailed deer as the vector is a possible explanation for the colonization of many forest species across landscapes (Myers et al. 2004). Seed dispersal through endozoochory as well as ectozoochory with a variety of vectors has the potential to explain the spread of wiregrass and bluestem across this vast ecosystem. This concept also gives rise to the threat of exotic encroachment on native understory species.

Table 1.
Common Species of Bluestem in the Longleaf Pine-Bluestem Range
big bluestem (*Andropogon gerardii* Vitm)
pinehill bluestem (*Andropogon divergens* (Hack.))
little bluestem (*Andropogon scoparius* Michx.)
slender bluestem (*Andropogon tener* (Nees) Kunth)
broomsedge bluestem (*Andropogon virginicus* L.)
bushy bluestem (*Andropogon glomeratus* (Walt) BSP.)
Elliott bluestem (*Andropogon elliotii* Chapm.)
fineleaf bluestem (*Andropogon subtenuis* Nash)
paintbrush bluestem (*Andropogon ternarius* Michx)

(Grelen and Duvall 1966)

Range Types of the South
Figure 1. shows the range types of the south. Included in these range types are the longleaf pine-bluestem and longleaf-slash pine-wiregrass ranges. The longleaf pine-bluestem range is largely located in southern Louisiana, in southeastern Mississippi, and in southwestern and central Alabama. Small portions of this range are also located in central Georgia, South Carolina, and North Carolina (Williams and others 1955). The longleaf-slash pine-wiregrass range covers almost the entire state of Florida, the southern portion of Alabama, and almost the southern half of Georgia. Small portions of this range are also located in the southwestern corner of South Carolina (Williams and others 1955). This map also shows the location of the shortleaf-loblolly pine-bluestem range. This range stretches from eastern Texas to Virginia covering a vast amount of the southeastern United States (Williams and others 1955). This range covers the of the longleaf pine ecosystem, which makes bluestem a very integral understory component.

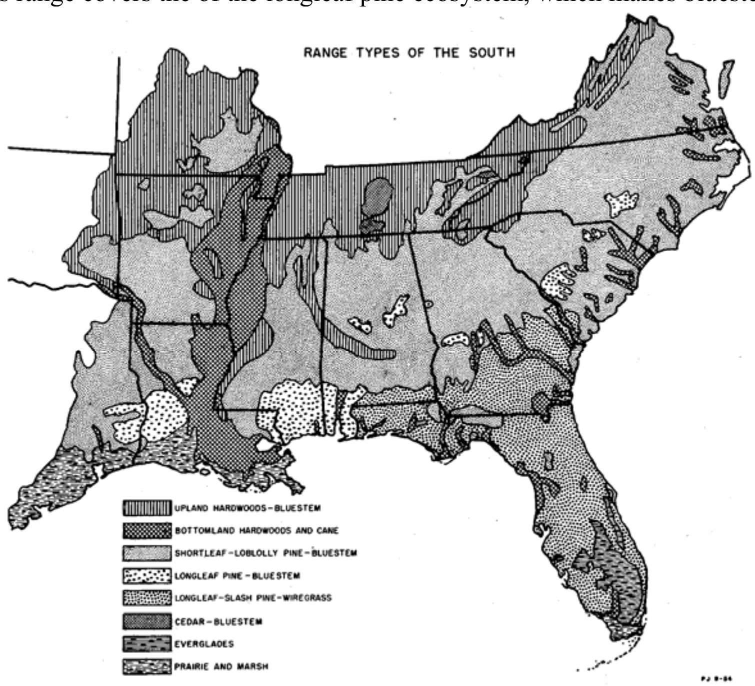

Figure 1. (Williams and others 1955)

Longleaf Pine - Bluestem Range
Figure 2. shows an estimation of the longleaf pine–bluestem range in its virgin state. This range extends from western Florida and southern Alabama west into Texas. This range has been altered due to the clear cutting of old-growth pines and alterations of the natural burn cycles. The natural stand composition that existed in pre-settlement times exists in few places. There has been a conversion of the overstory to loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliotii*) due to extensive planting and a failure to regenerate longleaf pine forests. Even though there

have been extensive disruptions to the stand composition, bluestem grasses have continued to be persistent across this landscape. They still represent one of the most important forage species in this range (Grelen and Duvall 1966).

Figure 2. (Grelen and Duvall 1966)

Bluestem and Wiregrass Ranges Within the Longleaf Pine Ecosystem
Figure 3. shows a current estimation of the range of bluestem and wiregrass species within the longleaf pine ecosystem. It includes more area in central and north portions of Alabama, Georgia, South Carolina, and Virginia than the other maps. This map shows the prominence of bluestem as a dominant understory species in the longleaf pine ecosystem. The map also provides a good representation of the overlap between the ranges of wiregrass and bluestem

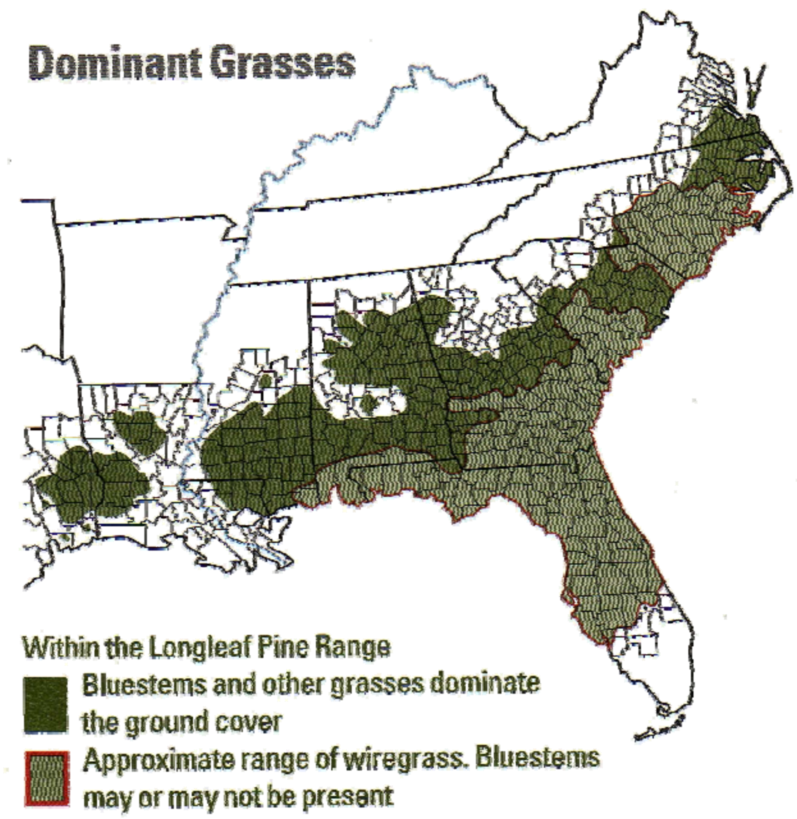

Figure 3. (E. Hart from Managing the forest and the trees a private landowner's guide to conservation management of longleaf pine)

Why bluestem should not be overlooked

1.) Loss of pristine old-growth forests

Bluestem is an integral understory component that should not be overlooked. Ground cover degradation, increasing urban interface, and the invasion of exotic species are all threats to the existence of pristine old growth longleaf pine stands (Varner and Kush 2004). States like Mississippi, Louisiana, and Texas contain little or no old growth longleaf stands, which is the heart of the longleaf pine-bluestem ecosystem (Varner and Kush 2004).

2.) Species diversity

The (Peet and Allard 1993) characterized the longleaf pine ecosystem into 5 xeric, 6 subxeric, 4 mesic, and 8 seasonally wet communities. The mesic longleaf pine woodlands which have a mixture of bluestem and wiregrass in the understory contained between 100 and 140 vascular plants per 1000m^2 which identifies it as one of the most species rich communities in temperate North America (Peet and Allard 1993; Peet et al. 1990). In old growth mountain longleaf pine stands located at Fort McClellan in the Blue Ridge Physiographic Province of Alabama, Varner et al. (2003) identified 72 native understory species. Paintbrush bluestem (*Andropogon ternarius* Michx.) was identified as one of the dominating understory species. Kush et al. (2000) found slender bluestem (*Schizachyrium tenerum)* to be the most frequent occurring species across all treatments associated with the study on the Escambia Experimental Forest in Brewton, AL. (Brockway and Lewis 2003) documented 148 vascular plant species in the longleaf pine bluestem ecosystem in the Conecuh National Forest in Covington County, AL.

4.) Persistence/Cost Effective

Even in the longleaf pine wiregrass range, bluestem can still dominate the understory. Wiregrass does not reestablish itself once it has been removed (Grelen 1978). An area where wiregrass has died out or been mechanically removed can be occupied by bluestem. Bluestem can also become a dominant component in the understory depending on management strategies. An old growth longleaf pine stand in Flomaton, AL had not been burned for 45 years. After a prescribed burn regiment was implemented, *Andropogon virginicus* seeded in naturally (Varner et al. 2000). To reestablish wiregrass after it has died out or been remove, extensive planting operations need to be executed. Bissett (1997) provided an estimate of $3,365/ha in an effort to reestablish wiregrass with a direct seeding method. Pittman and Karrfalt (2000) gave a production cost of $170/1000 for wiregrass seedlings. These costs are very important to landowners that are trying to restore native understory species in longleaf pine forests.

5.) Adaptations to prescribed fire

Wiregrass and bluestem are both well adapted to fire, which is important to the survival of the longleaf pine ecosystem. One advantage bluestem has is that it disperses its seeds by the wind unlike the fire dependent wiregrass (Miller and Miller 1999). On the other hand, wiregrass seed production requires fire to enter the stand in the late spring and early summer (Miller and Miller 1999). Without frequent summer burns, the existence and forage value of wiregrass can suffer while bluestem continues to flourish. Kush et al. (2000) found a higher species diversity for biennial winter burning than spring and winter burns in bluestem dominated understories. An advantage for bluestem is that it is not reliant on summer burns for survival, which allows more flexibility in scheduling burns. External limitations on prescribed burning continue to increase mainly as a result of conflicts with an increasing urban interface and number of smoke sensitive areas. Prescribed burn practioners do not need to place further internal restrictions on themselves and narrow the window of opportunity to burn a particular location only in the summer. As it becomes more and more difficult to burn, some fire is better than no fire.

6.) Wildlife and production agriculture benefits

Wiregrass and bluestem are also sources of forage for cattle and wildlife. After a burn, wiregrass and bluestem are both preferred forage. However, wiregrass is not preferred 3-4 months after a burn, while bluestem is still preferred (White and Terry 1979). Along with the food and fuel sources bluestem provides, it is also very useful as cover to wildlife. Even through the lack of fire and extensive changes in overstory composition, bluestem has been persistent in the longleaf pine-bluestem ecosystem (Grelen and Duvall 1966).

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EXAMINING GROWTH RESPONSES OF YOUNG LONGLEAF PINE TO VARIATIONS IN ENVIRONMENTAL CONDITIONS

John C. Gilbert, Ralph S. Meldahl, John S. Kush and William D. Boyer

Abstract: From 1969 to 1980, forty young longleaf pine (*Pinus palustris* Mill.) trees were measured on the Escambia Experimental Forest in Brewton, AL. All trees ranged from 1 to 1.5 meters tall and were evenly divided between a Lucy loamy sand and a Wagram loamy sand. Ten randomly selected trees from each soil type were shaded during the first year of the study by suspending a square meter of cheese cloth two feet above the leader. From 1969 to 1970 heights of the terminal leaders and the diameters of the trees were measured monthly and weekly depending on the period of the growing season. During the peak of the growing season, height growth measurements were taken daily and even hourly. After 1970, height and diameter measurements were recorded annually until 1980. To determine the effects of the environment on growth patterns, measurements of humidity, solar radiation, wind speed, and soil moisture were also recorded during the 1969 and 1970 growing seasons. An onsite weather station recorded air temperature and rainfall measurements daily during the entire study. Analyses of variance will be used to identify potentially significant differences in growth between shade treatments and soil type differences on different time scales. Multiple regression procedures will be used to identify potentially significant relationships between tree growth and the recorded environmental conditions.

HEIGHT OVER AGE CURVES FOR PLANTED LONGLEAF PINE

J.C.G. Goelz

Abstract: Predictions of height are needed in three different contexts. (1) Given a measurement of height at some known age, a prediction of site index (height of healthy dominant and co-dominant trees at an index age of typically 50 or 25 years) is desired for evaluating site productivity. (2) Given a known value of site index, there is a desire to know the development of height with age. This may be desired simply to explore patterns of height growth among different sites, or it may be needed in a growth and yield model that starts from "bare ground" with site index being one of the input variables. (3) Given a measurement of height at some known age, a prediction of height at some later age may be desired to update inventories between measurements or in a growth and yield model that projects measured stands to future conditions (rather than starting from bare ground conditions). I fit equations using a large dataset of planted longleaf pine. The work is part of a larger effort to develop a growth and yield model for longleaf plantations. I present graphs of equations developed for these three different purposes. The curves for purpose (1) and (3) are very similar to each other, but dissimilar to the curves for (2). The actual equations are very similar for all purposes, but it is the fitted parameters that vary.

Predictions of height are needed in three different contexts. (1) Given a measurement of height at some known age, a prediction of site index (height of healthy dominant and co-dominant trees at an index age of typically 50 or 25 years) is desired for evaluating site productivity. (2) Given a known value of site index, there is a desire to know the development of height with age. This may be desired simply to explore patterns of height growth among different sites (often called "site curves"), or it may be needed in a growth and yield model that starts from "bare ground" with site index being one of the input variables. (3) Given a measurement of height at some known age, a prediction of height at some later age may be desired to update inventories between measurements or in a growth and yield model that projects measured stands to future conditions (rather than starting from bare ground conditions).

Often, a single base-age invariant equation will be estimated that is intended to do all of these things with one equation. However, that will not be the most statistically-efficient approach. As I like to create models that are as accurate as possible, I chose to produce three different models.

I fit equations using a large dataset of planted longleaf pine. The work is part of a larger effort to develop a growth and yield model for longleaf pine plantations (Goelz and Leduc 2001; 2002; 2003; Goelz 2001). Part of the data set was used in Lohrey and Bailey (1977), although the plots have been remeasured several additional times since then. I present graphs of equations developed for these three different purposes. The curves for purpose (1) and (3) are very similar to each other, but dissimilar to the curves for (2). The actual equation forms are very similar for all purposes, but the fitted parameters that vary. They are basically revisions to the model of McDill and Amateis (1992). The curve forms are intrinsically base-age invariant, meaning they could potentially be used for all three purposes, but they are fit individually to provide more efficient models.

In figure 1, I contrast the "site curve", which predicts height at any age, given height at base age of 50 years (or site index), with the site index prediction equation, which predicts height at base age, given height at any age. The lines show an above-average site (90) and a below-average site (70). Note that the site curve and site prediction curve cannot be too dissimilar, since they both go through height at base age and are zero at age 5 (the length of the grass stage specified in this example). The difference is most clear at the youngest age that is graphed. The site index prediction equation is more extreme than the site curves; for high site (90), the site index prediction equation has greater height at young ages while at the lower site (70), the site index prediction equation has a lower height than the site curve. If the site curves were erroneously used to predict site index, and height at a young age was used, they would overpredict site index for site quality above the average and underpredict site index for stands of low site quality.

In figure 2, I contrast the site curves with the height prediction equations, which predict height at any age, given height at any other age. The endpoints of each site curve (at age 15 and 70) were used as predictor variables in the height prediction equation to generate two curves for comparison to each of the site curves. For example, the curve coincident with the site index 70 site curve at age 15 was generated by using the predicted height at age 15 of the site index 70 curve as the independent variable in the height prediction equation. Again, the curves estimated for different purposes are different, in spite of both of them representing height-over-age curves.

The site curve (model 2) differs considerably from the site index prediction equation (model 1) and the height projection model (model 3). While a single equation could be estimated to perform all tasks, more accurate predictions are obtained by using a model for the specific purpose at hand.

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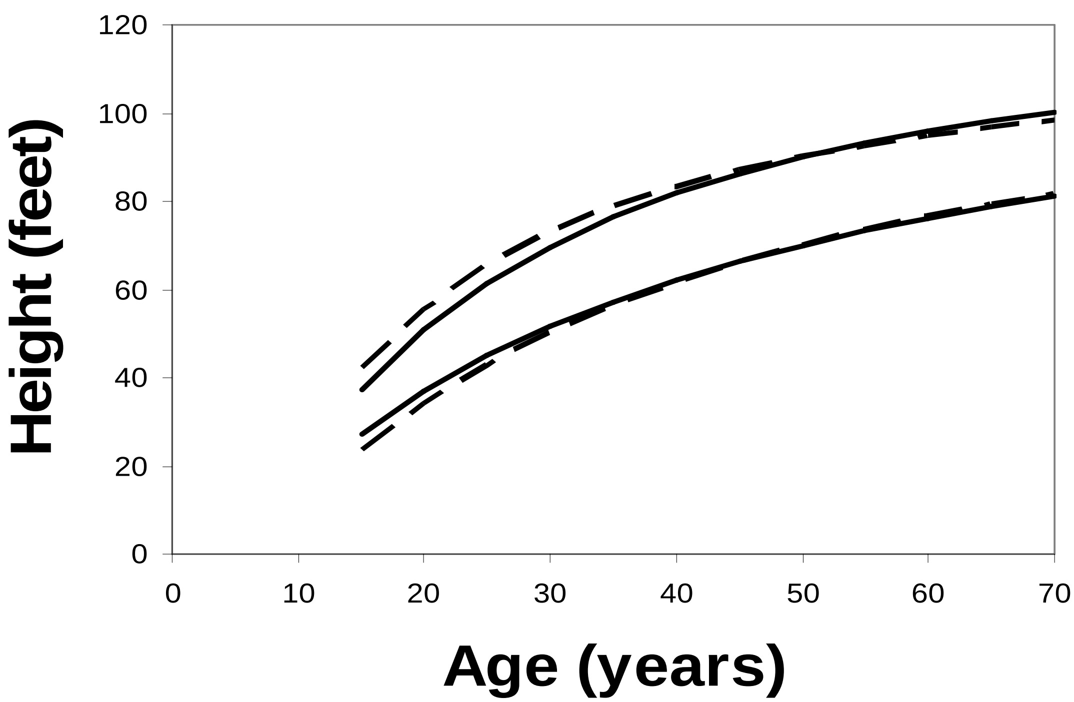

Figure 1. Site curves (prediction of height, given a known site index) for site indices of 70 and 90 are plotted with solid lines. Site index prediction equations (prediction of site index, given height at some other age) for the same site indices are plotted with dashed lines.

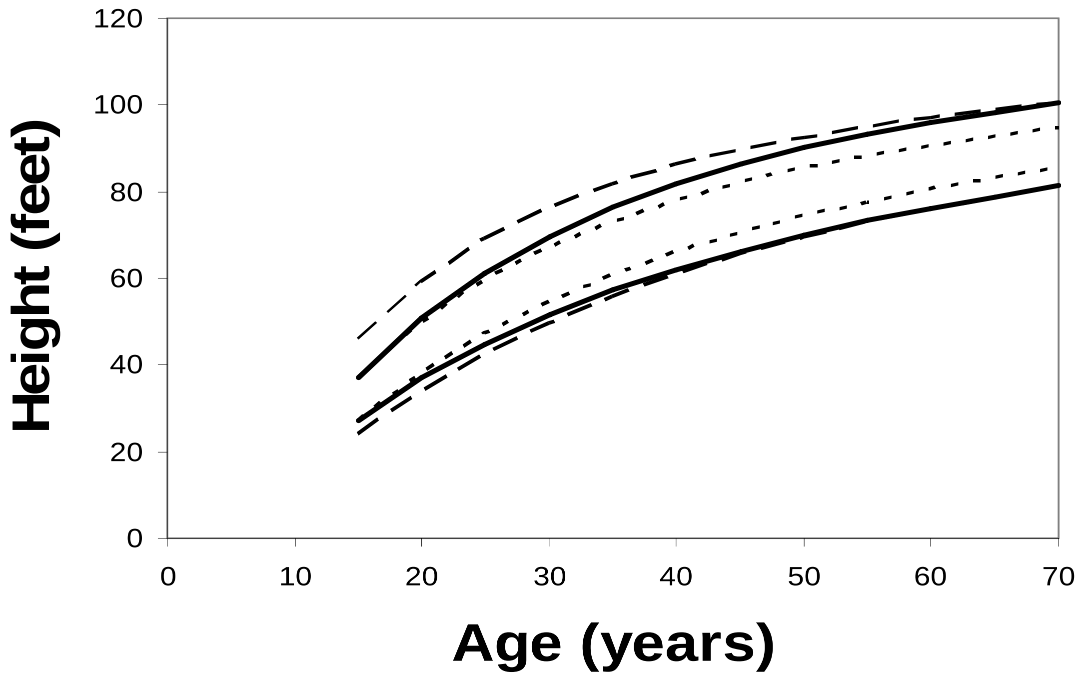

Figure 2. Site curves are plotted with solid lines for site index of 70 and 90. Height projection equations are plotted using age 15 (dotted lines) and age 70 (dashed) heights from the site curves as predictor variables for the height projection equation.

LAND USE LEGACIES AND UPLAND FOREST OVERSTORY STRUCTURAL CHANGE IN SOUTHWEST GEORGIA

Darroc Goolsby, Lindsay Boring and Michael Wimberly

Abstract: This project proposes to elucidate historical land use effects on hardwood succession in longleaf pine woodlands on the J.W. Jones Ecological Research Center at Ichauway in southwest Georgia. Land use legacies will be documented from historical documents, historical maps, and aerial photograph series. Aerial photograph series will be used to analyze the spatial and temporal patterns of canopy change. Age class distributions will be used to verify stand histories and document successional trajectories. These generalizations will provide useful data to land managers and conservationists working to restore longleaf pine ecosystems and maintain multiple use longleaf pine woodlands.

INTRODUCTION AND BACKGROUND

Forest overstory structure is determined by geomorphology, existing vegetation, disturbance, and species response to disturbance (Myers 1990). Fire drastically shapes the structural characteristics of longleaf pine (*Pinus palustris*) forests. While frequency and intensity of fires are important factors, the spatial and temporal extent and structure of fire patches also play a dominant role at the sub-landscape level (Glitzenstein et al 1995). In today's human impacted landscape, fire suppression and habitat fragmentation associated with land use legacies have caused many of the remaining longleaf pine woodlands to follow hardwood successional trajectories (Robbins and Myers 1992).

Quail hunting plantations provide a valuable but complex venue in which to study longleaf pine. Many of the remaining old growth and well conditioned longleaf stands occupy former and current quail management lands (Landers et al 1995). Prior to 1989, Ichauway was managed as a bobwhite quail hunting plantation. A generalized timeline for historic Ichauway Plantation and southwest Georgia is presented in Table 1.

The use of fire on quail plantations to maintain habitat and open the woodlands for easy access helped maintain these ecosystems from completely succeeding into mixed or southern hardwood forests. However, the common practice of annual burning also precluded effective longleaf pine regeneration and winter burning may have failed to control invading hardwoods (Jacqmain 1999). On Ichauway, decades of presumed cool season or annual fire regimes and woodland fragmentation have led to areas with extensive hardwood succession that is now undergoing mechanical removal. It is important to understand how land use legacies influence hardwood succession in order to make decisions about restoration and future management.

OBJECTIVES

The main objective of this research is to examine the effects of historical land use legacies on the spatial and temporal patterns of hardwood succession in upland longleaf pine ecosystems. Successional patterns will be examined through reconstruction of stand histories using historical aerial photographs and age class distributions.

Hypotheses presented are not mutually exclusive. These hypotheses cover a wide range of spatial and temporal patterns and it is likely that more than one will be applicable depending on the scale of inquiry. Use of these hypothetical models provides testable straw-man scenarios, or multiple working hypotheses, against which patterns that are revealed can be compared.

Hypothesis 1 – Diffuse Model

Hardwoods encroached (diffused) evenly across space and time, causing gradual successional changes due to temporal and spatial variability in fire frequency and extent in conjunction with land use legacies such as historical timber removal and turpentining.

Hypothesis 2 – Event Punctuated Model

Hardwood encroachment was event punctuated with periods of widespread hardwood recruitment and little to no pine regeneration. Historical pine timber removal combined with annual burning provided broad-scale opportunities for hardwood recruitment, while precluding broad-scale longleaf pine stand recruitment and establishment.

Hypothesis 3 – Nucleation Model
Land use activities created distinct features that served as spatial foci for hardwood encroachment. Fragmentation of longleaf pine woodlands by fields, food plots, timber removal, and homesites resulted in loss of fuel continuity that led to spatial heterogeneity of burned areas and expanded dominance of hardwoods.

METHODS
Land use and canopy change will be analyzed for the period of ~1930 to ~1994 using historical documents, historical aerial photograph series, and age class distributions derived from counting rings from hardwood stumps and increment bores from hardwoods and longleaf pines. Inferences about land use effects on longleaf pine woodlands will be drawn based on landscape analysis of the spatial distribution of hardwood successional areas and the temporal scale of those changes. Patterns found will be compared to the hypothetical models presented in order to make generalizations about the effects of land use legacies on succession in longleaf pine woodlands. Table 2 shows the three hypothetical models and criteria for validation.

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Table 1. Generalized timeline for Ichauway Plantation and southwest Georgia

Time	Land Use
Mid to late 1800s	*Widespread timber harvest * Widespread turpentining * Some settlement and agriculture
~1900 to ~1920	* Widespread timber harvest * Most of oldgrowth longleaf pine removed * Widespread turpentining * Livestock production * Increasing settlement and agriculture
~1920 to ~1940	* Acquisition of properties to form Ichauway Plantation * Quail management * Timber harvest * Turpentining * Livestock production *Dry-land agriculture *Some fire suppression
~1940 to ~1960	* Quail management * Timber harvest * Turpentine trees removed in timber harvest * Dry-land agriculture * Livestock production
~1960 to ~1990	* Quail management * Timber harvest * Dry-land agriculture * Decreasing livestock production * J.W. Jones Ecological Research Center created in 1991

Table 2. Hypothetical models, measurements, and hypothesis validation.

Measurement	Hypothesis 1 Diffuse	Hypothesis 2 Event Punctuated	Hypothesis 3 Nucleation
Age Class Distribution (ACD) – Stand History and Successional Trajectory	*Longleaf ACD generally peaked towards center of distribution or older age classes *HW age classes fairly even *Pine and HW age classes distributed evenly or randomly across patches and landscape (not clustered or clumped)	*Peaks in HW ACD – correlating with known management events and release of hardwood succession *Gaps in longleaf ACD correlating with timber removal or peaks correlating with regeneration	*Decreasing hardwood age with distance from fragmentation feature *Overall increase in longleaf ages with distance from fragmentation feature
Cover Type Patches From Historical Aerial Photo Series– Overstory Structure and Change	*Long time-scale disturbance such as change in fire regime and/or continual conifer removal *High probability of change from pine to mixed cover types for all patches regardless of proximity to fragmentation features *Examination of intermediate photos shows gradual cover change: pine to mixed to hardwood	*High probability of pine patches to change to hardwood patches, especially in patches with decreases in pine cover *Examination of intermediate photos shows no intermediate successional step	*Decrease in pine patch extent and frequency *Individual hardwood patches increasing in size through time *High probability of pine patch transition to hardwood patch with increasing probability of change closer to fragmentation feature

DIRECT SEEDING NATIVE HERBACEOUS SPECIES INTO PLANTED LONGLEAF ON AN AGRICULTURAL SITE

Mark J. Hainds, John Dickson and Rhett Johnson

Abstract: Approximately 200,000 acres of longleaf (*Pinus palustris*) have been planted through the Conservation Reserve Program (CRP) on agricultural sites in recent years. Restoration of the longleaf ecosystem and creation of good wildlife habitat are two goals of the CRP. Native legumes and other native perennial species are vital components in longleaf ecosystem restoration and good wildlife habitat. Yet, The Longleaf Alliance (LLA) and other organizations have noted very few native perennial herbs re-colonizing sites that were planted to longleaf on these agricultural sites. A representative stand was selected for direct-seeding of native legumes and other perennial herbs. Eight site preparation treatments were applied to a longleaf plantation established in 1996 & 1997 on a site previously occupied by a pecan orchard overstory with an introduced pasture grass understory. Following site preparation, the study site was direct seeded with herbaceous species native to the longleaf ecosystem. Plots were surveyed twice to assess establishment rates for direct seeded species and site preparation effects on introduced grasses. Principal herbaceous species at the time of study installation were bahia grass (*Paspulum notatum*), bermuda grass (*Cynodon dactylon*), and winter rye (*Lolium temulentum*).

PRESCRIBED BURNING RESEARCH IN LONGLEAF PINE ON THE KISATCHIE NATIONAL FOREST

James D. Haywood

Abstract: Fire research on the Kisatchie National Forest has spanned the last five decades leading to a greater understanding of fire behavior in longleaf pine forests. Based on early research, we believe the chief influence of burning in natural longleaf pine forests is not that fire increases pine yields but how fire influences overall stand structure and species composition. Without fire, mixed pine hardwood stands replace longleaf forests. Other vegetation management treatments can substitute for fire, but none is cost effective when treating more than a hundred thousand acres a year. In addition, we learned that young stands of longleaf pine benefit from springtime prescribed burns, a finding that helped spur an interest in growing season burning. In later work, herbaceous plant control was the key to getting seedling longleaf pine out of the grass stage and increasing height growth. In addition, prescribed burns should be initiated and continued even on sites where burns are apparently low in intensity and often spotty. Diverse herbaceous plant communities can establish on such sites, and so, restoring diverse plant communities may be less difficult than originally believed in the West Gulf Coastal Plain. The key is to keep burning.

Prescribed burning research on the Kisatchie National Forest has spanned the last five decades leading to a greater understanding of fire behavior in longleaf pine (*Pinus palustris* P. Mill.) stands. Based on early work, Grelen (1975) reported that biennial burning in May resulted in larger longleaf pine saplings than biennial burning in either March or July. The positive relationship between May burning and greater longleaf pine stature continued through 37 years (Table 1) (Haywood et al. 2001). However, when both longleaf and loblolly (*P. taeda* L.) pines were considered, the unburned plots produced nearly as much pine volume as the March burned plots and more than the July burned plots in this study. Thus, the chief influence of burning in natural stands is not on long-term pine yield but on how fire influences overall stand structure and species composition.

Table 1. Stand characteristics for either longleaf pine or both longleaf pine and loblolly pine following 37 years of prescribed burning in a natural longleaf pine stand in Louisiana; burning began when the longleaf pines were in the grass stage.

Taxa and treatments	Stocking (stems/ac)	Basal area (ft^2/ac)	Volume production (ft^3/ac)	Mean total height (ft)
Only longleaf pine				
Unburned	55	46.6	1,500	79
March burns	210	97.3	2,870	70
May burns	195	131.7	4,315	80
July burns	88	65.6	1,970	70
All pines				
Unburned	78	80.3	2,652	81
March burns	210	97.3	2,870	70
May burns	195	131.7	4,315	80
July burns	88	65.6	1,970	70

Without the repeated use of fire (such as the unburned plots in Table 1), a forest canopy develops with a basal area divided comparatively among longleaf pine (40% of basal area), loblolly pine (29% of basal area), and hardwood trees (31% of basal area) (Haywood et al. 2001). Beneath this canopy is a well-developed understory of woody plants and vines, but the deep shade and accumulation of litter nearly eliminates herbaceous vegetation and pine regeneration. Conversely, repeated prescribed burning can maintain longleaf pine forests. Midstory control and litter removal allows sunlight to reach the forest floor, and grasses and forbs naturally reestablish in forested uplands of the West Gulf Coastal Plain (Haywood et al. 1998).

These early studies showed the importance of prescribed burning in the management of longleaf pine and for establishing natural longleaf pine regeneration. A timely fire regime is the only vegetation management practice that is applicable over many thousands of acres yearly to reduce fuel loads and control hardwood trees and shrubs. Fire should be applied when woody stems start to become reestablished in the understory (Haywood et al. 2001). Frequency of burns is dependent upon site productivity and the desired or existing plant community. However, herbicides or mechanical means may be needed where vegetation is too large or extensive to control with prescribed burning.

When it becomes time to harvest timber, it would be ideal to retain longleaf pine trees either through shelterwood with reserved longleaf pine trees, group selection, or singletree selection. This better sustains the long-term ecological character of the longleaf pine ecosystem than removal of all trees by either the conventional shelterwood method or clearcutting (Farrar and Boyer 1991, Boyer 1993, Palik et al. 1997, Ross et al. 1997, Brockway and Outcalt 1998).

However, species composition and stand structure suited for conventional shelterwood, group selection, or singletree selection are not always present on sites where restoring longleaf pine is the management objective. When a site is in pasture, old-field, or there are too few longleaf pine seed trees, the best option for reestablishing longleaf pine is removal of the woody vegetation, site preparation, and planting. Barnett (2002) recommends planting container stock over bareroot seedlings to ensure better survival under adverse conditions.

In current research, I examined seedling longleaf pine growth after planting in either a grass-dominated open range (the grassy site) or after a mature loblolly pine-hardwood forest was clearcut followed by chop and burn site preparation (the brushy site). The longleaf pine seedlings emerged more rapidly from the grass stage on the brushy site than on the grassy site regardless of vegetation treatments (Figures 1 and 2). In fact, longleaf pines on the brushy site were as tall after three growing seasons as the longleaf pine on the grassy site were after six growing seasons.

Herbaceous plant control significantly increased the growth of longleaf pine regeneration on both sites even though woody plants were the primary understory vegetation on the brushy site (Figures 1 and 2). I partly attributed the differences in growth rate between the two sites to differences in the degree of herbaceous competition, with the grassy site having the most herbaceous vegetation and the least longleaf pine growth.

Differences in inherent site quality are likely influencing growth rate differences between the two sites as well (Figures 1 and 2). However, differences in the intensity of the prescribed burns may be more important. Grass dominated fuels carry intense prescribed burns in young longleaf pine stands, which can adversely affect seedling and sapling growth (Haywood 2002). At the brushy site, there was less grass and more erect forbs than at the grassy site, and this non-uniform, sparse, vertical fuel bed kept fire intensities low at the brushy site.

Woody plant control did not affect longleaf pine growth (Figures 1 and 2). On the grassy site, the fires were intense and the combination of burning and herbaceous plant competition may have kept the woody vegetation in check. On the brushy site, the fires were less intense but woody plant control still did not benefit the longleaf pine. Apparently, woody plant control is not beneficial in terms of seedling development, but woody plant control is needed to keep woody vegetation in check long enough for fuel conditions to reach a stage where more intense fires are possible. If the woody vegetation develops unchecked in young longleaf pine stands, an eventual return to mixed pine-hardwood forests will be the likely outcome because loblolly pine and hardwood brush will outgrow many of the longleaf pine seedlings (Haywood 2000, Haywood and Grelen 2000, Haywood et al. 2001).

However, some land managers may be willing to allow brush encroachment on sites where intense prescribed burns are not achieved during stand establishment with the opinion that by the time canopy closure is reached needle cast will improve fuel bed conditions and more intense fires will be possible. After stand closure, repeated burning coupled with a chemical or mechanical hardwood release treatment can be used to create the kind of open stand conditions that have proved difficult to achieve on the brushy site using early intervention practices (Figure 2).

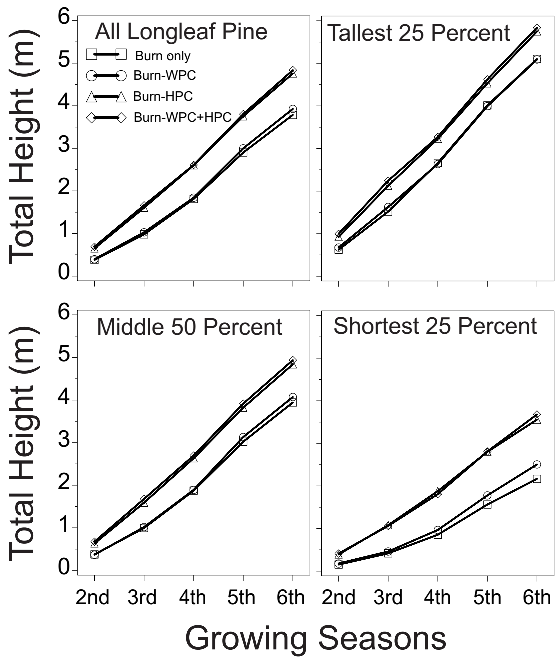

Figure 1. On the grassy site, total height of all longleaf pine trees and total height of the tallest 25%, middle 50%, and shortest 25% of the longleaf pine trees by treatment combination: HPC-herbaceous plant control and WPC-woody plant control.

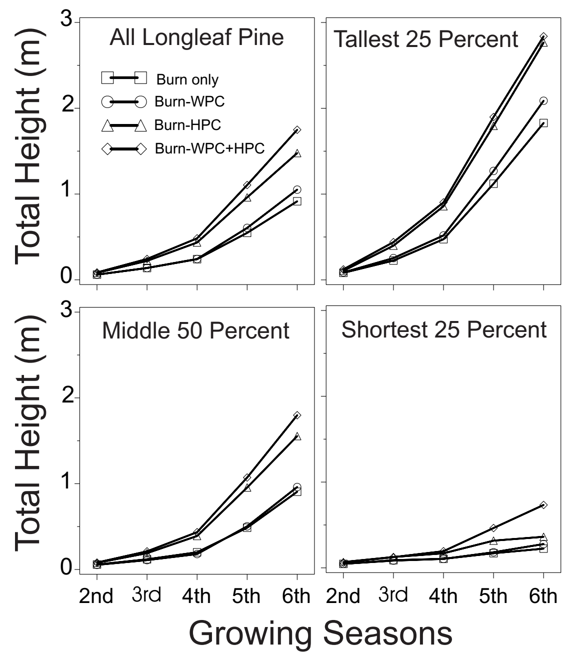

Figure 2. On the brushy site, total height of all longleaf pine trees and total height of the tallest 25%, middle 50%, and shortest 25% of the longleaf pine trees by treatment combination: HPC-herbaceous plant control and WPC-woody plant control.

If land managers focus on crop trees and not on the overall population of trees, the adequate growth rate of the tallest 25% of the longleaf pine trees on all treatments suggests that applying herbaceous or woody plant control in the first few growing seasons after planting is not necessary for adequate stand development (Figures 1 and 2). Good stands of longleaf pine can be achieved in the long term with less intensive management. Nevertheless, it is likely that where vegetation components have shifted away from the historical longleaf pine-grassland type, such as the brushy site, an aggressive burning program applied over several decades will be necessary to eventually decrease the number and stature of competing woody plants and favor herbaceous vegetation (Waldrop et al. 1992).

Diverse plant communities developed on both the grassy and brushy sites. On the grassy site, there was a well-established grassland community before the longleaf pines were planted. Eighty-five herbaceous species and 19 woody species were commonly found and 16 of the plant species were indicators of a well-developed understory in a longleaf pine forest in Louisiana (Turner et al. 1999). On the brushy site, many plants common in the original mature loblolly pine-hardwood forest were widespread after longleaf pine establishment. By the fourth growing season, 101 herbaceous species and 34 woody species were widespread on the brushy site, and 20 of the plant species were indicators of a well-developed understory in a longleaf pine forest. Therefore, the brushy site had a more diverse plant community than the grassy site. Based on visual observation of site conditions, this was surprising. Usually, loblolly pine-hardwood stands are thought to be degraded, requiring great effort to restore to longleaf pine grasslands. These studies demonstrate that in the West Gulf Coastal Plain, restoring a diverse understory plant community may be less difficult than originally believed on forestlands. The key is to keep burning.

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TWO PROTECTED SPECIES OF THE LONGLEAF ECOSYSTEM AT THE CAMP SHELBY TRAINING SITE, MISSISSIPPI

Matt Hinderliter and James Lee

Abstract: The 56,000 ha Camp Shelby Training Site (CSTS), located within the DeSoto National Forest in south central Mississippi, serves as a training facility for the Army National Guard and harbors several animal species of state concern. The site is dominated (~70%) by longleaf pine (*Pinus palustris*), and is managed by both the Army National Guard and the United States Forest Service. Species of concern endemic to the site include (but are not limited to) the federally threatened Gopher Tortoise (*Gopherus polyphemus*) and the Black Pine Snake (*Pituophis melanoleucus*), a candidate for federal listing. Current research at Camp Shelby focuses upon the direct impacts that management of the longleaf pine ecosystem (e.g. prescribed burning) has upon species (e.g. *G. polyphemus*), and considers the potential impacts that management activities may have upon species (e.g. *P. melanoleucus*). Current tortoise research includes a radiotelemetry project that compares the presence and absence of prescribed burning on tortoise habitat utilization. Since tortoises use both open, ruderal areas and open forested areas devoid of shrubby undergrowth, the project looks to determine whether tortoises can be persuaded to move into the forests if they are made more habitable by fire. Pine snake research at CSTS is focused upon the seasonal activity, movement patterns, and home range of the species; data which will be useful in making future management decisions. Data pertaining to both the tortoise and pine snake will be presented.

INTRODUCTION

The 56,000 ha Camp Shelby Training Site (CSTS), located primarily within the DeSoto National Forest in south central Mississippi serves as a training facility for the Army National Guard and harbors 17 animal species of state concern (Leonard *et al*., 2000). The site is dominated (~70%) by longleaf pine (*Pinus palustris*), and is managed by both the Mississippi Army National Guard (MSARNG) and the United States Forest Service (USFS). The goals of this poster are 1) provide a brief description of the Gopher Tortoise (*Gopherus polyphemus*) and Black Pine Snake's (*Pituophis melanoleucus lodingi*) natural history, 2) describe current studies being conducted on these species by The Nature Conservancy's Camp Shelby Field Office and 3) discuss future research ideas.

BLACK PINE SNAKES AT CAMP SHELBY

The Black Pine Snake, a candidate for federal listing by the USFWS, has a restricted range in Mississippi of only a few (14) southern counties. The CSTS contains thousands of acres of "prime" pine snake habitat, and the majority of pine snakes documented in the state fall within its boundaries (Duran, 1998b). "Prime" habitat is characterized by mature longleaf pine forest with loose, sandy soils, open canopies, moderately fire-suppressed midstories, and thick, grassy understories. Despite extensive work on Black Pine Snakes at CSTS (Duran, 1998a), little remains known of the subspecies daily activity patterns, and more can be learned regarding movement patterns and seasonal home range.

<u>Black Pine Snake Telemetry Study</u>

A two year project initiated by Evan Myers (former biologist for TNC) intended to examine daily and seasonal movement patterns in addition to further analysis of pine snake habitat preference. Starting in mid June 2004 traps were placed along the tops of sandy ridges, in areas where longleaf pine canopy cover did not exceed 70%. Traps varied in type and size, although in general consisted of at least one 1m tall by 8m long drift fence, with either a funnel or box trap attached to each end (see Fitch, 1987). Upon capture of a pine snake the animal was measured (snout to vent and tail length), sexed, and weighed. The individual was then removed from the field for 1-3d and implanted with a temperature sensitive radio transmitter (Holohil Systems Ltd.), after which time individuals were released at their point of capture. Implantation procedures followed those of Reinert and Cundal (1982) with a few modifications (see Hardy and Greene, 1999, 2000); all implantations were (to date) performed at the Saucier Veterinary Hospital under sterile conditions. Implanted animals are currently relocated three times a week at which time a number of environmental, habitat, and ethological variables are recorded. Below is a brief synopsis of some data collected to date; the reader is cautioned that these are very preliminary findings and should be thought of as trends rather than results.

Black Pine Snake Captures and General Trends

Since August six pine snakes have been captured and surgically implanted with radio transmitters (3 Males, 2 Females and 1 Juvenile). Of the individuals that have been relocated 10 or more times (N = 4, 2M:2F), males have a larger home range size (mean $\pm$ SD = 29.10 $\pm$ 1.48 ha) than females (20.73 $\pm$ 1.30) and tend to move more frequently (16 $\pm$ 4.24; 12 $\pm$ 2.83, respectively). Males also tend to spend on average 20% more time above ground than females. Table 1 summarizes home ranges and movements of Black Pine Snakes to date.

Future Goals for Black Pine Snake Research on Camp Shelby

Next year we will continue trapping for pine snakes, although a few modifications will be made to the project (budget and time permitting). These changes will include standardization of trap sizes, the use of automated temperature probes to monitor environmental conditions, and implantation of miniature temperature data loggers into snakes that will record body temperatures every few minutes (in which case costly temperature sensitive transmitters will be replaced with cheaper "locate only" models). The latter modification to the study will greatly aid in determining daily activity patterns (e.g. are snakes above or below ground?), which will aide future natural resource agencies, both in terms of developing survey protocols for Black Pine Snakes and when timing management activities.

Table 1. Summary of home ranges for Black Pine Snakes found at the Camp Shelby Training Site (2004). Home range size is in hectares. J = juveniles, M = males, F = females

Snake #	Sex	# Movements	Home range size
1	M *	19	30.14
2	F *	14	21.65
3	M *	13	28.05
4	J	10	4.85
5	F *	10	19.81
6	M	6	1.95

* Animals used in preliminary analysis.

GOPHER TORTOISES AT CAMP SHELBY

The Gopher Tortoise is a large, fossorial turtle that typically lives on well-drained, deep, sandy soils which it uses to excavate burrows and dig nests. In addition to soil type, other habitat requirements of Gopher Tortoises in Mississippi include a canopy open enough for basking and incubating eggs, and adequate herbaceous ground cover for forage. Tortoises generally excavate several burrows during their lifetime and readily use the burrows of other tortoises (Diemer, 1992). Tortoise burrows at Camp Shelby are found in the longleaf pine forests, although the majority of burrows are located on ruderal areas. These areas (e.g. firing points and ranges) are cleared of trees, kept in an herbaceous stage by annual dormant season mowing (Epperson and Heise, 2001), and are used extensively during military training. The United States Fish and Wildlife Service Recovery Plan (U.S. Fish and Wildlife Service, 1990) identified tortoises on the DeSoto National Forest as a recovery population, and this population occurs almost entirely on the Camp Shelby Training Site. It is thought to be the largest metapopulation of Gopher Tortoise in the western portion of their range (Jennings and Fritts, 1983).

Prescribed fire is used as a management technique on Camp Shelby; however, due to drought years and lack of funding, much of the pine forest habitat has not been burned as regularly as is necessary to maintain good Gopher Tortoise habitat. This has led to an increase in shrubby, midstory vegetation, an increase in canopy cover, and a decrease in herbaceous ground cover in many of the upland pine forests historically used by the tortoises; this may explain why tortoises inhabit firing points and ranges more frequently than the adjacent longleaf habitat (Auffenburg and Franz, 1982; Diemer, 1986).

Prescribed Burning and Gopher Tortoise Habitat Study

The ongoing four-year project (2001-2004) investigates whether the use of prescribed burning can improve the shrubby, overgrown forested areas to provide a more suitable habitat for gopher tortoises. This will be tested by measuring changes in the vegetation throughout the study and comparing the results to recommended guidelines for Gopher Tortoise habitat. With the use of radio-telemetry, we are also examining whether the improvement of these forested habitats can change the burrow usage by the tortoises living in ruderal areas.

The study sites for this project include 4 control sites with an unaltered pine forest buffer area around them, and 4 treatment sites where the buffer area has been burned. The eight sites chosen all had similar habitat quality, similar soils, and the presence of a tortoise colony. For several of the treatment sites, the midstory vegetation had become so overgrown that initially conducting a growing season burn could have proven potentially dangerous by killing many of the timber trees. Therefore it was decided to conduct dormant season burns during 2001/2002 to reduce some of the midstory vegetation. Growing season burns were conducted on treatment sites in late April of 2003.

Vegetative Analysis Design and Results

Two methods were used to collect vegetation data. Vegetation was sampled along transects to document changes in vegetation over time in both the treatment and control sites. We collected pre-treatment data in 2001 to establish baseline vegetation data for each study site, and transects were re-surveyed during the same time period for the next three summers. In addition, we determined vegetation at all the burrows used by tortoises to see what habitat characteristics are associated with burrow usage. To determine how tortoises respond to the changes in habitat we conducted these burrow surveys annually as well. On the transects and around the burrows, data collected in the quadrats included: 1)canopy cover, 2)herbaceous heights, 3)stem counts of woody species, categorized by diameter, 4)topographic position, 5)overall physiognomy, and 6)percent ground cover of herbaceous forms (total herbaceous, grasses, forbs, legumes, and woody/vines), shrubs, leaf litter, and bare ground. Data analyzed in 2003 showed a decrease in woody cover at all of the treatment sites and an increase in woody cover at all of the control sites. Preliminary analysis of subsequent data has shown that this trend continued, although percent cover of herbaceous forms has not been found to have significantly changed after burning.

Gopher Tortoise Radio-Tracking

Preliminary results of the radio-tracking study show that some of the tortoises display variable home ranges year to year, and most utilize burrows both in the open and in the surrounding forest. Movement patterns do not seem to follow specific seasonal changes, and in fact tortoises can be found both in ruderal and in forested burrows at any time of the year. Tortoises were more often tracked to the open, firing point burrows than forested burrows, regardless of whether the site had been burned, and several tortoises spent the entire time period exclusively on a firing point. However, there were three individuals (one male and two females) that spent the first two years of the study exclusively in burrows on firing points, except for this past summer when all three moved into forest interior burrows for the first time. All three were located at treatment (burned) sites. We do not know whether these movements were due to changes in habitat quality, since they could have moved to meet a behavioral or physiological requirement of which we are unaware, or possibly to avoid contact with humans. A potential future project investigates whether tortoises in close proximity to frequent military training show more stress than those in more pristine sites. This will be done by sampling from a large population of tortoises from several different habitat variables to look for bioindicators of stress.

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CHANGES IN PLANT SPECIES COMPOSITION IN RESTORED WET PINE SAVANNAS FOLLOWING A FIRE FREQUENCY REDUCTION

Sarah E. Hinman and J. Stephen Brewer

Abstract: Frequent fires are necessary to maintain plant species diversity in restored longleaf pine ecosystems. But what happens when reductions in fire frequency occur following restoration? Which species are lost or gained and why? We present preliminary results of a study of plant species composition and diversity in two wet pine savannas in southeast Mississippi. In 1997, two 20 x 50 m plots, each containing 16, 0.5 x 0.5 m subplots were established at different sites. Sites had been burned once every three years since the early 1980s. Presence-absence was measured in plots and subplots established in grass-sedge-pitcher plant-dominated areas at each site. Since 1997, neither site has been burned and beginning in the Fall 2003, we recensused the plots and subplots and have analyzed changes in species composition using blocked Multi-Response Permutation Procedures. In addition, we used Indicator Species Analysis to identify which species were lost or gained between 1997 and 2003. Plant species composition changed and species richness declined significantly within the subplots. Most of this change could be attributed to the loss of Drosera capillaris, Scleria reticularis, Rhexia lutea, Eriocaulon spp. and some rare species. Pinus elliottii increased significantly (all additions were seedlings). No significant additions of any shrub species occurred due to a lack of suitable perches for dispersal vectors. The study is ongoing and sites will be recensused after a scheduled fire to determine which species reappear following fire and what if any traits are shared by plants that are sensitive to fire frequency reductions.

DETERMINING THE CURRENT DISTRIBUTIONS OF CRITICALLY ENDANGERED LONGLEAF ECOSYSTEMS: A REGIONAL APPROACH USING REMOTE SENSING TECHNIQUES

John S. Hogland and Mark D. MacKenzie

Abstract: Land use change and harvesting pressures since the early 1600's have significantly reduced the amount of virgin forest across the US. In the Southeast, these human induced pressures have had a dramatic impact on longleaf ecosystems. Longleaf ecosystems historically thought of as the dominant coniferous ecosystems throughout the Southeast, now occupy only 1.2 million hectares of their original range. This loss of habitat has resulted in the listing of longleaf ecosystems as critically endangered.

Currently, the exact location and distribution of these endangered ecosystems are not known. Projects such as the forest inventory analysis have been useful in identifying the declining trends of longleaf ecosystems but are too coarse to answer questions pertaining to fragmentation, exact location, patch size, and financial resource allocation, in turn limiting the ability of organizations to effectively conserve and restore longleaf ecosystems. To aid organizations and land managers in answering important longleaf ecosystem questions, we are currently developing fine scale (30 m grain size) datasets, depicting the current distribution of longleaf ecosystems across portions of the Southeast.

EFFECTS OF BASAL AREA AND FOREST VEGETATION MANAGEMENT ON SELECTED UNDERSTORY CHARACTERISTICS IN LONGLEAF AND LOBLOLLY PINE PLANTATIONS

S.J. Hudson, D.H. Gjerstad, R. Johnson, G. L. Somers, B. Grand and S. Hermann

Abstract: There is an increasing need for scientific information regarding afforestation or reforestation practices for landowners with multiple use objectives, such as recreation, hunting, and/or observing nature and wildlife. In addition, many private, state, and federal organizations and agencies have become increasingly interested in promoting and establishing plantings of longleaf pine (*Pinus palustris* Mill). However, it is unclear which artificial regeneration management strategies should be implemented to enhance the ecosystem structures characteristic of longleaf pine. As a result, a study was initiated in the lower coastal plain of south central Alabama to compare the effects of commonly prescribed tree planting densities and forest vegetation management treatments on understory characteristics located in longleaf and loblolly pine (*Pinus taeda* L.) plantations after seven growing seasons.

Nonlinear models, derived from the information-theoretic approach, were used to examine the relationship between forest stand variables including basal area (BA), tree species (longleaf and loblolly pine), and forest vegetation management (FVM) treatments (FVM and no FVM), and other explanatory variables including percent cover of understory vegetation, litter (pine needles and dead vegetation), and bare ground; understory species richness; percent cover of preferred bobwhite quail foods; species richness of preferred bobwhite quail foods; litter depth (pine needles only); relative photosynthetically active radiation (PAR); and visual obstruction readings. Of the thirty-four biologically credible and interpretable nonlinear models tested, twelve were determined to have substantial support from the data.

Although trees were planted at similar stocking levels, basal areas of the two pine species did not overlap at age seven. A difference between the ranges of basal areas for the two species is relevant to ecosystem structure and wildlife value of the species and is of importance for landowners and forest managers who desire multiple-uses from their forestlands. Basal area was an important factor governing the understory characteristics. When longleaf and loblolly pine are planted at similar densities, longleaf pine allows the forest understory to remain in an early successional stage for a longer period of time than does loblolly. Basal areas in stands ranging from 4.3 m^2/ha to 13.6 m^2/ha for longleaf pine were comparatively better than ranges from 12.2 m^2/ha to 28.2m^2/ha for loblolly pine in promoting understory vegetation and light availability, species diversity, percent cover and species richness of preferred bobwhite quail foods, lower litter depths, lower litter cover, and greater visual obstruction of vegetation. Forest vegetation management also plays an important role in ecosystem structure and wildlife value. At age seven, FVM stands of longleaf and loblolly pine had lower vegetative cover and species diversity of understory vegetation, species richness and percent cover of preferred bobwhite quail foods, and visual obstruction of vegetation than non-FVM stands.

MANAGING FORESTS ON PRIVATE LANDS IN ALABAMA AND THE SOUTHEAST

S.J. Hudson, D.H. Gjerstad and K.L. McNabb

Abstract: The Alabama Forestry Foundation and the Alabama Forestry Commission have contracted with the School of Forestry and Wildlife Sciences at Auburn University to develop a reference book for forest landowners in Alabama and the Southeastern United States. The book is intended to help landowners better understand the forest resources they own and provide them with applied information useful to manage their own forests. It will be modeled after and serve as a companion book to *Managing Wildlife on Private Lands in Alabama and the Southeast* developed by the Alabama Wildlife Federation.

This book will give forest landowners the basic information they need to find and communicate with professionals to help them manage their land. It is not intended to replace advice given by resource professionals; but to supplement that advice. We realize that there are many sources of up-to-date educational and technical information available to forest landowners, however, these publications and reference materials are somewhat scattered throughout a host of many organizations and agencies. As a result, the goal of our publication is to provide "one stop shopping" so to speak, and serve as a clearinghouse for up-to-date forest management information, reference, and a source of technical assistance for forest landowners in Alabama as well as the Southeast.

This book entitled *Managing Forests on Private Lands in Alabama and the Southeast* is being prepared through a partnership with the Alabama Forestry Commission, the Alabama Forestry Foundation as well as forest product companies. A committee established within the Foundation has recommended appropriate content for the book. The committee is comprised of forest industry professionals, public agency personnel, and consulting foresters with expertise in forestry, wildlife and other natural resource management.

Our book will tentatively be about 550 pages in length and have a similar style as the Alabama Wildlife Federation book titled *Managing Wildlife on Private Lands in Alabama and the Southeast*. Leading forestry and natural resource experts will author each individual book chapter and/or section. The text will be complimented by many photographs, charts, diagrams, etc. Our goal is to produce a book to be visually appealing while at the same time allowing landowners to get a thorough and descriptive view of forest management practices.

Managing Forests on Private Lands in Alabama and the Southeast will be available on or around February 1, 2006.

EVALUATING SITE PREPARATION TREATMENTS FOR PLANTING LONGLEAF PINE IN PASTURES

H. Glenn Hughes

Abstract: Obtaining good survival of longleaf pine planted in pastures is often difficult. This project is testing five different site preparation treatments for regenerating longleaf pine on pastureland. The project will give landowners a "side by side" comparison of different site preparation treatments for longleaf pine.
The following site preparation treatments are being tested:

- Control (no treatment)
- Mechanical (sod scalper in 2002)
- Mechanical/Chemical (sod scalper in '02 + Summer '03 Arsenal herbicide)
- Chemical I (Fall '02 Arsenal only)
- Chemical II (Fall '02 + '03 Arsenal)

Arsenal herbicide was applied in Oct. 2002, at 24 oz/acre, and reapplied where indicated in late summer, 2003 at 6 oz/acre. Scalping was conducted in Nov. 2002 with a sod scalper (modified fire plow) pulled behind a tractor. Containerized longleaf seedlings were planted on all treatments in Dec. 2002 at a spacing of 8' x 10' (545 trees/acre), and there were 3 replications of each treatment.

Three data sets were collected; plant survival after one growing season (Jan. 04), height growth after first flush in '04, and number of fascicles per plant in '04. Although survival was high in all treatments due to favorable precipitation during the first growing season, height growth and number of fascicles per plant were significantly greater on all mechanical and chemical treatments compared to the control.

CONVERSION OF IMMATURE SLASH PINE PLANTATIONS TO MULTI-AGED LONGLEAF PINE FORESTS OVER TIME: A CONSERVATION SILVICULTURE APPROACH

S.B. Jack, J.B. Atkinson, M.A. Melvin and J.L. Gagnon

Abstract: Interest in ecosystem restoration and the present downturn in the pine pulpwood market have produced a need for strategies to convert off-site plantations of slash and loblolly pine to more complex, multi-aged longleaf pine forests. Typically, the conversion process includes clearcutting, site preparation, and planting the desired species. In this model, however, the benefits of having older trees on site (e.g., fuels for prescribed fire, wildlife habitat, carbon storage) are diminished for many years, and other attributes of the ecosystem (e.g., groundcover) are damaged or lost. One alternative is a gradual conversion process where mature trees of the off-site species are retained while the desired species becomes established. A study examining this gradual conversion process has been underway for several years in a 65 year-old slash pine plantation on Ichauway. We recently implemented similar activities in two off-site slash pine plantations (planted 1987) that are more representative of plantations in the region. In summer 2002, following a 5% timber cruise, 4 row thinning treatments (second, third, fourth and fifth-row) with selections between rows were applied. This first thinning reduced average stand basal area by 45% but did not result in large enough openings for successful longleaf planting. Prescribed fire and spot application of herbicides were used to control hardwoods following thinning. A second thinning operation is planned for 2007 followed by planting longleaf pine seedlings in canopy openings. This sequence of thinning and planting will be repeated periodically until longleaf natural regeneration can be utilized. Complete removal of the slash pine overstory is expected to take at least 50 years.

INTRODUCTION

Interest in ecosystem restoration and the present downturn in the pine pulpwood market have produced a need for strategies to convert off-site slash (*Pinus elliottii* var. *elliottii* Engelm.) and loblolly pine (*P. taeda* L.) plantations to more complex, multi-aged longleaf pine (*P. palustris* Mill.) forests. Typically, this conversion process includes clearcutting, site preparation, and planting of the desired species. In this model, however, the benefits of having older trees on site (e.g. fuels for prescribed fires, wildlife habitat, carbon storage) are diminished for many years, and other attributes of this ecosystem (e.g. groundcover) are damaged or lost. An alternative approach is to gradually convert the plantations to naturally regenerated longleaf pine forests over time. One study examining this gradual conversion process has been underway for several years in a 65-year old slash pine plantation. However, most often, landowners have much younger plantations to convert. To address this need, we have implemented a similar study in younger slash pine plantations which are more representative of plantations in the region.

Objectives for this study included:

1. Improvement of stand condition and health through the practice of good resource stewardship.
2. Conversion, over the long-term, of the overstory to a multi-aged longleaf pine forest.
3. Development of a demonstration area for young plantation management and, over time, for species conversion over long rotations.
4. Provide a template for potential adaptive management projects.

METHODS

Study Site

This conservation project took place at the Joseph W. Jones Ecological Research Center at Ichauway, a 29,000 acre ecological reserve in southwest Georgia. Over 18,000 acres of the property are in naturally regenerated, mature (70+ years), upland longleaf pine forests. In 1987, two slash pine plantations (96 acres total) were established on sites historically dominated by longleaf pine. In 2002, the trees were suppressed, fusiform rust was prevalent, and self-thinning was occurring. There was little or no ground cover under the closed canopy. The sparse groundcover reduced the ability to carry fire through the stands, contributing to patches of hardwood encroachment. Initial stand basal area was 75 ft^2 $acre^{-1}$, average diameter at breast height was 7.3 in. and average total height was 52 ft.

Timber Harvest

In summer, 2002, following a 5% timber cruise, four row thinning treatments (second, third, fourth and fifth row removals) with selections between the rows were applied. Individual trees selected for removal were chosen based on presence of fusiform rust, poor form, suppression or other damage. Selection (between row) thinning was conducted using a small 3-wheel feller-buncher to minimize damage to the residual stand.

Prescribed Fire and Herbicide
Prescribed fire and spot application of hexazinone were used to control hardwoods and slash pine regeneration after thinning.

RESULTS
Approximately 29 tons acre^{-1} of pulpwood was removed from these stands (total of 2,771 tons) during the first thinning operation. The majority of the trees were removed because they were located in take-out rows, followed by trees with poor form and suppressed trees (Figure 1). Basal area was significantly reduced by all thinning treatments (Figure 2). The average stand basal area (across all treatments) was reduced by 45% (to 41 ft^2 acre^{-1}). In all treatments, thinning shifted the diameter distribution to the right (Figure 3), a result of removing the smaller, suppressed trees from the stands. Eventually, the diameter distribution of these stands should approach that of an uneven-aged or multi-aged stand (Figure 4).

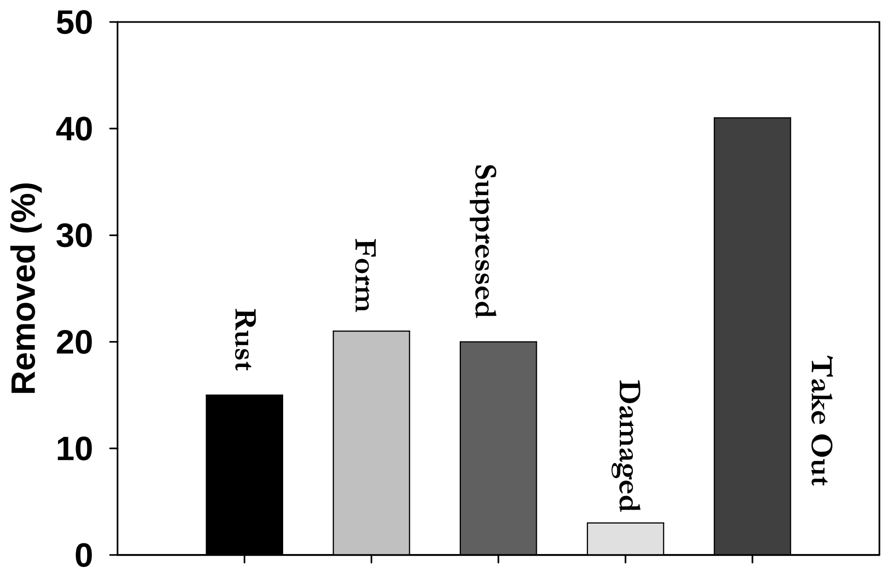

Figure 1. Reasons for removal of slash pine in a thinning operation in a 17-year old plantation.

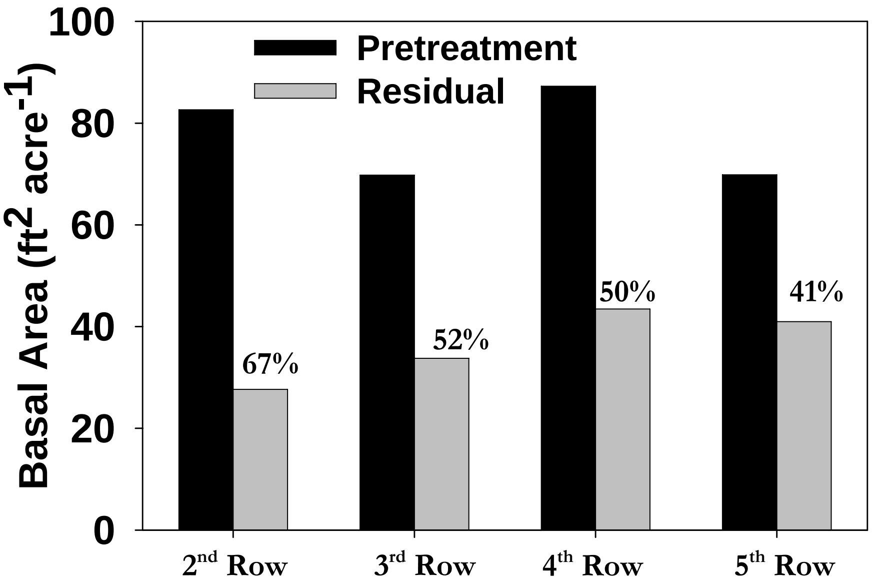

Figure 2. Basal area reduction (%) in a 17-year old slash pine plantation by thinning treatment.

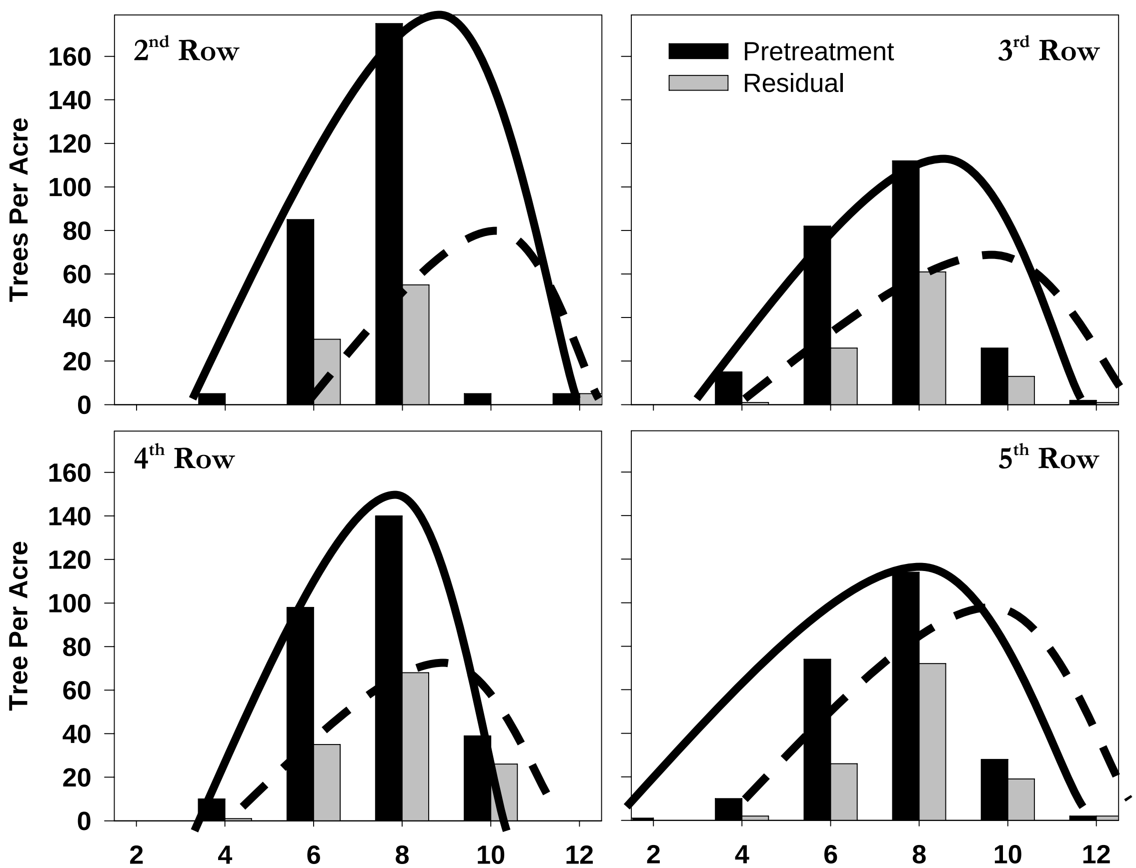

Figure 3. Diameter distributions of 17-year old slash pine plantations before and after thinning (2-inch diameter classes).

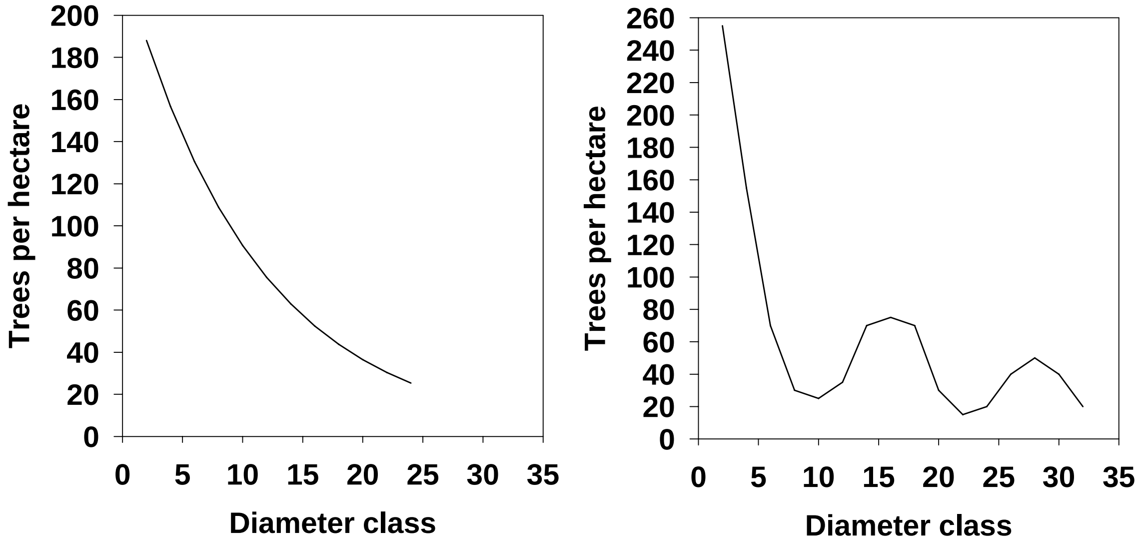

Figure 4. Diameter distributions of (a) an uneven-aged stand and (b) a multi-aged stand (by 2 inch diameter class).

FUTURE WORK

A second thinning operation is planned for 2007 with subsequent planting of longleaf pine seedlings in canopy openings. This sequence of thinning and planting will be repeated until natural longleaf pine regeneration can be established. Complete removal of the slash pine overstory is expected to take up to 50 years. Prescribed fire will be used on a two-year interval, along with spot applications of herbicide when necessary, to control hardwood encroachment.

ACKNOWLEDGEMENTS

Special thanks are extended to the J.W. Jones Ecological Research Center for providing funds for this project, Leon Neel for advice on conducting the thinnings, and Brandon Rutledge, Stacy Odom and Dee Davis for help with timber marking and cruising.

CHEMICAL CONTROL OF WOODY SPROUTS FOLLOWING MECHANICAL REMOVAL OF LARGE HARDWOODS WITHIN A LONGLEAF PINE MATRIX

S.B. Jack, J.L Gagnon, and M.A. Melvin

Abstract: Historically, frequent low-intensity wildfires prevented hardwood encroachment in mature longleaf pine (*Pinus palustris* Mill.) forests. When overstory pine stocking is reduced, however, especially when in conjunction with reduced fire frequency, hardwood encroachment can lead to a mixed pine-hardwood overstory and a change in the groundcover. To restore one such area on Ichauway, a 29,000 acre reserve in southwest Georgia, large hardwood stems were harvested and prescribed fire utilized to control hardwood brush. Because fuel loads were low due to low pine basal area, however, the sites did not burn effectively and small hardwood sprouts dominated the understory. Based on results from a pilot study, we implemented an operational project to compare effectiveness of three herbicides in rapidly restoring fuels while protecting longleaf pine regeneration, wiregrass (*Aristida beyrichiana* Trin. & Rupr.) and legumes (specifically goat's rue - *Tephrosia virginiana* (L.)). We applied the herbicide treatments on the 33 acre tract using 3 replications. Garlon 4F (4 qt acre^{-1}) and Arsenal (16 oz acre^{-1}) treatments were broadcast applied in the fall of 2002, while Velpar L (3 qt acre^{-1}) was band applied in spring 2003. Vegetation composition was monitored using a 1.6 ft^2 quadrat at points along a 1.5 x 1.5 chain grid. All treatments protected the species of concern. The Arsenal treatment was extremely effective in controlling oaks and woody shrubs and had a significantly higher percentage of goat's rue by May 2004. Garlon 4 initially killed hardwood sprouts; however, the response did not persist and sprouts were significantly higher in this treatment by fall 2003, likely due to application outside optimum conditions. Hardwood control on Velpar plots was intermediate to the other two treatments.

INTRODUCTION

Historically, frequent, low-intensity fires in the southeastern United States prevented large accumulations of fuel (Heyward 1939; Brockway and Lewis 1997), created a bare mineral soil seedbed for longleaf pine regeneration (Hodgkins 1958; Rebertus et al. 1989; Brockway and Lewis 1997; Brockway and Outcalt 2000; Provencher et al. 2001), impeded hardwood encroachment (Heyward 1939; Rebertus et al. 1989; Brockway and Lewis 1997), promoted flowering of certain species (such as wiregrass (*Aristida beyrichiana* Trin. & Rupr.); Mulligan et al. 2002), provided habitat for wildlife (Brockway and Lewis 1997; Brockway and Outcalt 2000) and controlled brown spot needle blight infection (Rebertus et al. 1989; Brockway and Lewis 1997; Brockway and Outcalt 2000).

When overstory pine stocking is reduced, however, especially when in conjunction with reduced fire frequency, hardwood encroachment can lead to a mixed pine-hardwood overstory and a change in the groundcover. Specifically, herbs, grasses and overall diversity are reduced while hardwood sprouts are increased. Over time, the hardwoods grow into the mid- and overstories, further degrading the sites (Heyward 1939; Rebertus et al. 1989) by reducing the amount of flammable litter. In addition, large diameter hardwoods are generally difficult to top-kill using prescribed fire (Heyward 1939; Rebertus et al. 1989; Provencher et al. 2001), therefore, alternative methods may be required for restoration in these degraded areas (Heyward 1939; Brockway and Outcalt 2000; Provencher et al. 2001).

Mechanical means can be used to remove large stems from the overstory; however, mechanical treatments alone can result in excessive hardwood sprouting (Provencher et al. 2001). The use of herbicides has been suggested as a means of effectively removing hardwoods, reducing competition and increasing light availability at the forest floor, thereby promoting the growth of grasses and herbaceous vegetation (Brockway and Outcalt 2000). Herbicides have been successfully used to restore degraded sandhill sites (Harrington and Edwards 1999; Brockway and Outcalt 2000; Provencher et al. 2001). And, in a pilot study (Gagnon et al. 2003), the efficacy of a Garlon 4/Tordon/Escort mixture in restoring fuels to field edges and hedgerows in a degraded condition was demonstrated.

The difficulty in prescribing herbicide treatments is chemicals which control hardwoods generally also affect either the grasses or herbaceous plants in the groundcover; i.e., we can control the brush but we will potentially also kill either the grasses or forbs, both of which we desire to maintain in the groundcover for fuels, nutrient cycling, wildlife and aesthetics. To determine which chemical formula is most effective in killing the hardwood sprouts while protecting the desirable vegetation, we examined the effects of three different chemical treatments, Garlon 4, Arsenal, and Velpar L. These herbicides were chosen for their different effects on groundcover plants.

METHODS

Study site

This adaptive management study was conducted at the Joseph W. Jones Ecological Research Center, at Ichauway, located in southwestern Georgia, USA, in the lower Gulf Coastal Plain. The 29,000 ha property contains approximately 18,000 acres of mature (70+ years) fire-maintained second-growth longleaf pine. The climate for this area is classified as humid subtropical with an average annual precipitation of 52 inches, distributed evenly throughout the year. Mean daily temperatures range from 69 to 93°F in summer and 41 to 63°F in the winter.

The soils in the 33 acre study area consisted of somewhat excessively drained or well-drained Kandiudults. Overstory vegetation, prior to hardwood removal, consisted of mixed longleaf pine hardwoods, and the dominant hardwood species were southern red oak (*Quercus falcata* Michx.) and live oak (*Q. virginiana* Mill.). The majority of large hardwood stems were mechanically removed during 2001. The density of the remaining overstory longleaf pine was sparse and the canopy was essentially open. Two-thirds of the area was burned in 2001, the remainder in 2002. Because fuel loads were low due to low pine basal area, however, the sites did not burn effectively and small hardwood sprouts dominated the understory. There was, however, a significant population of both wiregrass and goat's rue (*Tephrosia virginiana* (L.)).

Field Work

Building on the results of a pilot study (see Gagnon et al. 2003), we applied 3 different herbicide mixtures on the 33 acre tract using 3 replications (approximately 11 acres total per mixture). The herbicides included: Arsenal (active ingredient Imazapry), a post emergent spray for control of most annual and perennial grasses, broadleaf weeds, vines, briars and hardwood sprouts; Velpar L (active ingredient hexazinone), which provides both contact and residual control of annual, biennial and perennial weeds and hardwood sprouts; and Garlon 4 (active ingredient triclopyr), which controls annual and perennial broadleaf weeds and hardwood sprouts, but not annual grasses.

Garlon 4F (4 qt acre^{-1}) and Arsenal (16 oz acre^{-1}) were broadcast applied in the fall of 2002, while Velpar L (3 qt acre^{-1}) was band applied in spring 2003. By spring 2004, hardwood sprouts were abundant in the Garlon 4 treatment areas and the herbicide was re-applied to approximately 6 of the original 11 acres in July, 2004.

Changes in vegetation composition were monitored by placing a 2.7 ft^2 quadrat at temporary points along a 1.5 x 1.5 chain grid. Relative cover (of 100%) of vegetation in each of the following categories was recorded: wiregrass, other grass, forb (including legumes), vine, live oak, other oak, woody, debris, bare ground, shrub, fern, and goat's rue. General observations of the remaining overstory hardwoods and pines, as well as advanced longleaf pine regeneration, were also noted. Monitoring occurred in fall 2003 and 2004 and in the spring of 2004. All data were analyzed using ANOVA procedures and Duncan's Multiple Range Test in SAS. Significance was determined at α = 0.05.

RESULTS

Arsenal

Arsenal was effective in top-killing hardwood sprouts (Figure 1). As a result, the amount of bareground present in the spring of 2004 was highest for this treatment (7% vs. 1 and 2 % for the Garlon and Velpar treatments, respectively), creating space for legume and forb growth. By fall 2004, coverage of wiregrass (11%) and herbaceous plants (13%) was high, providing fuels for future prescribed fires. Two years after herbicide application, oak sprouts remained sparse (3%), however, other woody vegetation was highest among the treatments (11%) due to a proliferation of *Rubus* spp. in the openings created by hardwood dieback.

Velpar

Velpar initially top-killed all woody sprouts except for Sassafras (*Sassafras albidium* (Nutt.) Nees), which is tolerant of hexazinone. There was also mortality of the remaining large overstory hardwoods on the site. And, while wiregrass and forb coverage were lower than in the Arsenal treatment, they were not significantly lower by fall 2004 (11 and 9%, respectively). Although not indicated by the data, personal observation indicated that there was an increase in oak sprouts by the fall, indicating a need for either prescribed fire or re-application of the herbicide.

Garlon

Initially, the Garlon treatment was also effective in top-killing hardwood sprouts. However, by the spring of 2004, live hardwood sprouts were once again abundant (47% of groundcover vs. 10% and 14% for the Arsenal and Velpar treatments). The Garlon was applied late in the growing season, past the optimum date. We re-applied the treatment to half of the originally treated area in July 2004. By September, live hardwood sprouts were reduced to 3% of the groundcover in these re-treated areas (data not shown). However, there was also a corresponding decrease in forb coverage immediately following application (1% cover vs. 13, 11 and 9% for Arsenal, Garlon and Velpar, respectively).

CONCLUSIONS

All three chemicals in this study protected wiregrass, goat's rue and longleaf pine regeneration and promoted the development of fine fuels, but it is apparent that timing of application is quite important. That is, if applied at the appropriate time, Garlon can control woody vegetation and it is quite likely that Arsenal, applied during the growing season, would be detrimental to wiregrass. Most importantly, the chemical applications will not control hardwood stems indefinitely in these open canopy forests, and aggressive prescribed fire is required for continues control. Each of the chemicals are useful tools when thoughtfully matched with stated management objectives.

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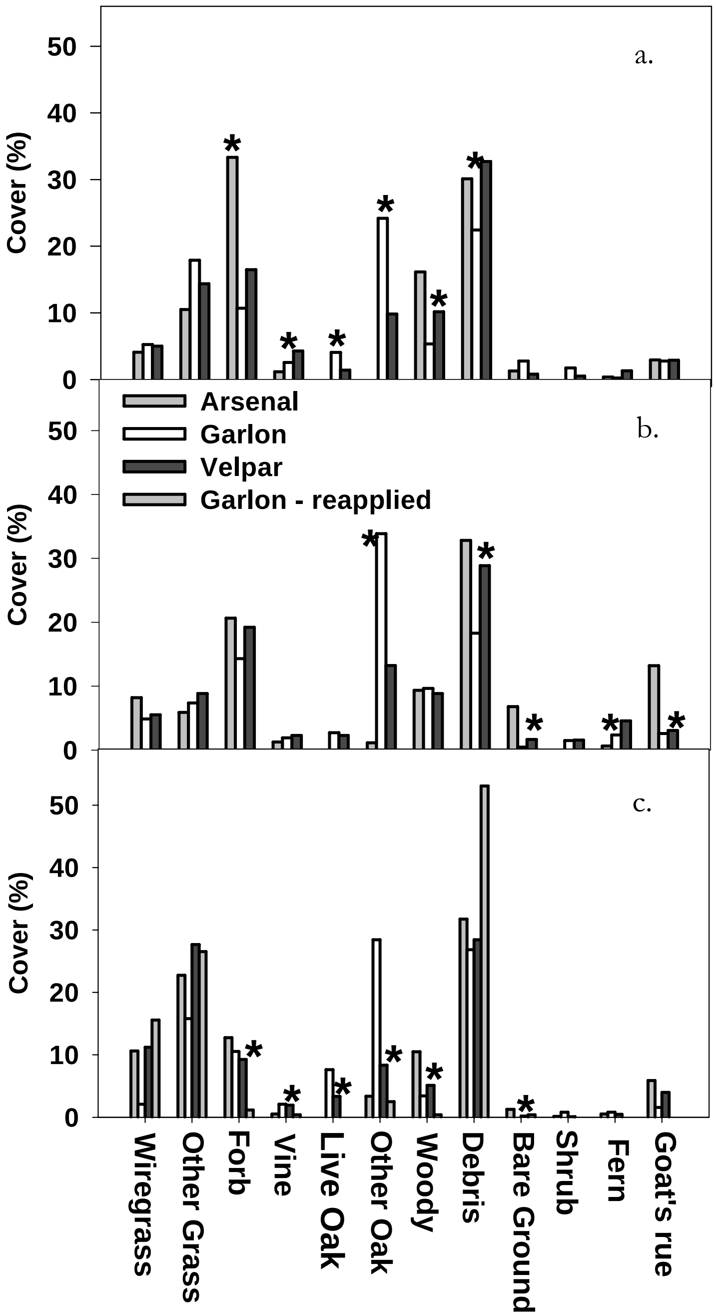

Figure 1. Percent cover by species group in (a) fall 2003 (b) spring 2004, and (c) fall 2004.

A DENDROCHRONOLOGICAL STUDY OF AN OLD-GROWTH STAND OF LONGLEAF PINE (*PINUS PALUSTRIS*) IN TALLADEGA NATIONAL FOREST OF NORTHEASTERN ALABAMA

Kevin Jenné and Robert Carter, Jr.

Abstract: Dendrochronology of old-growth stands of Longleaf pine, *Pinus palustris*, was calculated in the Talladega National Forest located in northeastern Alabama. Standard coring techniques were performed that consisted of strategic coring, drying, mounting and sanding of each core. Through comparative ring analysis, distinct disturbance patterns, such as clearing, were detected. This information was used to yield a timeline of disturbances spanning the last two centuries.

WILDLIFE ENTERPRISES ON MISSISSIPPI NON-INDUSTRIAL, PRIVATE LANDS

W. Daryl Jones, Ian A. Munn, Emily K. Loden, Stephen C. Grado, Jeanne C. Jones, James E. Miller, Ben C. West, and John D. Byrd

Forest landowners and agricultural producers in the southeastern U.S. have opportunities to earn supplemental incomes on their properties through fee access recreational arrangements. Wildlife and fisheries enterprises can include landowners leasing hunting rights, charging for fishing access, wildlife watching and photography, and ecotourism opportunities. In 2001, U.S citizens spent over $95 billion on fish and wildlife recreation (USDI 2001). Mississippians spent $211 million for recreational fishing, $361 million for recreational hunting, and $304 million watching wildlife. Wildlife and fish-related recreation and associated revenues generally depend on the integrity, health, and productivity of native ecosystems. Thus, carefully planned wildlife and fisheries enterprises can produce revenue for non-industrial, private (NIP) landowners while accomplishing conservation and restoration of important habitats, such as longleaf forests.

In 2003, we conducted a survey of NIP landowners in Mississippi and found that respondents are taking advantage of this economic opportunity by providing access to their lands for hunting. We mailed 1,584 questionnaires to a randomly selected group of NIP landowners taken from the 1995 Mississippi county land tax records. We received 491 useable questionnaires by return mail, resulting in a 31% response rate. The percentage of landowners who engaged in fee access wildlife and fisheries access on their properties was relatively small (18%) with most choosing to lease hunting rights. These respondents leased 74% of their land on average. Featured wildlife species offered through leases were white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo)*, squirrel, waterfowl, quail (*Colinus virginianus*), and dove (*Zenaida macroura*).

Landowners who leased hunting rights offered amenities, such as food plot establishment, blinds and stands, guest lodging facilities, and hunting guides as part of their operations. Respondents advertised fee hunting opportunities shown in descending order of importance by word of mouth, recommendations by family and friends, newspaper, and client referrals. On average, landowners collected $4.64/acre in annual gross revenues and spent $1.24/acre in operational expenditures, generating $3.40/acre in annual net revenues.

Respondents who leased were asked to rank problems associated with their operations, including accident liability concerns and loss of control of their property. Landowners who did not lease were asked about their perceptions or concerns with the activity. On average, landowners who leased did not experience problems with their operations while respondents who did not participate perceived that problems would exist if they initiated a business. Lastly, landowners were asked about the types of information needed to establish a wildlife enterprise. Respondents reported requiring information on wildlife habitat management, accident liability exposure and ways to reduce liability, and hunting laws and regulations.

Fee access wildlife and fisheries enterprises can benefit forest and agricultural landowners through income diversification, habitat management, regulation of hunter access to their properties, and control of poaching and land trespass. Forest management practices conducted to increase stand quality (i.e., thinning, prescribed burning, small gap harvests) enhance habitat for game and nongame species. Thus, forest landowners can diversify their income through the development of fee access recreational enterprises that often promotes restoration and conservation of the longleaf pine ecosystem.

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THE ENCYCLOPEDIA OF SOUTHERN FIRE SCIENCE

Deborah Kennard, Cynthia T. Fowler, William Hubbard and Mike Rauscher

Abstract: One of the most prominent issues in forest management today is fire. While a large body of information is available on fire and forest management, this information is not always in a form that is easy to locate and easy to use. The *Encyclopedia of Southern Fire Science* (ESFS; fire.forestryencyclopedia.net) addresses this problem by organizing and synthesizing this large body of fire science and translating it into an Internet-based encyclopedia system. ESFS is a cooperative effort between the USDA Forest Service, the Southern Regional Forestry Extension Office, and more than 10 research institutions and land management agencies across the South. ESFS compiles original syntheses of a broad range of topics including: fuels management and fire behavior; fire effects on air, water, soil, plants, and animals; ecology and management of fire-influenced communities; economic and health impacts of fire; uses and methods of prescribed fire; fire weather; smoke management; and wildfire occurrence, impacts, and mitigation. These syntheses are available to the public in a fully-linked and searchable encyclopedia hypertext system via the Internet, making access to this information universal, convenient, and free.

The information gap

A tremendous body of information exists on the ecological, economic, and social effects of fire and hazardous fuel reduction in longleaf pine forests. However, this knowledge is not easily accessible and not always in a form that is readily usable for managers. Most research still resides in highly technical, narrowly focused publications housed in libraries. As a result, a gap exists between what scientists know and what the management community is able to apply on the land. In this paper, we describe a tool that aims to bridge the gap between science and management: the *Encyclopedia of Southern Fire Science* (ESFS).

What is the *Encyclopedia of Southern Fire Science*?

The ESFS is a hyperdocument-based encyclopedia system composed of hundreds of syntheses on fire-related topics. The aim of the ESFS is to organize and remove redundancy from existing sources of fire-related information and present this knowledge in a user-friendly format. The Southern Research Station is cooperating with a variety of research institutions and land management agencies across the South to organize research information on a broad range of topics. These syntheses are available to the public in a fully-linked and searchable hypertext system via the Internet, making access to this information universal, convenient, and free. Unlike most Internet-based hyperdocuments, quality control of the encyclopedia is ensured through a complete peer-review process similar to traditional scientific journals. The ESFS is built on a content management system that allows the entire publishing process- from author contribution, peer review, technical editing, and final publishing- to be integrated into a single web-based system similar to on-line journals. The encyclopedia is both dynamic, making future updates easy, and nonlinear, allowing a greater level of knowledge integration than existing print media can accommodate.

Topics included in *Encyclopedia of Southern Fire Science*

Content in the *Encyclopedia of Southern Fire Science* provides brief descriptions of recently completed research that can reach users more quickly and directly than with traditional print media. By using hyperdocument technology, the structure of ESFS places new information in the proper context with logical linkages to related information. There are hundreds of topics included in the ESFS, organized into 7 major sections:

1. **Fire behavior:** explains basic information about fuels, fire weather, and fire behavior, and describes techniques for hazardous fuel reduction.

2. **Fire effects:** describes the effects of fire on air, water, soil, vegetation, and fauna.

3. **Fire ecology:** summarizes research on the fire ecology and management of more than 25 communities in the southeast, including extensive forest types such as longleaf, slash, and loblolly pine, and non-forest communities such as cane brakes, herbaceous wetlands, heath balds, dry prairies, and salt/brackish marshes.

4. **Fire and people:** synthesizes information on the human dimensions of fire in the South with coverage of topics such as the history of burning in the South, the relationship between human health and prescribed burning, the economics of fire, and fires in the wildland-urban interface.

5. **Prescribed burning:** summarizes the history of prescribed burning, uses of prescribed burning, methods for burning, public relations, and state and federal regulations governing prescribed burning

6. **Smoke management:** describes models of smoke movement, avoiding and reducing smoke, components of smoke, smoke and air quality, and air quality regulations

7. **Wildfire:** presents statistics of the occurrence of wildfires in the South, explains the impacts of these wildfires on human health and the local economy, describes new technologies for wildfire detection and strategies for wildfire prevention, mitigation, and rehabilitation.

More than 450 pages of encyclopedia content, representing more than half of the topics above, have been available as of November 2004. The remaining topics will be published on a monthly basis until the encyclopedia is completed in November 2005.

How to use the *Encyclopedia of Southern Fire Science*

ESFS was developed to be user-friendly, with several familiar tools for searching and navigating the site. Content within each of the seven major sections listed above are organized in a tree-like structure represented as a linked collapsible menu in the left frame of Fig. 1. As users browse within the encyclopedia using internal hyperlinks, their location is represented in the main drop-down menu and the linked collapsible menu. When a link reaches outside ESAFE, the different frame of the host site signals the move. Other examples of global navigation aids used in the encyclopedia are a complete table of contents, figure and table indices, and full-text search tools.

Figure 1. Home page of the Encyclopedia of Southern Fire Science (**http://fire.forestencyclopedia.net**).

Who will benefit from the *Encyclopedia of Southern Fire Science*

Using ESAFE, busy forest managers can more easily find answers to problems from their own desks. Some managerial questions that ESFS provides easy-to-find answers to are:

- What season and fire intensity is best to restore longleaf pine?
- How does fire affect communities associated with longleaf pine, such as pitcher plant bogs?
- How can I minimize the effects of a burn on soil and water quality?
- What common landscape plants are the most flammable in Florida?
- What fire education programs are available to residents of South Carolina?
- What are common fuel loads for longleaf pine forests?
- Will prescribed fire promote or control cogongrass?
- How does fire affect snakes?
- How can I reduce fuel loads if I live near an urban area?

The primary beneficiaries of ESFS are land and fire managers; but ESFS will also serve the information needs of landowners, policy makers, the media, educators, students, researchers, technology transfer agents, fire workers, and homeowners. By providing ready access to the right information in the right form, the encyclopedia will help all of these groups make more informed decisions by deepening their understanding of the environmental, social, economic, and political implications of fire, fuels, and recovery strategies. Additional beneficiaries of ESFS are technology transfer agents who are looking for effective techniques to reach their audiences.

Companion tools

ESFS is embedded in two separate, larger Internet-based science delivery projects. The first is the Forest Encyclopedia Network (FEN), also developed by the Southern Research Station. The FEN, launched in 2003, is a very broad- scope synthesis designed to eventually integrate major topics of research conducted in the Southern Research Station. The prototype for the FEN is the *Encyclopedia of Southern Appalachian Forest Ecosystems* (*ESAFE,* Kennard et al. in press), which contains over 1,500 pages of content. While still under development, the FEN illustrates the proof of concept for synthesizing fire science and management knowledge in the South. Users of ESFS will have seamless access to supporting content in the other encyclopedia volumes supported by FEN, such as the *Encyclopedia of Southern Forest Science* and the *Encyclopedia of Southern Bioenergy Resources,* plus future planned volumes.

The second science delivery project is the *Southern Fire Portal*, a web application that uses a common interface and technology to tie together multiple, related but independent applications including the Fire Research and Management Exchange System (FRAMES), the southern node of the National Biological Information Infrastructure (NBII), and Tall Timbers E.V. Komarek Fire Ecology Database. In a highly applied environment, the Southern Fire Portal will make the following resources available to their audiences: (1) data and tools (2) metadata, (3) state-of-the-knowledge literature syntheses (4) an index of publications, (5) a fire thesaurus, and (6) a strategy for integrating content. The Southern Fire Portal will be the gateway website for ongoing information and technology transfer between the fire management and research communities, and their publics in the southeastern United States.

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CHARACTERISTICS OF FALL LINE SANDHILL COMMUNITIES AND POPULATIONS OF SANDHILL TES SPECIES

Kathryn Madden, Rebecca Sharitz, Donald Imm, Tracey Tuberville and Steve Harper

Abstract: In the southeastern U.S., the federal government has extensive land holdings in the Fall Line ecoregion, which occurs between the Piedmont and Coastal Plain. This ecoregion supports a suite of rare or uncommon plant and animal species. The Department of Defense must address simultaneously the habitat sensitivities of these species along with demands associated with military training and other land-use activities. Thus, the goal of this project is to develop methods to evaluate effects of military training activities and forest management practices on the sustainability of sandhill communities and associated threatened, endangered and sensitive species (TES). GIS analysis and field sampling at Fort Benning, Fort Gordon, and the Department of Energy's Savannah River Site (SRS) have been used to delineate sandhill communities from adjacent forests. Results indicate a range of sandhill woodlands categorized into eight distinguishable groups with the use of TWINSPAN. Four oak species and two pine species dominate the canopies, which vary in composition along measured environmental gradients. Populations of selected sandhill TES plants and animals that occur on the three installations are being measured for habitat characterization. An experimental approach has been developed to re-introduce the gopher tortoise (*Gopherus polyphemus*) into sites managed for red-cockaded woodpecker habitat at the SRS.

LARGE-SCALE CONTAINERIZED SEEDLING PRODUCTION OF PERENNIAL HERBACEOUS SPECIES FROM THE WIREGRASS-LONGLEAF PINE ECOSYSTEMS

Doug Marshall

Abstract: The use of containerized seedlings is important for re-establishing perennial herbaceous species in the fire-maintained savannah ecosystems. However, large-scale production of these species is limited by a lack of knowledge about germination requirements and optimal greenhouse methods. Therefore, the U.S. Forest Service funded the University of Georgia to address these issues. In addition, as part of a larger reintroduction research program, UGA produced approximately 60k containerized seedlings over three years.

The majority of species germinated with moisture alone, indicating that dormancy was uncommon, although cold stratification increased germination for some grasses and forb. Several legume species required a heat pulse to break dormancy. While no grasses or forbs were found to be heat primed, the majority was tolerant of high temperatures, with seed mortality beginning between 60-80°C (140-176°F). The best methods for germinating seeds were either in terra-cotta containers or in shallow water baths, which allowed greater water absorption by seeds and easier handling.

For seedling establishment, the best results were achieved by growing germinates outside of soil in moist conditions for a few days and then transplanting a seedling into a container cell. This method drastically reduced labor costs, improved seedling growth and survivorship, and produced a more uniform crop. Once seedlings were transplanted, mist was used for watering in order to avoid seedling damage. In addition, seedlings were regularly subjected to 2-3 days of drought stress in order to encourage root growth at the expense of shoot growth. The majority of species only required 2 months of growth.

INTRODUCTION

The fire-maintained savannah ecosystems of the southeastern U.S. are characterized by high herbaceous plant diversity, including a large number of endemics. These savannahs have been drastically reduced in area due to habitat loss and fire suppression. As part of the conservation of these ecosystems, government agencies and NGO's are reintroducing perennial herbaceous species via seeds or containerized seedlings. Funded by the U.S. Forest Service, a research program at the University of Georgia has studied the propagation of selected perennial herbs from the Savannah River Site, S.C., as part of this conservation effort. For the 2003 growing season, 27 species were targeted for production and experimentation. Nineteen species were produced in sufficient numbers for outplanting by the U.S. Forest Service at the Savannah River Site and major advances were made in determining germination triggers, seedling production techniques, and minimal growth time requirements. This poster will first summarize research results on germination patterns, followed by recommendations for large-scale production of containerized seedlings. A U.S. Forest Service publication is planned that will go into greater detail.

METHODOLOGY AND ANALYSIS

The majority of seeds were collected from the Savannah River Site, South Carolina, with *Coreopsis lanceolata* and *Echinacea purpurea* collected in Texas. Each experimental treatment had five replicates of 50 seeds each and each replicate was contained inside an unsealed 9 cm petri dish with a moist filter paper. After being treated, the dishes were incubated under red-light emitting bulbs at room temperature. Petri dishes were checked daily for germination, with seedlings removed after germination, and 2 ml of tap water was added daily. Experiments were terminated after it became clear that either dormancy had not been broken or the germination rate had become insignificant.

For the chilling experiment, species was tested at four durations (0, 15, 30, and 45 days) at 39-40°F. Seeds were placed inside petri dishes and then placed in a cooler. While in the cooler, seeds were remoistened every two weeks as needed. For the heat priming experiment, seeds were heated in an oven at either 40, 60, 80, or 100°C, using a standard duration of eight minutes, along with a control. After the heating, the seeds were either placed inside petri dishes or on sand flats.

Germination was based on the number of germinates per given number of seeds of unknown viability. Since the same seed lot was used for both chilling and heat priming experiments, viability rates should be approximately equal. For germination results to be considered meaningful, at least one treatment had to reach at least 50% germination. Treatment effects were determined via Tukey mean separation tests

RESULTS

Contrary to what might be expected from a fire-regulated habitat, only 3 species, all legumes, required a heat pulse for germination. For the vast majority, 40 and 60^{o}C heat pulses had no effect on germination rates, with mortality beginning with the 80^{o}C treatment. The results suggest that most species tolerate fires rather than require them. Of 13 species tested, only 2 required cold stratification to induce germination while 3 benefited from chilling, suggesting that southeastern Coastal Plain winters are not a dominant force on inducing germination.

Three general germination patterns were observed: 1) a discrete pulse that only lasted a few days, 2) steady prolonged rate that lasted 2-3 weeks, and 3) a discrete pulse followed by a prolonged rate. The patterns are different colonization strategies that represent tradeoffs between how quickly germination occurs versus the risk of mass mortality. It appears that a germination pattern is common to a species, which has important implications for growers since germination percentages can be predicted. Another important discovery is that the number of days required for first germination also appeared to be common to a species. For example, *Petalostemum pinnatum* starts to germinate in less than 24 hours after being heated while *Aristida beyrichiana* requires seven days. It seems likely that this synchronization is an anti-predator defense.

APPLICATIONS OF FINDINGS

Once a species' germination pattern and germination triggers are known, then germinate production is relatively straight-forward. An initial germination trial will establish a seed lot's expected germination percentage, which can then be used to determine how many seeds need to be treated, when the bulk of germinates can be expected, and when an incubating seed lot will require labor. For example, if 1000 germinates are needed for a species which has a pulse-prolonged germination pattern, then enough seeds would be treated so that at least 1000 germinates are produced by mid-way through the expected pulse.

RECOMMENDED PRACTICES FOR CONTAINERIZED SEEDLING PRODUCTION

Collecting and storing seeds

The best seeds come from plants that have been fertilized and received ample moisture. Wind-dispersed seeds are ready when a gentle tug releases them. When collecting legumes, wait until pods start to turn brown. Do not mix legume seeds blindly. Discard all seeds that come from pods with fungus or weevil damage. Most seeds seem to remain viable for 2-3 years at room temperature in open paper bags.

Heat priming

After heating, place seeds in a water-containing dish with fungicide under red light. If no germination occurs after 2 weeks, try putting heated seeds on moist sand flats with a heat lamp. Play sand is best since it has good capillary characteristics and easy to heat sterilize, although crusts can form after a few weeks. Place the heat lamp so that it covers one-third of the flat and place seeds on a grid. The grid can be used to determine the temperature range needed for germination. For example, *Baptisia lanceolata* needs a heat pulse of 90^{o}C (194^{o}F) for 8 minutes followed by seedbed temperatures of 21-32^{o}C (70-90^{o}F). However, once seeds germinate, they have to be transferred to another container as the majority of seedling taproots are unable to penetrate the sand surface.

Cold stratification:

If seeds are small and wind-dispersed (e.g. *Liatris*) and don't mat easily, place them in a terra-cotta dish inside a larger dish with water and mist daily. If red light is not needed (e.g. *Aristida*), then cover dish to maintain high humidity. The terra-cotta absorbs excess water and is ideal for treating large numbers of seeds with minimal space. Since the seeds are suspended, it is easy to see germinates and pick them out. If seeds have a thick seed coat (e.g. *Coreopsis*), a corky covering (e.g *Echinacea*), or mat easily (e.g. *Sorghastrum*), then place the seeds in a single layer in a container or petri dish with enough water so that half the seed is covered.

Pre-transplanting growth

The best survival and growth of seedlings is achieved by growing newly-germinated seedlings hydroponically for the first few days. By initially keeping germinates in a moist environment, the seedlings are ensured sufficient moisture for cotyledon and tap root development without the danger of overwatering or being dislodged. In addition, a major source of seedling mortality is when the seed coat dries before being pushed off. Finally, having the germinates in a hydroponic setting allows greater control of containerized seedling quality since the grower can pick which seedling will go into the container. Thus, cells are stocked with seedlings of similar size at the same time with a single, vigorous seedling in the cell middle. This is far superior to a system that relies on a large number of seeds germinating in a cell over time and maintains a uniform crop.

If space is available, the best method for pre-transplanting growth for most species is a dish where the seedling roots are in contact with a thin water film. The ideal water level is high enough to keep roots moist with the majority of the cotyledon dry. If space is limited, then the terra-cotta method can be used. However, if seedlings have large taproots that grow rapidly (e.g. *Baptisia*, *Silphium*), they tend to have large, fleshy cotyledons. These types of seedlings get deformed if they develop while lying down. The best way to grow these seedlings is to place a wire mesh over a water bath and place the seedling so that the root is directed downward.

Transplanting

If the seedling emerges from a seed coat (majority of forbs), it is best to wait until the seedling pushes its seed coat off and cotyledons are fully erect. If seedling sends its cotyledon up through seed coat (grasses), wait until cotyledon is at least 4-5 mm. Transplant seedling into the center of the container cell, burying it so that the cotyledon is just above the soil surface (lateral leaves) or 2-3 mm exposed (single vertical leaf). For seedlings above water baths, transplant when the cotyledons are fleshy and fully lateral, but don’t wait too long or the root may get too big to remove without breaking.

POST-TRANSPLANTING MANAGEMENT

A guiding principle for production of quality seedlings should an emphasis on root growth. Remember that these seedlings are intended to be planted in droughty soils with low nutrient levels. Furthermore, most of the aboveground biomass will be lost after the first frost. It is vital that seedlings not have more aboveground biomass that can be supported by the root system once the seedlings are delivered to the customer. First-year survival and second-year expansion rates are far better measures of seedling quality than how pretty it looks in the greenhouse. At UGA, during the first month or so, seedlings were watered daily as needed with mist so that the soils were kept moist but not wet. Once seedlings were established, regular drought-periods (1-2 days) were used to stress seedlings so that root growth increased at the expense of shoot growth. The key is to dry seedlings down to the wilting point before resuming normal irrigation. For some species like *Eupatorium*, *Coreopsis*, and *Baptisia*, ample moisture will lead to excessive shoot growth that will lead to toppling. This type of species should be separated from other species for more restricted irrigation. No fertilization is recommended until the last two weeks before delivery in order to promote root growth. Watering should be reduced the day before delivery for the sake of reducing container weight as well as transpiration in seedlings. For the most of the UGA’s species, two months of growth was sufficient, with some species starting to flower by 3 months.

Species	Plant type	Germination effect		Comments	Recommended treatment	1st germination (# of days)
		8-min. dry heat	Chilling			
Anthaenantia villosa	Grass	None	Decreases	Small but steady decline	Moisture alone	5
Aristida beyrichiana	Grass	None	None		Moisture alone	7
Aristida purpurascens	Grass	None	Benefits		Chill for 30 days	7
Baptisia lanceolata	Legume	Required	N/A	Max at 90-100^{o}C	Heat at 90^{o}C for 8 min	10
Carphephorus bellidifolius	Forb	None	Benefits		Chill for 15 days	1
Coreopsis lanceolata	Forb	None	Increases rate		Chill for 30 days	1
Coreopsis major	Forb	None	Benefits		Chill for 30 days	2
Chrysopsis gossypina	Forb	None	None		Moisture alone	2
Echinacea purpurea	Forb	None	Increases rate		Chill for 45 days	2
Eragrostis refracta	Grass	None	None		Moisture alone	3
Galactia macreei	Legume	None	Decreases	Mortality likely from fungus	Moisture alone	2
Lespedeza hirta	Legume	Required	N/A	Max at 90^{o}C	Heat at 90^{o}C for 8 min	8
Liatris elegans	Forb	N/A	Required		Chill for 45 days	2
Liatris secunda	Forb	None	Required		Chill for 45 days	4
Liatris tenuifolia	Forb	None	N/A		Moisture alone	7
Petalostemum pinnatum	Legume	Required	N/A		Heat at 60^{o}C	1
Schizachyrium scoparium	Grass	None	None		Moisture alone	2
Sorghastrum secundum	Grass	None	N/A		Moisture alone	2
Sporobolus junceus	Grass	None	None		Moisture alone	5
Vernonia angustifolia	Forb	None	Required		Chill for 15 days	2

THE IMPORTANCE OF HEAT PULSES FOR TRIGGERING GERMINATION IN PERENNIAL HERBACEOUS SPECIES FROM THE WIREGRASS-LONGLEAF PINE ECOSYSTEMS

Doug Marshall

Abstract: In the wiregrass-longleaf pine ecosystems, fires are the main source of released resources. For perennial herbaceous species, successful seedling establishment may only occur after a fire, given the competitive advantage that established plants have. To determine if seeds are cued to passing fires, selected species were tested to determine the influences of 8-minute heat pulses of varying levels (25-100^{o}C) on germination.

Few species were found to have dormant seeds. Grass and forbs seeds were not affected by temperatures as high as 80^{o}C, indicating that while these species may be fire-tolerant, they were not heat-primed. Some legumes did have increased germination, with post-fire seedbed temperatures playing an important role. The influence of heat pulses on legume germination could not be predicted by seed size or growth habit. For example, heat-priming was found in the large-seeded legume *Baptisia lanceolata*, which uses tumbleweed-like seed dispersal; the wind-dispersed small-seeded *Petalostemum pinnatum*; and non-specialized medium-seeded *Lespedeza hirta*. In contrast, the animal-dispersed *Desmodium ciliare* and the explosively-dispersed vine *Galactia macreei*, both with small seeds, were not heat-stimulated, but were heat-tolerant.

These results suggest that for grasses and forbs, seed germination is triggered by other cues, such as increased temperatures and moisture availability, and are not dependent on passing fires. *Baptisia lanceolata*, *L. hirta*, and *P. pinnatum* are all dependent on a passing fire for significant germination. While some legumes may not require a heat pulse, they are still strongly dependent on ample moisture that may only exist after a fire has reduced eT.

COMPARISON OF RESIN DEFENSES OF TWO SOUTHERN PINES, *PINUS TAEDA* AND *PINUS PALUSTRIS*

Sharon J. Martinson

Abstract: Historically, longleaf pines (*Pinus palustris*) dominated the landscape of the southeastern U.S. During the last century, these forests were harvested and replanted with other species changing the forested landscape. Southern pine beetles (SPB) (*Dendroctonus frontalis Zimm.*), arguably one of the greatest biological agents of forest destruction, have always been present in this region. For the past 50 years beetle outbreaks have been monitored and the magnitude of destruction caused by these beetles has been realized. Two species of pine, *Pinus palustris*, and *Pinus taeda* (loblolly pine), are now common in these forests. Southern pine beetles (SPB) outbreaks occur more often in stands of loblolly pine. It has been thought that this pattern exists because longleaf pines have a greater capacity for resin production and defense against beetle attacks.

To determine the relationship between SPB attacks and tree resin defenses, I studied the patterns of resin defenses in both *Pinus palustris* and *Pinus taeda* across several forests in the southeastern U.S. I measured resin production in trees of both species where they co-occurred in stands as well as in stands that were mono-specific. I compared the patterns of resin defenses to the patterns of SPB outbreaks in the same areas, as well determining the relationship between tree resin and SPB reproduction. I found no significant difference in resin production between the two pine species, but there is a strong pattern in SPB outbreaks, with few of them occurring in longleaf stands. There may be other features of the longleaf forest that increase its resistance to SPB outbreaks.

MONITORING AND EVALUATION OF ECOSYSTEM RESTORATION ON LONGLEAF PINE FLATWOODS OF THE GULF COASTAL PLAIN

George L. McCaskill and Shibu Jose

Abstract: The Pt. Washington longleaf pine restoration study conducted through the University of Florida is focusing on determining the effects of post–site preparation and low level herbicide applications on longleaf pine seedling growth & survival, soil nutrient cycling, water quality, and plant species richness. First and second year data on the effects of the herbicides have been collected and are being analyzed. At this point it is necessary to find out if the site is headed for restoration on a path similar to natural patterns (few anthropogenic influences) or if it has been drastically altered. In simple terms, how are we doing at restoring this site to a healthy longleaf pine ecosystem?

This study will try to answer these questions by using plant species richness, a set of soil quality factors, and soil microbial biomass as environmental indicators, which will give a significant level of confidence in assessing the restoration trajectory. Secondly, by utilizing Chassahowitzka Wildlife Management Area, St. Marks National Wildlife Refuge, and Topsail Hill State Preserve as reference communities at clearly defined successional stages, the data can be ordered within very specific temporal and spatial scales. This scaling of the data will allow for differences in ecological conditions to be observed within effective chronosequencial and biogeographical gradients. Finally, ecological restoration will be tracked along these temporal and spatial scales by the use of a monitoring plan and modeling. Modeling will provide a tool for integrating the different ecological indicators and predicting the restoration trajectory of the longleaf pine site based upon the collection and analysis of reference community data through monitoring.

LAND USE HISTORY OF LONGLEAF PINE ECOSYSTEMS: CASE STUDIES IN THE RETENTION AND MANAGEMENT OF FORESTED LANDS

Josh McDaniel, John McGuire, Dean Gjerstad, Rhett Johnson and John Schelhas

Abstract: Using a combination of ethnographic and historical ecology research, this project examines the history and current state of longleaf pine forest management on private lands in the southeastern US. Interviews with landowners, land managers, and other stakeholders are used to provide qualitative explanations of land use decision making. The research focuses on factors that have led to the retention of longleaf forests in specific locales – The Carolina sandhills, Southwest Georgia, and the Mobile-Conecuh River watersheds of South Alabama. Using interviews with thirty-two landowners and stakeholders in the longleaf research, education/extension community, and analysis of historical aerial photos from the 1930s to the present, the project uses case studies to: (1) describe the history of longleaf pine management on private lands in the three study areas, (2) describes the cultural and economic factors that have led to the retention of longleaf pine on private lands, (3) develops a typology of longleaf ownership based on these factors, and (4) discusses the biodiversity implications of forest management under these ownership types.

A number of major events and forestry trends severely impacted longleaf forests in the 20th century, including: the "cut out and get out" period of intensive logging, fire suppression, and the growth of short-rotation, plantation forestry. However, we found through the case studies that these trends or periods affected the study areas differently. In the three study areas, private landowners were able to maintain longleaf forest management across generations. This persistence is related to common characteristics found among these families – similar origins as homesteaders, strong knowledge of forests and the forest industry, a pragmatic, conservation ethic, and long-term approaches to land management.

The case studies are used to develop a typology of longleaf ownership based on management objectives and history. We divide the owners into two types – the more pragmatic, utilitarian owners who are primarily interested in the financial returns from their land, and the owners who are more interested in the conservation, aesthetics, and recreational value of longleaf forests. Under the more utilitarian-oriented ownerships there is concern regarding the impact of harvesting and site prep on native groundcover and non-game wildlife habitat. The case studies also illustrate that many of these landowners are also actively managing to keep endangered species off their property. With the second type of landowner, the main biodiversity concerns pertain to the long-term sustainability of their efforts through generational transfer. Estate taxes and less conservation-minded heirs can undo decades of work in building a healthy forest. The project identifies the cultural and political factors that should be the basis for the development of policy instruments and incentives dedicated to the recovery and management of longleaf throughout its original range.

INSTRUCTING TOMORROW'S PRACTITIONERS TODAY: PRESCRIBED FIRE TRAINING IN UNIVERSITY NATURAL RESOURCE PROGRAMS

Mark Melvin, Kevin McIntyre, David Brownlie, Frank Cole and Michael Wimberly

Abstract: Currently, few opportunities exist for students in university natural resource programs to learn applied aspects of prescribed fire as a management tool. In the southeastern United States, fire is an ecological imperative for many coastal plain ecosystems and future natural resource management professionals need training in the use of prescribed fire as a management tool. The Joseph W. Jones Ecological Research Center, located in southwest Georgia, conducts basic and applied research on coastal plain ecosystems and has conservation as well as education programs as part of its mission. The Center is located at Ichauway, a 29,000 acre property that includes 18,000 acres of fire-dependent longleaf pine dominated forests. The Center has an active fire management program, burning over 10,000 acres annually. As part of its education program, a weeklong "Maymester" prescribed fire class is offered to upper-level undergraduate and graduate students. The course gives hands-on experience with all aspects of planning and implementation of prescribed fire as well as the ecological basis and historical uses of fire as a management tool. Instructors include representatives from the Jones Center, U. S. Fish and Wildlife Service, Georgia Forestry Commission, and the University of Georgia (UGA), and the course carries two semester-hour credits through UGA. Participants have included students in forestry and wildlife management from the UGA Warnell School of Forest Resources as well as conservation biology students from the Institute of Ecology. This course fills an important niche in the natural resource management curriculum, emphasizing both the science and the art of prescribed fire as a management tool.

NONNATIVE INVASIVE PLANTS OF SOUTHERN FORESTS

James H. Miller

Millions of acres of forestland in the southeast are being increasingly occupied by non-indigenous harmful plants—invasive alien weeds. Their range, infestations, and damage are constantly expanding. The actual infested acreage and spread rates are unknown, even though this information is essential for planning containment and eradication strategies and programs (U.S. Congress OTA 1993). The USDA Forest Service and state partners have initiated a cooperative survey of 32 exotic invasive plants; however it will take several years to collect initial data (details given at www.srs.fs.fed.us/fia/manual). Preliminary findings indicate that over half of all forest acres have one or two invasive intruders. All federal parks and forestlands in the southeast have exotic infestations (Hamel and Shade 1985, Hester 1991) and their increasing occupation has been linked to increasing human disturbance (Stapanian and others 1998).

Invasive plants are able to outcompete with native species and reproduce rapidly in the absence of predators from their native land, to form dense infestations that exclude most other plants, except some other exotics (Randall and Marinelli 1996). These infestations decrease forest productivity, threaten forest health and sustainability, and limit biodiversity and wildlife habitat on millions of acres (Wear and Greis 2002). Alterations to ecosystem structure, functions, and processes are occurring, yet their study has just begun (Ehrenfeld and others 2001). Many invasives, such as cogongrass, can alter natural fire regimes and increase risk of wildfire occurrence and damage (Lippincott 2000). The total impacts are as yet unforeseen.

Invasive plant biopollution is one of the greatest threats to biodiversity across the southern landscape and continues to attack our highly valued nature preserves and recreational lands. Their intrusion after fires vastly hampers restoration efforts such as with longleaf pine. These foreign invaders (often called exotic, alien, or noxious weeds) include trees, shrubs, vines, grasses, and forbs. This report summarizes pertinent facts for the most troublesome species invading the temperate portion of the southeast. Not described here are the more than 100 species of tropical and subtropical exotic plants invading south and central Florida (Langeland and Burks 1998).

Any successful effort to combat and contain invasive exotic plants requires an integrated pest (or vegetation management) approach (Miller 2003 and 1998, Tenn. Exotic Pest Plant Council 1996). Integrated programs incorporate all effective control methods, which may include: preventive measures (i.e., legal controls such as quarantines, border inspections, and embargoes), biological control agents using natural predators, herbicide technology, prescribed fire, livestock overgrazing, and mechanical and manual removal, as well as developed commercial uses. Preventive measures and biological control programs are best organized on a regional basis. Biocontrol agents are largely unavailable now, and although projects are underway, they will take years to develop (Simberloff and Stilling 1996).

Current treatment options for specific areas usually involve herbicides, prescribed fire, grazing, mechanical, and manual removal. Fire, grazing, and mechanical cutting treatments usually control only the above-ground plant parts, resulting in reduced height, but only temporary suppression. Manual treatment usually involves grubbing or pulling plants. This is very labor-intensive and can only be used on small-sized plants, resulting in limited but effective use on special habitats (such as recreational trails or nature preserves). Mechanical treatments include mowing, the use of tree shears, root-rakes, and harrows to cut and dislodge woody and rhizomatous plants, leaving soil bare for probable reinvasion and possible erosion. Nonetheless, these highly disturbing techniques have use against multi-species infestations of invasive woody plants.

Herbicide treatments often can be applied more easily and effectively following these other treatments. Herbicide treatments also minimize soil disturbance and leave the soil seed bank in place for native plant reestablishment. Carefully planned and executed herbicide applications can specifically target exotic plants and minimize impacts to native plant co-inhabitants (Miller 1999, 2003). Well-developed applicator directed techniques for selective control of exotic trees and shrubs are tree injection (and girdle-treat), basal sprays and wipes, cut stem applications, and foliar directed sprays (USDA For. Serv. 1994). Directed treatments of invasive vines and forbs usually involve foliar sprays using backpack sprayers. For treating extensive inaccessible infestations, broadcast applications of sprays and pellets, using helicopter and tractor-mounted systems, may be required. Yet, even in broadcast treatments, the use of selective herbicides coupled with application timing can safeguard native cohorts. For the treatment to be safe and effective, herbicide applicators must read, understand, and follow the herbicide label and its prohibitions before and during use. Continued surveillance and follow up treatments are often required to control exotic plant infestations. The most effective and efficient strategy is early detection and effective early treatment of initial invaders.

Invasive Trees

Exotic tree species hinder management of forests, rights-of-way, and natural areas replacing native plants, dramatically altering habitat and detracting from their beauty. Some presently occur as scattered trees, while others have increased to form dense stands. Most spread widely by prolific seed production and animal dispersal, while existing infestations increase by abundant root sprouting.

Tree-of-heaven, or Ailanthus, (*Ailanthus altissima* [P. Mill.] Swingle) was introduced as an ornamental tree in 1784 from Europe, although originally it came from Eastern China (Miller 1990). A short-lived species with no timber value, Ailanthus grows up to 80 ft tall, with long, pinnately compound leaves, slightly fissured gray bark, and large terminal clusters of greenish flowers in early summer. It occurs throughout the southeast, and is most abundant in Kentucky, Virginia, and Tennessee.

Silktree or Mimosa (*Albizia julibrissin* Durazz.) is a small, leguminous tree 30-50 ft tall, which was introduced as an ornamental from Asia in 1745. It reproduces by abundant seeds and root sprouts. Partially shade-tolerant, mimosa invades the forest mid-story and replaces native shrubs by root sprouting. It is most abundant in Mississippi, Alabama, and Georgia.

Princesstree or Paulownia (*Paulownia tomentosa* [Thunb.] Sieb. & Zucc. Ex Steud.) is a deciduous tree, reaching 60 ft tall, introduced from East Asia in the early 1800s. It is grown as an ornamental and in scattered plantations for high valued wood for export to Japan. It has large heart-shaped leaves with fuzzy hairs on both sides, and produces showy pale violet flowers in early spring, yielding pecan-like nuts in clusters. Paulownia reproduces by abundant seeds and root sprouts. It occurs throughout the southeast, and is most abundant in Kentucky, Virginia, and Tennessee.

Chinaberrytree (*Melia azedarach* L.), is another Asian introduction. This common ornamental is frequently found around old home sites. A medium tree, it grows to about 50 ft tall and spreads by bird-dispersed seeds. Chinaberry is common throughout the southeast, and is most abundant in Arkansas, Louisiana, Mississippi, Alabama, and Georgia.

Tallowtree or Popcorn Tree (*Triadica sebifera* [L.] Small) and formerly *Sapium sebiferum* [L.] Roxb.) is a shade-tolerant, small tree growing to 50 ft tall. It has light green heart-shaped leaves turning scarlet in fall, long drooping flowers in spring, and bundles of white waxy “popcorn-like” seeds in fall and winter. A prolific root sprouter, tallowtree also produces abundant seeds, which are spread by birds and water. Introduced from China to the United States Gulf Coast in the early 1900s, and encouraged by USDA as a seed oil crop from 1920 to 1940, tallowtree is still being sold and planted. It occurs in all southeastern states, except Oklahoma, Kentucky, and Virginia, with severe infestations in Texas, Louisiana, Mississippi, and Alabama.

Invasive Shrubs

Exotic shrubs often occur with exotic tree species and present similar problems. Herbicide control options are similar to trees; however, foliar sprays can be used more often and more effectively. All of these shrubs are abundant seed producers, and their fruit are commonly consumed and spread by birds.

Chinese Privet (*Ligustrum sinense* Lour.) and European Privet (*L. vulgare* L.) are shade-tolerant, tall shrubs or small trees growing to about 30 ft tall. These common southern ornamental shrubs were introduced from China and Europe only in the early to mid-1900s. Both have showy clusters of small white flowers in spring that yield clusters of small spherical, dark-purple berries during fall and winter. Seed spread by birds produce abundant seedlings, but privets also increase in density by stem and root sprouts.

Glossy privet (*Ligustrum lucidum* Ait. f.) and Japanese Privet (*Ligustrum japonicum* Thunb.) are shade-tolerant tall shrubs or small tree growing to about 40 ft tall, with leathery evergreen opposite leaves, 1 to 3 in. long. Showy dense clusters of small white flowers in spring yield abundant clusters of small round, dark purple berries during fall and winter. These privet were introduced from Japan and Korea in the 1700 and 1800s. They spread by seed carried by birds as well as by root sprouts and occur in the lower southeast.

Bush Honeysuckles
Amur Honeysuckle (*Lonicera maackii* [Rupr.] Herder), Morrow Honeysuckle (*L. morrowii*
Gray), Tatarian Honeysuckle (*L. tatarica* L.), and Sweet-breath-of-spring (*L. fragrantissima* [Lindl.] and Paxton) are tardily deciduous shrubs 6 to 16 ft tall, multi-stemmed with arching branches. The leaves are distinctly opposite, usually oval to oblong in shape, and range in length from 1 to 3 in. Fragrant, tubular flowers occur in pairs from May to June, being creamy-white, yellow or pink to crimson.. Abundant, paired berries of red to orange appear in fall to winter, with seeds being long-lived in the soil. All were introduced from Asia in the 1700s and 1800s as ornamentals and wildlife plants. They are widely invading and forming exclusive understory layers in lowland and upland forests. They occur in the northern part of the southeast.

Autumn Olive (*Elaeagnus umbellata* Thunb.) is a deciduous, bushy shrub, growing to 20 ft tall with alternate leaves, dark green above and silvery beneath. It produces abundant red spherical berries with silvery scales in the fall. Introduced from China and Japan, and still widely planted for wildlife habitat, strip mine reclamation, and shelter belts, autumn olive is spreading rapidly by birds and other animals. It is becoming a scattered understory tree in open forests throughout the southeast.

Silverthorn or Thorny Olive (*Elaeagnus pungens* Thunb.) is a popular ornamental evergreen, bushy shrub with long limber shoots projecting to 16 ft tall. It has alternate leaves, which in spring are silver and scaly on both top and bottom, and by midsummer become dark green above and silvery beneath. Thorns are widely scattered on its branches, subtended by red fruit with brown scales appearing in spring. The fruit are consumed and widely dispersed by wildlife, forming scattered infestations. This widely planted ornamental shrub was introduced from China and Japan. A shade tolerant species, it replaces native understory vegetation and prevents natural tree regeneration. It occurs in all southeastern states, except Texas, Oklahoma, and Arkansas.

Winged Burning Bush (*Euonymus alata* [Thunb.] Sieb.) is a shade tolerant, deciduous, bushy shrub to 12 ft tall with opposite leaves along stems with four corky wings. Introduced from northeast Asia in the 1860s, it is still widely planted as an ornamental. In fall, the leaves turn bright red, while orange fruit appear as stemmed pairs in leaf axils and are spread widely by birds and animals. *E alata* is increasingly invading forests, pastures, and prairies. It is forming dense stands which exclude native plants and eventually stop native tree regeneration. This problem is spreading in Oklahoma, Kentucky, Tennessee, Virginia, Georgia, North Carolina, and South Carolina.

Invasive Vines
Alien invasive vines are some of the most troublesome invaders because they often form the densest infestations, making herbicide applications difficult. Many of these vines overtop even mature forests and often form mixed species infestations with exotic trees and shrubs.

Japanese Honeysuckle (*Lonicera japonica* Thunb.) is a shade-tolerant, climbing, trailing woody vine with semi-evergreen leaves opposite the stem. Paired white to yellow flowers in early summer yield blackish berries in fall and winter. Introduced from Japan in 1806, this is probably the most widespread and insidious exotic species, occupying multiple strata in lowland and upland forests, replacing native vines and altering habitat and ecosystem processes. Japanese honeysuckle is sold as an ornamental, is valued as deer browse, and has some value for erosion control. It is still planted and cultured in wildlife food plots, and sustains deer herds at higher levels during winter. It occurs throughout the southeast, and spreads by widely rambling vines rooting at nodes, as well as by bird-dispersed seeds.

Kudzu (*Pueraria montana* Lour. Merr., formerly *Pueraria lobata* [Willd.] Ohwi) is a semi-woody leguminous vine, with lobed trifoliate leaves, which spreads by vine growth, rhizomes, and animal and water dispersed seeds. Introduced as an ornamental from Japan in 1876, kudzu was planted extensively for erosion control and forage in government sponsored programs from 1920 to 1950. It forms dense infestations excluding native plants, halting forest productivity, and changing habitat on millions of acres. As kudzu increasingly invades riparian habitat along rivers and streams by floating seedpods, hydrologic impacts are anticipated. This vine has become a popular southern icon, and provides some raw material for folk art. A biocontrol program has been initiated by the USDA Forest Service.

Oriental or Asian bittersweet (*Celastrus orbiculatus* Thunb.)is an attractive but very invasive vine, with elliptic to rounded deciduous leaves, 2 to 3 in. broad and long, alternating along a woody vine with drooping branches. Clusters of scarlet fruit appear in fall and remain during winter at most leaf axils, and are widely spread by birds. Introduced from Asia in the 1860s, *C. orbiculatus* is valued for its showy berries, which are used as home decorations in winter. The seeds are widely spread by birds. Oriental bittersweet colonizes disturbed forests and along forest edges, climbing by a twining process to damage adjoining trees, forming expanding thickets and decreasing plant diversity. It is invading from the northeast and is not yet found in Oklahoma, Texas, Louisiana, or Mississippi. American bittersweet (*Celastrus scandens* L.) has flowers and fruit only in terminal clusters and does not form extensive infestations.

Exotic Climbing Yams

Air yam (*Dioscorea bulbifera* L.) and Chinese Yam (*D. oppositifolia* L., formerly *D. batatas*) are twining and sprawling vines that cover vegetation, with heart-shaped leaves and dangling small yam-like tubers (bulbils) at leaf axils in mid- to late-summer. These tubers drop and form new plants. Even though the vines are deciduous, their rapid growth in a year can cover small trees. Native *Dioscorea* species do not produce "air potatoes" nor form infestations that cover trees. Chinese yam is from Asia and air yam is from Africa. Both were introduced as possible food sources in the 1800s, but they are ornamental and often spread by unsuspecting gardeners. They are also presently cultivated for medicinal use. These vines persistently colonize forests once established, since prolific bulbils form new plants. They expand throughout the understory to form exclusive infestations. Their distribution is scattered throughout the southeast, with air yam mostly in the southern Gulf Coastal Plain and Chinese yam more common in the Appalachians.

Wintercreeper or Climbing Euonymus (*Euonymus fortunei* [Turcz.] Hand. Maz.) is a trailing, climbing, or shrubby evergreen plant, with opposite, thick, dark-green or green-white variegated leaves. It is shade-tolerant, spreads to form a dense ground cover, and climbs by aerial roots. Abundant reddish-hulled orange fruit appears in fall and are widely spread by birds. Introduced from Asia as an ornamental groundcover and still widely planted, *E. fortunei* continues to form dense exclusive infestations decreasing diversity, hindering access, and altering habitat. It occurs in Kentucky, Virginia, Tennessee, Mississippi, Alabama, Georgia, North Carolina, and South Carolina.

Japanese Climbing Fern (*Lygodium japonicum* [Thunb. Ex Murr.] Sw.) is a viney deciduous fern with lacy, finely divided leaves and green to orange to black wiry stems that climb and twine to cover and smother shrubs and trees. Native to Asia and tropical Australia, it was introduced from Japan as an ornamental and is often spread by unsuspecting gardeners. This is one of three species of climbing ferns in the southeast. The American climbing fern (*L. palmatum* [Bernh.] Sw.) and old world climbing fern (*L. microphyllum* [Cav.] R. Br.), another exotic which grows in Florida, have once-divided leaves. All are perennial plants, growing from creeping rhizomes and spread by wind dispersed spores. Spore dispersal from exotic species result in rapid spread and widely scattered dense infestations, covering native herbs, shrubs, and eventually trees. *L. japonicum* is invading from the south to the north, and has yet to arrive in Oklahoma, Tennessee, or Kentucky.

Chinese Wisteria (*Wisteria sinensis* [Sims] DC.) and Japanese Wisteria (*W. floribunda* [Willd.] DC.) are woody, leguminous vines (or shrubs) with long pinnately compound leaves and showy spring flowers. They spread by rooting vine growth and less commonly by seeds. Both form dense infestations, unlike the native or naturalized American wisteria (*Wisteria frutescens* [L.] Poir.). These traditional southern porch vines were introduced from Asia in the early 1800s. They are spreading slowly except when near rivers and streams, forming dense infestations mainly around old home sites, often in mixtures with other exotic plants. Both hinder reforestation and access. Both commonly occur as scattered patches throughout the southeast.

Invasive Grasses

Invasive grasses continue to spread along highway rights-of-way and then into adjoining forestlands. Most alien invasive grasses are highly flammable, increasing fire intensities, and fostering their spread after wildfire or prescribed burns. Wildland firefighters and forest home sites are subjected to increased risks. Repeated applications of herbicides are required for control.

Cogongrass (*Imperata cylindrica* [L.] Beauv.) is a dense, erect perennial grass. Its wide yellowish-green leaves have off-center midveins and finely saw-toothed margins. Native to southeast Asia, it was introduced in the early 1900s, at first accidentally and then intentionally for soil stabilization and wrongly for forage. It has been rated as the world's seventh worst weed (Holm and others 1979). It spreads by wind-blown seeds in early summer and by rhizome movement in fill-dirt along highways, often yielding circular infestations. This grass is highly flammable and a fire hazard. It is mostly shade tolerant. Dense infestations increasingly occupy forest openings, opening forests, and rights-of-way in the southern Gulf Coast states, excluding most native plants, stopping forest regeneration, and destroying habitat. This process is hastened with burning. Cogongrass is invading from the Gulf

Coast states to the north, and has not yet arrived in North Carolina, Tennessee, Virginia, Kentucky, Arkansas, or Oklahoma.

Nepalese Browntop (*Microstegium vimineum* [Trin.] A. Camus) is an annual grass. Stems grow 1 to 3 ft, with alternate, lanceolate leaves to 4 in. long. It forms dense mats and consolidates occupation and spreads by prolific seed production in late summer. Seed remain viable for one to five years. This shade tolerant weed is native to temperate and tropical Asia, and was introduced near Knoxville around 1919. It is increasingly occupying creek banks, floodplains, forest roadsides and trails, damp fields, and swamps. It spreads into adjoining forests, forming exclusive infestations, and displacing all native understory plants. It occurs throughout the southeast except in Oklahoma.

Chinese Silvergrass (*Miscanthus sinensis* Anderss.) is a tall, densely clumped, perennial grass, with upright to arching, long-slender leaves with whitish upper midveins, 5 to 10 ft tall. Silvery to pinkish loose plumes appear in fall, with spotty seed viability. Native to eastern Asia, *M. sinensis* has been planted in all states for landscaping, recently using sterile cultivars. It is spreading from older fertile plants in all states except Arkansas, Oklahoma, and Texas. Still widely sold and planted as an ornamental, it is highly flammable and a fire hazard. It forms dense infestations along rights-of-way, and in disturbed upland forests, excluding native plants and altering habitat.

Invasive Forbs and Subshrubs

Forbs are broadleaf herbaceous plants. Control treatments are usually by foliar sprays of herbicides.

Garlic Mustard (*Alliaria petiolata* [Bieb.] Cavara & Grande) is a biennial herb and all plant parts have an odor of garlic. It grows in small to extensive colonies under forest canopies, with basal rosettes of leaves in the first year remaining green during winter, becoming 2 to 4 ft tall in the second year. Leaves are broadly arrow-point shaped, with wavy margins. The flowers form in terminal clusters and have four white petals. Introduced originally as a medicinal herb from Europe in the 1800s, garlic mustard is displacing native forest understory plants and drastically altering habitat. This species is a prolific seed producer with germination occurring only in spring, while seeds can lay dormant for two to six years. A biocontrol program has been started at Cornell University (Blossey and others 2001). Garlic mustard is invading from the northeast, and has yet to arrive in Florida, Alabama, Mississippi, Louisiana, or Texas.

Shrubby Lespedeza (*Lespedeza bicolor* Turcz.) and Chinese Lespedeza (*L. cuneata* [Dum.-Cours.] G. Don) were both introduced from Japan. Shrubby lespedeza is a shade-tolerant, shrubby legume, with three leaflets, growing up to 10 ft tall and producing small purple-pink pea-type flowers. Chinese lespedeza is a semi-woody plant to three ft tall with many small, three leaflet leaves feathered along erect, whitish stems. It forms tiny cream-colored flowers during summer. Both species produce abundant single-seeded legumes, with dispersal methods unclear. They have been planted extensively for wildlife food and soil stabilization. Although still planted for quail food, these plants often invade surrounding forests, replacing native plants throughout the southeast.

Site Rehabilitation after Alien Invasive Plant Control

The rehabilitation phase is the most important final part of an eradication and reclamation program. The establishment or release of fast growing native plants is required, which will out-compete any surviving exotic plant. Native plant seeds and seedlings are becoming increasingly available for planting for rehabilitation, but limited species and the absence of well-developed establishment procedures often hinder use. Native plant communities naturally reinitiate succession on many areas after exotic plants are controlled when the soil seed bank remains intact. Constant surveillance, treatment of new unwanted arrivals, and rehabilitation of current infestations are the necessary steps to manage exotic plant invasion on a specific site.

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A CASE STUDY OF ANURAN DECLINE IN A SUCCESSIONAL LONGLEAF PINE SAVANNA

Thomas Mohrman, Carl Qualls and Gary Hopkins

Abstract: Declines in frog populations have been reported throughout many of the world's habitats. Often these declines are popularized and cited as indicators of biodiversity loss (i.e. amphibian declines in tropical rain forests). Although anuran communities in longleaf pine habitats do not possess an equal species richness to that of tropical rain forests, they still offer insights in the health of our southeastern pine forests.

Between 1993- 1996 a survey of herpetofauna in the Gulf Islands Nation Seashore (GUIS) was conducted by Rich Seigel and Sean Doody. Part of this survey was conducted in the Davis Bayou park unit, of which sections have historically been longleaf pine savanna. *Bufo quercicus* and *Hyla femoralis* were among the frog species documented by this survey to occur in Davis Bayou. In 2004, however, herpetological sampling has shown that these two frog species are no longer present. With the absence of seasonal fires, the longleaf pine savanna of Davis Bayou has continued to undergo succession. The resulting loss of an open canopy and increase of a woody understory may have resulted in the disappearance of these two frog species. Currently, resource managers at GUIS have proposed the reintroduction of these species to the park in hopes of re-establishing viable populations.

Davis Bayou's successional history:
Davis Bayou is the Mississippi headquarters of the Gulf Islands National Seashore. Within Davis Bayou's 401 acres (162.2 hectares), a diverse number of habitats exist including: tidal marsh, bayhead swamp, maritime forest, wet pine savanna, and wet pine flatwoods. The longleaf savannas characteristic of Southern Mississippi were clear cut prior to the park's 1947 inception, leaving isolated longleaf pines, that were too small to harvest. These longleaf pine trees managed to persist, but with the absence of fire, hardwoods came to dominate, closing the canopy to the detriment of those species which prefer an open canopy. Areas in the park which have been identified as wet pine flatwoods, under natural fire regimes would remain wet pine savanna. Also note that urban development surrounds the wet pine habitats, creating a potential barrier for a natural re-introduction of frogs to the park.

In the spring of 2002, Park Service personnel conducted an ecological and safety burn of habitat surrounding remnant wet pine savanna. The burn resulted in an opened canopy and made available habitat for species such as pitcher plants and sundews.

Species Profiles
The oak toad, *Bufo quercicus*, is an abundant amphibian of southern pinewoods. Distributed in the lower coastal plain, this fossorial toad is found in areas with sandy soil and a grassy understory beneath an open canopy. The smallest member of the toad genus, *B. quercicus* reaches a maximum snout-to-vent length of 35mm. Identification is simple due to a conspicuous light stripe down the frog's back. It has a distinct high pitched call that closely resembles the sound made by a baby chicken, and is often heard during the day. Breeding is associated with warm and rainy weather from April to October.

The pine woods tree frog, *Hyla femoralis*, is commonly found in pine flatwoods and near cypress swamps. A small treefrog attaining a maximum snout-to-vent length of 40mm, their dorsum can be gray or brown with one or more irregularly shaped blotches, or rarely, monochromatic. Visual identification can be difficult since this treefrog resembles other species in its genus. Accurate identification can be made based on a row of small orange, yellow or white spots within a dark background on the rear of the thigh. Its call, however, is easily recognized, sounding somewhat like random Morse Code, with a snore. A large chorus sounds like a series of riveting machines all operating at once. Breeding calls can be heard from April to September. Frequently, the pine woods tree frog shares a breeding site with *Hyla squirella*, *Bufo quercicus*, and *Gastrophryne carolinensis*.

Herpetological sampling of Davis Bayou:
The 2004 anuran sampling regimen utilized several standard techniques to comprehensively survey all habitats within Davis Bayou. Three trap arrays were installed, each consisting of a drift fence with four box traps and four pitfall traps, 10 wood coverboards, and 10 metal cover boards. Each trap array was checked a total of 22 times for the duration of sampling. Additionally, 12 PVC pipe sampling tubes were deployed on trees to sample for treefrogs and were checked concurrently with trap arrays checks. Various aquatic habitats were sampled using minnow traps, for a total 261 trap days. Finally, survey personnel logged in a combined total 183 active search hours, and 12 frog

call surveys. A total of 11 anuran species were including; *Bufo terrestris*, *Acris gryllus*, *Hyla cinerea*, *Hyla gratiosa*, *Hyla squirella*, gray treefrog, *Pseudacris crucifer*, *Gastrophryne carolinensis*, *Rana catesbeiana*, *Rana grylio*, and *Rana clamitans*. Sampling was conducted in the months of March, April, May, and June.

The survey conducted by Seigel et al identified eight species; *Bufo quercicus, Bufo terrestris*, *Hyla cinerea*, *Hyla femoralis*, *Hyla squirella*, gray treefrog, *Rana catesbeiana*, and *Rana clamitans*. Similar methods were used to sample, however, unlike the 2004 survey, Davis Bayou was not designated a priority site by the NPS for the 1996 survey and therefor did not receive as much attention.

DISCUSSION

Ten years have approximately spanned between the two herpetological surveys. Davis Bayou has not been regularly burned (with the exception of the 2002 controlled burn) and succession has continued. As tree canopies have become more dense, the open tree canopy habitat preferred by oak toads, *B. quercicus* and pine woods treefrogs, *H. femoralis,* has slowly disappeared over time. Since natural succession appears to be the only dynamic in this part of Davis Bayou to have changed, it is likely that it has had an effect on the local disappearance of these two frog species. It is also important to note that both species have been heard calling from residential areas immediately adjacent to the park. These frogs are ubiquitous in the area, just no longer in the park.

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ECOLOGY OF LONGLEAF FORESTS IN MISSISSIPPI

Julie H. Moore

Abstract: In 1840 after traveling through the northern part of the Mississippi piney woods, historian John F. H. Claiborne wrote "The growth of giant pines is unbroken for a hundred miles or so, save where river or large water courses intervene…Much of it is covered exclusively with the longleaf pine; not broken, but rolling like the waves in the middle of the great ocean. The grass grows three feet high and hill and valley are studded all over with flowers of every hue. The flora of this section of the state and thence down to the sea border is rich beyond description (Claiborne 1906)." At that time longleaf forests may have occurred on over 7.7 million acres in Mississippi from the coastal lowlands bordering the Gulf of Mexico northward for 150 miles into the interior coastal plain and across the state from the Alabama border to the loess bluffs bordering the Mississippi River.

Despite Claiborne's tantalizing description, that could have attracted botanists, there is relatively little published information that adequately describes the characteristics of the distinctive Mississippi longleaf forest associations that were so important to the economy of the state for producing both forest products and livestock. In this region beyond the range of wiregrass, where turkey oaks are a rarity, open range laws encouraged frequent burning well into the 1940s maintaining open longleaf stands above species rich, bluestem dominated ground layers. The most common longleaf forest associations and some of the more unusual ones, as well as the uncommon wildlife species, found on the acres that still support longleaf stands are illustrated and discussed.

INTRODUCTION

Little has been written to document the longleaf associations found in Mississippi and even less to describe their similarities to longleaf in the Gulf coastal plain in contiguous states or the differences from longleaf associations along the Atlantic coastal plain. The following information is based on my personal observations while working as a plant ecologist in south Mississippi. It is intended as an introductory guide to the longleaf forests around Hattiesburg and in other regions of the state for visitors during the Fifth Longleaf Alliance Regional Conference.

Upon joining the Mississippi Natural Heritage Program as coordinator of a biological inventory of Camp Shelby National Guard Training Site, I began assembling information on the plant communities of the piney woods. Some of the then recently published information led me to think I would be working in longleaf sandhill communities (Stout and Marion 1993) that were familiar with from earlier work in the Carolinas and Georgia. I knew wiregrass (*Aristida beyrichiana)* would not be a component for the ground cover as it only occurs in the three most eastern coastal counties along the Alabama boundary. What I did not anticipate is the mesic loamy sands and fine sandy loams that support extensive rolling hill longleaf (rather than sandhill) forests and associated hillside seepages populated with pitcher plants. The species rich ground cover with numerous, and difficult to identify, bluestems were a surprise as were the ever present evergreen shrubs that replace scrub oaks as the dominant midstory.

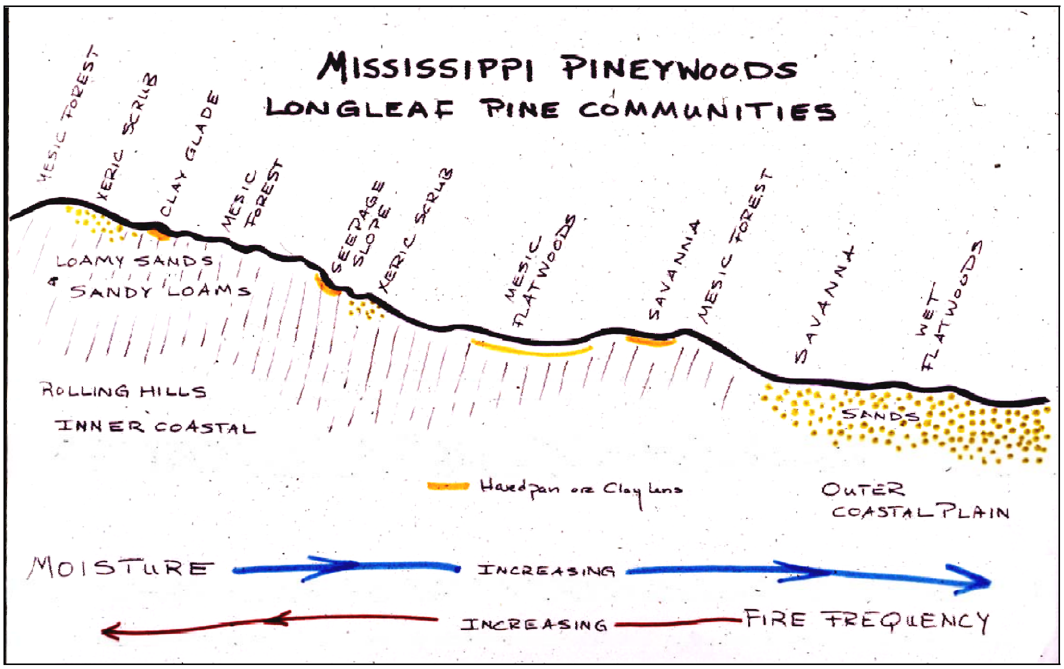
Fire as a forage management practice continued in the piney woods of Mississippi due to open range laws which supported an economy based on livestock as well as forest products. Woods burning, both natural and man set, had not been suppressed or viewed a destructive force in this relatively sparsely populated region as was the case in Atlantic states where thousand of acres of longleaf quickly became choked with scrub oak thickets due to fire suppression efforts. In 1897 it is estimated that there were still 7,700,000 acres in longleaf in Mississippi, which is why southern Mississippi was a major center of naval stores production in the early 1900's after the industry had moved westward across the south.

Livestock and naval stores were the main products of this region until the end of the 1890s and early 1900s when big timber companies began moving south from the north central states and quickly harvested the magnificent stands original growth longleaf. According to Napier (1986) " By 1908 U. S. foresters estimated that more than half of Mississippi's longleaf-pine forests had already become barren stump-doted wastelands, and that the rest would be exhausted in twenty-five years." By 1955 all the old growth forests had been harvested, even the old turpentine orchards, and only just over a million acres remained. By 1995 there were 225,300 acres in longleaf, a loss of 97% in less than 100 years. Based on 1990 records, 54% of the remaining longleaf was owned by private landowners, 35 % was in national forests, 7% was held by the timber industry and 4% by the state (Hughes 1999; Outcault 1996). Although more private landowners in Mississippi are replanting with longleaf, the loss of natural stands continues.

DISCUSSION

The most common longleaf association in the state is the rolling hills forest which is situated in the interior coastal plain generally at the higher elevations, see Figure 1. This is the rolling landscape on which Hattiesburg is situated. The high quality longleaf forests that still grow on orange to red sandy loams and loams sands of the rolling hills are usually closed canopied with a few scattered midstory trees such as southern red oak, black jack oak, sand hickory, and dogwood, with patches of evergreen shrubs made up of gallberry, sweet gallberry, yaupon, and wax myrtle, and a diverse, grassy ground cover. At the northern and western edge of the longleaf range in the state, loblolly and shortleaf pine are also components of the forest, the proportion varying with topography, exposure, soil type and past land use. Shortleaf pine, though always a minor component, is more common than loblolly in frequently burned forests and grows in association with longleaf both as a single tree and in stands on dry ridge crests. Loblolly and slash pine increase within longleaf stands as soil moisture increases.

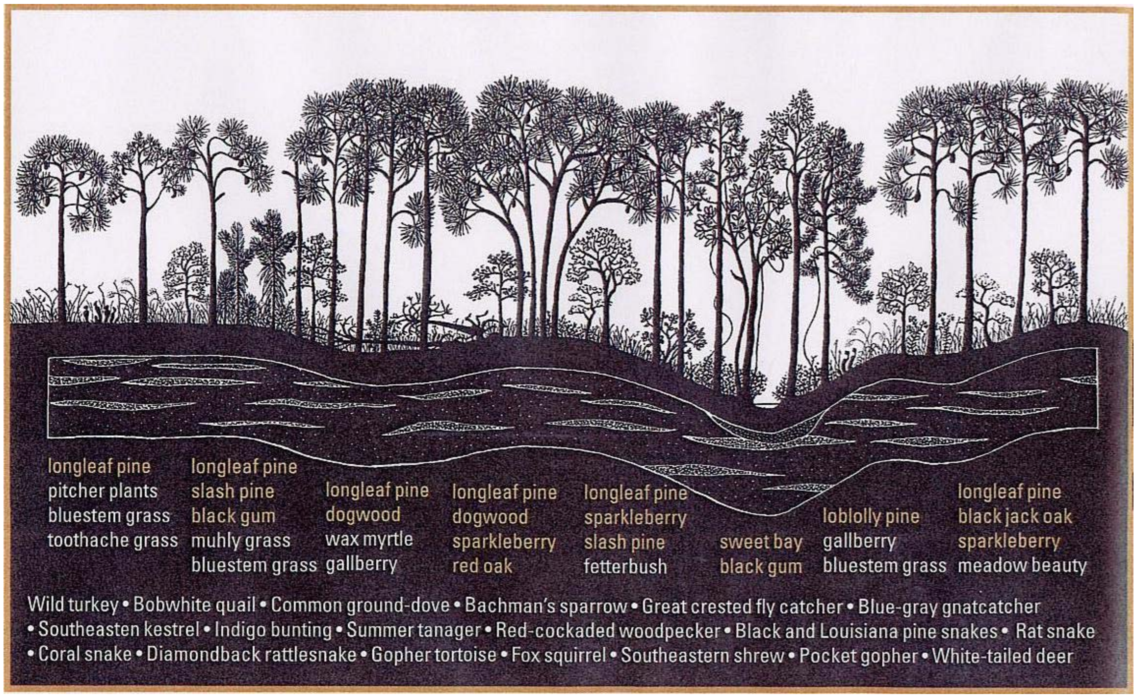
Figure 1. Mississippi Piney Woods Longleaf Pine Communities.



Although fire tolerant oaks are common, they seldom form dense stands unless burning has been suppressed for decades. Numerous species of bluestems (both *Andropogon* and *Schizachyrium* species) as well as three-awns, paspalums, dropseeds, muhly grasses, and panic grasses, as well as toothache and skeleton grass, are common components of the ground cover. In the season following a burn, the blue or chalky stems of little bluestem *(Schizachryium scoparium)* are distinctive. A year or two later, the lax, delicate greenish brown stems of slender bluestem *(S. tenerum)* are more obvious. Giant *(S. gerardii)* and Elliott's or sandhill bluestem *(Andropogon gyrans)* are often present but not abundant. Legumes, including several species of *Tephrosia, Cassia, Desmodium, Rhynchosia,* and *Lespedeza*, are numerous as are members of the sunflower family particularly silky grass, whorled-leaf and narrow-leaf coreopsis, and several species of aster and boneset. Ground cover diversity is high in undisturbed, frequently burned stands with as many as 100 species in a 10 by 50 meter plot and 105 in an exceptional plot. These numbers compare favorably with the high diversity savannas of the Atlantic coastal plain (pers. com. Bruce Sorrie).

In addition to the ubiquitous evergreen shrubs, the density of which depends largely on the frequency of burning, other common woody species include sparkleberry, black gum, sweet bay and horse sugar, their frequency depending upon the soil type. The illustration of the generic rolling hills longleaf in Figure 2 indicates topographic and soil features and characteristic plant and animal species (Moore 2001). The natural fire interval is estimated to have been from three to five years. When burning is less frequent, the under story quickly becomes a dense thicket of evergreen shrubs, the ground cover is suppressed and natural regeneration of longleaf is limited to sunny gaps where trees are killed by lightening or in narrow strips created when tornadoes blow down or break the crowns of the canopy trees, which is a more common phenomena in the Gulf coastal plain than the Atlantic coastal plain.

Figure 2. Rolling Hills Longleaf.



Where clay lenses are close to the surface conditions are moister, and here and there seepages occur that support pitcher plant wetlands with numerous colorful savanna and seepage bog species. While some seepages are perennial and limited in extent to a few acres, an unusual type over layered clay soils covers several hundred acres and supports a rare, endemic species, the Camp Shelby burrowing crayfish (*Fallicambarus gordoni*). Slash pine is now more common that longleaf in these extensive flats where water stands for prolonged periods during the winter and early spring, and in summer and fall the surface is extremely dry allowing fire to move from the adjacent rolling longleaf across these only seasonally wet sites.

An uncommon inclusion within the rolling hills longleaf forest is the xeric (dry) longleaf woodland found on white sands with widely spaced pines, turkey oak and saw palmetto and a patchy ground cover with lichens and occasionally prickly pear. The sand varies in depth from several to ten or twelve feet, but, with a few exceptions, these sandhill-like stands are limited in acreage and infrequent. A very distinctive and rare community within the rolling hills forest is the clay glade where dense, acidic clay has formed immediately below ridge crests resulting in growing conditions that support isolated or clumps of longleaf over a dense grassy ground cover dominated by muhly grass and herbaceous species such as colic root, rayless sunflower, sundew and occasionally butterwort that are common on flat, moist sites. It is on these sites that a few old growth longleaf remain as comparatively short, flat-topped trees. The glades are seldom more than an acre or two in size, and the topography quickly drops off into moist, shady mixed hardwood and mixed pine ravines.

Animal species characteristically associated with rolling hills longleaf forests are indicated in Figure 2. One of the best known is the gopher tortoise, a federally threatened species west of the Mobile and Tombigbee Rivers. Gopher tortoise colonies are not confined in this region to deep sands but are commonly found on sandy loams and loamy sands creating burrows above clay lenses and hardpans. The black pine snake is a particularly rare species found in this association. Its known range is southern Mississippi extending into similar longleaf habitats in Louisiana and Alabama. It is no where common today and is a federal candidate for listing. Although once thought to use gopher tortoise burrows, research at Camp Shelby has shown that this snake uses the root cavities of older growth pine stumps. Other rare snakes found in the pineywoods include the diamond-backed rattlesnake and coral snake.

On the Homochitto National Forest, almost due west of Hattiesburg in the southwestern part of the state, rolling hills longleaf and mixed longleaf-loblolly stands are found today only scattered on ridges surrounded by loblolly and mixed hardwood-loblolly stands. How common longleaf was in that region in presettlement times we will never know, but today is seldom found in this steeply rolling landscape in stands of more than 30 acres. The sandy loams and loamy sands are similar to the soils in the eastern part of the state. The herbaceous composition is also similar with little bluestem and slender bluestem being the most evident grasses, and the species diversity is also similarly high. Evergreen shrubs are less common although present and deciduous shrubs, such as beautyberry and various blueberries, are more abundant. Several of the remaining older growth longleaf and mixed pine stands are managed for the endangered red-cockaded woodpecker with frequent burning, and artificial cavities and inserts are used to supplement the natural cavities. Contiguous loblolly and shortleaf pine stands are also burned frequently to maintain an open under story for foraging territory.

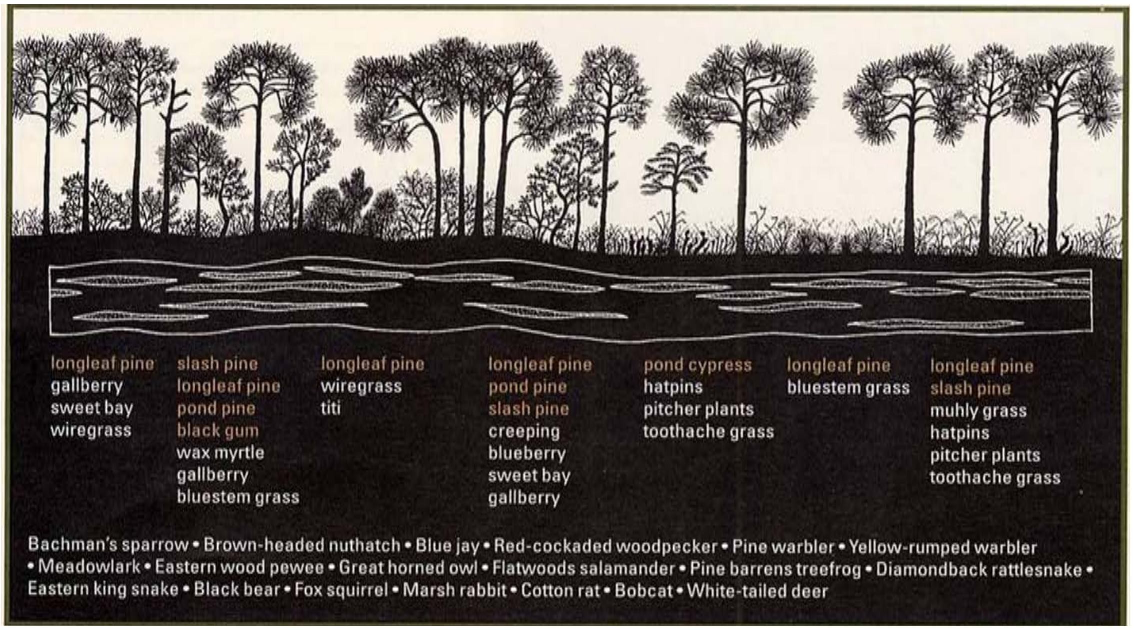
Interior coastal plain mixed pine flatwoods and savannas occur on less rolling terrain, see Figure 1. These longleaf associations grow on soils that are wetter, due usually to underlying hardpans or clay lens that retard drainage. Slash pine is typically a component in dense flatwoods forests where yaupon, sweet gallberry and wax myrtle are the major evergreen under story species with scattered black gum and sweet bay magnolia. Savannas are more open due to slightly better drainage and somewhat sandier soils. Pitcher plants with a variety of colorful orchids and Catesby's lily are common in these broad, level wetlands and in the shallow drains that form between low hills. The fire interval in these forests appears to be slightly longer, six to nine years, than in the rolling hills to the north due to the longer duration and frequency of standing surface water.

Moving southward and down slope (see Figure 1) into the outer coastal plain closer to the Gulf, the terrain is flat, with longleaf and slash pine growing on nutrient poor, wet organic sands. The presettlement proportions of longleaf and slash in the coastal savannas will probably never be determined given the history of harvest and altered fire frequency. Widely scattered, short, small diameter pines form open stands above a rich ground cover with the white topped and purple pitcher plants joining the more common yellow (winged) and the parrot pitcher plant. Sundews and butterworts are also present. Toothache grass and muhly grass abundant and, at the boundary with Alabama, wiregrass can also be found. Rose bud, spreading pogonia, and yellow and white fringed orchids, with yellow and pink meadow beauty, create colorful displays. In the wettest parts of the coastal savannas grow gnarled flat-topped pond cypress. These sparsely wooded coastal savannas are the year round habitat for the Mississippi sandhill crane. Some of the largest remaining acreages of this distinctive savanna association are found along Interstate Highway 10 within the Mississippi Sandhill Crane National Wildlife Refuge which was created to protect habitat for this endangered resident bird. The savanna illustration in Figure 3 (Moore 2001) lists characteristic plant and animal species. It is challenging to burn in this rapidly urbanizing region bisected by a major highway is challenging. The estimated fire interval for this wet flatland is two to five years.

CONCLUSION

Based on the good examples of actively managed longleaf that remain, we are fortunate to be able to envision what the vast longleaf forests of the state of Mississippi looked like over 100 years ago. However, despite considerable recent interest and research, we still do not fully understand this majestic tree and forest either as a natural system that needs good husbandry or as a viable economic forest resource.

Figure 3. Savanna Longleaf.



A heartfelt statement on longleaf from a forester many of you know, Leon Neel, sums up very well the longleaf pine (Crofton 2001). "I guess if every longleaf pine tree in the world was eliminated, the human race would still be here. But the point is, what is next to go? The only way to perpetuate our species is to respect where we came from – life itself. We don't even know what the value of this ecosystem is to us yet. We take these things for granted. We haven't learned the complexities of the longleaf ecosystem and how it affects us. It's a beautiful forest. Every day, night or day. In a rainstorm, it's still beautiful; it is just different. Any weather, any season of the year it's fantastic. You look out there and it's just stability represented out there. Of course, it's very fragile because man can destroy it in a minute, but you look at the forest and it looks solid. We need to make sure that this forest, in all its stability, is here for generations to come."

I hope you enjoy your brief time in the piney woods of Mississippi as much as I enjoyed working in them.

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GOPHER TORTOISE, *Gopherus polyphemus*, HATCHING SUCCESS IN DESOTO NATIONAL FOREST IS INFLUENCED BY EGG QUALITY AND THE NEST ENVIRONMENT

Krista Noel and Carl Qualls

Abstract: This study focuses on gopher tortoise hatching success in DeSoto National Forest, one of the last strongholds of this species in the western portion of its range. Previous studies have found low recruitment here, largely due to low hatching success of tortoise eggs. This study's objective is to determine the causes of the low hatching success of gopher tortoises in DeSoto National Forest. In 2002 and 2003, hatching success was compared between eggs that were artificially incubated and those incubated under natural conditions. The success rate for laboratory incubated eggs was approximately 60% in both years, compared to hatching success of 6% (2002) and 16.7% (2003) for eggs that remained in natural nests. This suggests that 60% were capable of successful development, while as many as 40% of the eggs had intrinsic problems. The low hatching success in nests implies unsuitability of some aspect(s) of the nest environment. Consequently, aspects of the nest environment were quantified to search for correlations between environmental factors and hatching success. Multivariate analysis revealed that nest temperature and clay content of the soil were most strongly correlated with hatching success. In 2004, the relationship between these environmental factors and hatching success is being experimentally examined with an artificial incubation experiment. Eggs are being incubated under different thermal regimes, and in soil substrates of different clay contents (based on conditions present in nests during 2003), to experimentally determine the direct effect of these environmental conditions on hatching success.

INTRODUCTION

The gopher tortoise (*Gopherus polyphemus*), a large terrestrial turtle that excavates and inhabits underground burrows, is the only native tortoise species east of the Mississippi River. These tortoises are found in dry upland coastal plain habitats that were historically maintained by frequent natural fires. Unfortunately, due to the loss, fragmentation, and degradation of their habitat, as well as low recruitment, gopher tortoise numbers are declining throughout their range (Auffenberg and Franz, 1982). The decline has been most pronounced in the western portion of the species' range (Louisiana, Mississippi and western Alabama), prompting these populations to be federally listed as "threatened" and the species to be listed as "endangered" by the state of Mississippi.

In Mississippi, the DeSoto National Forest (NF) is home to the largest population (or metapopulation) of gopher tortoises in the western portion of their range. Therefore, the federal recovery plan for this threatened species has targeted this population as critical for its recovery (U.S. Fish and Wildlife Service, 1990). Epperson and Heise (2003) recently found that tortoises on the Mississippi Army National Guard's Camp Shelby Training Site, within DeSoto NF, suffered from low recruitment, largely due to low hatching success of their eggs. The objective of this study was to determine whether the low hatching success of gopher tortoise eggs in DeSoto NF was due to poor egg quality (intrinsic factors), unsuitability of the nest environment (extrinsic factors), or a combination of the two. This objective was met by employing a combination of field and laboratory experiments.

METHODS

This study was conducted at three study sites (Camp Shelby, McLaurin, and Crossroads) within DeSoto NF; all sites are within 48 kilometers of each other. Gopher tortoise nests were located via hand probing of all active adult burrow aprons. Each nest was carefully excavated, and each egg was given an identification number with a non-toxic grease pencil. Eggs to be incubated under natural conditions were replaced as found, and then fitted with predator excluder cages to protect the eggs/hatchlings from predation and to retain the hatchlings upon emergence. The physical and environmental characteristics of all nests were recorded, and hatching success was determined for each nest. The purpose of the field study was to determine to what extent environmental factors and nest characteristics are correlated with hatching success and to compare hatching success in nests with hatching success in the lab. A sample of eggs from each nest was also incubated in the laboratory, under environmental conditions known to be conducive to successful hatching, to determine the effect(s) of intrinsic factors on hatching success. Two eggs from each clutch were randomly chosen for the artificial incubation trial and randomly assigned for incubation in two programmable environmental chambers, under two fluctuating temperature regimes. One egg from each clutch was placed in a chamber with a mean temperature of 28.3°C and the other egg was placed in a chamber with a mean temperature of 30.3°C. Instead of incubating the eggs at a constant temperature, we used a temperature regime that mimicked the diel fluctuations experienced by natural nests. The purpose of the two artificial incubation treatments was to determine what proportion of the eggs would hatch under essentially ideal incubation conditions, and thus whether there were egg quality problems affecting hatching success. Eggs were considered hatched when the young tortoise could be seen breaking through the shell. Immediately after recording carapace length and hatchling mass, a unique marginal scute carapace notch was given to each hatchling prior to being released on its nest burrow apron (Cagle, 1939). After hatching was completed, nests were excavated to retrieve all unhatched eggs, which were then dissected to examine the contents for traces of a dead embryo. This method of monitoring allowed us to determine the fate of all eggs in each nest. Hatching success, as a percentage, was calculated separately for eggs incubated in the laboratory and those incubated in natural nests. To avoid pseudoreplication, whole clutches, not individual eggs, were treated as independent replicates. Because the hatching success data were not truly continuous, a nonparametric Wilcoxon Matched Pairs Signed Rank test was used to compare the mean hatching success rates of nest incubated eggs and laboratory incubated eggs.

RESULTS

Mean hatching success for laboratory incubated eggs was 58.8% (Table 1), with 22 of 36 eggs hatching. Of the 14 eggs that failed to hatch in the laboratory, five (35.7%) did develop to a point, and the remaining nine eggs (64.3%) contained no discernable embryo. Nest incubated eggs had a mean hatching success rate of 16.7% (Table 1). Thirteen of the 52 eggs that failed to hatch in the field (25%) had a dead (mostly late stage) embryo inside. One of the 52 eggs hatched but the hatchling was found dead in the nest cavity. Thirty-eight of the 52 eggs (73%) that did not hatch contained no sign of an embryo. The 38 eggs that contained no sign of an embryo when dissected do not necessarily represent eggs that never contained an embryo; an embryo could have been present at some point but may have decomposed during the time that elapsed before excavation. Only one natural nest, from Camp Shelby, had 100% hatching success in the field. In 2003, five of the 21 nests, all from Camp Shelby, experienced complete hatching failure, with zero eggs hatching in the nest or in the laboratory.

Mean hatching success was higher for eggs incubated in the laboratory (n = 17, mean = 58.8%, SD = 44.14) than for those incubated in natural nests (n = 17, mean = 16.7%, SD = 27.64). A Wilcoxon Matched Pairs Signed Ranks test indicated that this difference was statistically significant (df = 16, W = 35.0, $p = 0.003$). In the 2002 pilot study, hatching success was similarly different between laboratory incubated (60%) and nest incubated (6%) eggs.

Two partial least squares analysis models were generated, to predict hatching success in nests from the data collected on nest characteristics and environment. Nest temperature and clay content of the soil were most strongly correlated with hatching success in these models. Other factors influencing hatching success included the percent ground cover of shrubs and canopy cover of trees to the east. Canopy cover of trees to the east and percent ground cover of shrubs were positively correlated with hatching success, while average daily maximum nest temperature, average daily nest temperature range, and percent clay content in the soil were negatively correlated.

DISCUSSION

As was seen in the 2002 pilot study, the hatching success of eggs incubated in the laboratory was significantly higher than that of eggs in natural nests. The eggs in the laboratory were incubated under conditions that are known to be favorable, yet these eggs still experienced approximately 40% mortality. The consistent failure (in 2002 and 2003) of approximately 40% of the eggs to hatch in the laboratory, under suitable incubation conditions, suggests intrinsic problems with this proportion of the eggs. This study did not examine what aspect(s) of the eggs may be responsible for the failure of 40% of the artificially incubated eggs to hatch successfully. It is possible that some of the eggs were not fertilized, contained insufficient nutrient supplies for complete development, suffered developmental defects (perhaps due to inbreeding or parental senescence), or were affected by handling of the eggs during excavation and/or transport. Because great care was taken when handling and transporting the eggs, failure to hatch from handling stress should be insignificant. Some of the eggs that failed to hatch contained a well-developed embryo, indicating that these eggs were viable and fertilized, but the embryos died during development. Unfortunately, we were unable to distinguish between failed eggs that contained an embryo that died early in development and ones that never underwent any embryonic development at all. It was also not possible, without further evidence, to determine whether embryos died from intrinsic or environmental causes.

It would be expected that approximately 40% of the eggs in natural nests would fail to hatch, from intrinsic problems, as seen in the laboratory incubation trials. However, eggs in natural nests experienced 83% failure, significantly more than 40%, indicating that eggs failed to hatch due to both intrinsic factors and extrinsic factors. Logically, the additional 43% that failed to hatch must be due to some aspect(s) of the nest environment (i.e., temperature, moisture, and/or gas exchange conditions were inappropriate). Multivariate analysis showed that nest temperature and percent clay content of the soil are correlated with hatching success. Oxygen demands of embryos increase with higher temperatures, and the gas exchange abilities of eggs in a nest decrease with higher clay content of the soil. Thus, eggs that are buried in high clay content soils maybe more likely to suffocate, especially after periods of extensive rain. The risk of suffocation is exacerbated by high nest temperatures, and by high soil moisture.

The low hatching success of gopher tortoise eggs in south Mississippi appears to be attributable to a combination of intrinsic (egg quality) and extrinsic (nest environment) factors. Currently eggs are being incubated under different thermal regimes and in soil substrate of varying clay contents to further identify factors that directly influence hatching success. The finding of this research should prove valuable to management and recovery efforts for this imperiled species.

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Table 1: The mean percent hatching success in the lab, mean percent hatching success in the field, and the number of clutches per site for 2003.

Hatching Success 2003			
Site	**Nests/Clutches**	**Mean % Hatching Success in Lab**	**Mean % Hatching Success in**
Camp Shelby	12	45.8	13.9
Crossroads	2	75	16.7
McLaurin	3	100	27.8
Total	17	58.8	16.7

RESTORING STRUCTURE AND COMPOSITION OF LONGLEAF PINE ECOSYSTEMS OF THE GULF COASTAL PLAINS

Kenneth W. Outcalt

Abstract: Longleaf communities of the middle and upper Gulf Coastal Plains historically had an overstory dominated by longleaf pine (*Pinus palustris*) with pockets of other southern pines and occasional hardwoods, while the understory was grass dominated with lesser amounts of woody shrubs. The open grassy understory was maintained by frequent, every 2 to 5 years, low intensity fires. The objective of this research project is to develop realistic management options that can be used to manage fuels and restore this ecosystem. Research is being conducted in cooperation with Auburn University at the Solon Dixon Forestry and Education Center near Andalusia, Alabama. Treatments include an untreated control (no fire or other disturbance), prescribed fire only, mechanical removal of selected trees, and a combination mechanical removal of trees and prescribed fire. Although there was not a large change in either relative composition or diameter distributions, thinning created more open stands with fewer small hardwoods. The redistribution of logging slash facilitated prescribed burning just 2 months after the thinning operation. Cover of understory shrubs was reduced by both thinning and burning with the combination treatment the most effective. Burning caused the greatest reduction in small understory hardwoods while thinning alone had no effect. For larger midstory hardwoods, however, burning alone resulted in no change while thinning reduced their density significantly. Thus, fire is needed to control understory hardwoods while thinning is needed to reduce larger midstory hardwoods. Therefore, the combination treatment may be the quickest treatment for restoring structure and composition to this ecosystem.

INTRODUCTION

Historically, prior to fragmentation of the landscape, lightning ignited fire was a frequent natural occurrence (every two to eight years) across much of the South (Abrahamson & Hartnett 1990, Ware and others 1993). These fires regulated plant composition and favored those species that survived frequent burning. Native American burning augmented these natural fires. This burning kept fuel loads low, thereby reducing the probability of more severe wildfires. The South was one of the first areas where land managers recognized the usefulness and need for frequent prescribed burning to control fuel levels. A large influx of people from other regions of the country where fire is not as prevalent has occurred over recent decades. They do not understand the need for burning and only see the temporary negative aspects of smoke and ash and a blacked area. Increasingly this population growth has occurred on the edge or within forested areas creating a significant amount of wildland to urban interface. This has made prescribed burning much more difficult. Litigation from smoke on highways and an increase in rural highway traffic has also reduced the amount of prescribed burning, especially on private lands.

Reduced burning has resulted in significant changes that are undermining the health and long-term sustainability of many southern communities. Longleaf pine ecosystems for example were once the most prevalent type in the Southeast occupying as much as 23 million hectares, stretching from southeastern Virginia south to central Florida and west into eastern Texas (Stout and Marion 1993). This longleaf pine-grass ecosystem was maintained by frequent fires that inhibited the establishment and growth of competitive but less fire-tolerant species (Clewell 1989). Today longleaf occupies less than 5 percent of its original extent (Outcalt and Sheffield 1996). The continuing reduction of this important forest type threatens a myriad of life forms characteristic of, and largely dependent on, longleaf pine habitat.

Widespread treatments are needed to restore ecological integrity and reduce the high risk of uncharacteristically severe and destructive wildfires in these forests. Among possible treatments, however, the appropriate balance among cutting, mechanical fuel treatments and prescribed fire is often unclear. For improved decision making, resource managers need better information about the consequences of alternative management practices involving fire and mechanical, i.e. fire surrogate treatments. The objective of this study is to develop realistic management options that can be used to treat fuels and restore ecosystems. Reported here are the initial effects of these fire and fire surrogate treatments on stand structure and composition in typical gulf coastal plains longleaf stands.

METHODS

This study is part of the national Fire and Fire Surrogate study funded by the Joint Fire Science Program. However, this location received much of its funding from the National Fire Plan to include an ecosystem not in the original nationwide study. It is located about 35 km southwest of Andalusia, Alabama on the Solon Dixon Forestry

Education Center, which is owned and operated by Auburn University School of Forestry. Much of the 2150 ha forest is dominated by longleaf pine but other southern pines are also abundant including loblolly (*P. taeda*), shortleaf (*P. echinata*), slash (*P. elliottii*), and spruce pine (*P. glabra*). In many areas, especially the numerous lower bottoms, there is a substantial hardwood component dominated by oaks (*Quercus* spp.). The understory is dominated by woody shrubs with yaupon holly (*Ilex vomitoria*) the most abundant and lesser amounts of blueberries (*Vaccinium* spp.) and gallberry (*I. glabra*).

The four treatments were prescribed burning only, thinning only and their combination along with an untreated control. These were applied utilizing a randomized block design with three blocks. Stands were selected from all possible areas that were pine dominated with a significant amount of longleaf, were historically longleaf pine dominated, and were at least 12.5 ha. Trees were marked in selected stands at the end of 2001. Selected trees were sold to a commercial logger who began thinning in January of 2002 and finished operations by early April. Limbing was done near the stump with chainsaws. Logging slash was redistributed by hand to move concentrations away from remaining crop trees. Prescribed burning was done during April and May utilizing backing, flank, and spot fires (Outcalt 2003).

Each stand consisted of a core area of 12.25 ha with a surrounding 20m buffer. There were 36 grid points on a 50m by 50m spacing in each stand with ten rectangular 20m by 50m plots established between selected grid points. The overstory tree layer (all trees > 15cm at dbh) was sampled on the entire 20 by 50m plot, while midstory trees (3.1 to 14.9 cm) were sampled on 10 by 50m sub-plots. Diameters and species were recorded for all overstory and midstory stems before treatment application and one growing season post treatment. Cover of understory shrubs greater than 1.37 m tall was determined by ocular estimation before and after treatments on two 10 by 10m sub-plots located at each end of the 20 by 50 plots. Pretreatment data were analyzed with analyses of variance and post treatment data were compared with analyses of covariance using pretreatment levels as the covariate.

RESULTS

Prior to treatments total basal area ranged from 15.4 to 23.4 m^2/ha. Longleaf pine was the most prevalent species on all sites except stand 15, which was dominated by loblolly pine (Figure 1). Most stands also contained a considerable amount of hardwood, especially oaks. Thinning treatments targeted hardwoods and other pines to reduce their prevalence while increasing the dominance of longleaf pine. However, longleaf pine was also harvested where it was deemed appropriate to reduce stocking and remove inferior trees. On average across all stands thinning removed 10 percent of slash pine basal area, 15 percent of longleaf, 18 percent of loblolly, and 49 percent of other pines. The most heavily harvested were the hardwoods with oak basal area reduced by 55 percent and other hardwoods by 58 percent.

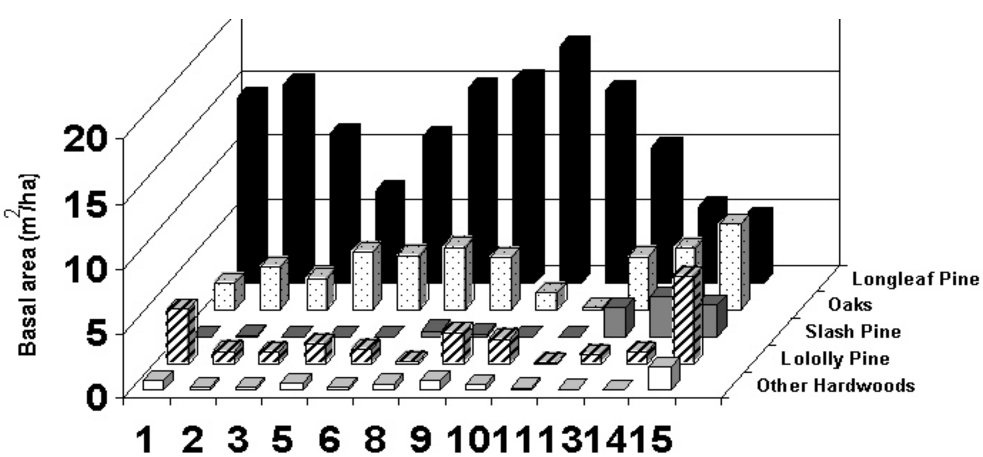

Figure 1.—Pretreatment basal area (m^2/ha) of overstory trees > 15cm diameter by stand and species group.

Midstory hardwoods were present in all stands prior to treatment with an average density from 104 stems/ha in stands that were selected for burning to 240/ha in the thin and burn stands. There were no significant changes in midstory hardwood density in control stands over the first 2 years. Burning alone did not significantly reduce midstory stocking. Some hardwood stems were harvested during thinning and additional individuals were knocked down by logging equipment. This resulted in a significant decline in midstory density on thinned only (216 pre vs. 87/ha post) and thinned and burned stands (240 pre vs. 42/ha post).

Density of the smallest diameter hardwoods stems (0.01 to 1.00 cm) was not affected by the thinning operation (Table 1). Burning, however, significantly reduced this size class of hardwood stems with over a ten fold reduction in both burn only and thin and burn stands. It appears that thinning may have reduced the density of understory hardwood stems in both the 1.01 to 2.00 and 2.01 to 3.00 cm diameter classes, but densities were still not significantly different from stocking in control stands. The effect of burning however, was quite pronounced in these larger size classes of understory hardwoods, where burned stands had very few of these larger hardwood stems one growing season following treatment.

Understory tall shrub cover averaged between 8.5 and 13.6 percent prior to treatment. All treatments significantly reduced tall shrub cover. Thinning reduced shrub cover from 13 to 4 percent and burning reduced it from 8.5 to 6 percent. The combination treatment caused shrub cover to decline from 12 to less than 1 percent.

Table 1. Density of understory hardwood stems before and one growing season after treatment of longleaf pine stands on the Solon Dixon Forestry Center.

	Stem DBH 0.01-1.00 cm		**Stem DBH 1.01-2.00 cm**		**Stem DBH 2.01-3.00 cm**	
Treatment	Before	After	Before	After	Before	After
	-Stems/ha-					
Control	478a*	500b	100a	143b	23a	33b
Burn	806a	68a	220a	13a	44a	10a
Thin	412a	394b	268a	131b	80a	39b
Thin & Burn	500a	42a	86a	3a	30a	4a

*Letters denote significant differences within a column at .05 level.

DISCUSSION

Thinning can be used to readjust structure and composition of the midstory and overstory layers of longleaf communities of the Gulf Coastal Plains region. By selectively targeting species that have increased during the period of reduced fires, a stand can be set on a trajectory to become a more open and fire adapted community where overstory health can be maintained with prescribed burning. These stands can be treated with growing season burns soon after thinning to dispose of slash and reduce wildfire hazard. This requires movement of logging slash away from the base of remaining trees. Because of this additional work and the more careful burning required with these higher fuel loads, treatment cost will be higher than normal. It took an average of 2.5 person hr./ha to redistribute logging slash and 5 person hr./ha to prepare and burn stands. In addition the burns were more spotty but still successful with proper planning and execution. The additional costs for slash moving and burning could be reduced by waiting 18 to 2 months for slash to decay before the site is burned. Once the stand has readjusted to growing season burns, costs will be more typical of prescribed burning in the region.

The cover of understory shrubs can be reduced by both thinning and burning. Burning is also the most effective means of removing small understory hardwood stems. Larger stems however, i.e. those bigger than 3.0 cm in diameter are quite resistant to burning and even those between 2 and 3 cm were more resistant than smaller stems. Thus, burning did not effectively reduce midstory hardwoods with a single burn. Others have also reported that young hardwoods are also quite susceptible to top kill by fire; and frequent fires can keep hardwood sprouts at low stature in longleaf stands (Komarek 1977; Landers and others 1990). Once stems become larger however, they are more resistant to future surface fires (Rebertus and others 1993). Repeated burning at frequent intervals is required to kill larger hardwoods and reduce the density of hardwood rootstock (Waldrop and others 1987). Therefore, although the combination thinning and burning treatment will be more costly, it is also the quickest method for restoring stand structure and overstory composition to these longleaf pine communities of the Gulf Coastal Plain. It will require continued prescribed burning on a regular basis to maintain these stands and further their development into a more open longleaf pine dominated overstory with a diverse herbaceous dominated understory.

ACKNOWLEDGEMENTS

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COMPETITIVE RESPONSES OF SEEDLINGS IN LONGLEAF PINE WOODLANDS: SEPARATING ABOVE AND BELOW GROUND EFFECTS

Stephen D. Pecot, Robert J. Mitchell, Brian J. Palik and Lindsay R. Boring

Abstract: Recent interest in restoring greater age structure to even-aged longleaf pine (*Pinus palustris* Mill.) stands has led to the exploration of overstory retention approaches that resemble the complex structure of natural disturbance. However, the benefits of overstory retention are tempered by increased competition between seedlings and the overstory. We conducted a study to quantify above- and belowground effects on the responses of planted longleaf pine seedlings and understory plants in a second-growth longleaf pine savanna. Resource competition was studied by severing overstory root connections with the understory plant communities through trenching in three locations within the study site: within the savanna matrix, at gap edges, and in the center of gaps. Paired control plots with no root disturbance were also located in similar overstory conditions. The understory was removed in one-half of each plot by an herbicide treatment (glyphosate). Container-grown longleaf pine seedlings were planted. Pine survival and growth (total biomass after 3 years), as well as productivity of herbaceous and woody understory components were recorded. Light reaching the understory was estimated by hemispherical photographs (gap fraction), and soil resources (soil moisture and N) were measured using time domain reflectometry and ion-exchange membranes, respectively. Light reaching the understory increased as overstory stocking decreased (light gaps). We found no evidence of belowground gaps due to overstory mortality if the understory community was intact; however, removing the understory increased soil N and water, and trenching amplified this effect. Longleaf pine seedling survival increased with greater shade when the understory and belowground communities were intact. Understory herbaceous productivity increased with light, and hardwood plant response to gaps was explained primarily through decreased belowground competition with adult pines. Longleaf pine seedling growth followed opposite patterns of survival. Longleaf pine seedling growth increased with increasing light when the understory community was left intact. In the absence of an understory longleaf pine seedling growth was controlled by both above- (light) and belowground (soil N) sources. These data suggest that care be exercised to ensure the presence of advanced regeneration of longleaf pine grass-stage seedlings before artificial gaps are created when uneven-aged approaches to management are considered.

ECONOMICS OF PINE STRAW PRODUCTION

Bill Pickens

Abstract: Pine straw is an increasingly popular mulch for landscapers, gardeners and homeowners in the southeastern US. Pine straw harvest in NC and Georgia is estimated to support a $50 million and $25 million industry respectively. While pine straw from both loblolly and slash pine is marketed, longleaf pine is a preferred mulch product because of its superior needle characteristics. Longleaf pine's longer needles bale better, retain a distinguished reddish color, and most importantly last significantly longer. Production areas must first be "cleaned up" to facilitate the raking and baling operation. Herbicides, hand cutting, and prescribed fire are used to remove understory vegetation particularly hardwood brush. Market standards require bales are free of limbs, pine cones, and hardwood leaves. Maintaining a basal area of 90 square feet per acre helps control understory competition and maximizes yields. Raking every 2-3 years is recommended to allow enough needles to accumulate thus increasing cost efficiency, and reduce adverse impacts to the soil and stand health. The amount of straw one can expect from a stand depends on stand density and site quality. Heavy needle fall in October and November and strong springtime demand make winter a good time to rake. A typical longleaf stand can average 75 -100 bales per acre per year. Pine straw is most commonly sold on a per bale basis to producers who do the raking and baling. The price ranges from $0.75 to a $1.50 per bale. Larger landowners may elect to rake and bale their own straw to realize a greater profit margin. Labor and expenses to bale straw average $1.50 per bale. With average wholesale prices of $3.50 per bale landowners can realize up to $2.00 per bale profit. The cost to purchase specialized raking and baling equipment reduces landowner returns. Hypothetically, straw raking every other year can increase the IRR by 1.5% and NPV by $234/acre over a 50-year rotation.

INTRODUCTION

The popularity of pine straw by homeowners and landscapers as groundcover mulch has increased substantially over the last 25 years. Management of longleaf pine forests for the production of pine straw supports a profitable industry across the Southeast. In North Carolina retail sales of baled pine straw are estimated between $30 to $50 million per year. Pine straw provides a valuable and consistent source income to forest landowners encouraging the establishment and long term management of the longleaf pine forests.

Though loblolly and slash pine contribute to the market, longleaf pine needles are generally regarded as the best of all pine straw. Longleaf pine straw is the preferred mulch product because of its superior characteristics. Longleaf pine's longer needles are easier to bale, retain a distinguished reddish color, and last significantly longer. In addition to providing the normal benefits to plant growth and health pine straw mulch forms a loose groundcover that allows water to infiltrate easily, does not wash out of the beds, and covers a larger area at a lower cost. Longleaf pine straw's earthy texture and color is attractive in many landscapes and aesthetically pleasing to the homeowner. Of all the species suited for pine straw mulch, longleaf is the Cadillac.

MANAGEMENT CONSIDERATIONS

Stand renovation

Pinestraw is typically sold in small bales. Bales that are free of cones, limbs, and hardwood leaves are preferred by users and bring the best market price. Therefore, the first step needed to bring a stand in production is too clean-up the debris and eliminate the hardwood brush. Brush removal increases the baling efficiency and maximizes the raking area of the stand.

Hardwood brush is controlled using herbicides, prescribed burns, mechanical removal or a combination. Several herbicides and application methods are labeled and provide effective control of woody brush and hardwood trees in pine stands. The decision on which to use is based on the species you want to control and stand's specific site conditions particularly soil type. Hexazinone applied in a grid using pellets or backpack sprayer works well on stands predominately occupied by well-established oaks. Imazapyr works well on maple, sweetgum, persimmon, or other hard-to-kill weeds. Triclopyr applied in the winter as a thinline basal, injection, or stump treatment or during the growing as a directed spray also provides effective control and provides the landowner a year round treatment option. The best advice for specific herbicide rate and timing recommendations is to consult a pesticide company representative.

Often, especially with the turkey oak, broadcast applications takes two years to fully kill the trees and have a narrow application window. To speed up this process Bladen Lakes State Forest uses a combination of mechanical, herbicides, and fire to renovate stands (Powell 1993) They mechanically cut and remove the hardwood trees as low to the ground as possible and immediately treat the freshly cut stump with herbicide. A prescribed burn is conducted to control small brush and reduce the amount of unwanted debris. With wet stump method treatment is scheduled year-round and by eliminating the waiting period for the herbicide to work it allows the landowner to immediately begin raking. Follow-up treatment on root sprouts is often needed.

Establishment

Pine straw production provides an incentive for landowners to establish longleaf pine on suitable agricultural fields or cutovers. Whether one is establishing longleaf on a cutover or old field consider spacing the seedlings to accommodate the raking and baling equipment. Generally, the recommended spacing for planting longleaf pine seedlings range from 8 x 10 feet to 10 x 12 feet depending on site and seedling type. However for mechanical raking and baling leave every 5th row 15 feet wide to provide room for the tractor and baler. Establishment success is greatly increased by: intensive site preparation such as herbicide application and mechanical scalping prior to planting, plant high quality containerized seedlings, plant seedling at the proper depth, and control competition through the first growing season (Hainds 2001).

Fertilization

Frequent raking of pine needles over an entire rotation can remove a significant amount of nutrients and the subsequent potential loss of productivity. It is estimated that one raking removes 5-15 lbs/acre of N, 0.5 - 1.5 lbs/acre of P, 0.5-5 lbs/acre of K, 2.5 -12.5 lbs/acre of Ca, and 0.8 lbs/acre of Mg (Blevins 1996). While longleaf pine can be characterized as a nutrient "sipper" not requiring large amounts of nutrients to maintain adequate growth, removals to this extent may effect tree growth and health over the length of rotation. To some extent removal of the competing vegetative offsets nutrient loss since available nutrients increase when fewer plants are present to deplete the supply.

Fertilization not only replaces nutrients lost during raking but also increase needle production and diameter growth. Sandhills Gameland in NC reported a 50% increase in straw production the 2nd year after application (Blevins 1996). A study in NC reported a 68% increase in needle production over a 2-year period following the application of 80lbs of N per acre (Environmental Impact 2002). A study located in the SC Forestry Commission Sand Hills State Forest showed 40% - 50% increase in diameter growth (Dickens 1998).

The need to fertilize is based on a foliar analysis from the dominant trees in the stand . Select one dominant tree per 10 acres for foliage sampling. Collect samples in the dormant season from the one terminal branch located in the top third of the crown. Remove needles from the first flush of the previous growing season, refrigerate and mail to plant tissue analysis lab.

Blevins suggests the foliar sufficiency levels for longleaf pine found in Table 1.

Table 1. Foliar sufficiency levels for Longleaf Pine *(Pinus palustris)*

N	P	K	Ca	Mg
…………………..Concentration (%)…………………..				
0.95	0.08	0.30	0.10	0.06

Base the need to fertilize on a foliar analysis. The maximum recommended single application rate (elemental) for longleaf pine is: 100 lbs of N/acre, 25 lbs of P/acre 50 lbs of K/acre, 100 lbs of Ca/acre, and 25 lbs Mg/acre. Urea is commonly used as a nitrogen source for forestry since it leaches less than ammonium nitrate. Triple superphosphate provides P and diammonium phosphate (DAP) is widely used to provide both P and at least part of the N needed. Dolomitic lime provides a source of Ca and Mg but, also increases pH that under certain conditions is not desirable.

Fertilization is most effective when applied in mid or late winter. To ameliorate raking deficiencies fertilize once every 10 years. Fertilization once every 6 years will maintain an increased foliage production level and diameter growth, but may not be cost effective. In forestry fertilizer is commonly applied by helicopter. However renovated pine straw stands with wide rows may allow ground application using a farm tractor.

Yield
Pine straw yield is related tree density and site quality. Blevins states that these two parameters account for 77% of the variability in straw yield. Dry, low quality site is expected to yield fewer bales than a moist, high quality site. Vigorous middle age stands produce better yields than older low-vigor stands. Regardless of quality most producers try to maintain stand basal area at 90 - 100 square feet per acre to maximize straw yield as well as help control understory vegetation and provide accessibility for tractors, trailers, and vehicles (NCDFR 1997). Table 2.estimates annual pine straw production and was developed from data collected from 29 plots in North and South Carolina (Blevins 1995).

Table 2. Predicted annual pinestraw production for longleaf pine.

Basal Area (ft^2/acre)	**Site Index (base age 50)**			
	60	70	80	90
	Pinestraw Production (pounds/acre/year - oven dried*)			
80	2200	2500	2900	3200
100	2500	2900	3300	3700
120	2700	3200	3600	4100
140	2900	3400	3900	4400
160	3100	3600	4100	4600
180	3200	3700	4200	4800

Adapted from Blevins
*A 30 pound bale with 17% moisture content is equivalent to a 25 pound oven-dried bale

Expected yield in terms of bales per acre is compounded because bale size and weight vary depending on baling equipment used. The most common bale size is 12" x 14" x 28-32" and weighs about 30 lbs (Holder 2004). A typical longleaf site with 90 basal area would average about 70 - 100 bales per year.

Needles fall throughout the year but the heaviest shedding occurs in October and November (Weigert 1972) Buyer preference for fresh straw combined with strong spring sales make late fall or winter an ideal time of year to harvest. Straw must be dry before baling.

Stands are ready to harvest soon after the canopy closes. Raking in stands as young as 8years old can occur, but most producers wait until the stands are 12-18 years old before the first harvest. Generally younger stands between age 20-35 with a 30-35% crown ratio produce the highest yield.

Harvest Methods
Longleaf pine straw is gathered into piles by hand raking using a pitch fork or yard rake or by mechanical rake. Stand density, amount of understory vegetation, tract size, and contractor availability dictate the harvest method used. Smaller tracts and tracts that don't allow access or maneuverability of equipment are usually hand raked. For large tracts with wide rows and clean understory machine raking is fast and efficient.

Once the straw is raked it is baled by hand or machine hay baler. When using a hand or box baler the straw is raked into piles. To facilitate mechanized baling needles are raked into windrows. This is accomplished by hand or to increase production rate and efficiency by a modified hay rake shortened and strengthened so it is better suited for in-woods operations. Plantations are better suited for mechanized baling since the evenly spaced rows allow the raking of straw into long windrows on every 5th row. Natural stands require much maneuvering of the hay baler and the windrows are by necessity shorter and less straight. In these settings hand raking and baling are often preferred.

While boxing or hand baling is the most primitive and labor intensive pine straw harvesting methods it is perhaps the most common. With the boxing method the operator places straw into a bale size crate equipped with a lever "plunger". He uses the plunger to compress the needles. Repeating the process, a tight bale is produced. The bale is tied by hand with twine. A small 3-man crew can harvest about 100 bales a day. Ideal for dense stands and small tracts boxing is particularly competitive when inexpensive labor is available or capital is limiting. A detailed schematic for building a box baler is found on the Texas Cooperative Extension web site, http://TexasPineStraw.tamu.edu (Taylor 2003).

A more efficient method is to use mechanized hay balers. Smaller hay balers more common to Europe increase production rates by 2-3 times. A three-man crew can produce 250-300 bales per day using a mechanized baler in a clean widely spaced longleaf plantation.

Raking Frequency
Raking straw every other year is generally regarded as the most efficient for several reasons. Stands with several years of needle accumulation do not necessarily have more needles since the older needles decompose. Fresh, red needles are preferred by homeowners. For this reason many contractors rake on an annual basis. However, lower yields at the same harvest cost per acre decrease returns. Because of concerns for possible negative effects on tree growth and soil productivity, the NC Division of Forest Resources does not recommend annual raking.

Another raking regime that is less intensive and perhaps helps to maintain the longleaf ecosystem is to rake three consecutive years, allow the stand to rest one year, and burn the following year (rake, rake, rake, rest, burn) (Hamilton 2003).

Selling Methods
Landowners have three options to sell pine straw.

1. Rake and bale and sell wholesale or retail.
2. Lease their land for baling rights on "lump-sum" or "by-the-bale" basis.
3. Haul loose straw to a bulk "buying station".

The first method requires access to or expenditure to buy the necessary equipment. The harvesting operation requires a small tractor, a trailer for hauling out of the woods, one or more hand balers, and manpower.

Under a lump-sum lease agreement the harvester pays the landowner a set amount per acre per year to rake, bale and transport the straw. The contractor usually agrees to clean the stand as part of the agreement. Cleaner, higher quality stands command better prices. Prices vary from $30 to $75 per acre based on straw quality and yield.

With the other leasing agreement, pay by the bale harvest, the contractor pays the landowner for each bale harvested. As with the other lease method the contractor cleans, rakes, bales, and transports the pine straw, so there is no cost to the landowner. The disadvantage is that the landowner must account for each bale harvested trusting the contractor to provide an accurate total. Depending on the stand quality a contractor will pay the landowner $0.75 - $1.50 per bale.

Perhaps the easiest and least expensive method requires only a pitchfork to gather and a vehicle to transport loose straw to a buying station. Here the landowner sells the loose straw to a buyer whom than bales, stores and markets the pine straw. A standard size pick-up truck with side rails holds up to 20 bales of loose pine straw.

Economics
Bladen Lakes State Forest in NC rake their own straw using a 4-man crew, a machine baler, and tractor mounted hay rake. They estimated the crew produces 29 bales per hour in a clean stand. Cost of equipment, supplies, and manpower is estimated at $1.50 per bale. The straw is retailed by the BLSF at $3.85 per bale resulting in a net profit of $2.35 per bale and a per acre return of $282 (Powell 1993).

Landowners who contract the harvest of their pine straw on a 2-year raking schedule can expect a net profit of $90 - $120 per acre every other year. This assumes the landowner receives $.75 -$ 1.00 per bale and yields 120 bales per acre.

Other costs to consider include the renovation and fertilization costs. While clean-up cost varies depending on specific stand conditions an average cost that includes herbicides and manpower is estimated at $85 acre. Old field renovation is significantly lower since there are fewer hardwoods or woody shrubs to control and a mower is effective in controlling most of it. Fertilization cost about $50 per acre but is offset by increased needle production.

The SC Forestry Commission Sand Hills State Forest reported an increase in return of $28 to $94 per acre as a result of increased needle production 2 years after fertilization (Dickens 1999).

To capture a true picture of the return of pine straw one must analyze it in economic terms. Here we go into the world of discount rates, net present value (NPV), and internal rate of return (IRR). Hamilton presented an economic analysis comparing the expected return of a longleaf stand managed for timber to one managed for both timber and pine straw production (Hamilton 2002)

His simulated stand was on good quality site with site index 55 base age 25 years. Growth and yield values were calculated using a composite of models developed by Bailey and Lohrey, empirical stand data collected from Bladen lakes State Forest and Duke Forest, and educated estimations. A discount rate of 4% is used for the financial analysis. A detailed financial analysis is shown in Table 3.

For timber production the calculated return is based on thinning every 5 years and a final harvest at age 50. Costs for establishment, herbicide treatment for release, and periodic prescribed burns are included. He also assumed a 60/40 Pole to sawtimber ratio at final harvest using the shelterwood method and no increase in timber prices.
For pine straw production he thinned twice at age 30 and 40 to a basal area of 75 and a final shelterwood harvest at age 50. Cost for establishment, stand renovation, fertilization (2x's age 26 and 40) and periodic burns are included. Straw production yield was estimated at 75 bales per acre with a value of $0.75 per bale, a very conservative figure. The harvest schedule is to rake for 3 consecutive years, rest the stand for one year, and the following year conduct a prescribed burn. The schedule's objective is to manage the stand while trying to maintain bio-diversity and site quality.

Table 3. Longleaf pine plantation financial analysis

	Timber	*Timber + Pine Straw*
NPV	$1117	$1375
NAE	$52	$64
IRR	9.4 %	10.1 %

* based on stumpage prices for pulpwood @$17/cord, sawtimber @ $287/MBF, and Poles@$450/MBF (Scribner)

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FIRE: USE IT OR LOSE IT!

Kevin M. Robertson, William E. Palmer and Ronald E. Masters

Abstract: The purpose of this presentation is to reiterate the ecological importance of frequent fire for maintenance of upland ecosystems in the South. We present the Red Hills experience, where fire use has remained the dominant land management practice, as an exception to regional trends. We summarize information on obstacles for conducting prescribed fire based on phone interviews with 15 wildlife and forestry professionals from 12 Southern states. We also compare and contrast burning regulations across the Southeast to assess the regional consistency of prescribed fire regulations and promotion of prescribed fire. Our results suggest that wildlife and forestry professionals as well as most private forest land owners share common ideas about the importance of fire for maintaining southern pine ecosystems and that increasing the use of prescribed fire is needed. Knowledge of how to burn does not appear to be an obstacle. Nevertheless, only a portion of the area that should be burned for wildlife and fuel management goals is being burned each year (70% of federal lands, 35% of state lands, <5% of private lands). On private lands, landowner and fire practitioner concern about liability is the greatest obstacle to burning and will likely increase in the near future. On public lands, funding and political priority are key limitations to burning. We conclude that needs for preserving the culture of prescribed burning and its many benefits include 1) more cost-share and preferably incentive payments to encourage adoption of prescribed fire, 2) provision of reliable actuarial data and business plans to insurance companies to encourage them to insure burn practitioners, 3) expansion of at-cost (or for-profit) prescribed burn services provided by state agencies to meet current demand, 4) permitting systems that take into account habitat type and recent burn history, 5) greater consensus on management objectives between wildlife and forestry agencies, and 6) increased education in urban areas about the benefits of prescribed burning.

INTRODUCTION

The purpose of this presentation is to re-emphasize the ecological importance of frequent fire for maintenance of upland ecosystems in the South and the potential threats to losing the right to use prescribed burning as a management tool. The Red Hills Region of southern Georgia and northern Florida is presented as an example of an area where fire use has remained the dominant land management practice, in contrast to most of the Southeast at present. Obstacles to prescribed fire are addressed based on information collected through phone interviews with wildlife and forestry professionals from 12 southern states (Palmer et al. 2004). Also, prescribed fire regulations across the Southeast are compared to assess the regional consistency of prescribed fire regulations and promotion of prescribed fire. Finally, thoughts are presented regarding the future of prescribed fire in the Southeast and what needs should be considered to expand the use of fire in the South.

SOUTHERN FIRE ECOLOGY AND CULTURE

In most ecosystems of the Southeast, the natural plant and animal communities require relatively frequent fires for maintenance of their ecological integrity (Robbins and Myers 1982, Sparks and Masters 1996). Historically until the past few decades, use of frequent fire was an integral part of rural Southern life (Stoddard 1931, Pyne 1982). In addition to fires initiated by lightning, fires were purposefully set by Native Americans for agricultural objectives, wildlife management, and pest control. These practices were largely adopted by settlers, and public attitudes toward the use of fire were favorable (Pyne 1982). The fire culture continued to maintain pine and oak savannas, favoring fire-adapted plant and wildlife species (Stoddard 1931, Komarek 1964, Robbins and Myers 1982, Frost 1998).

After the turn of the 20th century, a concerted legal and educational effort was initiated by the government to reduce burning as part of a policy to promote commercial forestry and to replace range and row crop economies (Pyne 1982). At the same time, researchers and forest managers were demonstrating the importance of fire as ecological process and a management tool for wildlife and forestry (Stoddard 1931). This initiated decades of debate within the land management community on the importance of fire for protection of forest resources and later the protection of biodiversity. Meanwhile, fire was suppressed for decades in most areas within the South.

Today, the fire culture of the South persists only in isolated areas. It is possible that efforts to restore the once pervasive fire heritage may not be strong enough to increase fire use (Brennan et al. 1998). In the increasingly populated South, counties surrounding metropolitan areas are under increasing pressure to reduce aerial emissions, and prescribed burning has frequently been a target for such (insignificant) reductions. Millions of acres of industrial pine plantation lands exclude fire. Publicly-owned lands have suffered from decades of fire exclusion or their ecological value has been greatly reduced because of low fire frequencies (Brennan et al. 1998). The loss of fire across most of the Southern landscape has resulted in dramatic declines in a large number of plant and animal species dependent on the open, herbaceous-dominated communities maintained by fire.

The Red Hills Region stands as an example where frequent fire is still used on private land. Each year in the Red Hills, prescribed burning is applied to about 300,000 acres of private lands within a 4 county area in North Florida and South Georgia. The result of this frequent use of fire is low wildfire danger, high ecological integrity of fire-adapted plant communities, high populations of game and other wildlife populations that are declining elsewhere, and high quality timber production (Masters et al. 2003). For instance, the Red Hills has largely maintained the amount and quality of biodiversity that Stoddard recorded over 80 years earlier (Masters et al. 2003). For example, in contrast to their precipitous declines throughout the rest of the South, northern bobwhite populations have been maintained at natural population levels during the past 100 years (Brennan et al. 2000).

In the Red Hills, the use of frequent fire (1-2 year burn intervals) keeps fuel loads and fire intensity low. Burning takes place literally bordering public school properties, shopping centers, and suburban communities and within 10 miles of the urban centers of Tallahassee Florida and Thomasville Georgia with little resistance from the public. Thus, where the public is properly educated to the importance of fire, public agencies make fire a priority, knowledge of fire has been passed across generations, and fire frequency has been maintained, fire can still be used on private lands in modern landscapes to maintain fire-adapted ecosystems and meet multiple land management objectives.

OBSTACLES TO BURNING

To get a better sense of why fire was not being used more often on public and private lands, staff at Tall Timbers Research Station interviewed 15 state forestry professionals and wildlife biologists from 12 Southern states (Palmer et al. 2004). Professionals we interviewed shared the view that fire was an important process to sustaining Southern upland ecosystems. Every respondent also thought more prescribed fire was needed to achieve that goal in their state, as well as other goals, including wildfire protection. All respondents listed species and/or ecosystems harmed by low fire frequency in their state. Thus, it is clear that common values with regard to fire are shared among those responsible for state land management.

The perception of how well prescribed burning goals are being met depended on land ownership. Respondents ranked federally-managed lands as most likely to meet the needs of these ecosystems, followed by state and private lands (burning 70%, 35%, and <5% of what needs to be burned, respectively). When state forestry professionals were ask to rank the primary objective for burns conducted on state-owned lands, they ranked fuel reduction as the number one objective in ten of 13 cases, the other options being timber management, game management, or biodiversity management. Burning for biodiversity was ranked either third or fourth (last) in ten of 14 cases. Given that maintenance of native species requires a higher frequency of burning than fuels management, it is likely that even lands with prescribed burning programs are not being burned frequently enough to meet biodiversity goals (Brennan et al. 1998).

Obtaining a permit to conduct a burn was not considered to be a problem. However, most of those interviewed represented the agencies that grant permits. Biologists consistently ranked permitting as a problem whereas state forestry officials did not.

ATTEMPTS TO PROMOTE PRESCRIBED BURNING

In 1990, Florida pioneered a legislative approach to promoting prescribed fire that would be imitated by most other southern states during the subsequent decade. The development of laws that would be referred to as the Florida Prescribed Fire Act (FS 590.125) was largely in response to pressure from regional "prescribed fire councils" represented by private, non-profit, and government-employed individuals sharing a common interest in the right to use fire as a management tool. Their approach to protecting the future of prescribed burning was to 1) increase public confidence in the practice of burning by specifying and raising standards of safety and training and 2) limiting the liability of prescribed fire practitioners. Thus, the legislature established a training program for Certified Burners who would be protected from liability related to smoke or fire escape unless negligence was proven. Responsible use of fire was defined in part by having a written burn plan (prescription) to guide the decision of when to burn and notifying and receiving consent from the state forestry agency.

Similar legislation subsequently has been established in Georgia (1992), Mississippi (1992), Louisiana (1993), South Carolina (1994), Alabama (1995), Virginia (1997), North Carolina (1999), and Texas (1999) and is pending votes from the legislature in Oklahoma. Given the current trend, it is likely that other southern states will adopt similar legislation in the future. However, it is currently not clear whether or not such "prescribed fire acts" have influenced the use of prescribed fire in the South. In general, the new laws have not yet been tested in the courts (Haines and Cleaves 1999) and so lack the power of precedent. According to communications with state officials, it is the fear of liability, not the lack of education, that remains the most significant obstacle to the application of prescribed fire by private land-owners (see also Cleaves and Haines 1995, Eshee 1995, Monroe 2002). Companies that offer insurance to prescribed fire contractors also seem unconvinced by the legal protection. Although the service of such private contractors is in the highest demand ever throughout the Southeast, contractors are few in number in the states where they have not disappeared entirely because of prohibitive insurance costs. Texas has taken the novel approach of limiting the sum for which a prescribed fire practitioner may be sued, provided they are certified (Texas NRCA 153:001-081). Also, there is an initiative underway to collect actuarial data on prescribed burning to present to insurance companies along with a business plan and estimate of client base to encourage them to provide insurance. The efficacy of these approaches remains to be seen.

According to communications with state forestry agencies, liability is a less serious obstacle to burning for the agencies than it is for private landowners and contractors. In states where prescribed burning services are offered by the agency (at an $8-$15 per-acre fee), significantly more acres are burned by the agency than by private landowners. However, such services are offered only in Alabama, Louisiana, and South Carolina. In these states, it was reported that the demand for burning is not being met, primarily because of increasing shortages in budgets and staffing. Also, tree-planting and fire suppression are mandated as the higher priorities of the agencies, and resource-consuming wildfires tend to occur when prescribed fires would most effectively be applied.

The support of government funding aimed at private landowners for the promotion and application of prescribed fire is generally indirect and not specifically required under the provisions of government programs. Federal cost-share programs which potentially provide incentives for prescribed burning (e.g., Wetlands Reserve Program, Environmental Quality Incentives Program, Wildlife Habitat Incentives Program, Conservation Reserve Program) require management plans to be developed and followed by the landowner under the supervision of a government agency representative. Thus, the degree to which these programs benefit prescribed fire depends on the expressed goals of landowners and guidance provided by agency representatives rather than on policy established by these programs.

Economic incentives programs are provided by several states (Alabama, Louisiana, Mississippi, North Carolina, South Carolina, Texas, Virginia) and can include prescribed burning as part of management plans authorized for assistance (Granskog et al. 2002). However, each of these focus on forest productivity as the primary goal, which encourages timber densities that are too high and fire frequencies that are too low to provide habitat for indigenous plant and animal species.

CONCLUSIONS

Wildlife and forestry professionals share in common the view that fire is important for maintaining most natural ecosystems in the South and that increasing the use of prescribed fire is needed. However, fire frequency in most cases remains too low to sustain existing fire-adapted plant communities and wildlife populations into the future (Brennan et al. 1998). The only notable exceptions are where a fire culture has persisted in portions of Florida, Alabama, Georgia, South Carolina, and Oklahoma. Actions can be taken now to promote the use of frequent prescribed fire on public and private lands, including the provision by state forestry agencies of field units focused on conducting prescribed burns at cost, education of the insurance industry to provide insurance to prescribed fire contractors, and focusing cost-share and economic incentive programs specifically on promoting prescribed fire on private land. Time is of the essence while the remnants of the once extensive Southern fire culture still exist.

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COGON GRASS – A BURNING ISSUE

Patty Rogers

Abstract: Fire and the Longleaf Pine are friendly allies, but not when Cogon Grass comes to visit.

This invasive species, identified as the 7th worst weed in the world, becomes a threat to longleaf plantations when it is allowed to make its home under their canopy. Cogon Grass, left unchecked, chokes out pine seedlings and other vegetation, leaving a wasteland for wildlife and threatening a landowner's profitability.

During a control burn, a mature stand of Cogon Grass generates temperatures in excess of 850°, which can ruin a forest landowner's investment. Cogon Grass is a lover of fire, bouncing back and becoming even more widespread following a fire event.

The Southeastern section of Mississippi is inundated with Cogon Grass and action has to be taken to control the spread. Cooperative efforts are underway with landowners, the Mississippi Department of Agriculture and Commerce (Bureau of Plant Industry), the Mississippi Department of Transportation, USDA Forest Service and Natural Resources Conservation Service, Farm Bureau and the Mississippi Coastal Plains RC&D Council (a non-profit organization) to educate landowners and provide assistance in the control.

Additional education of all landowners throughout the state is needed to involve local government and help in the control and eradication of this noxious weed.

CROWN PHYSIOLOGY AND GROWTH OF SAPLING LONGLEAF PINE AFTER FIRE

Mary Anne Sword Sayer and Eric A. Kuehler

Abstract: Fire affects forest stand variables that control whole-crown carbon fixation potential. When repeated throughout a rotation, therefore, fire has an impact on stemwood growth and carbon allocation among the foliage, stem and roots. Some foliage damage and therefore, less carbon fixation are expected with the use of prescribed fire in the longleaf pine (*Pinus palustris* Mill.) ecosystem. We need a better understanding of how the frequency and intensity of fire affect foliage damage, post-fire recovery of carbon fixation potential, and carbon allocation in longleaf pine. This information will provide physiology-based guidelines relevant to the timing and burning conditions that minimize leaf area limitations to stemwood growth and sustain forest productivity. In 2000, a study was initiated in a 4-year-old longleaf pine plantation on the Kisatchie National Forest, Rapides Parish, LA to evaluate the long-term effects of repeated prescribed fire on the physiology and growth of sapling longleaf pine. Prescribed fire was applied at ages 4 and 7 yr. Fascicle physiology, branch phenology, peak leaf area, annual biomass production (foliage, stemwood, fine root), and soil chemical and physical properties have been monitored since age 6 yr. Post-fire observations suggest that leaf area in the lower crown was reduced, but fascicle physiology in the lower crown, leaf area production in the upper crown and branch phenology throughout the crown were enhanced by prescribed fire. As the study continues, mechanisms that contribute to the recovery of carbon fixation potential after fire will be investigated. Early results of the study will be presented.

INTRODUCTION

Fire affects foliage and thus, whole-crown C fixation potential. When repeated throughout a rotation, fire has a potential impact on stemwood growth and C allocation among the foliage, stem and roots. Depending on frequency and intensity, prescribed fire causes foliage damage that may lead to a long-term reduction in stand growth. Past research, however, is inconclusive regarding the effect of repeated prescribed fire on tree growth (Boyer 1987, Waldrop et al. 1987, Brockway and Lewis 1997).

Longleaf pine ecosystems benefit from prescribed fire every two to four years (Brockway and Lewis 1997, Outcalt 2000). We need a better understanding of how the frequency and intensity of fire affect the foliage dynamics and C allocation of this fire-adapted species, as well as knowledge of physiological mechanisms that restore this species' C fixation potential after fire. This information will provide physiology-based guidelines relevant to the timing and burning conditions that minimize leaf area and physiological limitations to stemwood growth and sustained forest productivity.

We hypothesize that the fascicle physiology and leaf area dynamics of sapling longleaf pine are affected by prescribed fire. Effects may be negative with lower physiological function of residual foliage and reduction in leaf area by crown scorch. Alternatively, effects may be positive by accelerated rates of net photosynthesis and leaf area production immediately after fire. Our present objectives are to report the effects of prescribed fire on the fascicle physiology, crown leaf area, and branch phenology of sapling longleaf pine one year after burning.

MATERIALS AND METHODS

Study site

The study is being conducted in two longleaf pine plantations on the Calcasieu Ranger District of the Kisatchie National Forest, Rapides Parish, LA. In either 1996 or 1997, one study site each was prepared for planting by chopping and burning and treatment plots (22 x 22 m; 0.048 ha) were delineated and blocked. Three vegetation management treatments were applied in two blocks at one location and in three blocks at the second location. One location each was planted, 1.8 x 1.8 m, in March of 1997 or 1998 with container-grown longleaf pine seedlings from one genetically improved, Louisiana seed orchard source.

Soils

The soil at one study site is predominantly Ruston with some Gore and Malbis. The Ruston fine sandy loam is well drained, and moderately permeable. The Gore silt loam is moderately well drained, and very slowly permeable. The Malbis fine sandy loam is well drained to moderately well drained, and moderately slowly permeable. The soil at the second site is Beauregard silt loam which is moderately well drained, and slowly permeable.

Experimental design

The study design is a randomized complete block design with three treatments and five blocks. Two or three blocks were established at one of two locations in consecutive years. Plots were blocked by apparent permeability. The vegetation management treatments are: (1) Control (C): No vegetation management after planting, (2) Biennial prescribed burning in May-June (B): Strip-headfires were applied in June 2000 and May 2003, and (3) Chemical control of woody and herbaceous vegetation (H): Preplant broadcast application of Roundup (glyphosate, 5% solution) , post-plant application of Velpar L (hexazinone, 0.4% solution) in 0.9 m bands over seedlings in spring for two years and direct application of Garlon 4 (triclopyr) as needed to woody competition as a directed foliar spray until runoff (5% solution), or as a directed basal spray (20% solution).

Measurements

Fascicle physiology. In fall 2003, three saplings of average height per measurement plot were randomly selected. In May, July and September 2003, the physiology of detached fascicles from the upper and lower one-half of crowns were measured with a portable photosynthesis system (Model 6400, Li-Cor, Inc. Lincoln, NE) and standard needle chamber equipped with a LED light source. All physiological measurements were conducted at 1400 umol m^{-2} sec^{-1} photosynthetic photon flux density (PPFD) between 0900 and 1500. Measured variables were net photosynthesis (P_n), transpiration (E), and stomatal conductance (g_s). Measurements are expressed on a leaf surface area basis.

Leaf area production. For each treatment plot, 33rd percentiles of sapling height in early 2003 were determined. In September 2003, three healthy saplings, one randomly selected from each 33rd percentile, were destructively harvested from the two-row buffer of each treatment plot.

The live crown was divided and fascicles were excised from the upper and lower one-half of crowns. Foliage that developed in 2002 was pooled and foliage that developed in 2003 was separated into three age classes: cohort 1, cohort 2 and cohorts 3 and greater. Foliage was dried to equilibrium at 70°C and weighed. Before drying, five fascicles each of the 2002 foliage and cohort 1 of 2003 in the upper and lower crown were sub-sampled for development of regression equations that predict total leaf area (TLA) from foliage dry weight. The TLA of foliage samples was determined by the displaced needle volume method (Johnson 1984). Equations developed for the 2002 foliage were used to predict the TLA of the 2002 foliage, and those for the first flush of 2003 were used to predict the TLA of all cohorts produced in 2003. Stems and upper and lower crown branches were dried to equilibrium at 70°C and weighed.

Branch phenology. For each of 6 randomly selected saplings of average height per measurement plot, two live branches each in the upper and lower one-half of crowns were permanently marked. Internode length and fascicle length were measured in June through August 2003 at a 2- to 3-week interval after prescribed burning in May 2003.

DATA ANALYSES

Fascicle physiology was analyzed by analysis of variance using a randomized complete block split plot in space and time design with five blocks. Vegetation management treatment was the whole plot effect, and crown level and date were sub-plot effects. Similarly, stem dry weight (SDW) and TLA in September 2003, and monthly internode and fascicle lengths during June through August 2003 were analyzed using a randomized complete block design with five blocks. Comparison of total leaf area among cohorts was done by analysis of covariance using a randomized complete block design with stem dry weight as the covariate. Relationships between total leaf area and stem dry weight were evaluated by linear regression analyses. Main and interaction effects were considered significant at $P \leq 0.05$ and significantly different treatment means were compared with the least significant difference test at $P \leq 0.05$.

RESULTS

Values of P_n, g_s, and E were significantly greater in the upper crown than in the lower crown. Significant main effects of vegetation management treatment indicated that P_n, g_s, E were lower on the H plots than on the B plots and that values on the B and C plots were similar. This response is attributed to differences in light availability among the treatments. Saplings on the H plots were larger than those on the C and B plots. As a result, crown closure and shading on the H plots caused light limitations that were not apparent on the C and B plots.

Both P_n and g_s were significantly affected by an interaction between crown position and treatment. In general, upper crown P_n and g_s were greater on the C and B plots compared to the H plots, and lower crown P_n and g_s were greater on the B plots compared to the C and H plots. Differences in lower crown physiology on the B and H plots were due to light limitations in the lower crown of the H plots. We attribute differences in lower crown physiology on the

C and B plots to less competition for light in the lower crown of the B plots compared to the C plots. Observation of P_n by date indicates that significant increases in P_n on the B plots occurred in July 2003, but not in September 2003 (Figure 1). Burning-induced increases in P_n may have been limited to two to three months, or stand conditions in September 2003 could have restricted P_n across the treatments.

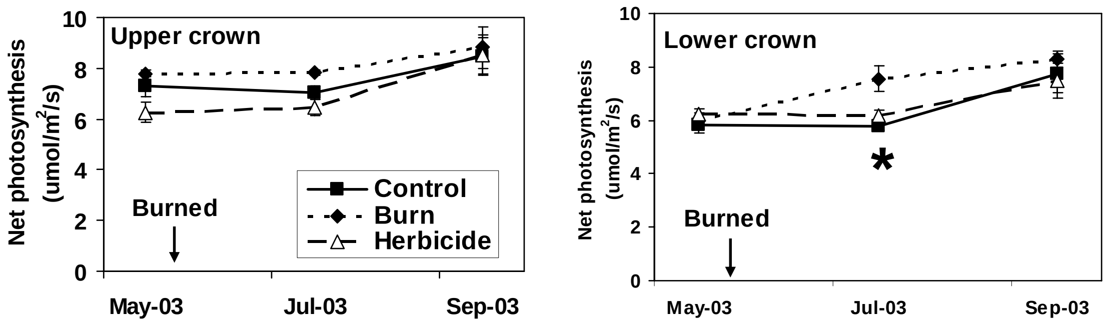

Figure 1. Net photosynthesis in the upper and lower one-half of 5-year-old sapling longleaf pine crowns before prescribed burning in late May 2003 and afterward in July and September 2003 in central Louisiana.

Values of TLA and SDW per tree were significantly greater on the H plots compared to the C and B plots, and TLA and SDW per tree were similar between the C and B plots. When mean values of TLA per cohort in the upper and lower crown were adjusted by SDW, two significant treatment effects were observed. First, the TLA of the first flush of 2003 in the lower crown was significantly lower on the B plots compared to the C plots. We attribute reduced first flush TLA in the lower crown on the B plots to crown scorch. Second, the TLA of the second flush of 2003 in the upper crown was significantly greater on the B plots compared to the C plots. Furthermore, we observed a greater amount of upper crown second flush TLA per unit of SDW on the B plots compared to the C and H plots (Figure 2). Because prescribed fire causes foliage and branch damage in the lower crown and the second flush of 2003 initiated immediately after burning, we hypothesize that the pattern of C allocation to flush growth in the upper and lower crown, stem growth and root production differed between the B plots and the C and H plots with a greater proportion of C allocated to the upper crown on the B plots compared to the C and H plots.

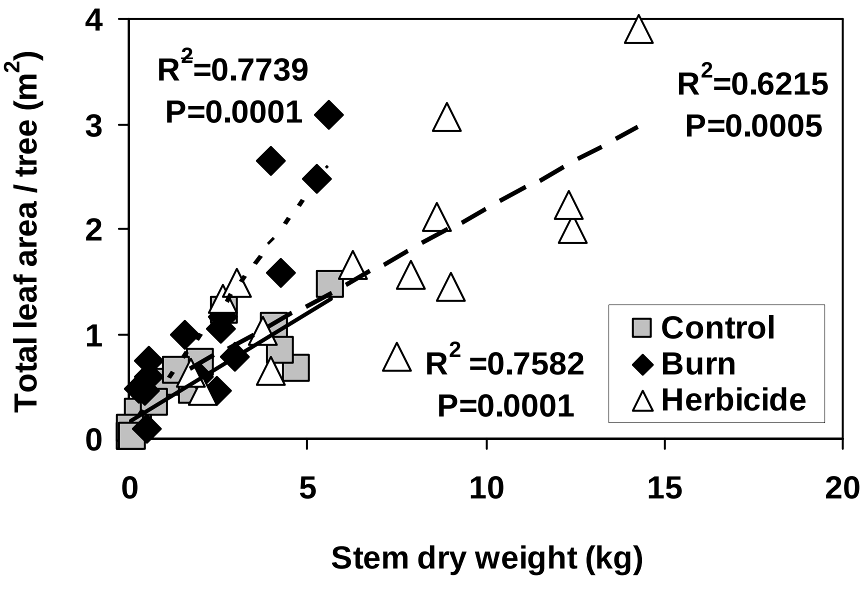

Figure 2. Relationship between total leaf area of the upper crown second flush and stem dry weight of 5-year-old sapling longleaf pine in September 2003 after a late May 2003 prescribed fire in central Louisiana.

First flush expansion in the lower crown, and first flush fascicle expansion in the upper crown were significantly affected by vegetation management treatment. Specifically, expansion of the first flush in the lower crown was significantly less on the C plots compared to the H and B plots in June and July 2003. The expansion of first flush fascicles in the upper crown was significantly greater on the B plots compared to the C and H plots in June and July 2003. There were no significant treatment effects on the expansion of second, third and fourth flush internodes and fascicles.

Our results demonstrate potential reductions in longleaf pine C-fixation potential by fire with the loss of leaf area in the lower crown. However, we also observed an increase in lower crown P_n and an increase in upper crown second flush TLA with prescribed fire. Research will continue to evaluate how the negative and positive effects of prescribed fire affect whole-tree C allocation and biomass production by longleaf pine.

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CONSERVATION AND ECOLOGY OF THE BLACK PINE SNAKE (*Pituophis melanoleucus lodingi*) IN MISSISSIPPI

Danna B. Smith and Carl Qualls

Abstract: The black pine snake (*Pituophis melanoleucus lodingi*) is a colubrid snake that is historically endemic to longleaf pine forests, ranging from southwestern Alabama to extreme eastern Louisiana. This taxon has piqued recent conservation concern due to geographic isolation as well as the ongoing fragmentation of remaining longleaf pine habitat. From March 2004 through July 2004, data on the distribution and habitat associations of the black pine snake in southern Mississippi was collected. Habitat characteristics such as soil type, dominant canopy tree species, canopy cover of trees, amount of shrubs in the understory, amount of herbaceous understory, estimated recency of fire, slope, and exposure aspect were quantified and recorded. Nine new records for this elusive taxon were collected, of which four were roadkill. With several black pine snake populations identified through the 2004 field season, prospective research for 2005 includes more exhaustive surveys of targeted areas coupled with radio telemetry of captured snakes. For each captured snake, habitat data will continue to be collected, and temperature sensitive radio transmitters will be used in an attempt to correlate black pine snake behavior and location with ambient temperature. Small mammal traps will also be employed in order to elucidate prey dynamics of areas with substantial black pine snake populations. Since our current knowledge of black pine snake ecology is limited, data gained from this study will greatly aid efforts to protect and restore this snake in Mississippi.

INTRODUCTION

First identified by Frank Blanchard as a new subspecies in 1920, the black pine snake, due to its fossorial and elusive nature, has always been considered rare. A taxon found solely within the historic range of longleaf pine forests in Mississippi, Alabama, and Louisiana, there is a paucity of information concerning this taxon in the scientific literature. Much of the information available in the literature concerns captive specimens or laboratory trials (Cliburn 1957, 1962, 1976). Since an estimated sixty-one percent of known historical black pine snake populations have been extirpated or are in decline (based on the Contiguous Habitat Model), the black pine snake recently became a candidate for federal Endangered Species Act listing and is already state-listed with the status of "endangered" in Mississippi (Duran 1998). The main factor leading to the rarity and decline of this taxon is habitat destruction; specifically, the conversion of longleaf pine forests into developed areas, intensely managed silvicultural areas, or agriculture. The isolated populations of black pine snakes which persist in the state of Mississippi are somewhat of an anomaly considering that longleaf forest, which is highly correlated with black pine snake distribution (Duran 1998), has been reduced to less than 5% of its historical range (Outcalt and Outcalt 1994). In order to effectively manage longleaf habitat for black pine snake populations, much information is needed concerning the life history and habitat use of this taxon throughout its current range.

METHODS

Herpetological surveys for the black pine snake were conducted from March 2004 through July 2004. Sites throughout the historic range of the black pine snake in Mississippi, with appropriate habitat (i.e. sandhills), were surveyed using standard herpetological techniques. In total, twenty sites in eleven counties in southern Mississippi were surveyed (Perry, Stone, Forrest, Jackson, Harrison, Hancock, Pearl River, Greene, George, Wayne, and Jones). A combination of drift fences, pitfall and funnel traps, coverboards (only in Wayne, Greene, and Jones Counties), road surveying, and manual searching was used. Each site was surveyed for fourteen consecutive days in the spring of 2004 and fourteen consecutive days in the summer of 2004. General habitat data was collected at each site where sampling occurred. The following characteristics of each site were quantified: soil type, dominant canopy tree species, canopy cover of trees, amount of shrubs in the understory, amount of herbaceous understory, estimated recency of fire, slope, and exposure aspect. For each black pine snake captured, a myriad of biological data was recorded. Life history data included mass, snout-vent length, total length, sex, and reproductive status. Every specimen was individually marked (using a PIT tag), then released at the site of capture.

RESULTS

Nine new records for the black pine snake in Mississippi were obtained, four of which were snakes found dead on various roads within the survey range (Table 1). These new records occurred in five counties: Wayne, Perry, George, Forrest, and Stone. Of special note were two snakes captured on Luce Packing Company land in George County; a county which previously had only two records for this taxon (Duran 1998).

DISCUSSION

With previously documented populations confirmed and new black pine snake populations identified in the 2004 field season, prospective research for 2005 includes intensive surveys of these areas. In addition to drift fences, road surveys, and manual searching, a camera will be used to scope both stump holes and gopher tortoise burrows, and drift fences will be arranged to encircle stump holes in hopes of targeting black pine snakes in their hibernacula. Since Duran's radio-telemetry study found that black pine snakes were found underground (in stump holes, armadillo holes, etc.) 65% of the time, the aforementioned methods may prove more efficient at capturing individuals than standard drift fences (Duran 1998). For each captured snake, habitat data at the site of capture will continue to be collected, and each snake will be fitted with a radio transmitter to conduct telemetry studies for multiple populations of black pine snakes. Furthermore, we hope to quantify the prey dynamics of areas populated by black pine snakes using small mammal surveys. Diet analysis of black pine snakes will also be conducted by analyzing ingested prey and scat. By quantifying habitat and life history data for several populations of black pine snakes, we hope to gain insight into the types of management practices necessary to conserve and restore this taxon in Mississippi.

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Table 1 Localities for *Pituophis melanoleucus lodingi* records for 2004 field season.

Location	County	Date
Chickasawhay District	Wayne	5/13/2004
Crossroads	Perry	5/30/2004
Beaver Dam Rd.	Stone	6/01/2004
Luce Packing Co. Land	George	6/06/2004
Luce Packing Co. Land	George	6/09/2004
Chickasawhay District	Wayne	6/11/2004
Chickasawhay District	Wayne	6/22/2004
Chickasawhay District	Wayne	6/29/2004
Highway 13	Forrest	7/10/2004

PLANTING DENSITY FOR LONGLEAF PINE: IT DEPENDS ON YOUR OBJECTIVES AND WHO YOU ASK

David B. South

Abstract: There are two schools of thought regarding how many longleaf pine seedlings should be planted per acre. The "plant-'em thick" school recommends planting more than 600 trees per acre (TPA) while the "plant-'em thin" school recommends planting less than 500 TPA. Some recommend planting 445 container seedlings per acre (14 feet between rows and 7 feet between trees) if the landowner's objective is to establish a stand that would produce both sawtimber and wildlife habitat. Those interested in producing mainly pulpwood, chip-n-saw and pinestraw might recommend 700 TPA.

INTRODUCTION

Wahlenberg (1946) said: "The spacing of trees in plantations depends on the survival expected and on economic considerations, such as costs of establishment, major products, market for thinnings, and effects of stand density and crown differentiation on natural pruning of the stems. The tendency has been to space too widely. Six by 6 feet is now generally recommended, and 5.5 by 5.5 feet is considered advisable where pulpwood thinnings can be made." "If longleaf and slash pine are planted for timber production without thinnings, the trees should be spaced 6 by 8, 7 by 7, or 8 by 8 feet. For naval stores, spacings of 10 by 10 or 12 by 12 feet are suggested." Therefore, two schools of thought existed 70 years ago. One school recommended planting 680 to 1400 trees per acre while the other recommended 300 to 440 trees per acre.

There are several possible explanations why some recommended planting more than 600 longleaf pine seedlings per acre. These include: (1) using traditional tree planting recommendations that date back 50 years or more; (2) assuming a low price ratio between longleaf pine sawtimber and pulpwood ($S/P); (3) using poor quality longleaf pine seedlings; (4) not taking into account the value of an "open stand" to wildlife species; (5) assuming planting 1,200 TPA will produce more sawtimber in 30 years (6) assuming logging costs do not vary with log size; (7) assuming everyone's land is close to a mill; (8) assuming that average branch size of longleaf pine is the same size as for loblolly pine; (9) assuming that planting 445 TPA will result in a reduction in wood quality, stumpage values and the production of poles; (10) assuming planting 445 TPA will result in shorter trees than trees planted at 1200 TPA; (11) assuming the government will be paying for most of the establishment costs; and (12) ignoring the economic analyses that indicated higher land expectation values with wider tree spacings.

At the beginning of the 20th century, the number of trees planted per acre in Europe varied between 1,000 and 40,000 TPA (Schenck 1907). By the middle of the century, some recommended planting 1,200 longleaf pine seedlings per acre (Ware and Stahelin 1948; Wakeley 1954; Dennington and Farrar 1983). At the start of the 21st century, the most common spacing reported for loblolly pine was 10 feet by 8 feet (i.e. mode = 544 TPA) while the average planting density was 602 TPA (Dubois et al. 2003). Today, most managers of longleaf pine want to manage for wildlife and/or sawtimber. As a result, a majority of managers who manage for natural regeneration target a stocking level of 200 to 600 TPA (Figure 1).

SAWTIMBER PRODUCTION

When stands are not thinned, then sawtimber production at a given age will be related to the number of trees planted. For example, one growth and yield model indicates more sawtimber will be produced at age 30 yr when planting 200 to 300 TPA (Figure 2). This is because keeping stocking rates high will keep many trees from reaching a sawtimber DBH. For example, a thinned stand (with a stocking of 412 trees per acre at age 41 years) still produced trees with an average DBH less than 8 inches (Figure 3).

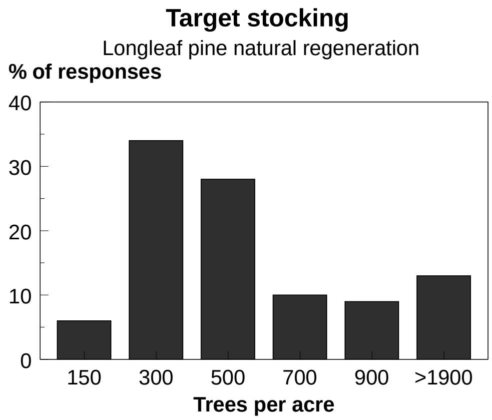

Figure 1. A 1995 survey of 32 longleaf pine organizations determined that 62% of the managers target an established tree stocking of 200 to 600 TPA (Boyette 1986).

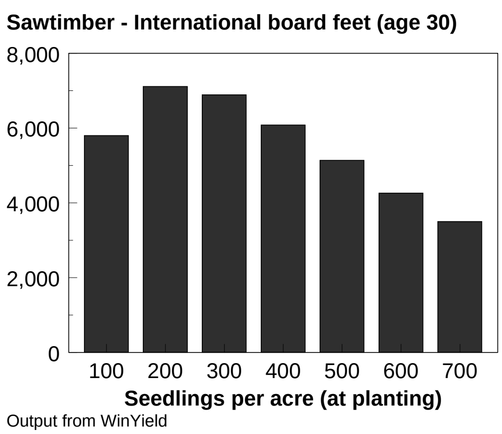

Figure 2. Predicted effect of initial stocking rate on sawtimber harvest of an unthinned, old-field longleaf pine plantation using WinYield. Site index = 70 feet (base age 50 yr).

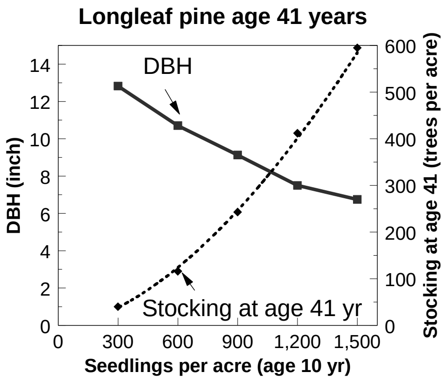

Figure 3. Effect of initial trees per acre on average DBH and on final stocking at age 41 for a natural stand of longleaf pine. Multiple thinnings were conducted at the lower stocking rates while no thinnings were conduced when planting 1,500 TPA.

PINESTRAW PRODUCTION

The returns from pinestraw production are typically high and could amount to \$0.50 to \$1/bale for the landowner. When pinestraw is the goal, then stands with basal areas of 100+ sq.ft./acre will result in more bales production than stands with 50 sq.ft./acre or less (Figure 4).

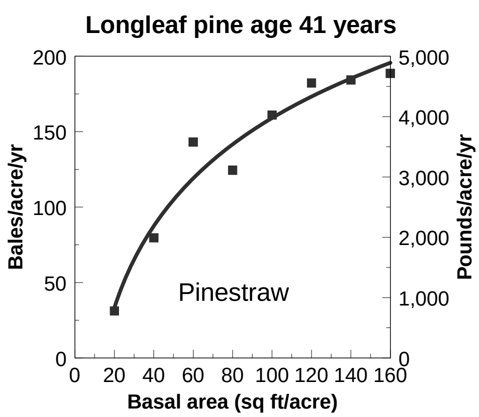

Figure 4. Predicted effect of stocking rate on annual pinestraw harvest (Rayamajhi and Kush 2001).

POLE RODUCTION

The production of poles is of interest to many landowners since the stumpage value might be \$25/ton greater than for sawtimber. In most naturally regenerated stands, the production of poles is greatest at ages of 50 to 60 years (Figure 5). In one 46-year old stand, the production of poles was about the same from 60 to 120 sq. ft. of basal area (Figure 6). Establishing 1500 TPA and leaving the stand unthinned can greatly reduce the production of poles since many trees will not reach the minimum DBH by age 46 yr.

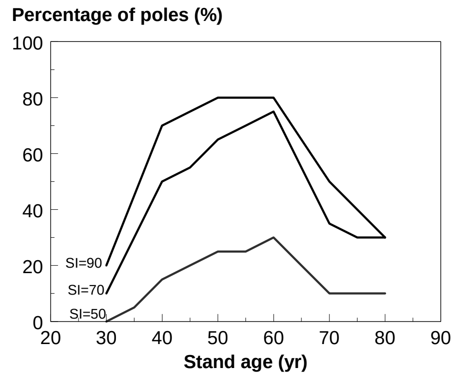

Figure 5. Effect of stand age and site index on the percentage of longleaf pine sawtimber yields (cubic feet per acre) as poles (Source T.R. Miller Mill Co., Brewton, AL; Yanquoi 1992).

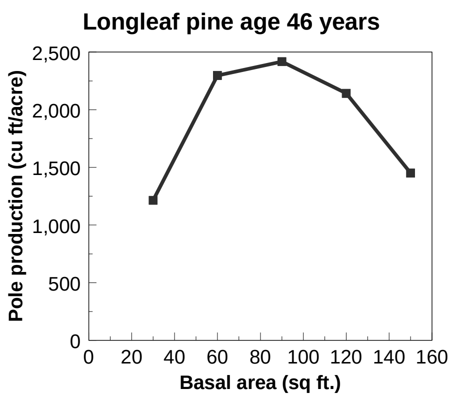

Figure 6. Effect of basal area targets on pole production for one longleaf pine stand at the Escambia National Forest.

LOGGING COSTS

The distance to the mill affects the number of longleaf pine seedlings to plant. The greater the transportation costs for a ton of wood, the fewer the trees planted per acre. This is because the sawtimber price/pulpwood price increases as transportation cost per ton increases. On average, about two-thirds of the value of pulpwood at the mill is the cost of harvesting and trucking to the mill (Figure 7). However, at some distant locations, transportation costs can eat up all the value of pulpwood. Therefore, it makes more sense to grow mostly sawtimber and poles if the longleaf pine plantation is far from a pulp mill.

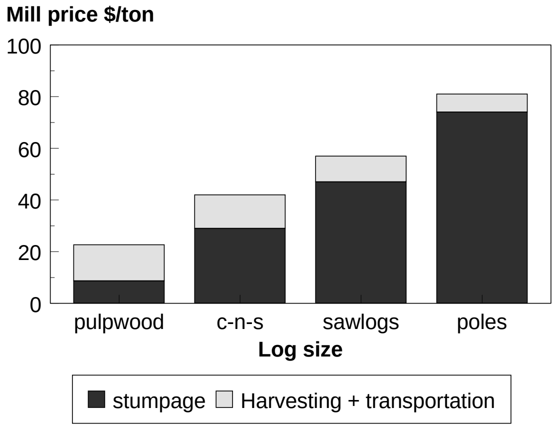

Figure 7. Stumpage value and mill value of longleaf pine pulpwood, chip-n-saw (c-n-s), sawlogs and poles. Typically, about 2/3 of the mill value of pulpwood is harvesting and transportation costs. Only about 1/7 of the mill value of poles is due to harvesting and transportation costs.

POOR QUALITY SEEDLINGS

In the old days, poor quality bareroot seedlings were planted because nursery managers often seeded too thick in the nursery (a target of 30 to 50 seedlings per square foot). Hand planters preferred this type of seedling because longleaf pine with small roots could be planted quickly. Nursery managers also liked this type of seedling because it required much less bed space than seedlings that required 6 seedlings per square foot. As a result, thousands of acres of longleaf pine plantations failed due to planting poor quality seedlings. Fortunately, seedling quality has increased since the 1950s and now nurseries provide both morphologically improved longleaf pine stock and container-grown stock. Both result in greater seedling survival than longleaf pine seedlings produced before 1960.

WILDLIFE BENEFITS

Wildlife habitat is one of the primary objectives of landowners who manage longleaf pine (Boyette 1996). Therefore, a spacing of 445 TPA will be more beneficial to browsers than a spacing of 890 TPA (Allen et al. 1996; Yarrow and Yarrow 1999). An acre of longleaf pine in an “open” stand can produce about 850 lbs of forage per month compared to 450 lbs per month in a moderately dense stand (Smith et al. 1955).

WOOD QUALITY

In general, the quality of lumber produced from naturally regenerated stands of longleaf pine is higher than that produced from loblolly pine (Campbell 1964). Many would assume this also holds true when comparing plantation-grown longleaf pine with plantation-grown loblolly pine (of equal diameter).

Specific gravity of longleaf pine is closely related to the strength of the lumber. For longleaf pine, lower stocking **does not** result in wood of significantly lower specific gravity. This myth has been in the forestry field for over 50 years. When comparing longleaf pine with 5.5 rings per inch to trees with 7 rings per inch, the specific gravity was 0.55 vs. 0.56, respectively (Bray and Paul 1930). As a result, “strength and width of rings are not closely related” (Wahlenberg 1946). Qualified researchers who compare pine trees of the same age conclude “there is no inherent relationship between growth rate and specific gravity.” Table 1 shows that specific gravity is not significantly affected by treatments that increase diameter growth of longleaf pine. Table 2 shows that although lower stocking does reduce the rings per inch, the effect of density on the percentage of basal area in juvenile wood is minimally affected. A stand with about 300 TPA at age 20 is not shorter on average than stands with more than 800 TPA (Table 3). It has been known for some time that height of dominants and co-dominants of longleaf pine is not usually affected by stand density (Ware and Stahelin 1948; Russell and Derr 1956).

Table 1. The effect of silvicultural treatments on final stocking, diameter at breast height (DBH), height, specific gravity and juvenile wood percentage of a 25 year-old longleaf pine plantation (Clark and Schmidtling 1989).

Treatment	Final trees per acre	Average DBH (inches)	Average Height (feet)	Specific gravity	% basal area in juvenile wood
Cultivation	267	6.1 a	48 a	0.58 a	52 a
No cultivation	122	7.3 b	55 ab	0.57 a	19 b
Cultivation + medium NPK	239	8.8 c	60 b	0.55 a	48 a

Values within a column followed by the same letter do not differ at the 0.05 level of probability (Duncan's Multiple Range Test).

Table 2. The effect of spacing on predicted diameter at age 10 years (DBH yr10), at age 30 years (DBH yr30), rings per inch (at groundline), and predicted % basal area in juvenile wood (at DBH) according to WinYield model for old-field longleaf pine plantation (SI = 70).

Initial trees per acre	DBH yr10 (inches)	DBH yr30 (inches)	Rings per inch	% basal area in juvenile wood*
200	3.4	9.6	6.2	12.8
400	2.9	9.1	6.6	10.3
600	2.7	8.6	7.0	10.2
700	2.7	8.5	7.0	10.3

* Assumes rings 11 to 30 represent mature wood. Assumes 3 years to reach a height of 4.5 feet.

Table 3. The effect of stocking (at age 20 years) on average diameter (DBH), average height, height of tallest 30 trees per acre, percent crown ratio and volume per acre for naturally regenerated longleaf pine (Farrar 1985).

Trees per acre yr20	DBH yr20 (inches)	Average height (feet)	Height of tallest 30 trees (feet)	Mean crown ratio (%)	Volume (cubic feet)
298	5.2	39.3	44.5	60	1044
597	4.2	35.9	44.9	53	1293
892	3.6	33.0	46.5	45	1372
1168	3.3	32.2	47.4	37	1489
1410	3.3	33.4	42.2	33	1563

KNOTS

Knots are the major cause of degrade in lumber. Since knot size is important for lumber strength, it is amazing how little information is available on the effect of stocking on knot size of plantation longleaf pine. For natural stands of longleaf pine, knot size is related to stocking but the number of longleaf pine knots that are greater than 2 inches (in the first log) is very small (Figure 8).

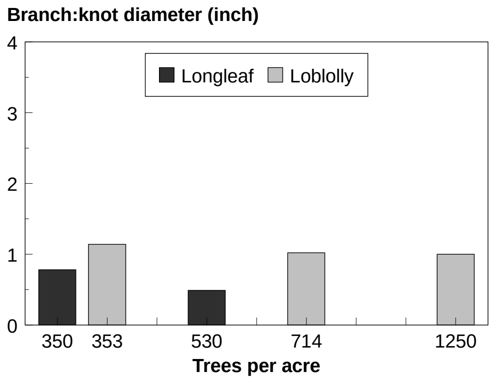

Figure 8. Effect of stocking on average branch diameter of 38-year-old, plantation-grown loblolly pine (Baldwin et al. 2000) and on average knot diameter of 20- to 30-year-old, natural longleaf pine (Paul 1938).

ECONOMICS

The effect of compounding has an influence on planting recommendations for longleaf pine. Although lumber from a 50-year-old, 13" diameter tree is worth more to a sawmill than lumber from a 30-year-old, 13" diameter tree, the effect of discounting makes a 30-year-rotation more attractive to a landowner who plants old-cropland with longleaf pine (Figure 9). Landowners who are willing to accept a lower discount rate (e.g. 2% to 4%) can justify longer rotations.

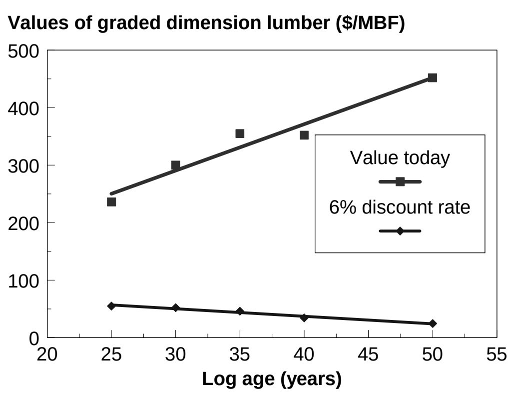

Figure 9. The effect of log age and discount rate on the value of graded dimension lumber (adapted from Biblis and Carino 2002). Today, a 50-year old longleaf pine log that is 13 inches in DBH (and 16 feet long) is worth more to a sawmill owner than a 25-year-old log of similar volume (upper line). However, when using a 6% discount rate, a 13-inch log harvested in year 2030 is worth more (in 2005 dollars) to a private landowner who invests in tree planting, herbicides, fertilization, etc. than a 13-inch log harvested in 2055. Likewise, at a 6% discount rate the present value of a ton of chip-n-saw logs (sold 25 years from today) is worth more to a landowner today than a ton of poles (sold 40 years from today). This fact is often overlooked by some who favor planting many longleaf pine seedlings per acre.

When conducting an economic analysis for longleaf pine, 7 factors should be included: (1) stumpage price for pulp, CNS, sawlogs, poles, pinestraw; (2) hunting leases; (3) volume production for each product; (4) establishment costs and silvicultural costs; (5) rotation length; (6) interest rate; and (7) risks due to southern pine beetles, hurricanes, fire. All 7 factors should be considered before selecting the proper spacing for meeting the landowner's economic objectives.

Caulfield and others (1992) found that with loblolly pine, the land expectation values generally increased as the planting density decreased from 900 TPA to 300 TPA. Teeter (2005) reported similar findings for longleaf pine plantations (Figure 10).

SUMMARY

The decision on "how many trees to plant" is relatively simple assuming the determining factor is based on economics. However, in many cases, factors such as aesthetics, opinions and peer pressure alter the decision making process.

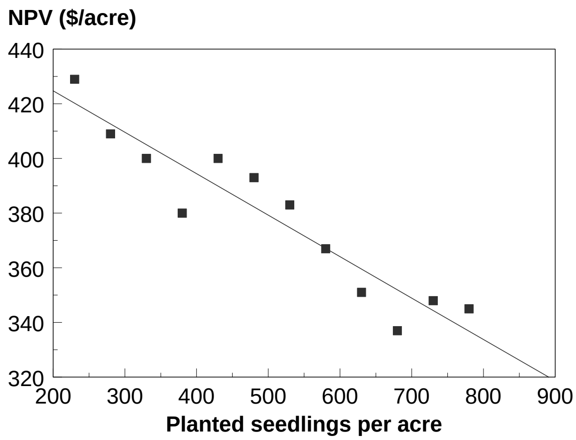

Figure 10. An example of an net present value (NPV) analysis for longleaf pine using a 7% discount rate on a site index 90 land (base age 50 yr). Factors excluded from this analysis were: risk, hunting leases, pole production, pinestraw production and value of forage to wildlife species (Teeter 2005).

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RED-COCKADED WOODPECKER RESTORATION AT ICHAUWAY

Jonathan M. Stober

Abstract: In March of 1999 the Joseph W. Jones Ecological Research Center at Ichauway began restoration of a red-cockaded woodpecker (*Picoides borealis*) population constrained by a lack of suitable cavities and demographic isolation. A baseline survey found only 8 usable cavities scattered across >20,000 ac of suitable habitat and only 1 remaining male woodpecker in 1997. Four artificial cavity inserts were installed at each of the 22 cluster locations, on 0.4 mi intervals in 2000 acres of longleaf pine habitat. The first translocated subadult was a female that paired with the remaining solitary male red-cockaded woodpecker in 1999. Twenty-six subadult woodpeckers were translocated to Ichauway from spring 1999 to fall 2003; 19 (73%) remained on site through one breeding season. The woodpecker population expanded from 1 active cluster and 1 successful nest in 1999 to 15 active clusters and 11 successful nests in 2004 with just over 50 birds presently. Woodpecker restoration focuses on cavity and habitat management. Longleaf pine habitat is managed with frequent growing and dormant season prescribed fires (1-2 year rotation) and mechanical removal of midstory hardwoods. Cavities are maintained in optimal condition by removing southern flying squirrels (Glaucomys volans) and nest material. The red-cockaded woodpecker population at Ichauway is enrolled in a safe harbor management agreement and serves as the private lands mitigation site for the Red-cockaded Woodpecker Conservation Plan for the Georgia Department of Natural Resources. A demographically isolated solitary group on private lands will be mitigated on Ichauway fall 2004.

QUALITY WHITETAIL DEER MANAGEMENT IN THE LONGLEAF PINE WOODLANDS OF ICHAUWAY

Jonathan Stober and Bobby Bass

Abstract: Protection, reintroduction and recovery of whitetail deer (*Odocoileus virginianus*) populations has created secure and, in many situations, ecologically destructive herds. Ichauway provides an example of a deer herd in longleaf pine woodland that has been managed to remain within its ecological bounds. The whitetail deer management goal is to safely maintain a deer herd to minimize negative ecological impact and maximize population health. Ichauway's management objectives are to maintain an even sex ratio with 10-15 deer/mile^2. Ichauway is dominated by 23,000 acres of longleaf pine grassland habitat and is bordered and bisected by the Flint River and Ichaway nochaway Creek, respectively. Deer densities were inherited from historic management and have been maintained by habitat and harvest management. Upland areas are managed with frequent prescribed fires and aggressive removal of hardwood fire shadows. Whitetail harvest on Ichauway allows each hunter one free choice harvest either buck or doe. Otherwise hunters are required to harvest 2 does before another buck is harvested. For a decade this management has maintained the deer herd at approximately 13 deer/mile^2 with an observed sex ratio of 1.88F:1M. On average 75 does are harvested each season with 1.5 and 2.5 year-old does comprising 40-50% of the harvest. Adult doe and buck body weights consistently average 120 lbs and 200 lbs, respectively. Lactation of yearling does approaches 40% and mature bucks typically have green Boone and Crocket scores above 120. Information from hunter effort, harvested animals, and population indices are used to monitor the herd's status and set harvest recommendations.

LONGLEAF ECOSYSTEM RESTORATION: LONG ROTATION ECONOMICS

Larry Teeter and Greg Somers

INTRODUCTION

Forest management is primarily concerned with the establishment and manipulation of forests stands in an efficient manner in order to meet a set of objectives. In many cases these objectives are financial (particularly among private landowners). Increasingly, however, the objectives reflect complex attitudes about such things as the role of forests in maintaining biological diversity or providing habitat for threatened or endangered species such as the red-cockaded woodpecker (RCW). These objectives for forest management are shared by private and public landowners alike (Bliss et al. 1993). However, a serious constraint to implementing management strategies to meet these objectives is the expected return on investments in silvicultural activities necessary to establish the stand. For many landowners, recovering these establishment costs (and an acceptable return on the investment) in a reasonable amount of time remains the primary objective, after which, objectives such as managing for wildlife habitat can be pursued.

Governments' interests in attaining these complex objectives and the financial realities of today's shrinking government budgets require forest managers to know that their investments in activities such as stand establishment are economically sound. This study was initiated to determine if it was financially feasible for the U.S. Forest Service (Savannah River Station) to expand red-cockaded woodpecker habitat areas using plantation management strategies. If feasible, the use of plantations would drastically accelerate the habitat expansion rate relative to natural regeneration methods. The specific objective of this research then was to identify opportunities for managing planted longleaf pine (Pinus palustris Mill.) in an efficient manner when target habitat conditions are prescribed in terms of future stocking conditions and rotation lengths are set at a minimum of 120 years.

BACKGROUND

Longleaf pine is a valuable economic species in much of the southern U.S. However, it's extent is dwarfed by the more widespread stands of loblolly (Pinus taeda L.) and slash pine (Pinus elliottii). It is likely that for this reason, little work has been done to outline the economic viability of alternative management strategies for longleaf pine. Yanquoi (1992) outlined previous longleaf pine growth and yield work and included Schumacher and Coile (1960) and Lohrey and Bailey (1974) for unthinned natural and plantation stands, respectively, and Lohrey (1974) and Farrar (1979, 1985, and 1990) for thinned plantations and naturally regenerated stands. More recent work was reported by Somers and Farrar (1991) who combined information obtained from plot data with commonly held beliefs about the nature of stand development to improve projections of stand basal area and mortality.

Work in this project draws on the growth and yield work of Somers and Farrar (1991) and incorporates parameter recovery techniques (Hyink and Moser 1983) to develop diameter distributions for stands projected by the growth and yield model. The data underlying the work of Somers and Farrar (1991) is described by Kush et al. (1986) and consists of 203 permanent plots each with at least one remeasurement in naturally regenerated, even-aged longleaf pine stands located in central and southern Alabama, southern Mississippi, southern Georgia, and northern Florida. In addition, new remeasurement data, updating that reported by Kush (1986), was incorporated in the model.

METHODS

GROWTH AND YIELD

Somers and Farrar (1991) used regional long term study data on longleaf pine (Kush 1986) to derive biomathematical growth equations for the species. These equations simultaneously project future tree survival and basal area at the stand level. The data used covered a wide range of site quality and stand ages. Site quality ranged from site index 45 to 95 (based on Farrar 1978) and stand age ranged from 9 years to 100 years. Based on studies reported by Farrar (1979, 1985) a seven-year grass stage was assumed for the naturally regenerated longleaf pine.

Teeter, Somers, and Sullivan (1993) developed a stochastic dynamic program to study optimal forest harvest decisions for loblolly pine. They used WTHIN (Cao et al. 1981), a diameter distribution based stand level growth and yield model for loblolly pine, to simulate growth rate and effect of stand treatments (thinnings) on growth rate. The WTHIN model predicts volume of wood by diameter class which can then be evaluated using appropriate price information.

Existing longleaf pine growth equations (Somers and Farrar 1991) and a few new equations from our examinations of recent data were substituted in WTHIN for the loblolly pine equations to simulate growth and yield of longleaf pine. The Somers and Farrar (1991) equations were also refit to avoid the ingrowth capabilities of their model. The following are the equations that were necessary to develop a complete system like WTHIN for longleaf pine:

1. Survival trees and basal area projection equations as in Somers and Farrar (1991).
2. A site index equation.
3. A basal area prediction equation to initialize the model by Somers and Farrar (1991).
4. Equations to predict arithmetic average and minimum DBH.
5. An equation to predict average tree height for a given DBH.
6. Volume equations to predict individual tree volumes using DBH and/or tree height information.

The equations used can be obtained from the author.

MANAGEMENT MODELING

The dynamic programming model developed was based on previous work conducted by Teeter et al. (1993) and provides a means for determining financially optimal thinning decisions for a large number of potential forest management situations. For example, site class, initial planting density, establishment costs, stumpage prices, and the timing and intensity of potential thinnings can all be varied. Variables used to characterize the state of the management system include: 1) age, 2) stems per acre, 3) basal area per acre, and 4) whether or not the stand has been previously thinned. Separate simulations were conducted for a range of site classes ($SI70_{50}$, $SI80_{50}$, $SI90_{50}$) and two discount rates (5% and 7%).

The model considered basal area states (conditions) from 40 ft^2/ac. to 210 ft^2/ac. in 2.5 ft^2 intervals (70 states) and stems per acre ranged from 10 to 800 in 2.5-tree intervals (318 states). Removals could be made in increments of 5 ft^2 of basal area with a minimum removal level set at 30 ft^2. Although this minimum thin constraint may seem somewhat arbitrary, it is generally supported as an economic threshold for harvesting operations by common practice on industry managed lands in much of the South. Current basal area determined the number of harvest decisions evaluated for each unique combination of state variables.

Thirty harvest levels (including zero) were compared for states at the highest basal area level. Transitions for basal area and stems per acre states (accounting for tree growth and mortality) were determined by the growth and yield model developed as a part of this research project. The diameter distribution information obtained from the growth and yield model was used to determine the mix of products (pulpwood, chip-n-saw, and sawtimber) available from the stand in the current stage (year) and when associated with prices[1], the current value of those products. The price-size relationship used in this study is depicted in Figure 1. The state variable C_t (see below) indicates whether or not the distribution is truncated on the left (reflecting that smaller diameters have been removed by a previous thinning). The general recursive relationship describing this system is:

Where: $$V_t\ (T_t, B_t, C_t) = MAX_D\ [\pi\ (T_t, B_t, C_t, D) + \beta V_{t+1}\ (T_{t+1}, B_{t+1}, C_{t+1})]$$

V_t	=	Expected present value of following the optimal policy from stage *t* to rotation age
T_t	=	Trees per acre at time *t*
B_t	=	Basal area per acre at time *t*
C_t	=	0-1 variable indicating whether a stand has been previously thinned
MAX	=	Maximization operator
D	=	The set of available thinning intensities
B	=	Immediate net returns which depend on T_t, B_t, C_t, and D
$	=	A discounting factor

[1] Prices were obtained from Timber Mart South and from local data supplied by the Forest Service, SRS.

The crux of the analysis was to determine if planted longleaf pine can be managed to generate a reasonable return while leaving a minimum of 40 ft^2 of basal area as woodpecker habitat. Current standard practice involves planting and then, beginning at about age 20, returning to the stand every ten years to determine if at least 30 ft^2 of basal area can be removed through thinning. If sufficient volume is not present, a return visit is scheduled for 10 years later.

This situation was evaluated using the new growth and yield model as was the dynamic programming model that allowed at least 40 ft^2 of basal area to remain on site at all times and a profit maximizing clearcut strategy to evaluate the cost of the habitat measures. Costs of site preparation were obtained from *Forest Landowner* and were assumed to cost \$111.50 per acre. Actual costs at SRS vary from \$25/ac to \$140/ac. A planting cost model, which includes seedling costs, was developed from data supplied by SRS:

Planting cost = \$20 + \$0.16 * the number of trees per acre planted

Each planting density/site index scenario was evaluated at two discount rates, 5% and 7%. The only other cost included in the analysis was a 7% charge for sale administration applied to revenues at each harvest (this was the best average estimate of administration costs that could be derived from SRS records).

RESULTS

Figure 2 indicates the trend in net present value for the range of initial densities examined for each site index ($SI70_{50}$, $SI80_{50}$, $SI90_{50}$) at the 5% discount rate using the profit maximizing dynamic programming model (in which basal area never drops below 40 ft^2). From the graph, the effect of site index on returns is easily recognized, higher sites produce higher NPVs. It also highlights the fact that low density plantings are most profitable, but that positive returns are available at all initial densities except for the highest densities on $SI70_{50}$ sites. A high penalty exists for planting too many trees on a particular site, but this penalty decreases as the site improves. On $SI90_{50}$ sites NPV declines 25.5% as density increases from 300 to 800 trees planted. On $SI80_{50}$ sites the decline is greater at 38.3% and on $SI70_{50}$ sites the decline is greatest, over 100%. At the higher discount rate, however, Figure 3 indicates that the optimal harvest strategies (for maximizing profit and meeting minimum habitat requirements) are only uniformly economical on the best sites ($SI90_{50}$). Only low initial densities (<435 stems/ac) yield positive returns on $SI80_{50}$ sites at the higher discount rate, and positive returns are unobtainable at the higher rate on $SI70_{50}$ sites.

These results compare favorably with simulations based on Forest Service standard 10-year entry harvest strategies. No final harvest is planned under either the DP-based optimal thinning model or the standard 10-year entry model. The assumptions of the standard 10-year entry model are that a stand is entered for the first time at age 20. If sufficient basal area exists in the stand a thinning is conducted. Otherwise the stand is scheduled to be reassessed 10 years later. Thinnings require a harvest of at least 30 ft^2/ac. of basal area to be deemed economically viable, and early thinnings are designed to reduce stand basal area to around 60 ft^2/ac.

Figure 4 indicates the results of these simulations at the 5% discount rate and compares them to the DP-based optimal thinning NPVs and the "profit maximizing clearcut strategy" (one that optimally schedules thinnings *and* allows for a final harvest) associated with 3 example initial densities. According to the results, the DP-based optimal thinning model produces similar to higher NPVs at all but one initial density (750) and only on $SI80_{50}$ sites relative to the results of our standard 10-year entry model. Such a small advantage for the standard 10-year entry model is likely a function of the fact that the DP formulation only allows harvests in increments of 5 ft^2 of basal area, whereas the 10-year entry model is not limited in that way. So, for example, if the DP model evaluated a stand with 74 ft^2 of basal area, only 30 ft^2 could be harvested while meeting the requirement that at least 40 ft^2 remain as a residual. The standard 10-year entry model would harvest 34 ft^2 in a similar situation.

The optimal clearcut management strategy is simply provided (Figure 4) for comparison purposes as a gauge of the financial opportunity costs associated with the implicit non-timber objectives of the other two management methods. Clearcut regimes are profitable at all densities and on all 3 sites at the lower (5%) discount rate. They are unprofitable at densities greater than 650 trees per acre on $SI70_{50}$ sites at the higher discount rate and profitable at all other combinations of site class and density. Using the data supporting Figure 4 as an example, a clearcut management strategy is 77% more profitable (in terms of NPV) than the DP-based strategy at the lowest density on the best sites.

Figures 5-6 present information to illustrate the timing and removal quantities associated with the DP-based thinning patterns, and to emphasize the economic value associated with low density plantings. In general, a first thinning at around age 20 is appropriate when medium to high initial densities are used. At lower densities, the average first thinning age increases to about 25 or 30 years. Two thinnings are generally the rule for SI70 and SI80 sites, with the last thinning coming at around age 50 for the SI70 sites and at ages 35-45 for the SI80 sites (depending on initial planting density). Model results suggest that to produce the highest NPVs at a 5% discount rate, SI90 sites generally should be thinned 3 times (even though Figure 6 indicates 2 thinnings at an initial density of *750* tpa) with a first thinning ranging from age 20 to 30 (depending on initial density) and final thinnings occurring between ages 45 and 50 (see Figure 7).

DISCUSSION

It is interesting to note that in general, longleaf management under either the DP-based method or the 10-year entry method in the absence of a final harvest (clearcut) opportunity is unprofitable at the higher interest rate (7%) except on the best sites (SI90). Higher density plantings on SI70 sites are also unprofitable at the 5% rate using either method of management. This is in sharp contrast to the profitability of regimes that include a clearcut (see Figure 4), and emphasizes the cost of producing non-market forest benefits (in this case, habitat).

An alternate scenario was considered where we examined the effect of reducing the residual basal area requirement for habitat to 20ft^2 per acre (which has recently been suggested by some to be adequate). Although this improved the profitability of all regimes, and was able to produce a positive return at 5% for the low site-high density scenario described above, it was not sufficient to turn negative returns into positive ones on low sites at the 7% rate. On SI80 sites, this change in the residual basal area requirement allowed for positive returns at all initial densities at both discount rates.

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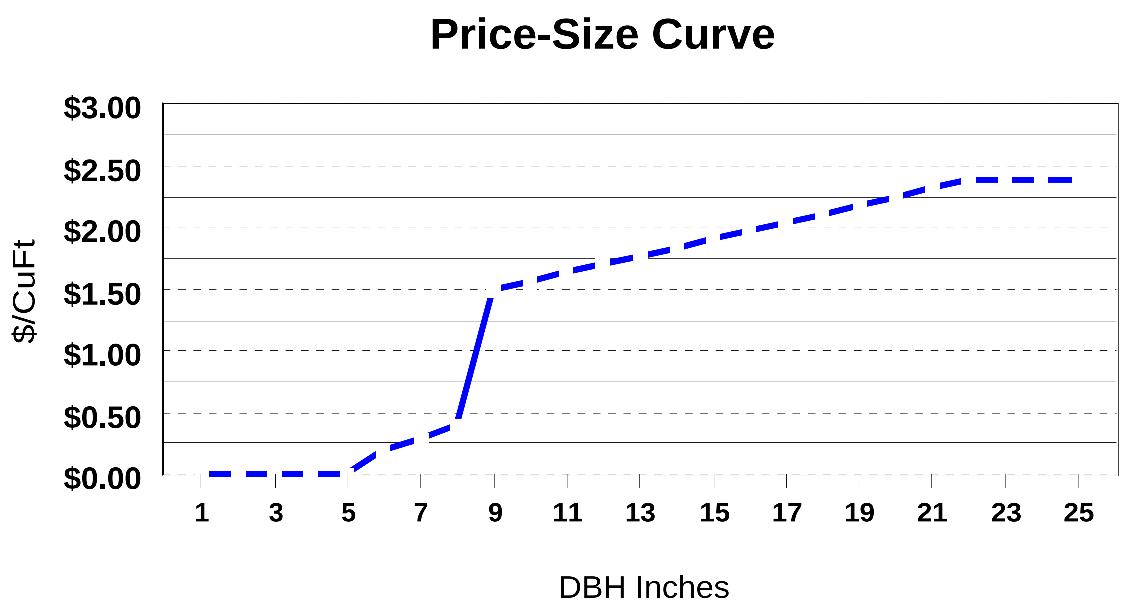

Figure 1. Hybrid price-size curve based on relationships established by Vardaman (1989) and Savannah River Station stumpage prices.

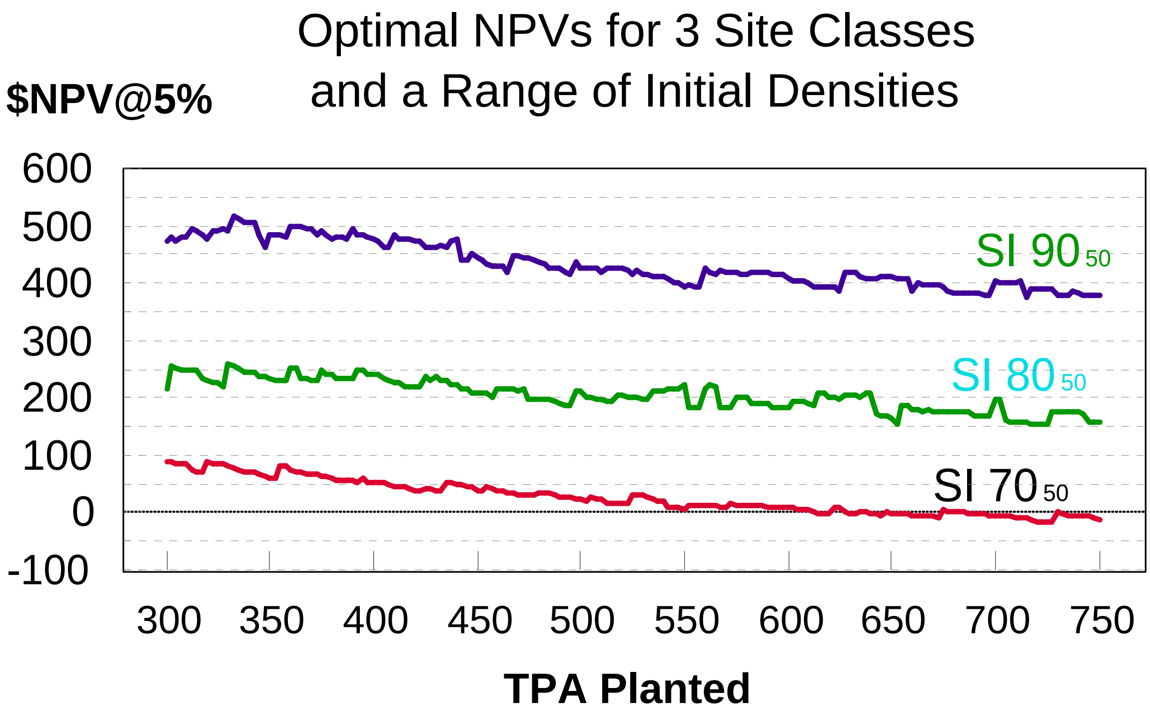

Figure 2. DP-based optimal NPVs for 3 site classes and a range of initial densities at a 5% real discount rate.

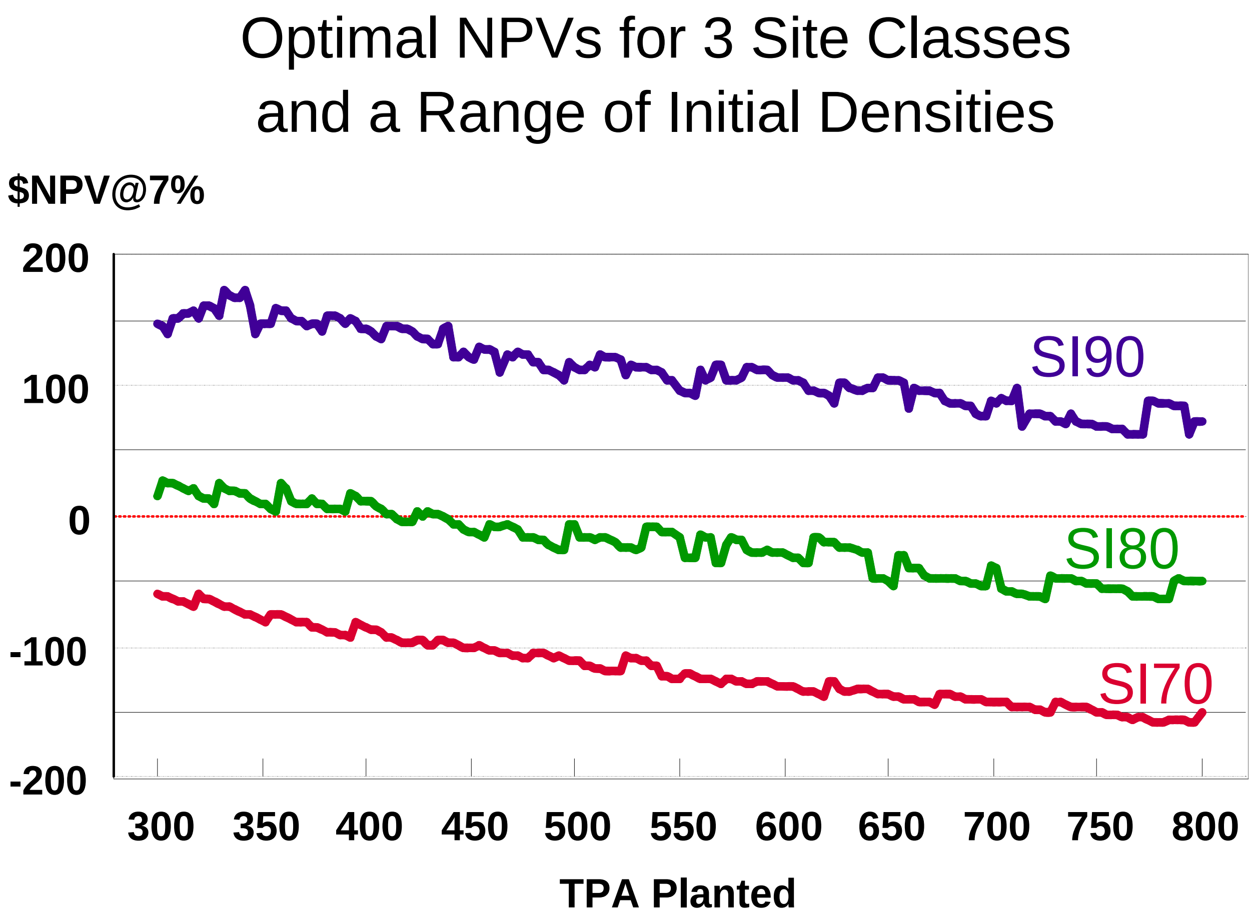

Figure 3. DP-based optimal NPVs for 3 site classes and a range of initial densities at a 7% real discount rate.

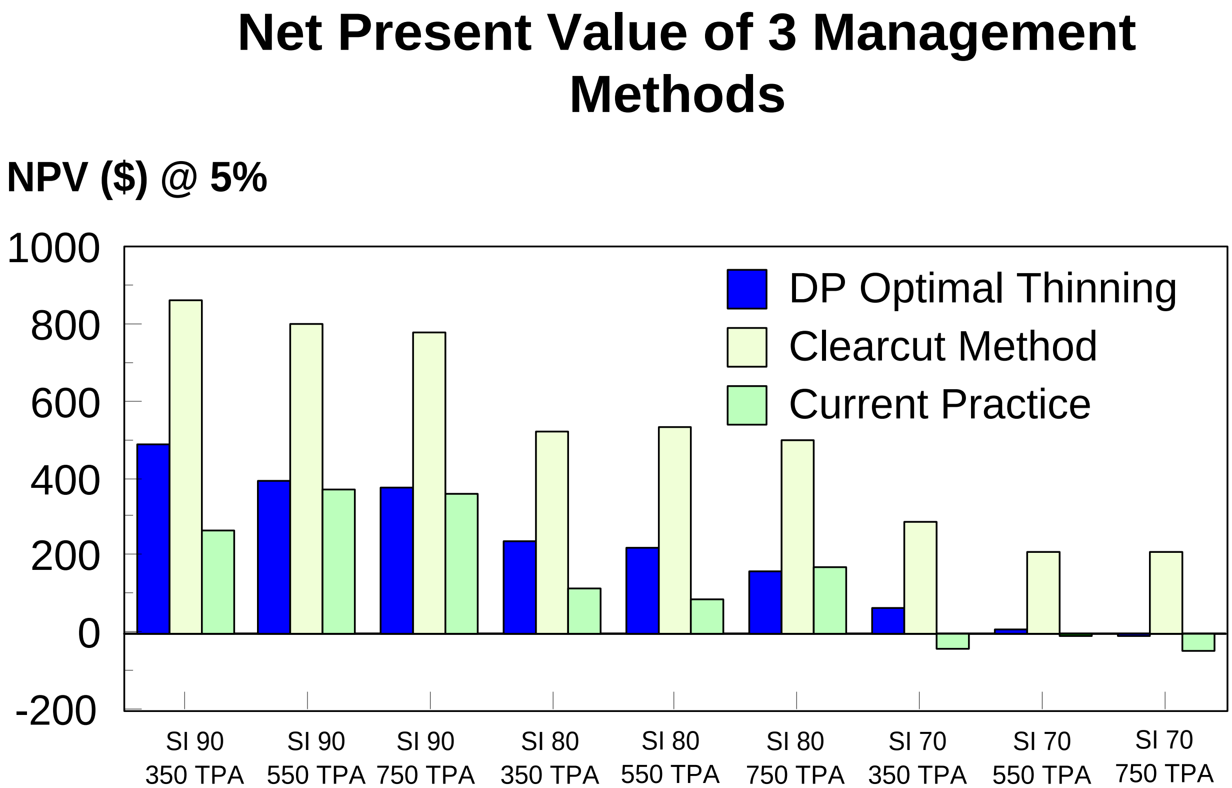

Figure 4. Comparing the NPVs of 3 management methods for 3 site classes, 3 planting densities and at a 5% real discount rate.

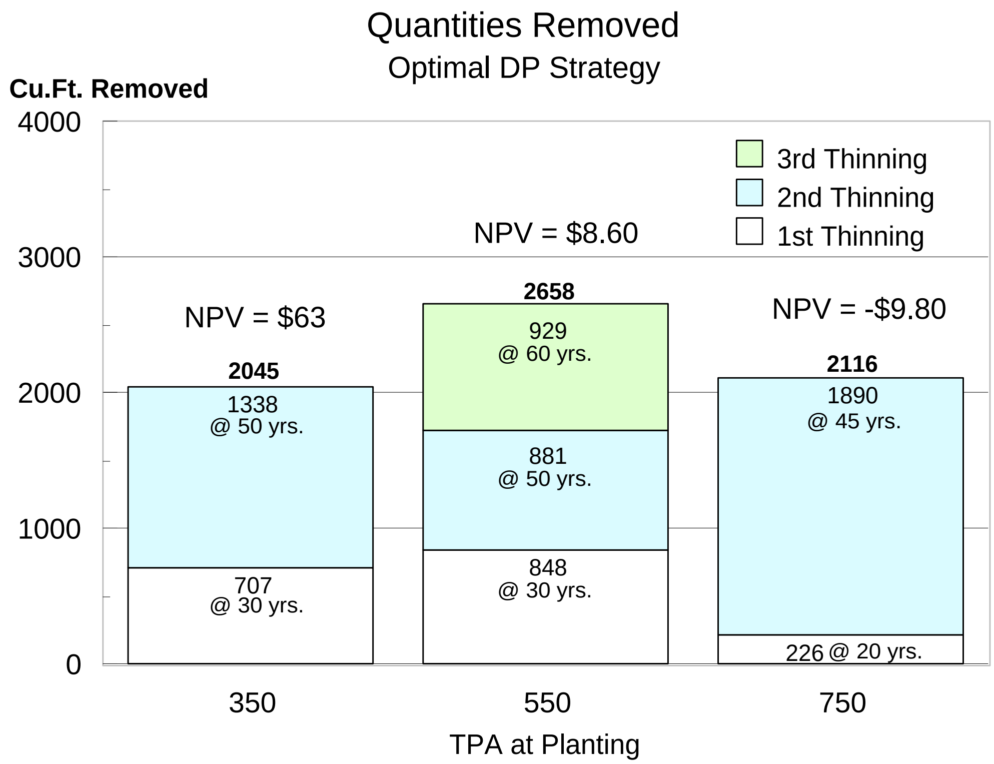

Figure 5. Harvest times and harvest volumes for the optimal DP-based strategy at 3 planting densities on SI70 sites using a 5% discount rate.

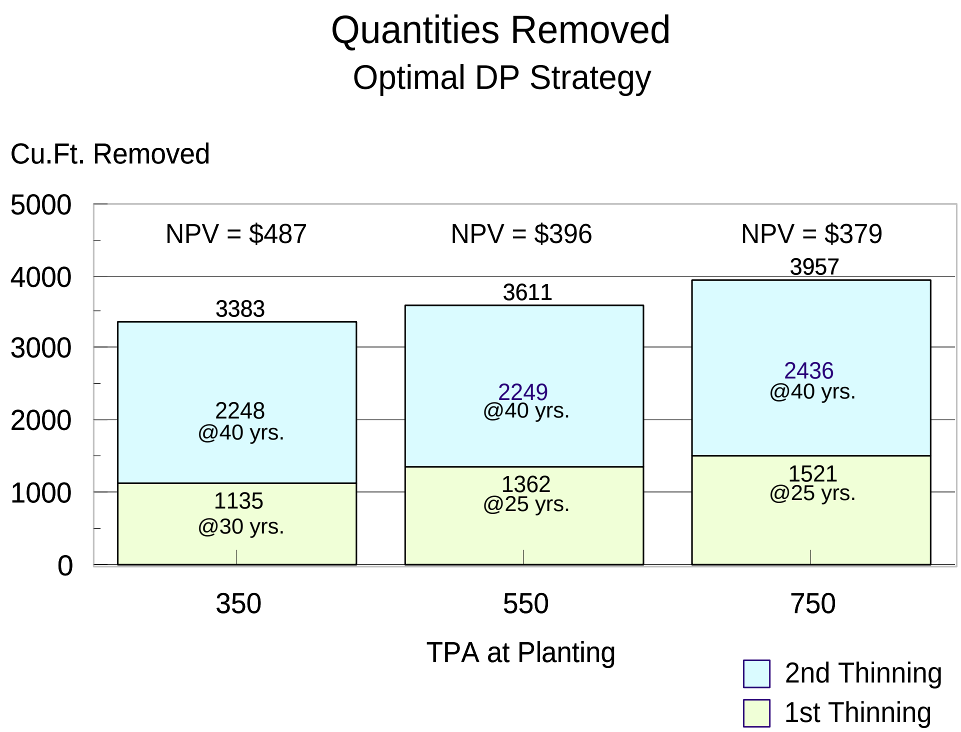

Figure 6. Harvest times and harvest volumes for the optimal DP-based strategy at 3 planting densities on SI90 sites using a 5% discount rate.

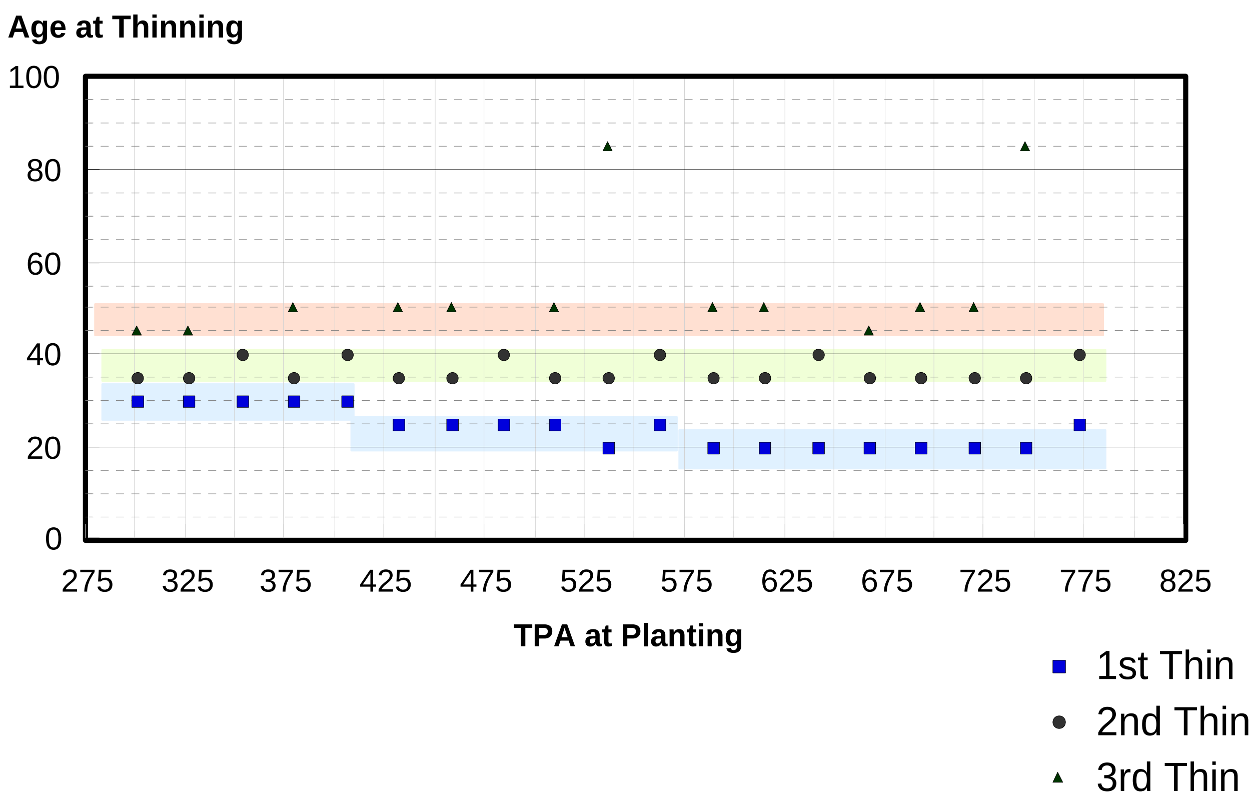

Figure 7. Highlighted ranges indicate an average thinning age for a range of initial densities – SI90, 5% discount rate, optimal DP-based strategy (no clearcut).

REBUILDING AN ECOSYSTEM: RESTORATION AND MANAGEMENT OF LONGLEAF PINE ON OKEFENOKEE NATIONAL WILDLIFE REFUGE

Fred Wetzel and Ron Phernetton

Abstract: The history of Okefenokee National Wildlife Refuge's (ONWR) 33,000 acres of upland communities is similar to that of the longleaf pine/ wiregrass communities that covered millions of acres of the southeastern United States. Changes in the fire regime caused primarily by fragmentation of the landscape, careless logging, naval stores operations, and other factors, resulted in an almost total conversion of these communities to other, less fire dependent, pine based communities, leaving only remnant stands of longleaf pine. With the removal of regular reoccurring fire, the understory components of these communities gradually converted from grasses, perennials, and low shrubs to dense stands of tall shrubs.

More than two decades ago, ONWR's management staff began the task of restoring longleaf pine and its associated communities. Because of the presence of the endangered red-cockaded woodpecker (RCW) and other species dependent upon these communities, restoration is a gradual process of replacing small patches or individual trees, and planting 2 to 15 acre openings without destroying existing stands that make up critical foraging and nesting habitat for the RCW.

This poster illustrates the aggressive techniques and strategies utilized by ONWR's staff to restore and manage longleaf pine. Examples include developing Memorandum of Understanding with neighboring industrial landowners for foraging habitat, planting entire stands, creating patch regeneration areas, mounding micro beds in areas with elevated water tables, promoting natural regeneration through selective thinning, applying prescribed fire to all upland acres, and managing natural fire on all upland acres within the wilderness boundary.

The history of Okefenokee National Wildlife Refuge's (ONWR) 33,000 acres of upland communities is similar to that of the longleaf pine/ wiregrass communities that covered millions of acres of the southeastern United States. Changes in the fire regime through fire exclusion, early settlement and continuing fragmentation of the landscape, careless logging, naval stores operations, and other factors, resulted in an almost total conversion of these communities to other, less fire dependent, pine based communities, leaving only remnant stands of longleaf pine. With the removal of regular reoccurring fire, the understory components of these communities gradually converted from grasses, perennials, and low shrubs to dense stands of tall shrubs.

The fire dependent longleaf pine ecosystem provides more diversity than most other upland forest communities and supports a wide variety of wildlife species, many of them adapted to fire. A wide range of longleaf pine communities covers several physiographic areas from sandy ridges to wetlands, once totaling almost 90 million acres. Only fragmented remains of these communities now exist, mostly located on public lands.

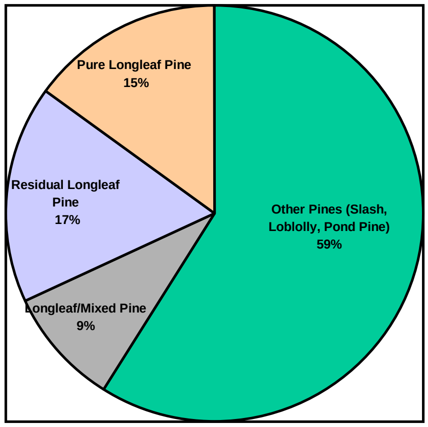

Figure 1. Percentage of forest types currently on the ONWR.

More than two decades ago, ONWR's management staff began the task of restoring longleaf pine and its associated communities. Because of the presence of the endangered red-cockaded woodpecker (RCW) and other species dependent upon these communities, restoration is a gradual process of replacing small patches or individual trees, and planting 2 to 15 acre openings without destroying existing stands that make up critical foraging and nesting habitat for the RCW.

Forest management compartments contain 16,000 acres (4% of refuge area). Most of the stands date from the turn of the century logging operations, the 1932 fire or the 1954 fire. The Forest Habitat Management Plan does not set a strict rotation guideline, but recommends that up to 5% of a management compartment be regenerated each 10 year prescription cycle to provide replacement stands. This suggests a 200 year rotation, longer than the expected life of slash, loblolly and pond pines but less than the possible 350 year life of longleaf pine. In practice, cuttings are dictated by habitat requirements. Some longleaf stands or individual trees may remain for their full, expected lifetime. The forest management compartments contain about 3,000 acres of plantations. Where prescribed fire has been used on a regular basis, RCW colonies are common. Where fire has not been used in the past, high hardwood understories discourage woodpecker use. All of the major islands have now been included in the refuge burning program.

Several techniques are utilized to restore longleaf pine on suitable sites. Techniques used on wilderness islands must conform to refuge wilderness management guidelines.

Selective Thinning - Selective thinning is used to remove undesired pines, gradually converting stands to predominantly longleaf pine. On wilderness islands stand maintenance is sometimes accomplished with prescribed fire (Thermal Thinning).

Patch Regeneration - Small openings, one to three acres in size are regenerated, duplicating natural regeneration following lightning strikes, small fires and insect killed spots.

Natural Regeneration - Prescribed fire and selective cutting are used to stimulate natural regeneration where longleaf pine remains for a seed source. Even where only a few residual longleaf pine per acre exist, heavy thinning around the old trees will gradually establish patches of longleaf regeneration

Shelterwood/Seed Tree Stands - Mixed stands may be restored to pure longleaf stands by removing all other pine species, leaving longleaf pine seed source. After regeneration has taken place the old trees may be retained or removed.

Direct Seeding - Where insufficient longleaf exists to provide a seed source, direct seeding is used to establish longleaf pine stands. The seed bed is prepared by fire or mechanical means.

Seedlings -- After intermittent success with hand planted bare root seedlings only containerized longleaf seedlings are planted today. Hand planting allows a more natural appearance to be structured into the new stand.

Transition areas between, traditional uplands and the wetland savannas present the toughest restoration problems. A technique used in these areas is called mounding. This method of site preparation is not to be used for all site preparation operations. Mounding is intended for use when the water table is high, often due to decreased evapotranspiration in poorly drained areas following stand destroying wildfires or silvicultural operations. This method of site preparation has several environmental and silvicultural benefits:

- Mounding raises the seedling above the ground surface, significantly improving drainage.
- Several inches of bare soil on the mound surface reduces competition from native ground cover until the seedling becomes established.
- Bare soil on the mound surface reduces the intensity of fire on the seedlings for several years.
- Surface vegetation and liter is incorporated within the mound, increasing organic material and nutrients available to the seedling.
- Mounding disturbs very little of the native ground cover, including any remnant longleaf pine community species.
- Each mound is approximately 2 feet long, 1 foot wide, and1-1/2 feet high, leaving a hole about 2 feet by 1 foot deep.
- Mounding does not disrupt the natural drainage of the site.
- The sides of the hole slough off and fill in, eventually leaving a shallow depression. These shallow depressions appear to serve as ephemeral water areas.
- Survival of containerized longleaf on these mounds is about 90%.
- No additional site preparation treatments are needed when used in combination with normal prescribed fire applications.

Management of Existing Longleaf Pine Stands on Okefenokee NWR

High, Dry Ridges
These areas are very well drained and usually contain longleaf pine and oaks. The sites are generally too dry for other pine species to invade, even with no fire. These stands are generally managed on a purely all aged basis. Natural regeneration is common even with the prescribed fire regime used on this refuge. No example of this type is found in the wilderness.

Pure Longleaf Pine Stands in Flatwoods
These stands occurred naturally and have been maintained by natural and prescribed fire. New age classes may be established in small areas by cutting small patches or by establishing shelterwood stands on larger areas. In wilderness areas regeneration is naturally established where mature trees die or are killed.

Mixed Longleaf Pine, Slash Pine Stands
Most of Okefenokee's upland pine areas are of this type, probably occurring when the longleaf pine was cut around the turn of the century allowing slash pine to invade into the stand from adjacent ponds or the swamp edge. These stands are gradually being converted to pure longleaf utilizing selective thinning and fire to establish natural regeneration as described above. In wilderness areas, fire is used to accomplish similar results.

Pure Slash Pine Stands on Suitable Longleaf Sites
These stands occurred when slash or other species invaded longleaf sites after clear cutting or when other species were planted on former longleaf sites. Clear cutting and replanting is necessary to re-establish longleaf in these areas. Where longleaf stands are adjacent, heavy selective thinning and fire can be used to gradually establish longleaf regeneration as described above. In wilderness areas growing season fire allows longleaf to slowly be re-established from the edges of existing longleaf stands.

Planted Longleaf Pine Stands
Although planted longleaf stands will eventually provide suitable red-cockaded woodpecker habitat, trees planted in rows are not as aesthetically desirable as seeded or natural stands. As soon as the planted longleaf begins to produce seed, patch cuts will be made to establish new age classes of natural regeneration.

This poster illustrates the aggressive techniques and strategies utilized by ONWR's staff to restore and manage longleaf pine. The U.S. Fish and Wildlife Service encourages its managers to seek out ways to manage the habitat that best benefits the native fauna and flora. Once the silvicultural foundation is in place managers can begin developing and improving the following 4 components.

- strong partnerships with adjoining landowners,
- aggressive prescribed fire on and off the Refuge,
- allowing natural fire to assume a more historic role, and
- advancing technology to predict fire behavior.

Strong partnerships are maintained through the Greater Okefenokee Association of Landowners (GOAL). This is an alliance of more than 20 private, state, industry, and federal partners committed to integrated stewardship. The staff has also developed Memorandum of Understandings with neighboring industrial landowners for foraging habitat.

Prescribed fire applied from the ground and the air has allowed a successful transition from primarily winter (dormant) season fire on management compartments to natural timing (growing) season fire. To correctly apply fire to the landscape the timing, intensity, and frequency must resemble a natural occurrence. This requires departing from dependable, routine dormant season fire and adapting to growing season, fire which is much harder to prescribe and conduct. Approximately 60% of all prescribed fire on the ONWR is natural timing fire.

The most far-reaching departure from tradition is the use of natural fire for resource benefits. The Okefenokee NWR offers managers the unique opportunity to allow fire to shape the landscape once again with out the negative political ramifications found in so many other settings.

The most current Technology is utilized in the application of fire programs using fuel modeling that predict fire behavior, spread properties, and risk assessments. In the near future, the latest satellite imagery will be utilized to further refine these modeling efforts and expand predictive capabilities to habitat delineation, and hydrology.

This poster illustrates the aggressive techniques and strategies utilized by ONWR's staff to restore and manage longleaf pine planting entire stands, creating patch regeneration areas, mounding micro beds in areas with elevated water tables, promoting natural regeneration through selective thinning, applying prescribed fire to all upland acres, and managing natural fire on all upland acres within the wilderness boundary.

PRODUCTION OF A LANDSCAPE SCALE MULTIFACTOR PREDICTIVE MODEL FOR FIRE DISTURBED LONGLEAF PINE FORESTS OF THE TALLADEGA MOUNTAINS, ALABAMA, USA

B. L. Womack and R.E. Carter

Abstract: A key step in the management of forested ecosystems is the identification of land units that are similar relative to type, structure, and productivity of vegetation Such land units can be identified through analysis of multivariate vegetation, soil and landform variables. The environmental variables found to be significantly related to vegetation can be used to produce a predictive model. Such a model was developed for the Talladega National Forest in Alabama, USA. The Talladega National Forest has one of the last remaining intact montane longleaf pine (*Pinus palustris*) ecosystems. Land units were identified across an environmental gradient from longleaf pine dominated ridgetops to oak dominated riparian zones. The ridgetops historically were maintained as longleaf pine forests by lightning and Native American caused fires.

RARE PLANT SPECIES ON CAMP SHELBY TRAINING SITE, MS

Lisa Y. Yager and Steven W. Leonard

Abstract: Historically, the majority of Camp Shelby Training Site (CSTS) burned regularly and supported a mosaic of longleaf forests with an open understory of hardwoods and a dense, bluestem grass-dominated groundcover. Interspersed within this mosaic were slope hardwood forests, narrow creek drainages, floodplains and pitcher plant wetlands. Past fire exclusion and other land management activities have significantly altered plant communities and natural ecological processes on CSTS. However, due in part to prescribed and other fires, large areas still retain many of the characteristics (structure, species abundance, and composition) of the historical landscape. These areas with their longleaf forests and associated communities support a diversity of plant species. Nearly 70 plant species located on the MS Natural Heritage Program's rare plants list have been documented on CSTS. Six species new to Mississippi including the Louisiana quillwort (*Isoetes louisianensis*), which is federally listed as endangered, *Dryopteris ludoviciana*, *Eleocharis melanocarpa*, *E. robbinsii*, *Sagittaria isoetiformis*, and *E. tricostata* have been documented on CSTS since 1995. *Pteroglossaspis ecristata*, not seen in Mississippi since 1967, was also documented this year (2004). Data on natural communities and associated rare species reported in the 2000 Mississippi Military Department Biological Inventory of Camp Shelby and collected by The Nature Conservancy's Camp Shelby Field Office in following years will be presented. Management needed to maintain these rare plants and their habitats will also be discussed.

INTRODUCTION

Historically, the majority of Camp Shelby Training Site (CSTS) burned regularly and supported a mosaic of longleaf forests with an open understory of hardwoods and a dense, bluestem grass-dominated groundcover. Interspersed within this mosaic were slope hardwood forests, narrow creek drainages, floodplains and pitcher plant wetlands. Past fire exclusion and other land management activities have significantly altered plant communities and natural ecological processes on CSTS. However, due in part to prescribed and other fires, large areas still retain many of the characteristics (structure, species abundance, and composition) of the historical landscape. These areas with their longleaf forests and associated communities support a diversity of plant species. Nearly 70 plant species located on the MS Natural Heritage Program's rare plants list have been documented on CSTS. Species rarely or never collected in Mississippi prior to CSTS surveys (1995-2004) include the Louisiana quillwort (*Isoetes louisianensis*), which is federally listed as endangered, *Dryopteris ludoviciana, Eleocharis melanocarpa, E. robbinsii, Sagittaria isoetiformis, E. tricostata, and Pteroglossaspis ecristata*. This poster will present data on natural communities and associated rare species reported in the 2000 Mississippi Military Department Biological Inventory of Camp Shelby as well as data collected by The Nature Conservancy's Camp Shelby Field Office in subsequent years.

Surveyed Area

Located within the Piney Woods subprovince of the Gulf Coastal Plain physiographic province in Mississippi,Camp Shelby Training Site (CSTS) is one of the largest National Guard Training installations in the US. It includes land owned and managed by The Department of the Army (3,361 acres), The Department of Defense (6,000 acres), State of Mississippi (8,300 acres), and the U.S. Forest Service (117,000 acres). The majority of the CSTS acreage is managed as a unit of the DeSoto National Forest with military training integrated with multiple use management under a special use permit.

Longleaf Pine-Saw Palmetto Scrub

Open longleaf forest with saw palmetto and drought tolerant herbaceous species occurring on deep sandy soils

Associated Rare Species:
Aristida condensata (Sandhills Three Awn)
Carex tenax (Wiresedge)
Dalea carnea var. *gracilis* (Pine Barrens Prairie Clover)
Stylisma pickeringii var. *pattersonii* (Patterson's Bindweed)

Management:
Prescribed burn every 4-5 years. If necessary, remove hardwoods chemically or mechanically. Defer from timber harvest, if possible, and allow natural regeneration. Minimize soil disturbing activities. Remove off-site pines and restock with longleaf, if past management dictates.

Pine Flatwoods
Longleaf and slash dominated forests with a subcanopy of evergreen shrubs and/or herbaceous groundcover on poorly drained sites

Associated Rare Species:
Cleistes bifaria (Spreading Pogonia)
Ilex amelanchier (Juneberry Holly)
Ilex myrtifolia (Myrtle Holly)
Platanthera integra (Yellow Fringeless Orchid)
Ruellia pinetorum (Pine Barren Ruellia)

Management:
Prescribed burn every 2 years to control hardwoods and evergreen shrubs. Avoid clear cuts and allow natural regeneration. Maintain natural hydrology.

Longleaf Pine with Blackjack Oak Forest
Open longleaf forest with scattered blackjack oaks and other hardwoods and a well-developed herbaceous groundcover typically occurring on sandier soils

Associated Rare Species:
Agrimonia incisa (Incised Groovebur)
Botrychium jenmanii (Alabama Grape-fern)
Dalea carnea var. *gracilis* (Pine Barrens Prairie Clover)
Epigaea repens (Trailing Arbutus)
Polygala leptostachys (Southern Milkwort)
Pteroglossaspis ecristata (Giant Coco Orchid)
Sorghastrum apalachicolense (Open Indian Grass)

Management:
Prescribed burn every 2-3 years and include growing season burns in the rotation. Control invasive weeds.

Slope Forest
Hardwood-dominated forests with sparse groundcover on moderate to steep slopes

Associated Rare Species:
Carex impressinervia (Southern Few-fruited Sedge)
Carex picta (Painted Sedge)
Chrysogonum virginianum (Green-and-gold)
Cornus alterniflora (Alternate-leaf Dogwood)
Epigaea repens (Trailing arbutus)
Hexalectris spicata (Crested Coral-root)
Mikania cordifolia (Florida Key Hempweed)
Rhapidophyllum hystrix (Needle Palm)
Schisandra glabra (Scarlet Woodbine)
Stewartia malacodendron (Silky Camellia)

Management:
Although these communities seldom burn naturally and thus would not need to be placed on a prescribed fire rotation, prescribed fires from adjacent areas should be allowed to move down slope (no fire breaks). If harvest is necessary, it should be selective and stands should be allowed to regenerate naturally to maintain their mixed

character. Before implementing any land management activities, managers should always consider the high erosion potential on these slopes.

Longleaf Pine-Hardwood Forest
Longleaf pine forest mixed with scattered southern red oak, flowering dogwood, and other hardwoods on mesic to hydric sites. Depending on fire frequency evergreen shrubs or a diverse herbaceous groundcover predominate.

Associated Rare Species:
Agrimonia incisa (Incised Groovebur)
Botrychium jenmannii (Alabama Grape-fern)
Chrysogonum virginianum (Green-and-gold)
Dalea carnea var. *gracilis* (Pine Barrens Prairie Clover)
Epigaea repens (Trailing arbutus)
Gaylussacia nana (Dangleberry)
Ruellia pinetorum (Pinebarren Ruellia)
Sorghastrum apalachicolense (Open Indian Grass)
Stewartia malacodendron (Silky Camellia)
Uvularia floridana (Florida Bellwort)
Tridens caroliniana (Carolina fluffgrass)
Tridens chapmanii (Chapman's redtop)
Management:
Prescribed burn every 2-3 years and include growing season burns in the rotation. Control invasive weeds.

Bottomland Hardwood-Pine Forests
Hardwood-dominated forests with sparse ground-cover occurring on floodplains and creek bottoms

Associated Rare Species:
Epidendrum conopseum (Green-fly Orchid)
Isoetes louisianensis (Louisiana Quillwort)
Marshallia trinervia (Broad-leaf Barbara's Button)
Melanthium virginicum (Virginia Bunchflower)
Triphora trianthophora (Three Birds Orchid)

Management:
Although these communities seldom burn naturally and thus would not need to be placed on a prescribed fire rotation, prescribed fires from adjacent areas should be allowed to move within these communities (no fire breaks). Avoid clearcuts and allow natural regeneration to maintain mixed character. Avoid land management activities likely to impact water flow or create sedimentation problems.

Ponds
Forested or unforested areas with prolonged periods of standing water

Associated Rare Species:
Eleocharis melanocarpa (Black-fruited Spikerush)
Eleocharis robbinsii (Robbins Spikerush)
Eleocharis tricostata (Three-ribbed Spikerush)
Nymphoides aquatica (Big Floating-heart)
Nymphoides cordata (Floating-heart)
Sagittaria isoetiformis (Slender arrowhead)
Stylisma aquatica (Southern Water Morning-glory

Management:
Maintain hydrology. Allow fires to back into pond margins.

Black Gum-Bay-Pine Swamp
Hardwood-dominated forests sometimes with dense evergreen midstories occurring along narrow creek drainages.

Associated Rare Species:
Chamaecyparis thyoides (Atlantic White Cedar)
Dryopteris ludoviciana (Southern Shield Wood-fern)
Gordonia lasianthus (Loblolly Bay)
Ilex amelanchier (Juneberry Holly)
Isoetes louisianensis (Louisiana Quillwort)
Juncus gymnocarpus (Naked-fruited Rush)
Lindera subcoriacea (Bog Spice Bush)
Macranthera flammea (Flame Flower)
Melanthium virginicum (Virginia Bunchflower)
Peltandra sagittifolia (White Arum)
Pinguicula primuliflora (Southern Butterwort)
Platanthera cristata (Crested Fringed Orchid)
Rhynchospora crinipes (Hairy-peduncled Beakrush)
Utricularia purpurea (Purple Bladderwort)

Management:
Maintain natural hydrology. Allow prescribed fire from adjacent uplands to burn into drains (no fire breaks). Avoid clear-cutting and allow natural regeneration. Avoid activities in uplands which increase sedimentation.

Pitcher Plant Wetlands
Seepage, terrace, and depressed drainages which support pitcher plants and a diverse herbaceous groundcover, sometimes with scattered evergreen shrubs, hardwoods, and pines

Associated Rare Species:
Agalinis aphylla (Coastal Plain False-foxglove)
Aristida simpliciflora (SouthernThree-awned Grass)
Calopogon barbatus (Bearded Grass-pink)
Calopogon oklahomensis (Oklahoma Grass-pink)
Cleistes bifaria (Spreading pogonia)
Ilex myrtifolia (Myrtle holly)
Macranthera flammea (Flame Flower)
Panicum nudicaule (Naked-stemmed Panic Grass)
Parnassia grandifolia (Large-leaved Grass-of-parnassus)
Platanthera blephariglottis (Large White Fringed Orchid)
Platanthera integra (Yellow Fringeless Orchid)
Rhynchospora macra (Large Beakrush)
Rhynchospora stenophylla (Chapman beakrush)
Xyris drummondii (Drummond's Yellow-eyed Grass)
Xyris scabrifolia (Harper's Yellow-eyed Grass)

Management:
Prescribed burn every 2-3 years and include growing season burns in the rotation. Maintain natural hydrology (no firebreaks, drainage ditches, etc.) and protect against sedimentation. Protect wet soils from rutting by trucks, ATV's, etc. If applicable, remove planted slash pine when substrate is dry.

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INDEX OF AUTHORS

ATTENDEES

Allen Albritton
Mississippi Forestry Commission
301 North Lamar St. Suite 300
Jackson, MS 39201

Tim Albritton
State Staff Forester
715 Albritton Lane
Wetumpka, AL 36093
334-887-4560

Mark Anderson, Forester
341 Ralph Rawls Road
Hattiesburg, MS 39402
601-545-1541

James Atkinson
jimmy.atkinson@jonesctr.org
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Chadwick Avery
chadwick.avery@eglin.af.mil
96 ABW/EMSNF
501 Deleon St. Suite 101
Eglin AFB, FL 32542
850-883-1141

Ray Aycock
ray_aycock@fws.gov
U.S. Fish and Wildlife Service
6578 Dogwood View Parkway
Jackson, MS 39213
601-965-4900

Wilson Baker
1422 Crestview Avenue
Tallahassee, FL 32303
850-222-6874

John Barczak
john.barczak@us.army.mil
SFIM-AEC-TSR
5179 Hoadley Road
APG, MD 21010
410-436-1562

Jan Barlow
jan@datasyn.com
3507 Prentiss Avenue
Moss Point, MS 39563
228-475-6370

Jim Barnes
jbarnes@mfc.state.ms.us
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Andy Barwick
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Chad Basinger
ORISE Forester
Oak Ridge Institute for Science
202 Old Rockford Road
Sylacauga, AL 35150
256-741-5808

Bobby Bass
bobby.bass@jonesctr.org
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

James Bates
jim_bates@fws.gov
P. O. Box 52560
Fort Benning, GA 31995
706-544-6422

Barbara Bell, Silviculturist
bbell@fs.fed.us
U. S. Forest Service
9912 Highway 28 West
Boyce, LA 71409
318-793-9427

Kathryn Bell
1550 Simpson Road
Odenville, AL 35120
205-629-6461

Wayne Bell
1265 Georgia Highway 133 North
Moultrie, GA 31768
800-633-4506

Larry Bishop, Forester
lbishop@fs.fed.us
U. S. Forest Service
1720 Peachtree Road
Atlanta, GA 30309
404-347-2067

Kimberly Bittle
57 Taff Drive
Crawfordville, FL 32327
850-926-3561

Bob Bittner, Biologist
bob_bittner@fws.gov
U. S. Fish and Wildlife Service
6620 Southpoint Drive South, Suite 310
Jacksonville, FL 32216
904-232-2580 (120)

C.J. Blanton, Owner
1091 NE Daylily Avenue
Madison, FL 2340
850-973-2967

Jason Blanton, Owner
1091 NE Daylily Avenue
Madison, FL 32340
850-973-2967

Gabriel Blossom
Box 5018
Hattiesburg, MS 39406
601-266-5419

Robert Bonnie
robertb@edf.org
1875 Connecticut Avenue NW
Washington, DC 20009
202-387-3500

Lindsay Boring
lindsay.boring@jonesctr.org
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Lynne Boyd
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Robert Boyd, President
1058 Cato Road
Mendenhall, MS 39114
601-940-7806

Blaine Boydstun
P. O. Box 1960
Clarkesville, GA 30523
706-754-6221

William Boyer
bboyer@fs.fed.us
USDA Forest Service
852 Terrace Acres Drive
Auburn, AL 36830
334-821-3932

Allen Braswell
Installation Forester
4655 Cutter Mill Road
Augusta, GA 30907
706-791-9932

Jerry Brewer
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Dale Brockway
dbrockway@fs.fed.us
U. S. Forest Service
520 Devall Drive
Auburn, AL 36849
334-826-8700

Judd Brooke
8401 Brookewood Drive
Perkinston, MS 39573
228-518-1259

Robert Brooks
robert_brooks@fws.gov
4270 Norwich Street
Brunswick, GA 31523
912-265-9336 (25)

Ed Brown, Forester
P. O. Box 76
Tellico Plains, TN 37385
423-476-9700

Mary Brown, Silviculturist
Wayah Ranger District
90 Sloan Road
Franklin, NC 28734
828-524-6441

Randy Browning
randy_browning@fws.gov
U. S. Fish and Wildlife Service
113 Fairfield Drive
Hattiesburg, MS 39402
601-965-4900

Brian Buchner
5317 Musket Ridge
Austin, TX 78759
512-834-8040

John Buckley, Forester
P. O. Box 1861
Brandon, MS 39043
601-825-0222

Bryan Bulger, Student
U.S. Forest Service
320 Green Street
Athens, GA 30602
706-559-4312

William Burns
burnswf@anad.army.mil
Anniston Army Depot
7 Frankford Avenue, Bldg. 1
Anniston, AL 36201
256-235-4217

Rodney Busby, Research Forester
RM T-10034,PSB,701 Loyola Avenue
New Orleans, LA 70113
504-589-7129

Kyle Bush
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Aaron Campbell
Research Tech, UGA
7 Cherry Hills Drive
Aiken, SC 29803
803-640-5338

Robert Carter
rcarter@jsucc.jsu.edu
JSU Department of Biology
700 Pelham Road North
Jacksonville, AL 36265
256-782-5144

Sarah Cathey
J.W. Jones Ecological Research Center
508 SW 34th Street
Gainesville, FL 32607
229-734-4706

Phillip Chambers, Graduate Assistant
Department of Forestry
Mississippi State, MS 39762

Cecil Chambliss
70 Franklin Place
Hattiesburg, MS 39402
601-579-9023

Robert Clanton, Owner
Clanton Forestry and Appraisal
53 Pompano
Hattiesburg, MS 39402
601-408-0941

Jeff Clark
1141 Bayview Avenue, Suite 101
Biloxi, MS 39530
228-374-5022

Matthew Cole
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Kristina Connor
P. O. Box 9681
Mississippi State, MS 39762
662-325-2145

Eugene Cooper
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

James Copeland
Jim.copeland@cnet.navy.mil
9125 Mt. Carmel Road
Meridian, MS 39305
601-679-2482

Ron Cox
52 Cablebridge Road
Perkinston, MS 39573
601-928-5837

C. D. Crain
The Nature Conservancy
P. O. Box 4125
Baton Rouge, LA 70801
409-284-4374

Barbara Crane, Regional Geneticist
1720 Peachtree Road NW
Atlanta, GA 30309
404-347-4039

Van Crump
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

James Currie
1020 West Beach Boulevard
Pass Christian, MS 39571
228-452-9622

Mark Dale, Consulting Forester
Total Forest Management
P. O. Box 1452
Monticello, MS 39654
601-587-4446

Michael Davis
mike.davis@usm.edu
Box 5018
Hattiesburg, MS 39406-5018
601-266-5419

Drue Deberry, VP
Habitat Conservation
1111 19th Street NW Suite 780
Washington, DC 20036
202-463-5188

Jeff Dematteis
Mississippi Forestry Commission
301 N. Lamar Street, Suite 300
Jackson, MS 39201
601-359-2835

Roger W. Dennington
rogerdennington@mindspring.com
1840 Lipscomb Road
Social Circle, GA 30025
770-464-0090

David Dickenson
3415 Cumming Hub Y
Canton, GA 30114
770-720-3526

John Dickson
Private Lands Biologist
P. O. Box 774
Vidalia, LA 71373
601-807-8555

Spencer Dixon
Mississippi Forestry Commission
301 N. Lamar Street, Suite 300
Jackson, MS 39201

John Dupre, Forester
U. S. Forest Service
1015 North Pinckney Street
McClellanville, SC 29458
843-887-3257

Larry Earley
larryearley@mindspring.com
126 Forest Road
Raleigh, NC 27605
919-838-0590

Dean Easton
dean_easton@fws.gov
U. S. Fish and Wildlife Service
Route 2 Box 3330
Folkston, GA 31537
912-496-7366

Lori Eckhardt, Postdoctoral Researcher
leckha1@lsu.edu
Louisiana State University
302 Life Sciences Building
Baton Rouge, LA 70803
225-578-4512

James Elledge
158 Myrick Road
Lumberton, MS 39455
601-408-8792

Todd Engstrom
tengstrom@tnc.org
Greenwood Project Director
4340 Highway 84 W
Thomasville, GA 31792
229-226-4784 (101)

Becky Estes
Estesbl@auburn.edu
108 M. White Smith Hall
Auburn, AL 36849
334-728-1373

Bob Fairbank
Mississippi Power Company
P. O. Box 4079
Gulfport, MS 39502
228-865-5651

Reggie Forcine
reggie_forcine@fws.gov
U. S. Fish and Wildlife Service
Route 2 Box 3330
Folkston, GA 31537
912-496-7366

Larry Ford, Management Forester
lford@gulf-states.com
P. O. Box 617
Columbiana, AL 35051
205-669-3141

Samuel Fowler, Associate Director
fowlesr@auburn.edu
Alabama Cooperative Extension System
109B Duncan Hall
Auburn, AL 36849
334-844-5542

Robert Franklin, Area Agent
Conservation Forester
P. O. Drawer 1086
Walterboro, SC 29488
843-549-2595

Howard Freerksen
605 W. Main
Russellville, AR 72801
479-964-7223

Jennifer Gagnon
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Bill Garland
bill_garland@fws.gov
Mountain Longleaf National
Wildlife Refuge
P.O. Box 5087
Fort McClellan, AL 36205
256- 848-6833

Dan Garvey
P. O. Box 6742
Metairie, LA 70001
504-583-8498

James Garvey
P. O. Box 6742
Metairie, LA 70001
504-836-7440

Amy Gaskill, Student
3204 Swann Drive
Nacogdoches, TX 75964
936-615-5365

Eric Gee
2900 Indiana Avenue
Kenner, LA 70065
504-443-4474

Robert Gehri
Principal Research Specialist
P. O. Box 2641
Birmingham, AL 35291
205-257-6720

John Gilbert
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn University, AL 36849
334-844-1060

Shauna Ginger
shauna_ginger@fws.gov
U.S. Fish and Wildlife Service
6578 Dogwood View Parkway
Jackson, MS 39213
601-965-4900

Dean Gjerstad
gjerstad@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn University, AL 36849
334-844-1020

Richard Gooch
richard_gooch@fws.gov
1875 Century Boulevard, Suite 200
Atlanta, GA 30345
404-679-7124

Darroc Goolsby
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Susan Grace
sue_grace@fws.gov
61389 Highway 434
Lacombe, LA 70445
985-882-2008

John Green, ILR
3202 Jamestown Road
Hattiesburg, MS 39402
601-264-2349

Farroll Gunter
136 Rose Lake Road
Lexington, SC 29072
803-957-6722

John Guthrie, MSU-ES
P. O. Box 348
Purvis, MS 39475
601-794-0671

John Guthrie, Jr., President
Guthrie & Sons, Inc.
P. O. Box 400
Wiggins, MS 39577
601-928-4262

Mark Hainds, Longleaf Alliance
lla@alaweb.com
Solon Dixon Forestry Education Center
12130 Dixon Center Road
Andalusia, AL 36420
334-222-7779

Mark Hamilton
Mississippi Forestry Commission
301 North Lamar Street Suite 300
Jackson, MS 39201

Pam Hamilton
#9 Fathom Circle
Hattiesburg, MS 39402
601-818-6749

Bruce Hammons
1550 Simpson Road
Odenville, AL 35120
205-629-6461

James Harris
1729 South Main Street
Poplarville, MS 39470
601-795-9371

Rick Hatten
rhatten@gfc.state.ga.us
Chief of Forest Management
P. O. Box 819
Macon, GA 31202
478-751-3486

Russell Hatten
Stone County Economic Dev
P. O. Box 569
Wiggins, MS 39577
601-928-5418

Ronnie Haynes
ronnie_haynes@fws.gov
U.S. Fish and Wildlife Service
1875 Century Boulevard, Suite 200
Atlanta, GA 30345
404-679-7138

James Haywood, Research Forester
dhaywood@fs.fed.us
U. S. Forest Service
2500 Shreveport Highway
Pineville, LA 71360
318-473-7216

Nelson Hearn
Mississippi Forestry Commission
301 N. Lamar Street, Suite 300
Jackson, MS 39201

Sharon Hermann
hermasm@auburn.edu
Department of Biological Sciences
Auburn, AL 36849
334-844-3933

Jay Herrington, Fish & Wildlife Biologist
jay_herrington@fws.gov
U. S. Fish and Wildlife Service
6620 Southpoint Drive South, Suite 310
Jacksonville, FL 32216
904-232-2580 (136)

John Hiers
4340 U.S. Highway 84 West
Thomasville, GA 31792
229-226-1744

Flinda Hill
Mississippi Power Company
P. O. Box 4079
Gulfport, MS 39502
228-865-5651

Matt Hinderliter
Gopher Tortoise Specialist
The Nature Conservancy Camp Shelby
CSTS-ENV Building 6678
Camp Shelby, MS 39407
601-558-2931

Sarah Hinman, Graduate Student
1005 South 16th Street
University of Mississippi
Oxford, MS 38655
662-915-7203

Kirk Hinson
southernseed@alltel.net
Southern Seed Company, Inc.
P. O. Box 340
Baldwin, GA 30511
706-778-4542

Daryl Hodges
P. O. Box 579
Bristol, FL 32321
851-643-2282

Gilbert Hoffman
206 Donwood Place
Hattiesburg, MS 39401
601-583-4378

David Hoge
dhoge@fs.fed.us
USDA Forest Service
1720 Peachtree Rd. NW, Room 811
Atlanta, GA 30309
404-347-1649

John Hogland
hoglajs@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1008

Alan Holditch
NRCS, Suite 1321 Federal Building
100 West Capital Street
Jackson, MS 39269
904-965-4139

Stephen Hudson
hudsost@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1026

Glenn Hughes, MSU-ES
P. O. Box 348
Purvis, MS 39475
601-794-0671

Felicia Humphrey, Forester
2946 Chestnut Street
Montgomery, AL 36107
334-241-8146

Chester Hunt, Forester
1123 Columbia-Purvis Road
Columbia, MS 39429
601-441-7209

Tommy Hutcherson, Forest Technician
hutchersont@benning.army.mil
U.S. Army, ATZB-TWN-L
Fort Benning, GA 31905
706-544-6120

Mary Ann Iverson
108 Beechwood Drive
Hattiesburg, MS 39402
601-266-5682

Steven Jack
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Rick Jacob, Director of Conservation Forestry, The Nature Conservancy
1639A Ryan Street, Suite 16
Lake Charles, LA   70601
337-436-2650

Randy Jarzyniecki, Forester
1477 North Denshee Drive, Apt. 2207
Auburn, AL 36830
706-544-7720

Richard Jeffers, Silviculturist
rjeffers@fs.fed.us
1720 Peachtree Road, NW, Suite 816
Atlanta, GA 30309
404-347-4153

Steve Jennings, Silviculturist
3125 Conner Boulevard
Tallahassee, FL 32399
850-414-9906

Bill Johnson, Owner
Southern Mississippi Pine Straw
P. O. Box 331
Purvis, MS 39475
601-668-7310

Rhett Johnson
johnsee@auburn.edu
Solon Dixon Forestry Education Center
12130 Dixon Center Road
Andalusia, Al 36420
334-222-7779

David Jones
U.S. Forest Service
320 Green Street
Athens, GA 30602
706-559-4312

Walter Jones
P. O. Box 394
Mississippi State, MS 39762
662-325-6768

Robert Kindrick
rkindrick@callawaygardens.com
Ida Cason Callaway Foundation/
The Preserve
P. O. Box 2000
Pine Mountain, GA 31822
706-663-6737

Tim Knight
16375 U.S. Highway 29
Andalusia, AL 36420
334-222-2555

John Kush
kushjoh@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1065

Jason Kutack, ILR
200 South 24th Avenue
Hattiesburg, MS 39401
601-582-1083

John Lambert
P. O. Drawer 328
Sumrall, MS 39482
601-758-4970

Eloise Larson
Larson & McGowin, Inc.
P. O. Box 2143
Mobile, AL 36652
251-438-4581

Keville Larson
Larson & McGowin, Inc.
P. O. Box 2143
Mobile, AL 36652
251-438-4581

Keith Lawrence, Deputy Forest Supervisor
USDA Forest Service
100 West Capital Street, Suite 1141
Jackson, MS 39269
601-965-4391 (151)

Charles Anthony Lee
Reforestation Technician
USDA Forest Service
16375 U.S. Highway 29
Andalusia, AL 36420
334-222-2555

Jim Lee, Biologist
The Nature Conservancy Camp Shelby
CSTS-ENV Building 6678
Camp Shelby, MS 39407
601-558-2931

Mike Lee
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Robert Lee
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Thomas Leslie, President
542 St. Charles Avenue
Atlanta, GA 30308
404-521-2324

Robert Lewis
250 Ranger Station Road
Tellico Plains, TN 37385
423-253-2520

Mike Lick
U. S. Forest Service
P. O. Box 248
Wiggins, MS 39577
601-928-4422

Ralph Locklear, Forestry Tech
Building 09062 Longstreet Road
Fort Bragg, NC 28310
910-396-2510

Michael Low
96 ABW/EMSNF
501 Deleon Street, Suite 101
Eglin AFB, FL 32542
850-883-1141

Dwain Luce
dgluce@bellsouth.net
Luce Packing Company
P. O. Box 8743
Moss Point, MS 39562
228-474-6383

Greg Luce
greg.luce@mserailroad.com
Luce Packing Company
P. O. Box 8743
Moss Point, MS 39562
228-474-6383

Margaret Luce
Luce Packing Company
P. O. Box 8743
Moss Point, MS 39562
228-474-6383

Susan Luce
Luce Packing Company
P. O. Box 8743
Moss Point, MS 39562
228-474-6383

Kathryn Madden
Drawer E
Aiken, SC   29802
803-725-7268

Lawrence Mahler
P. O. Box 359
Summerdale, AL 36580
251-423-3331

Sonya Mahler
15705 North Juniper Street
Foley, AL 36535
251-937-7176

John Maitland
218 Majestic Drive
Columbia, SC 29223
803-751-4622

Raymond Majesty
Ram Marion Plantation
1965 Tanglewood Drive
Glenview, IL 60025
847-724-2552

Robert Makowski
96 ABW/EMSNF
501 Deleon Street, Suite 101
Eglin AFB, FL 32542
850-883-1141

Douglas Marshall, UGA
Warnell School of Forest Resources
Athens, GA 30605
706-296-6273

Timothy Marston
marstont@jackson.army.mil
2563 Eessayonx Way
Fort Jackson, SC 29207
803-751-7233

Sharon Martinson
25 Parkhurst Street
Lebanon, NH 03766
601-313-4779

Todd Matthews
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Jay McClain
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Len McCombs
P. O. Box 2035
Hattiesburg, MS 39403
601-544-0541

Howard McCullough
howard_mccullough@fws.gov
U.S. Fish and Wildlife Service
Route 2 Box 3330
Folkston, GA 31537
912-496-7366

Will McDearman
will_mcdearman@fws.gov
U.S. Fish and Wildlife Service
6578 Dogwood View Parkway
Jackson, MS 39213
601-965-4900

Dennis McDevitt
146 Foxberry Road
Eldon, MO 65026
573-392-7800

Cynthia McDonald
9912 Highway 28 West
Boyce, LA 71409
318-793-9427

Gary McGinnis
3086 Martha Berry Highway NE
Rome, GA 30165
706-295-6021

John McGuire
mcguijo@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1032

Nelwyn McInnis, Program Manager
P. O. Box 1497
Covington, LA 70434
985-809-1414

Richard McInnis
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Anna McKenney
P. O. Box 5018
Hattiesburg, MS 39406
601-266-5419

Donald McKenzie, NBCI Coordinator
wmidm@ipa.net
2396 Cocklebur Road
Ward, AR 72176
501-941-7994

Norman McLeod
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Steve Meeks
187 Flanders Road
Kite, GA 31049
912-536-3844

Ralph Meldahl
meldahl@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1060

Mark Melvin
mark.melvin@jonesctr.org
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Roger Menard
2500 Shreveport Highway
Pineville, LA 71360
318-473-7298

Joe Miles
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Ben Miley, Conservation Branch Tech
Building 5884 ATZR-FLN-C
Fort Benning, GA 31905
706-544-7718

Thomas Mohrman
118 College Drive, Box #50
Hattiesburg, MS 39406
601-266-5907

Roberta Moltzen, Deputy Regional Forester
1720 Peachtree Road NW
Atlanta, GA 30309
404-347-2693

Jason Monroe, Forestry Tech
1870 Pittman Grove Ch. Road
Raeford, NC 28376
910-263-2048

Ben Moody
P. O. Box 14
Poplarville, MS 39470
601-795-8396

William Moody
125 Rose Lake Road
Lexington, SC 29072
803-808-2205

Manning Moody, III
Wildlife Biologist
P. O. Box 248
Wiggins, MS 39577
601-928-4422

Gerald Moore
Pine Belt Foresters
P. O. Box 266
Petal, MS 39465-0266
601-543-4179

John Moore
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Julie Moore, Biologist
Julie_H_Moore@fws.gov
U.S. Fish and Wildlife Service
428 Cedar Avenue
McLean, VA 22101
703-358-2096

Ronnie Myers
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201
601-359-2826

Kimberly Naylor
9912 Highway 28 West
Boyce, LA 71409
318-793-9427

C. Nelson, Project Leader
23332 Highway 67
Saucier, MS 39574
228-832-2747

Gloria Nielson, Forester
3473 Highway 35 South
Forest, MS 39074
601-469-3811

Krista Noel
3317 West 4th Street, Apt. 94
Hattiesburg, MS 39401
601-266-5907

Paul Orr, Forestry Inf. & Edu. Chief
P. O. Box 1628
Baton Rouge, LA 70821
225-925-4500

Kenneth Outcalt, Research Ecologist
koutcalt@fs.fed.us
U. S. Forest Service
320 Green Street
Athens, GA 30602
706-559-4312

Stephen Overton, Forester
12000 SR 25
Hector, AR 72843
479-284-3150

Dale Pancake, Assistant Director
pancadc@auburn.edu
Solon Dixon Center
12130 Dixon Center Road
Andalusia, AL 36420
334-222-7779

James Parker
james.parker2@benning.army.mil
Land Management Branch
ATZB-PWN-L
Fort Benning, GA 31905
706-544-7081

Walter Passmore
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201
601-925-5264

Barry Pessoney
113 Fairfield Drive, Suite 110
Hattiesburg, MS 39404
601-296-1173

George Pessoney
113 Fairfield Drive, Suite 110
Hattiesburg, MS 39404
601-296-1173

Tom Peterson, Director
Forest Management Timber
1720 Peachtree Road NW
Atlanta, GA 30309
404-347-7396

Joseph Pettigrew
Pettigrew Forestry Consultant
P. O. Box 592
Kiln, MS 39556
228-493-8733

Ronald Phernetton
ronald_phernetton@fws.gov
U.S. Fish and Wildlife Service
Route 2 Box 3330
Folkston, GA 31537
912-496-7366

Jim Phillips
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Bill Pickens, Silviculturist
bill.pickens@ncmail.net
NC Division Forest Resources
2411 Old US 70 West
Clayton, NC 27520
919-553-6178(233)

David Price
2010 Adeline Street
Hattiesburg, MS 39401
601-545-7264

George Pritchett
HC 34 Box 137
Evergreen, AL 36401
251-578-2847

Lisa Pritchett
HC 34 Box 137
Evergreen, AL 34601
251-578-2847

Brad Pulliam
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Carl Qualls
118 College Drive #5018
Hattiesburg, MS 39406
601-266-6906

Linda Randolph, Operations Asst.
Appalachian Ranger District
P. O. Box 128
Hot Springs, NC 28743
828-622-3202

Carol Revel
851 Sea Cliff Drive
Fairhope, AL 36532
251-928-9313

Robert Revel
851 Sea Cliff Drive
Fairhope, AL 36532
251-928-9313

John Rhine, Biological Tech
The Nature Conservancy Camp Shelby
CSTS-ENV Building 6678
Camp Shelby, MS 39407
601-558-2931

Charles Rice
P. O. Box 850
Purvis, MS 39475
601-794-2010

Chester Richardson, Sel. Tres.
dginc@dixiegreen.com
Dixie Green, Inc.
P. O. Box 262
Centre, AL 35960
256-927-5185

Randy Roach
randy_roach@fws.gov
U. S. Fish and Wildlife Service
P. O. Box 1190
Daphne, AL 36526
251-441-5872

Kevin Robertson
13093 Henry Beadel Drive
Tallahassee, FL 32313
850-893-4153

Patty Rogers
P. O. Box 506
Perkinston, MS 39573
601-528-8903

Clayton Rouse, MSU-ES
P. O. Box 348
Purvis, MS 39475
601-794-0671

Baxter Rowley
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

C. J. Sabette
The Nature Conservancy Camp Shelby
CSTS-ENV Building 6678
Camp Shelby, MS 39407
601-558-2931

Mary Sauer, Plant Physiologist
2500 Shreveport Highway
Pineville, LA 71360
318-473-7216

Robert Scoggin
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Randy Shaw
Forest Resource Consultant, Inc.
P. O. Box 111
Picayune, MS 39466
601-255-2825

Doug Shelburne
SMURFIT-STONE
4346 Parker Springs Road
Brewton, AL 36426
251-827-9480

Richard Shelfer
325 John Knox Road
Suite F-100
Tallahassee, FL 32303
850-523-8553

James Shores
jshore@fs.fed.us
USDA Forest Service
9901 Highway 5
Brent, AL 35034
205-926-9765

Mary Shores
11 Windsor Drive
Tuscaloosa, AL 35404
205-554-7643

Robert Simmons, UGA
8668 Highway 106 South
Hull, GA 30646
706-255-3796

Terrell Simmons, Owner
Simmons Tree Farm
545 Snipesville Road
Denton, GA 31532
912-222-8239

Darlene Slater
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201
601-359-2803

Jim Sledge
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201
601-359-2800

Robert Smiley
USDA Forest Service
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Robert Smistik
Integrated Resource Analyst
P. O. Box 248
Wiggins, MS 39577
601-928-4422

Danna Smith
The University of Southern Mississippi
195 Hickory Grove Road
Lumberton, MS 39455
601-796-3524

Eddie Smith
P. O. Box 348
Purvis, MS 39475

Jo Ann Smith, Silviculturist
2500 Shreveport Highway
Pineville, LA 71360
318-473-7191

Latimore Smith
The Nature Conservancy
P. O. Box 4125
Baton Rouge, LA 70801
409-284-4374

David South
southdb@auburn.edu
School of Forestry & Wildlife Sciences
108 M. White Smith Hall
Auburn, AL 36849
334-844-1022

Lesley Spaulding
lspaulding@fs.fed.us
USDA Forest Service
2309 Highway 46
Heflin, AL 36264
256-463-2272

Hunter Speed, Forester
P. O. Box 189
Jessieville, AR 71949
501-984-5313

Vickie Stallings
stallvl@auburn.edu
Solon Dixon Forestry Education Center
12130 Dixon Center Road
Andalusia, AL 36420
334-427-1029

Peter Stangel
1875 Century Boulevard, Suite 200
Atlanta, GA 30345
404-484-5813

Ronald Stephens
1755 Cleveland Highway
Gainesville, GA 30501
770-297-3020

Linda Stine
113 Fairfield Dr., Suite 110
Hattiesburg, MS 39402
601-296-1173

Jonathan Stober
jstober@jonesctr.org
J.W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Rodney Stone
968 Highway 15 South
Laurel, MS 39443
601-428-0594

Wayne Stone
Forest Service Representative
654 West Frontage Road
Wiggins, MS 39577
601-928-4422

Eric Strickland
3025 Mabus Drive
Augusta, GA 30909
706-651-0630

Eric Stuewe, President
Stuewe & Sons, Inc.
2290 SE Kiger Island Drive
Corvallis, OR 97333
541-757-7798

Charles Tarver, President
Forest Investment Associates
15 Piedmont Center, Suite 1250
Atlanta, GA 30305
404-261-9575

Scott Taylor
J. W. Jones Ecological Research Center
Route 2 Box 2324
Newton, GA 39870
229-734-4706

Larry Teeter
teeteld@auburn.edu
201 M. White Smith Hall
Auburn, AL 36830
334-844-1045

Micah Thorning
9912 Highway 28
Boyce, LA 71409
318-793-9427

Don Tomczak, Silviculturist
dtomczak@fs.fed.us
USDA Forest Service
1720 Peachtree Road NW, Room 816
Atlanta, GA 30309
404-347-7475

Diane Tyrone, Wildlife Biologist
P. O. Box 248
Wiggins, MS 39577
601-928-4422

R. E. Vann
123 Woodland Drive
Murphy, NC 28906
828-837-5152

Gregg Vickers, Forester
605 W. Main
Russellville, AR 72801
479-964-7241

Bennie Vinson, Chief Forester
Alabama Power Company
P. O. Box 2641
Birmingham, AL 35291
205-257-4622

Elizabeth Waldorf
2611 Parkview Drive
Biloxi, MS 39531
228-388-5591

Kathryn Wallace, District Silviculturist
USDA Forest Service
P. O. Box 278
Double Springs, AL 35553
205-489-5111

Keith Ward, Manager
F&W Forestry Services, Inc.
855 Pear Orchard, Suite 100
Ridgeland, MS 39157
601-991-2121

Clay Dobbs Ware, Forester
clay_ware@fws.gov
U. S. Fish and Wildlife Service
23734 Highway 1
McBee, SC 29101
843-335-6383

Sarah Watkins
Luce Packing Company
P. O. Box 8743
Moss Point, MS 39562
228-474-6383

David Watts
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

George Weick
gweick@fs.fed.us
USDA Forest Service
415 S. First Street, Suite 110
Lufkin, TX 75901
936-639-8572

Fred Wetzel
fred_wetzel@fws.gov
U. S. Fish and Wildlife Service
Route 2 Box 3330
Folkston, GA 31537
912-496-7366

Jerry Windham, Forest Silviculturist
jwindham@fs.fed.us
USDA Forest Service at
100 W. Capitol Street
Jackson, MS 39269
601-965-4391

Jack White
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Philip Wilson
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

Brent Womack
blwomack1@yahoo.com
2652 Marshall Fuller Road
Dallas, GA 30157
256-452-7002

Beth Wood
P. O. Drawer 1206
Orangeburg, SC 29116
803-534-6280

Lisa Yager, Project Coordinator
lyager@tnc.org
The Nature Conservancy Camp Shelby
CSTS- ENV Building 6678
Camp Shelby, MS 39407
601-558-2931

Diomides Zamora, Student
5988 Highway 90 Building 4900
Milton, FL 32583
850-983-5216 (116)