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Influence of row spacing and debris distribution on vegetation and small mammals in Louisiana pine plantations

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INFLUENCE OF ROW SPACING AND DEBRIS DISTRIBUTION ON VEGETATION AND SMALL MAMMALS IN LOUISIANA PINE PLANTATIONS

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ABSTRACT

Site preparation after clearcuts directly affects surrounding small mammal populations. Differences in bed row spacing and arrangement of debris can impact structure and composition of vegetation communities, which influence small mammal habitat. We surveyed vegetation and small mammals in 2 different row spacings (14 ft and 20 ft) and 2 different debris distributions (piled and scattered) in 4 clearcuts owned by Weyerhaeuser in Louisiana during 2006-2007. Our objectives were to examine effects of row spacing and debris distribution on vegetation, to look at responses of small mammal densities to row spacing and debris distribution, and to see how small mammals responded to resulting vegetation. Study areas included 2 clearcuts in north Louisiana and 2 in south Louisiana. All study areas were newly harvested loblolly pine (*Pinus taeda*) plantations. Sampling techniques in the field included vegetation surveys and live trapping of small mammals. General trends included the following: vegetation responses to treatments were overall uniform throughout treatments. In year 2, grass, forbs, and woody vegetation proliferated in both row spacings and debris arrangements. Vines grew in predominantly in 20 ft spacing. Small mammal responses to treatments depended on species examined. *Peromyscus* spp. favored all study areas irrespective of treatment. House mouse (*Mus musculus*) used mostly 14 ft spacings and the combination of 20 ft spacing with piled debris. Cotton rat used both spacings and preferred piled debris. Small mammals responded to changes in vegetation as succession progressed. Woody vegetation, grass, forbs, and vines were important predictors in habitat selection. Both row spacings and debris arrangements in this study benefited small mammals. Future research could examine later successional stages and how wildlife adapt to changing vegetation.

CHAPTER 1. INTRODUCTION

Introduction

<u>Overview</u>

Forestland in the southeastern United States exceeds 35 million ha. Of the 5.5 million ha owned by the forest industry, nearly half are in pine plantations (USDA Forest Service 2002). The predominant management technique used by southeastern forest industry is plantation silviculture (Gresham 2002). This artificial regeneration approach focuses on clearcut harvesting, intensive management, and short stand rotations. Since the goal of intensive management is to stimulate rapid dominance of the target species, a combination of mechanical and chemical site preparation methods are often used (Cain 1991, Miller 1980). A common strategy in the southeast is to rake debris into windrows and create raised beds for planting. This elevation above the watertable buffers the seedlings against the potential for poorly drained soils. Raised beds also allow seedlings a competitive edge for light, nutrients, and water from encroaching vegetation. Herbicides and fertilizers provide the seedlings with additional competitive advantage (Haywood 2005). While these site preparation methods are necessary for pine growth and vigor, care must be taken to minimize negative impacts on surrounding wildlife.

Because of the widespread adoption of the Sustainable Forestry Initiative by forest industry, forest managers are increasingly expected to manage for wildlife habitat and other issues relating to biodiversity (Sustainable Forestry Initiative Inc. 2005, Miller et al. 2004). One of these management goals is the minimization of deleterious effects to wildlife from chemical and mechanical site preparation. Mechanical techniques include shearing, raking, chopping, disking, bedding, and ripping, which can cause soil compaction from use of heavy equipment. Removal of cover vegetation and debris can strip the soil of valuable nutrients and moisture,

leaving sites vulnerable to erosion and loss of topsoils (USDA 1997). While chemical management methods may have some operational advantages over mechanical means, they tend to have greater potential for indirect effects on wildlife (George 1960, Sparling 1996). Herbicides that favor the establishment of forbs, soft mast, and invertebrate production can benefit small mammal communities (Cox 2000). Finally, in addition to site preparation, changing seral stages resulting from disturbance also affect small mammal habitat and resources.

Small mammals play a vital role in maintaining ecological diversity in forest systems, serving as primary prey to larger birds, reptiles, and mammals as well as aiding in seed dispersal (Perry and Thill 2005). They also consume some insect pests that can contribute to severe outbreaks in forest communities (Hanski 1987). Many small mammal species depend on early successional vegetation to provide valuable resources for food, shelter, nesting, and travel corridors. Increases in soft mast and insects from growth of vegetation following clearcuts result in greater numbers of small mammals throughout harvested stands (Perry and Thill 2005).

Forest Management Issues in Louisiana

In Louisiana, timber commodities are a leading contributor to the economy with >48% of its total land area dedicated to forestry. Softwood growth represents 63% of the annual yield in timber products (Vlosky and Chance 1995). Nearly half of all forested land in the United States is held by private landowners in the southeast. Almost one quarter of forested land is held by industry landowners (Kline et al. 2002).

Traditional forest management aims to maximize merchantable yield while demonstrating sensitivity to other forest values such as ecological conservation and environmental aesthetics (Zeide and Sharer 2000). Louisiana pine plantations have historically been planted on a rotation of 25–35 years using 4.3 m (14 ft) row spacing for planting. Seed

bedding and debris piling and burning have been used to facilitate drainage and decrease vegetation encroachment (Zeide and Sharer 2000).

Recent changes in forestry practices can be attributed to a number of factors. Available acreage for private industry landowners is increasing due to shifting land uses (Alig et al. 1986). Decreasing supply from western national forests has raised demand from the southeastern timber products industry (Kline et al. 2002). Acquisition of large amounts of forested land is increasingly considered advantageous by many industrial foresters.

The decrease in rotation periods also has affected traditional trends in forestry (Prisley and Malmquist 2002). Intensive management utilizes a wide range of practices to dramatically increase growth and yield in a short period of time. Rotation period decreases as yield increases. Most softwoods in Louisiana have been managed for secondary forest products, and are therefore grown on short rotations of <20 years (Zeide and Sharer 2000).

Weyerhaeuser Company is a leader in the forest products industry. Having operated in the state of Louisiana for the past 10 years, Weyerhaeuser manages over 15 million ha of forest land worldwide (Weyerhaeuser 2004). Along with forest management, their timberlands operations include seed orchards, nurseries and greenhouses, and forestry research. In the presence of evolving trends in the forest industry, Weyerhaeuser strives to better understand these changes and the implications to managing their harvesting operations. An adaptation under consideration is to manage their row spacing differently by increasing it from 4.3 m to 6.1 m (20 ft).

Wider row spacing has both economic and biological implications. Additional space for tree diameter growth can contribute to the overall improvement of individual trees and tree size classes. It also can improve overall timber quality, which can benefit future growth and yield

(Baldwin and Cao 1999). Secondarily, there is also the potential for benefits to wildlife populations from an increase in non-pine vegetation in the stand. Herbivorous rodents and soricid insectivores use early successional vegetation for cover, nesting, and food resources. (Humphrey et al. 1999). Small mammals also profit from the extended window of early successional growth due to delayed canopy closure. Certain species of state and federal concern benefit from extended windows of early succession. The northern bobwhite (*Colinus virginianus*), gopher tortoise (*Gopherus polyphemus*), and several early successional bird species depend on resources provided by this vegetation structure for their conservation. The gopher tortoise, listed as threatened at the federal and state levels, uses upland pine forests with well-drained sandy soils for burrowing as well as thick understory for food resources. Northern bobwhites are a species of national concern due to the continuing decline of their habitat from clean farming and dense planting in pine plantations (Dimmick et al. 2002).

Finally, a variety of research efforts have focused on the importance of varying levels of woody debris on small mammal communities in mature forests (Barnum et al. 1992, Osbourne and Anderson 2002), but relatively little research has examined relationships between woody debris and small mammal populations in recently harvested forests. Coarse woody debris is an important resource for many forest dwelling mammals (Harmon et al. 1986). Fallen logs and snags as well as debris from logging operations can be especially useful for travel, nesting, and predation cover in open canopy, shrubby landscapes (Zollner and Crane 2003). Bellows et al. (2001) found that small mammals prefer pine plantations with shrubs and downed woody debris to plantations with no understory and bare ground. Whereas most literature has focused on the volume of woody debris in relation to small mammals (Osbourne and Anderson 2002), more

research is necessary on how the arrangement of woody debris affects small mammal populations.

Objectives

The 2 main goals of this research were (1) to examine responses of vegetation growth in loblolly pine (*Pinus taeda*) plantations with 2 different row spacings and debris distributions and (2) to observe effects of the same treatment arrangements on small mammal densities. Specifically, we focused on:

1. Describing species composition and structural components of vegetation within treatments
2. Quantifying debris volume
3. Determining densities of small mammals within treatment areas
4. Relating mammal densities to vegetation species composition and structural components.

Study Area

The research was conducted twice annually during the growing seasons of 2006 and 2007 in two areas of north-central Louisiana (sites A and B) and two areas of southeast Louisiana (sites C and D) (Figure 1.1). The sites in north-central Louisiana were in Winn and Jackson parishes, approximately 27.4 km from Jonesboro ($32^0$2'N, $92^0$6'W). Mean annual rainfall was 127.0 cm, and mean annual temperature averaged 18.3^0C. Soil type was a fine sandy loam (Soil Survey Staff 2004). Elevation ranged from 46–183 m above sea level (Cole 2006). Southeast Louisiana sites were in Tangipahoa and Washington parishes, approximately 41.8 km from Franklinton ($30^0$8'N, $90^0$1'W). Mean annual rainfall was 147.3 cm, and mean annual temperature averaged 18.9^0C. Soil type was a very fine sandy loam (Soil Survey Staff 2004). Elevation ranged from 0–91 m above sea level (Cole 2006). All sites are owned by Weyerhaeuser and

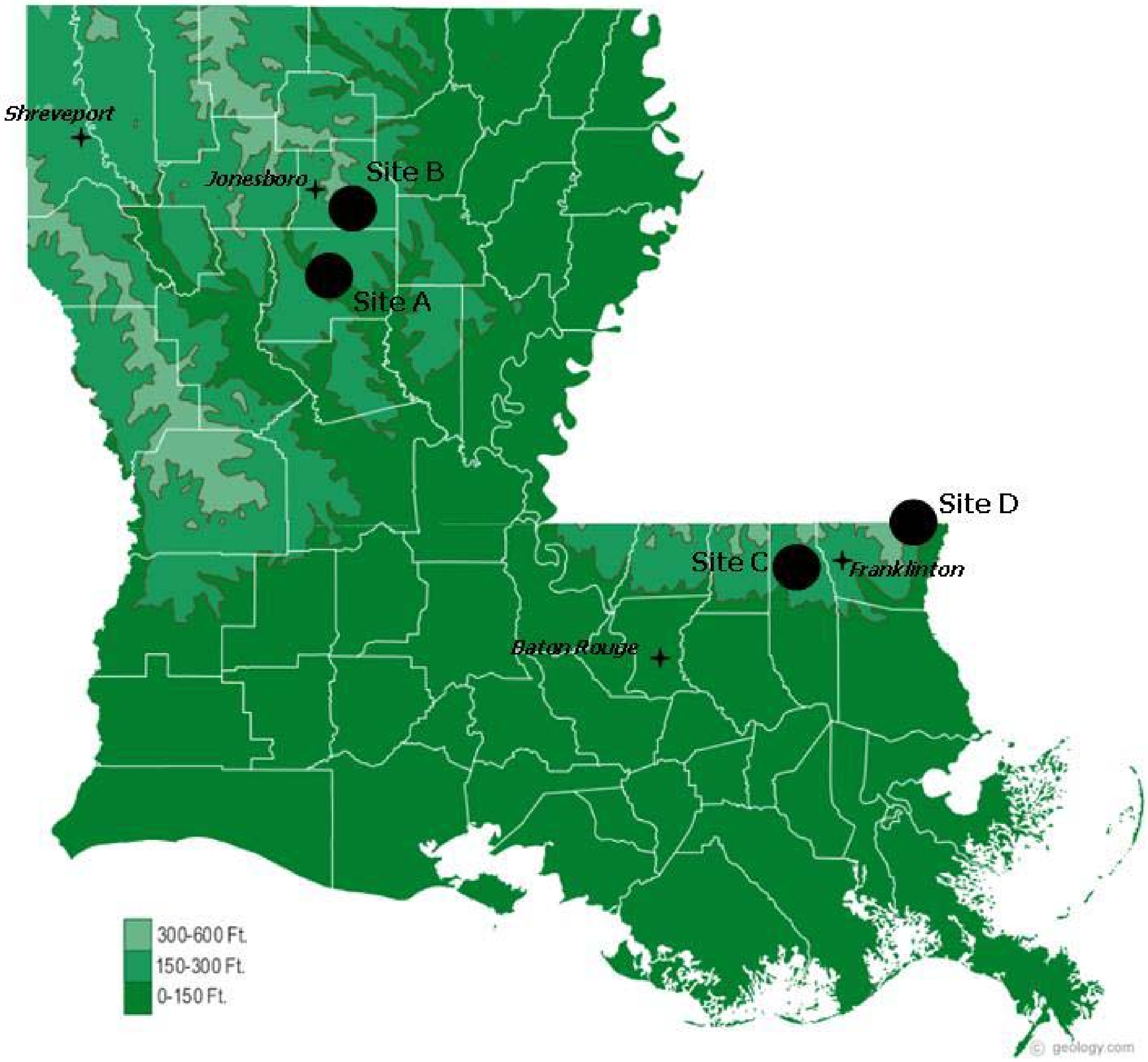


Figure 1.1. Map of study sites in north and south Louisiana, 2006-2007.

Company and are intensively managed loblolly pine plantations. Timber commodities produced include wood fiber and saw timber. All stands were >20 years old prior to clearcutting in spring/summer of 2005. Sites were fertilized with diammonium phosphate and urea after shearing. Following planting, herbicides triclopyr (Garlon^{TM}) and imazapyr (Arsenal^{TM}) were applied. Further herbicide treatments will occur after 6 years and again after 12 years at first thinning. Study design was a randomized complete block design. We blocked on site, and all treatments occurred on each site. Four plots (experimental units) of 10.1 ha were selected within each study site, which was approximately 60.7 ha in size, each with similar site preparation. Within each site, 2 randomly assigned row-spacing treatments of 20.2 ha each were established, including a 4.3 m (14 ft) and 6.1 m (20 ft) spacing. Spacing of trees within rows was held constant. Additionally, each 20.2 ha block was divided into half, and each half received a different treatment specific to the distribution of logging debris after harvesting. One treatment consisted of logging debris being piled into windrows, which involved five large piles of debris isolated to a few locales within each stand. The other treatment consisted of logging debris being distributed (scattered) throughout the stand following harvest, primarily through the laying of debris between rows of seedlings. The resulting configuration of the 4, 10.1 ha experimental units within each site resembled combinations of each row spacing and debris arrangement (Figure 1.2).

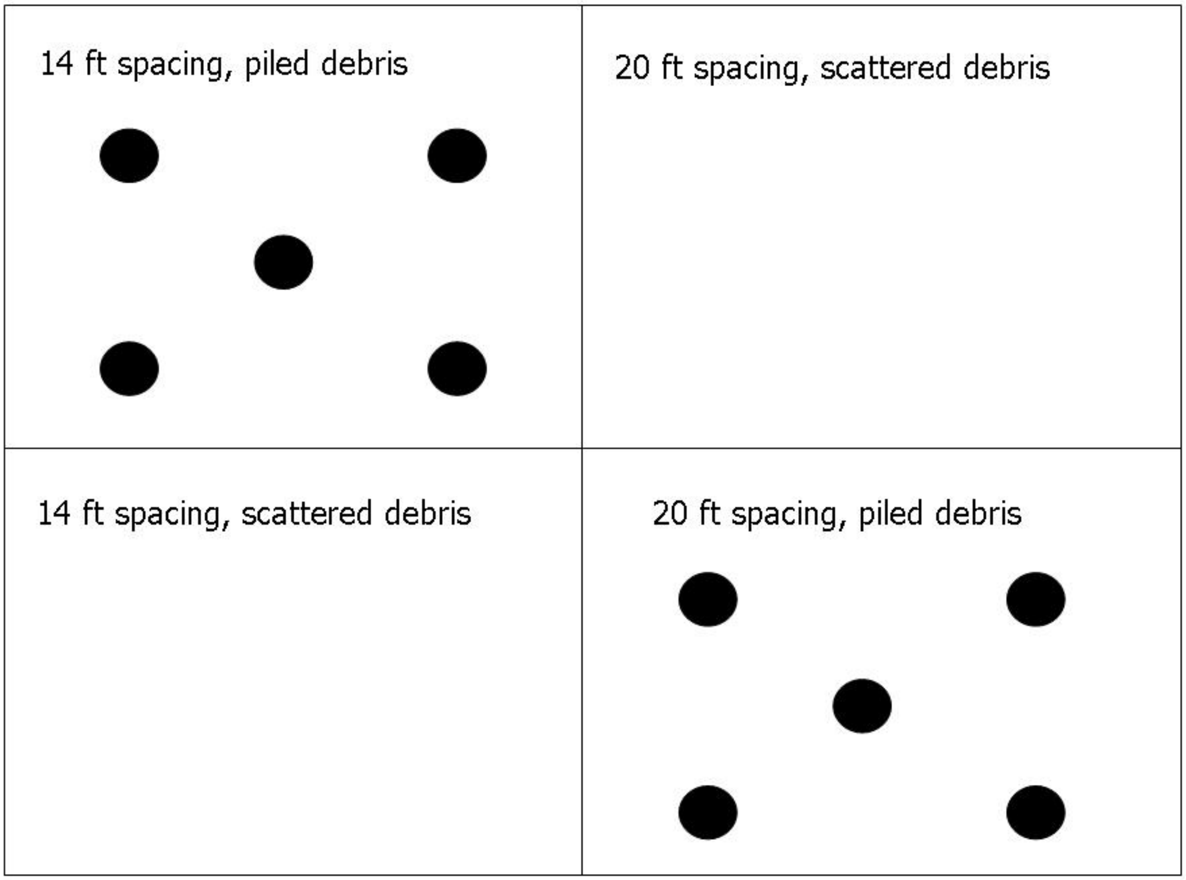


Figure 1.2. Schematic of configuration of experimental units within each study site.

CHAPTER 2. EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON VEGETATION COMPOSITION

Introduction

Site preparation affects vegetation structure and composition (Haeussler et al. 1999, Archibold et al. 2000, Pelzer et al. 2000, Bock and Van Rees 2002). The objectives of site preparation are to reduce competing vegetation, address logging debris, improve soil conditions, and facilitate planting (Shiver and Martin 2002). Benefits to fiber production after mechanical site preparation include improved tree growth by increased availability of water and nutrient resources through greater quantity and quality of soil volume available to tree roots (Allen and Lein 1998). Site preparation treatments benefit plant species diversity by establishing well-adapted pioneer vegetation on the forest floor (Newmaster et al. 2007). As the stand ages, plant diversity and abundance increases (Hartley 2002). In addition to site preparation, changing seral stages resulting from row spacing and debris distribution also affect plant community composition and structure.

Wider row spacing has both economic and biological implications. Additional space for tree diameter growth can contribute to the overall improvement of individual trees and tree size classes. It also can improve overall timber quality, which can benefit future growth and yield (Baldwin and Cao 1999). Secondarily, increased exposure to sunlight and better hydrology can enhance establishment of sensitive vegetation communities as well as pioneer species (Osbourne and Anderson 2002). Plant species that are removed during site preparation can persist in logging debris and serve as important sources of propagules for recolonization. Harvesting, disturbance intensity, soil compaction, and downed woody debris are strong predictors of developing understory (Newmaster et al. 2007).

As pine plantation area increases in the southeast (Trani et al. 2001), it is important to understand how stand initiation techniques affect vegetation communities. Previous studies have focused on varying levels of woody debris in mature forests as well as spacing issues independent of debris arrangement. This research examines responses of vegetation to combinations of 2 different row spacings and debris distributions in 1-2 year-old pine plantations in Louisiana.

Methods

Study Area

The study occurred during 2006 and 2007 on 4 sites. Vegetation sampling was conducted annually during the growing seasons of 2006 and 2007 in 2 areas of north-central Louisiana (sites A and B) and 2 areas of southeast Louisiana (sites C and D) (see Figure 1.1, Chapter 1). The sites in north-central Louisiana were in Winn and Jackson parishes, approximately 27.4 km from Jonesboro ($32^0$2'N, $92^0$6'W). Mean annual rainfall was 127.0 cm, and mean annual temperature averaged 18.3^{0}C. Soil type was a fine sandy loam (Soil Survey Staff 2004). Elevation ranged from 46–183 m above sea level (Cole 2006). Southeast Louisiana sites were in Tangipahoa and Washington parishes, approximately 41.8 km from Franklinton ($30^0$8'N, $90^0$1'W). Mean annual rainfall was 147.3 cm, and mean annual temperature averaged 18.9^{0}C. Soil type was a very fine sandy loam (Soil Survey Staff 2004). Elevation ranged from 0–91 m above sea level (Cole 2006). All sites are owned by Weyerhaeuser Company and are intensively managed loblolly pine plantations. Timber commodities produced include wood fiber and saw timber. All stands were >20 years old prior to clearcutting in spring/summer of 2005. Sites were fertilized with diammonium phosphate and urea after shearing. Following planting, herbicides triclopyr (Garlon^{TM}) and imazapyr (Arsenal^{TM}) were applied.

The experiment was established using a randomized complete block design. We blocked on site, and all treatments occurred on each site. Four plots (experimental units) of 10.1 ha were selected within each study site, which was approximately 60.7 ha in size, each with similar site preparation. Within each site, 2 randomly assigned row-spacing treatments of 20.2 ha each were established, including a 4.3 m (14 ft) and 6.1 m (20 ft) spacing. Spacing of trees within rows was held constant. Additionally, each 20.2 ha block was divided into half, and each half received a different treatment specific to the distribution of logging debris after harvesting. One treatment consisted of logging debris being piled into windrows, which involved 5 large piles of debris isolated to a few locales within each stand. The other treatment consisted of logging debris being distributed (scattered) throughout the stand following harvest, primarily through the laying of debris between rows of seedlings. Configuration of the 4, 10.1 ha experimental units within each site is detailed in Figure 1.2, Chapter 1.

Sampling Techniques

Vegetation data were collected in conjunction with those of Taylor (2008) and were used for independent analyses. Within each 10.1 ha experimental unit, 5, 0.04 ha (0.1 acre) circular plots were systematically established diagonally across the stand to account for potential differences in aspect, slope, and microclimate. Within each circular plot, we measured vegetation composition, vertical obstruction, average vegetation height (m), maximum vegetation height (m), and litter depth (cm) at plot center and 10 m in each cardinal direction. We measured vegetation composition with a 1 m^2 Daubenmire frame to determine percentage coverage of grass, forbs, woody, vine, debris, bare ground, and fern (Daubenmire 1959). We measured vegetation height with a 1.0 m Robel pole (Robel et al. 1970) to determine vertical obstruction and average and maximum vegetation heights (Jones and Chamberlain 2004). We used a 0.5 m

pole with 0.1 cm increments to measure litter and debris depth. We determined an absolute count of number of stems <10 cm diameter within each plot to determine stem density of pines and hardwoods, primarily to quantify potential mid- and overstory species. We used the line intercept method (Canfield 1941) on a 10 m diagonal north to south through plot center to determine plant species diversity and provide a measure of floristics 0.5 m above ground. Plants were identified to genus and to species when possible following Miller and Miller (1999) and USDA (2008) (Appendix 2.1).

To quantify coarse woody debris in treatments with scattered debris arrangement, all individual pieces of large woody debris were measured. Length (L) and diameter (d) of debris (≥10.2 cm diameter) at center of piece were measured using a distance tape and caliper, respectively. All debris within each plot was measured once during winter sampling at the initiation of the study. Volume of debris was calculated using the formula for cylindrical volume, $V = \sum (\pi \frac{1}{2} d^2 L)$.

Debris in treatments with piled debris arrangement was measured by calculating volume for entire debris accumulations irrespective of size of individual pieces (Hardy 1996). Five piles in each 10.1-ha experimental unit with piled debris were measured once during winter sampling at the initiation of the study. Since piles were a combination of air and wood, it was necessary to establish net volume of debris within the pile. We assigned a simple geometric form to the piles, then calculated gross volume and net volume (Thevenet et al 1998, Hardy 1996). We measured length (L), width (w), and height (h) of the pile and used the formula for volume of a half-ellipsoid shape to calculate gross volume, $V = (\pi w L h) / 6$. Net volume involved multiplying gross volume by an appropriate packing ratio to account for air space (packing) within the pile. Packing ratio is a measure of debris to the space within the shape of the pile (Hardy 1996). Low

ratios indicate sparse debris in loosely packed piles. High ratios indicate compact debris in densely packed piles. Volume of debris across each site was obtained by calculating the sum of the volumes in each experimental unit (Loeb 1999, Osbourne and Anderson 2002).

Data Analysis

We characterized vegetation attributes by averaging across measurements taken from the 5 0.04 ha vegetation sampling plots in each experimental unit. These data were useful in detecting possible relationships among vegetation characteristics with sites and treatments. Additionally, they aided in detecting temporal trends in vegetation over the 2 years of the study.

Because vegetation data were highly correlated, a principal component analysis (PCA) was used to restructure the data and describe habitat variables more appropriately (PROC FACTOR; SAS Institute 2003). Highly correlated variables often lead to collinearity or singularity problems in subsequent analyses (Littell et al. 1996). Principal component analysis reorganizes the variables into combinations that do not suffer these problems (Johnson and Wichern 2001). We used VARIMAX rotation in all PCAs after principal component construction had begun. To reduce the number of variables, we used scree plots and determined the number of principal components to retain (Jackson 1993), which were 4 and 5 in years 2006 and 2007 respectively.

The analysis was conducted using an information-theoretic approach of model selection and multi-model inference (Burnham and Anderson 2002). We used Akaike's Information Criterion (AIC; Akaike 1973) and the small sample correction (AIC_c; Hurvich and Tsai 1989) as a basis for model selection. Model averages were based on Akaike weights, which determine model fitness. Each phase of the analysis involved *a priori* models, which were used to minimize spurious effects and aid in more reliable predictions.

Because of ecoregional effects and inherent differences in vegetation among sites and between years, we blocked the design on site and arranged our models separately by year. We were uninterested in year-to-year variation, which we believed would overshadow treatment effects. We developed *a priori* candidate models to describe vegetation responses to treatment effects (Table 2.1). Effects modeled included the reduced set of principal components for both years (Table 2.2).

A generalized linear mixed effects model was used to separately examine each component. We used a mixed effects model (PROC MIXED; SAS Institute 2003) to test fixed effects and determine possible treatment effects on vegetation components. When a statistical difference was detected, least squares means were used to evaluate the magnitude of the difference. The test of random effects assessed responses of sites to vegetation components. Following Lukacs et al. (2007), components were tested both with and without fixed treatment effects one at a time because vegetation components could not be assessed together given the low degrees of freedom.

Results

Year 2006

Based on eigenvalues ≥ 1, 4 principal components were retained for the 2006 vegetation data set, accounting for 82% of the variance (Tables 2.3, 2.2). These components were used to develop a list of candidate models to describe vegetation responses to fixed treatment effects and random site effects (Table 2.1). Vegetation was similar across sites and treatments during the first growing season (Tables 2.4, 2.5) (Figure 2.1). Our examination of least squares means supported no differences among treatments. Volume of woody debris in the scattered debris areas was low at all sites (mean = 3.09 m^3 ha^{-1}, SD = 1.25). We found greater amounts of debris

Table 2.1. List of candidate models to describe vegetation responses to fixed treatment effects and random site effects in north and south Louisiana, 2006-2007.

Year	Model	Year	Model
2006[a]	PC1 {treatment + *site*[b]}	2007[c]	PC1 {treatment + *site*}
	PC1 {*site*}		PC1 {*site*}
	PC2 {treatment + *site*}		PC2 {treatment + *site*}
	PC2 {*site*}		PC2 {*site*}
	PC3 {treatment + *site*}		PC3 {treatment + *site*}
	PC3 {*site*}		PC3 {*site*}
	PC4 {treatment + *site*}		PC4 {treatment + *site*}
	PC4 {*site*}		PC4 {*site*}
			PC5 {treatment + *site*}
			PC5 {*site*}

[a]2006 components: PC1 = grass and bare ground, PC2 = forbs, PC3 = woody, PC4 = yaupon.
[b]Italicized type indicates the random variable.
[c]2007 components: PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

Table 2.2. Principal components (PC, eigenvalues >1) derived from vegetation variables associated with sites in north and south Louisiana, 2006-2007. Associated variables are those with a correlation coefficient of >0.5 with each respective PC.

Year	PC	Associated Variables	Interpretation
2006	PC1	(+) Grass, vertical height, litter depth, vines (-) Bare ground, vines	Grass and bare ground
	PC2	(+) Forbs, vertical height, woody stems (-) Vines, grass	Forbs
	PC3	(+) Woody, woody stems	Woody
	PC4	(+) Yaupon (-) Slope gradient	Yaupon
2007	PC1	(+) Woody, fern, vertical height, woody stems (-) Bare ground	Woody
	PC2	(+) Forbs (-) Litter depth, woody	Forbs
	PC3	(+) Grass, vines (-) Bare ground	Vines
	PC4	(+) Grass, vines	Grass
	PC5	(+) Yaupon	Yaupon

Table 2.3. Summary of principal components analysis of 15 vegetation variables in north and south Louisiana, 2006.

	Component			
Variables	1	2	3	4
Eigenvalue	5.5	3.6	2.1	1.2
Variance explained	0.36	0.24	0.14	0.08
Slope gradient ≥20%	-46	0	-6	**-63**[a]
Percent cover bare ground	**-93**	22	-10	11
Percent cover grass	**99**	6	2	9
Percent cover forbs	-25	**91**	-7	-8
Percent cover woody	-25	16	**87**	-11
Percent cover vines	**-56**	**-69**	-4	-25
Percent cover fern	-11	-12	-8	-11
Percent cover yaupon	-25	3	-24	**84**
Vertical height >0.5 m	**67**	**65**	15	-5
Litter depth >3 cm	**97**	2	-12	1
Woody stems >5	-1	**52**	**76**	4
Line intercepts proportion of grass	-47	**-76**	-25	-24
Line intercepts proportion of forbs	-23	**92**	2	-5
Line intercepts proportion of woody	18	-32	**78**	-15
Line intercepts proportion of vines	**98**	-2	-13	0

[a]Bold type indicates variables included in that component

Table 2.4. Model selection results[a] from generalized linear model of treatment effects[b] and sites on vegetation principal components in north and south Louisiana, 2006-2007.

	2006[c]				2007[d]			
Model	AIC_c	ΔAIC_c	w_i	K	AIC_c	ΔAIC_c	w_i	K
PC1 {treatment + site}	24.60	6.10	0.05	7	45.70	14.40	0.00	8
PC1 {site}[e]	**18.50**	**0.00**	**0.95**	**6**	49.70	18.40	0.00	7
PC2 {treatment + site}	40.30	21.80	0.00	7	**31.30**	**0.00**	**0.97**	**8**
PC2 {site}	42.50	24.00	0.00	6	38.70	7.40	0.02	7
PC3 {treatment + site}	41.60	23.10	0.00	7	42.50	11.20	0.00	8
PC3 {site}	43.80	25.30	0.00	6	44.40	13.10	0.00	7
PC4 {treatment + site}	42.60	24.10	0.00	7	43.40	12.10	0.00	8
PC4 {site}	46.80	28.30	0.00	6	49.90	18.60	0.00	7
PC5 {treatment + site}					47.10	15.80	0.00	8
PC5 {site}					50.90	19.60	0.00	7

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥1% of the w_i.

[b]Treatment effects were row spacings, debris arrangements, and interactions of row spacing and debris arrangements.

[c]2006 components: PC1 = grass and bare ground, PC2 = forbs, PC3 = woody, PC4 = yaupon.

[d]2007 components: PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

[e]Bold type indicates top-ranked models for 2006 and 2007.

Table 2.5. Mean[a] and standard error (SE) for raw data of vegetation treatment[b] means across sites in north and south Louisiana, 2006-2007.

	2006 Treatments				2007 Treatments			
	14P	14S	20P	20S	14P	14S	20P	20S
Vegetation Characteristic	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Slope (%)	11.50 (1.50)	14.00 (2.45)	10.67 (0.67)	14.00 (2.45)	11.50 (1.50)	14.00 (2.45)	14.40 (2.32)	14.00 (2.45)
Daubenmire frame (% cover)								
Bare ground	39.46 (14.14)	27.58 (10.74)	23.88 (11.81)	29.05 (9.04)	13.24 (5.37)	18.45 (5.79)	24.87 (6.89)	13.79 (4.68)
Debris	7.77 (3.53)	17.82 (8.58)	8.36 (4.68)	20.55 (7.01)	2.88 (1.88)	3.32 (2.20)	6.59 (3.94)	4.85 (2.37)
Grass	31.66 (21.16)	38.90 (18.99)	36.83 (20.78)	31.72 (16.01)	30.80 (15.55)	26.80 (7.27)	17.14 (3.83)	25.93 (12.02)
Forbs	11.35 (6.23)	6.56 (2.79)	6.35 (2.62)	12.78 (5.15)	13.49 (5.77)	11.92 (2.71)	14.05 (2.50)	13.38 (4.19)
Woody	4.46 (1.74)	2.96 (2.31)	3.75 (1.85)	5.35 (2.46)	5.55 (0.99)	6.40 (2.44)	9.14 (5.17)	11.25 (5.49)
Vines	6.64 (3.27)	3.75 (1.34)	7.48 (6.37)	3.67 (1.58)	3.27 (1.22)	3.04 (1.97)	1.09 (0.39)	3.09 (1.14)
Fern	0.03 (0.03)	0.95 (0.83)	0.04 (0.04)	0.16 (0.16)	0.03 (0.03)	0.19 (0.15)	0.05 (0.05)	0.35 (0.35)
Yaupon	0.00 (0.00)	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.06 (0.03)	0.18 (0.15)	0.09 (0.09)
Vertical height (m)	0.43 (0.13)	0.36 (0.08)	0.40 (0.16)	0.49 (0.11)	0.50 (0.10)	0.56 (0.09)	0.51 (0.11)	0.70 (0.12)
Litter depth (cm)	3.41 (3.13)	3.47 (2.65)	3.32 (2.74)	3.38 (2.14)	3.27 (3.18)	3.34 (2.70)	1.86 (1.49)	1.02 (0.73)
Woody stem count								
Pines <10 cm	0.10 (0.06)	2.50 (2.30)	0.00 (0.00)	2.10 (2.03)	0.00 (0.00)	0.05 (0.05)	0.00 (0.00)	0.20 (0.20)
Pines 10 cm–1.4 m tall	5.05 (2.56)	4.85 (2.05)	1.80 (1.80)	3.65 (2.11)	8.15 (0.49)	7.65 (1.03)	5.48 (0.20)	7.15 (0.17)
Pines >1.4 m tall	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.05 (0.05)	0.00 (0.00)	0.00 (0.00)
Hardwoods <10 cm	0.65 (0.38)	1.25 (0.73)	0.60 (0.60)	0.45 (0.29)	0.05 (0.05)	0.10 (0.10)	1.12 (0.71)	0.20 (0.12)
Hardwoods 10 cm–1.4 m tall	7.45 (2.63)	7.65 (6.26)	8.33 (4.26)	6.75 (4.53)	4.95 (2.25)	7.65 (3.47)	8.68 (1.84)	10.05 (4.90)
Hardwoods <10 cm	0.15 (0.10)	0.25 (0.13)	1.33 (1.23)	1.45 (1.25)	0.25 (0.15)	1.10 (0.72)	0.96 (0.68)	1.25 (0.60)

[a]Mean was obtained across vegetation sampling plots (n = 5) in experimental units (n = 4) within each site (n = 4).

[b]14P = 14 ft spacing with piled debris, 14S = 14 ft spacing with scattered debris, 20P = 20 ft spacing with piled debris, 20S = 20 ft spacing with scattered debris.

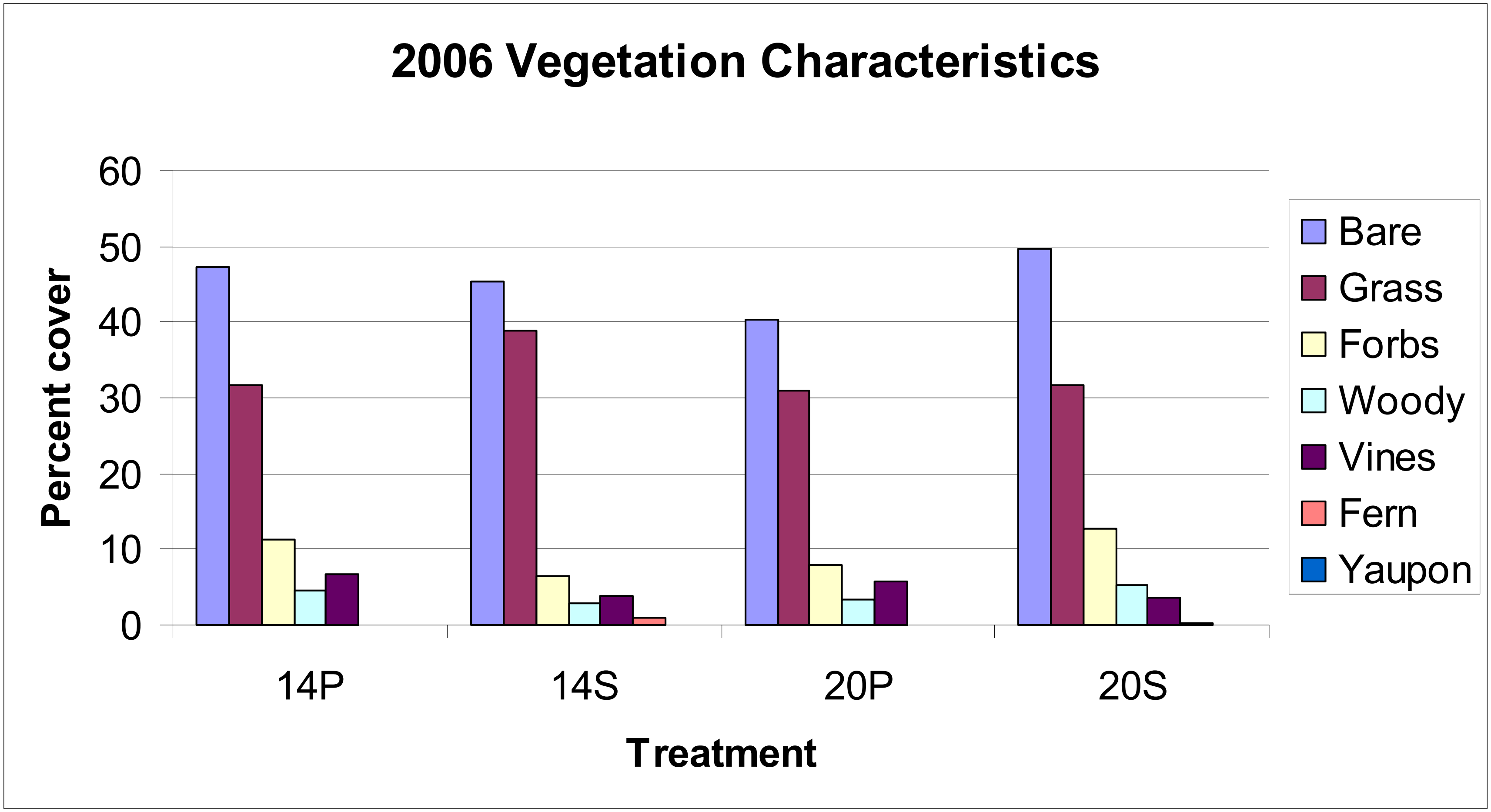


Figure 2.1. Vegetation characteristics based on ground cover variables used in principal components analysis for north and south Louisiana, 2006.

in experimental units with piled debris than in areas with scattered debris (mean = 113.37 m^3 ha^{-1}, SD = 61.64). Differences observed are not biologically relevant and are simply an artifact of how the calculations were done (Table 2.6).

Year 2007

Based on eigenvalues ≥1, 5 principal components were retained for the 2007 vegetation data set, accounting for 84% of the variance (Tables 2.7, 2.2). These components were used to construct a set of *a priori* candidate models to describe vegetation responses to fixed treatment effects and random site effects (Table 2.1). Abundance of forbs differed across treatments during year 2 (Table 2.4). We found greater amounts of forbs in sites with 20 ft spacing ($t_{\alpha,0.05}$ = 2.46, *d.f.* = 9, *P* = 0.036) and in treatments with scattered debris ($t_{\alpha,0.05}$ = 2.67, *d.f.* = 9, *P* = 0.026) (Table 2.8). Similar to year 1, vegetation structure was similar across sites (Table 2.5) (Figure 2.2).

Discussion

In year one, we found grasses and bare ground dominating all treatments. This is likely due to site preparation influences during the first growing season following treatment. Silvicultural treatments involving soil disturbance often result in higher cover of grasses (Peltzer et al. 2000). After soil disturbance and mechanical site preparation, seed banks are stimulated and vegetation reproduction is enhanced (Newmaster et al. 2007). Common grasses we encountered were bluestem grasses (*Andropogon* spp.), rosette grasses (*Dicanthelium* spp.), and paspalum grasses (*Paspalum* spp.). Bluestem grasses are one of the most common first invaders of new forest plantations and occur in open areas and edges. Bluestem usually increases after herbicide use (Miller and Miller 1999). The high growth rate and dense root system of bluestem grasses serve as competitive advantages for water, nutrients, and soil space (Balandier et al.

Table 2.6. Pile sizes (m) and packing ratios of 2 experimental units on each site with piled debris in north and south Louisiana, 2006.

Site	Pile *length* × *width* × *height* (m)					
	1	2	3	4	5	Packing ratio (%)[a]
A	58 × 24 × 4	23 × 20 × 5	28 × 25 × 4	20 × 19 × 3	23 × 21 × 4	15
	31 × 23 × 4	23 × 17 × 3	14 × 13 × 3	29 × 21 × 4	31 × 28 × 5	15
B	14 × 13 × 3	31 × 17 × 4	31 × 26 × 3	49 × 23 × 4	18 × 18 × 3	10
	39 × 19 × 5	31 × 19 × 4	21 × 18 × 4	22 × 18 × 3	46 × 19 × 4	15
C	16 × 18 × 3	14 × 10 × 3	15 × 14 × 2	11 × 15 × 4	23 × 18 × 4	10
	15 × 19 × 4	21 × 17 × 3	12 × 16 × 4	14 × 22 × 4	18 × 25 × 3	15
D	12 × 10 × 2	12 × 14 × 3	13 × 14 × 5	11 × 11 × 3	18 × 11 × 3	25
	16 × 10 × 4	12 × 12 × 5	10 × 8 × 2	9 × 9 × 2	12 × 13 × 3	25

[a]10% = loosely packed piles containing ≤25% fine debris, 15% = moderately packed piles containing approximately 50% fine debris, 25% = highly compact piles containing ≥80% fine debris.

Table 2.7. Summary of principal components analysis of 15 vegetation variables in north and south Louisiana, 2007.

Variables	Component 1	2	3	4	5
Eigenvalue	4.3	3.9	1.8	1.4	1.2
Variance explained	0.29	0.26	0.12	0.09	0.08
Slope gradient ≥20%	-25	41	-43	22	-45
Percent cover bare ground	**-55**[a]	-2	**-65**	-38	-13
Percent cover grass	-6	-38	**87**	-9	-14
Percent cover forbs	25	**75**	-9	39	19
Percent cover woody	**93**	-17	-6	1	-11
Percent cover vines	31	30	-9	**76**	-21
Percent cover fern	**73**	16	-13	-5	28
Percent cover yaupon	-5	6	10	-2	**80**
Vertical height >0.5 m	**68**	42	29	6	-42
Litter depth >3 cm	4	**-62**	49	-35	-34
Woody stems >5	**87**	-1	2	22	-2
Line intercepts proportion of grass	-4	2	3	**95**	3
Line intercepts proportion of forbs	-6	**92**	-16	-5	-20
Line intercepts proportion of woody	**65**	**-61**	34	-3	-23
Line intercepts proportion of vines	-10	-6	**91**	0	24

[a]Bold type indicates variables included in that component

Table 2.8. Least squares means (LSMeans) supporting differences among treatments in north and south Louisiana, 2006-2007.

Effect	Estimated Difference in LSMeans	Standard Error	DF	*t* Value	*P* value
Spacing: 14 ft versus 20 ft	-0.4536	0.1843	9	2.46	0.036
Debris: piled versus scattered	-0.4913	0.1843	9	2.67	0.026

Significance was set at P ≤ 0.05.

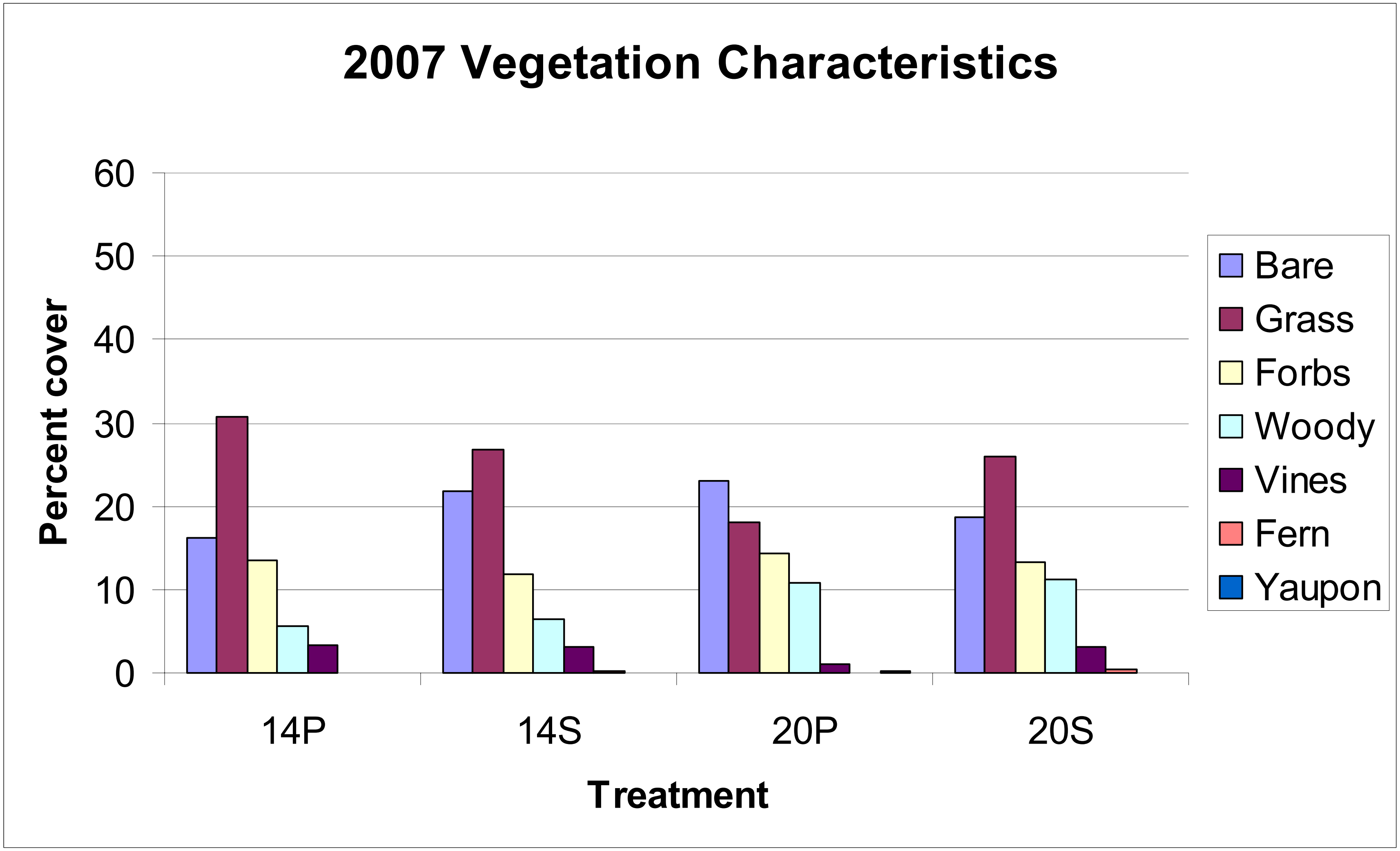


Figure 2.2. Vegetation characteristics based on ground cover variables used in principal components analysis for north and south Louisiana, 2007.

2006). Proliferation of these grass species over time may have negative effects on pine growth and vigor. By year 2, grasses had declined extensively in all treatments, likely because of herbaceous control and succession to other vegetation species.

We encountered mostly pioneer species that commonly appear in the first few years following silvicultural disturbance. Newmaster et al. (2007) classified herbaceous species that persist following site preparation treatments to be shade intolerant, more deeply rooted, and to have more aggressive reproductive systems. Early herbaceous colonizers also are better adapted to rapidly establish in newly disturbed sites. The proliferation of forbs in year one may be due to increased sunlight to the wider spacing, allowing species to more readily compete for nutrients, water, and space. By year 2, woody vegetation in treatments with 20 ft spacing had increased dramatically. Site preparation influences abundance of woody plants through soil disturbance and stimulation of seed banks (Balandier et al. 2006). Non-crop trees and other woody vegetation can monopolize resources at the expense of crop trees, compromising the growth and survival of target species. Newmaster et al. (2007) found that richness and abundance of woody vegetation are strongly related to the intensity of site preparation and only increase with time and disturbance. Intensive site preparation treatments used in pine plantations can stimulate certain shade intolerant, early successional woody species. Exposed mineral soils, strong nearby seed source in surrounding forests, disturbance of the seed soil bank, and higher light levels at our sites may have contributed to the increase in woody vegetation in the 20 ft spacing in the second year.

Qualitatively, treatments with scattered debris had more woody vegetation in both years. Blackberries (*Rubus* spp.) are common associates of forest plantations (Cain and Shelton 2003). Because of long-term seed storage in the soil seed bank and the ability to quickly dominate

disturbed sites, blackberries are competitors to pine seedlings during regeneration. We found several species of potential overstory species in our treatments with scattered debris. These included red maple (*Acer rubrum*), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), cherries (*Prunus* spp.), and oaks (*Quercus* spp.). These non-crop overstory trees can overtop target tree species and establish co-dominance in the final stand (Balandier et al. 2006). Both woody vegetation and herbaceous forbs increased in treatments with scattered debris in year 2. Newmaster et al. (2007) found abundance and richness of woody and herbaceous plants to be directly related to displacement of downed woody debris. The forest floor can affect regeneration of crop trees and surrounding vegetation by retaining woody debris and conserving nutrient reserves in the soil (Hartley 2002). Leaving downed woody debris also can conserve nutrients by avoiding soil scarification (Hautala et al. 2004). Improved site productivity because of retention of debris throughout treatments with scattered debris arrangements could have stimulated abundance of woody vegetation and herbaceous forbs in year two.

Vines were predominant in treatments with piled debris arrangements in year one, although differences among treatments were not statistically significant. Newmaster et al. (2007) suggested that displacement of downed woody debris is the leading cause of changes in species richness and abundance. Removal of existing vegetation, soil seed bank, and downed woody debris creates an exposed mineral soil seedbed and results in plant communities characterized by invasive, early successional species (Bock and Van Rees 2002). The most abundant vine we encountered was morningglory (*Ipomoea* spp.), some of which are exotic and invasive. Soil scarification through debris piling may account for vines persisting in treatments with piled debris arrangements in the first year.

Our measurements for volumes of piled debris were disproportionately higher than measurements for scattered debris because of differences in calculation methods. We calculated pile volume by considering the entire accumulation of debris in each pile. Slash piles may contain up to 10 times more soil than woody material by mass (Morris et al. 1983). Manning and Edge (2008) found volumes ranging from 61–287 m^3 ha^{-1} in piles, which were comparable to ours. In treatments with scattered debris arrangements, we totaled the volumes of single pieces of coarse woody debris. Our volumes for scattered debris treatments were comparable to those Siitonen (2001) found in intensively managed forests (2–5 m^3 ha^{-1}).

Management Implications

Mechanical site preparation affects resulting vegetation composition and structure. Early successional vegetation can be managed through intensive forest management. Our research demonstrates that wider row spacing may stimulate growth of herbaceous forbs initially. However, soil disturbance may promote woody encroachment in the future. We found that areas where downed woody debris was retained were more productive than those where the soil is scarified and debris is piled. We suggest that forest managers consider using wider row spacing combined with woody vegetation control if woody encroachment is a concern. We further suggest retaining downed woody debris to preserve soil nutrients and stimulate quality microsites for soil seed banks.

CHAPTER 3. EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON SMALL MAMMAL DENSITIES

Introduction

Vegetation communities resulting from managed regeneration sites have direct impacts on densities of small mammals. Although pine growth has been shown to be positively affected by chemical and mechanical control of herbaceous and woody competition (Cain 1991, Knowe et al. 1992, Lauer et al. 1993, Miller et al. 1991, Schabenberger and Zedaker 1999, Lauer and Zutter 2001), indirect effects to surrounding floristics can negatively affect small mammal habitat. A growing management goal of the forest industry is to minimize deleterious effects to wildlife from chemical and mechanical site preparation (Miller et al. 2004). In addition to site preparation, changing seral stages resulting from row spacing and debris distribution also affect small mammal habitat and resources.

Wider row spacing has both economic and biological implications. Additional space for tree diameter growth can contribute to the overall improvement of individual trees and tree size classes. It also can improve overall timber quality, which can benefit future growth and yield (Baldwin and Cao 1999). Secondarily, there is also the potential for benefits to wildlife populations from an increase in non-pine vegetation. Herbivorous rodents and soricid insectivores use early successional vegetation for cover, nesting, and food resources. (Humphrey et al. 1999).

Coarse woody debris also is an important resource for many forest dwelling mammals (Harmon et al. 1986). Fallen logs and snags as well as debris from logging operations can be especially useful for travel, nesting, and predation cover in open canopy, shrubby landscapes (Zollner and Crane 2003). Bellows et al. (2001) found that small mammals prefer pine

plantations with shrubs and downed woody debris to plantations with no understory and bare ground.

Small mammals respond directly to effects of site preparation, bed spacing, and debris distribution following clearcutting. Previous studies have focused on varying levels of woody debris in mature forests as well as spacing issues independent of debris arrangement. Our research examined responses of small mammal densities to combinations of 2 different row spacings and debris distributions in newly-established loblolly pine (*Pinus taeda*) plantations in Louisiana.

Methods

Sampling Techniques

We conducted live trapping of small mammals twice annually during winter (January–February) and summer (June–July) 2006 and 2007 in 2 areas of north-central Louisiana (sites A and B) and 2 areas of southeast Louisiana (sites C and D) (see Figure 1.1, Chapter 1). All sampling protocols were approved by the Louisiana State University Agricultural Center Institutional Animal Care and Use Committee (Protocol Number A-03-04). Small mammals were captured using Sherman live-traps for 7 consecutive days during winter and summer. Within each experimental unit, 25 traps were distributed systematically within a 60 × 60 m grid, with 15 m between each trap. Traps were baited with a combination of peanut butter and oats. Cotton microfilament was added to assist in thermoregulation, and traps were covered with 22 × 28 cm cardboard for protection against heat. We checked traps each morning after sunrise. During periods with red imported fire ant (*Solenopsis invicta*) activity, the contact insecticide bifenthrin (Talstar^{TM}, FMC Corporation) was dispersed every other day in and around the trap area to prevent bait depredation and mutilation of captured mammals. Once captured, each

individual was toe-clipped (Baumgartner 1940) to allow unique identification upon recapture. Each individual also was weighed, aged, and sexed. Additionally, we recorded identification code based on toe-clipping pattern, trap number, and site location.

Data Analysis

The analysis was conducted using an information-theoretic philosophy of model selection and multi-model inference (Burnham and Anderson 2002). We used Akaike's Information Criterion (AIC; Akaike 1973) and the small sample correction (AIC_c; Hurvich and Tsai 1989) as a basis for model selection. Model averages were based on Akaike weights, which determine model fitness. Each phase of the analysis involved *a priori* models, which were used to minimize spurious effects and aid in more reliable predictions.

The analysis was conducted in 3 phases using methods developed by Converse et al. (2006). First, we estimated abundances of small mammals based on closed mark-recapture models. Second, we estimated effective trapping area of each trapping grid. We combined abundance and effective trapping area to estimate densities of small mammals, and finally, analyzed effects of treatment (i.e., row spacing and distribution of debris) on mammal densities in a weighted regression analysis.

Abundance

We estimated abundance by species across all experimental units for both seasons in both years. The conditional likelihood model used was the Huggins (1989, 1991) closed capture-recapture model for full heterogeneity. This model predicts individual heterogeneity of capture probability, heterogeneity due to temporal effects, and behavioral responses to capture (Model M_{tbh}; Otis et al. 1978). Animal encounter histories were used in generating abundance estimates, which were based on capture probabilities and numbers of individuals caught. Abundance

estimates were generated using Program MARK 5.0 (White and Burnham 1999). To minimize variance of the estimates, we treated all experimental units as groups to analyze each group in each year and season. Combining data was only for the estimation of detection probability. This method is more statistically efficient because analyzing abundance in experimental units and years separately would increase the variance across estimates (Converse et al. 2006).

We proposed several models of detection probability for dominant species in the data set. Dominant species were defined as having a sample size of >100 uniquely marked individuals. For all dominant species, which were house mouse (*Mus musculus*), hispid cotton rat (*Sigmodon hispidus*), and *Peromyscus* species, we included a behavioral response to capture, an individual heterogeneity response, and a time response to reflect fewer captures the first 2 days of the encounter history because captures increased after day 3 of the 7-night trapping period. Data collection also indicated that site, experimental unit, year, season, and treatment interactions were important effects to model. We arranged effects into all possible combinations and estimated abundance with a total of 24 models for all 3 dominant small mammal species. We averaged the estimates and variance-covariance matrices based on model weights to account for model selection uncertainty (Burnham and Anderson 2002, 2004).

Effective Trapping Area

When conducting mark-recapture using trapping grids, effective trapping area needs to include the home range of the animal. Since a single home range can exist beyond the trapping grid, effective trapping area can be larger than the trapping grid itself. We used mean maximum distance moved (MMDM) as a method to estimate effective trapping area to which abundance estimates would be applied (Wilson and Anderson 1985).

We calculated the maximum distance moved (m) between any 2 traps for every individual caught twice or more in an experimental unit in 1 year. We combined abundance estimates with this data for a more efficient approximation of MMDM. We created multiple linear regression models to estimate MMDM (PROC REG; SAS Institute 2003). For all species in all sites, we considered models with MMDM examining effects of site, year, season, and treatment interactions of spacing and debris. We estimated MMDM with 8 models combining these effects in addition to a constant model. We added a buffer to each grid equal to one-half the MMDM for each model (Otis et al. 1978, Wilson and Anderson 1985). We averaged the estimates and variance-covariance matrices based on model weights to account for model selection uncertainty (Burnham and Anderson 2002, 2004).

Densities and Variance-Covariance Matrices

We arrived at density by dividing abundance by effective trapping area. Densities were calculated for each dominant species in each experimental unit for each year. We developed variance-covariance matrices of density estimates to be used in the weighted regression to examine treatment effects. These were computed by delta method transformations of the model-averaged variance-covariance matrices of the abundance estimates and the model-averaged variance-covariance matrices of effective trapping area (Seber 1982, Converse et al. 2006). Since the variance-covariance matrix is singular, variance cannot equal zero in weighted analysis. When no animals of a given species on an experimental unit in a given year were caught, variances of the abundance variance-covariance matrices were zero. To correct for this and create positive variances, we fit a linear regression (R 2.4.1, Venables et al. 2006) of the natural log of positive variances against their corresponding density estimates and determined the regression intercepts (Franklin 1997, Converse et al. 2006). We replaced the variance of the zero

densities with the exponential of the new intercept. We developed means of the density estimates and asymptotic standard errors. These were computed by delta method transformations of the density estimates and standard errors (Larson 1992).

Treatment Effects

We used weighted least-squares regression to analyze treatment effects (Draper and Smith 1998). A traditional unweighted regression was inappropriate because of the nonzero sampling covariance in the density estimates. These were generated from the abundance and effective trapping area estimation when data across experimental units, season, and year were combined.

We developed *a priori* models to describe density responses to treatment effects. Effects modeled included row spacing, debris distribution, year, season, site, and treatment interaction. We estimated treatment effects with 16 models combining these effects in addition to a constant model.

Weighted regression involves computation of a vector of effect sizes and an associated variance-covariance matrix (Draper and Smith 1998). We selected models and made inferences using AIC_c (Akaike 1973, Hurvich and Tsai 1989) for each model (Burnham and Anderson 2002). Multi-model inferential methods included Akaike weights (amount of model evidence computed as ΔAIC_c), model-averaged effect sizes, and 95% confidence intervals.

Vegetation Effects

All vegetation sampling was conducted once annually during the summer growing seasons of 2006 and 2007. These data were collected in conjunction with Taylor (2008), and vegetation data sets were used for independent objectives. Small mammal density estimates and vegetation characteristics (Chapter 2) were used in a weighted regression to describe associations

between small mammal densities and habitat preferences. We used the same principal components identified in Chapter 2 for relating to small mammal abundance.

We developed *a priori* models to describe density responses to vegetation effects. Effects modeled included the reduced set of principal components for both years. We estimated density responses to vegetation effects with principal components and the treatment effects in addition to a constant model. We selected models and made inferences using AIC_c (Akaike 1973) for each model (Burnham and Anderson 2002).

Results

<u>Treatment Effects</u>

We captured 945 individual small mammals representing 8 species during 11,200 trap nights during 2006–2007. Most age classes across all dominant species were adult and subadult (Table 3.1). Dominant species included house mouse (*n* = 259 marked individuals), hispid cotton rat (*n* = 181 marked individuals), and *Peromyscus* species (*n* = 423 marked individuals), which were grouped by genus to minimize observer bias and misidentification due to frequent hybridization among the species (Osbourne and Anderson 2002). Other species captured were considered incidental and were not included in this analysis (Table 3.2).

In year one, densities of *Peromyscus* spp. were 34% greater in the 20 ft spacing than in 14 ft spacing regardless of debris arrangement (Table 3.3) and 40% greater in 20 ft spacing with piled debris than in 20 ft spacing with scattered debris. Densities of cotton rats were 16% greater in 14 ft spacing than in 20 ft spacing regardless of debris and 70% greater in 14 ft with piled debris than in 14 ft with scattered debris (Table 3.4). Densities of house mice were 46% greater in 20 ft spacing with scattered debris than in 20 ft spacing with piled debris (Table 3.5).

Table 3.1. Proportion of age classes by season for each dominant species captured across 4 sites in north and south Louisiana, 2006-2007.

Species	*n*	Age class	Proportion (%)	
			Winter	Summer
Cotton rat	181	Juvenile[a]	6	8
		Subadult[b]	22	29
		Adult[c]	8	27
House mouse	259	Juvenile	7	3
		Subadult	42	25
		Adult	5	18
Peromyscus	423	Juvenile	16	3
		Subadult	43	12
		Adult	13	13

[a]Recognized by size smaller than adults with scant fur and pink skin showing.
[b]Recognized by adult size, but absence of adult features.
[c]Recognized by enlarged genitalia in males and enlarged teats in females.

Table 3.2. List of incidental species captured across all sites in north and south Louisiana, 2006-2007.

Species	Total captures
Eastern harvest mouse (*Reithrodontomys humulis*)	46
Marsh rice rat (*Oryzomys palustris*)	25
Least shrew (*Cryptotis parva*)	3
Shorttail shrew (*Blarina brevicauda*)	2
Longtail weasel (*Mustela frenata*)	1

Table 3.3. Mean density estimates (ha), asymptotic standard errors (SE), and total captures (*n*) of *Peromyscus* related to row spacing and distribution of logging debris on 4 sites in Louisiana, 2006-2007.

		Density Estimates (ha)		
Year	Treatment	Mean (SE)	Range	*n*
2006	Spacing 20 ft	2.9 (1.1)	0.0 – 21.7	150
	Spacing 14 ft	1.9 (0.5)	0.0 – 22.6	255
	Debris piled	2.6 (0.8)	0.0 – 22.6	187
	Debris scattered	2.2 (0.7)	0.0 – 21.7	218
	Interaction 14 ft spacing/piled debris	1.6 (0.3)	0.0 – 22.6	126
	Interaction 14 ft spacing/scattered debris	2.2 (0.6)	0.0 – 21.1	129
	Interaction 20 ft spacing/piled debris	3.6 (1.2)	0.0 – 18.2	61
	Interaction 20 ft spacing/scattered debris	2.1 (0.9)	0.0 – 21.7	89
	Winter season	2.9 (0.7)	0.0 – 22.6	241
	Summer season	1.9 (0.8)	0.0 – 12.4	164
	Northern sites	0.9 (0.4)	0.0 – 21.7	269
	Southern sites	4.1 (1.2)	0.0 – 22.6	136
2007	Spacing 20 ft	7.4 (2.1)	0.0 – 70.2	376
	Spacing 14 ft	8.7 (2.3)	0.0 – 68.8	380
	Debris piled	9.1 (2.3)	0.0 – 62.8	363
	Debris scattered	6.9 (2.0)	0.0 – 70.2	393
	Interaction 14 ft spacing/piled debris	10.9 (2.7)	0.0 – 61.7	216
	Interaction 14 ft spacing/scattered debris	6.0 (1.8)	0.0 – 68.8	166
	Interaction 20 ft spacing/piled debris	7.3 (2.0)	0.0 – 62.8	147
	Interaction 20 ft spacing/scattered debris	7.5 (2.2)	0.0 – 70.2	227
	Winter season	7.2 (1.8)	0.0 – 70.2	453
	Summer season	8.8 (2.6)	0.0 – 41.5	303
	Northern sites	9.5 (2.5)	0.0 – 70.2	465
	Southern sites	5.5 (1.6)	0.0 – 33.9	291

Table 3.4. Mean density estimates (ha), asymptotic standard errors (SE), and total captures (*n*) of cotton rat related to row spacing and distribution of logging debris on 4 sites in Louisiana, 2006-2007.

Year	Treatment	Density Estimates (ha)		
		Mean (SE)	Range	*n*
2006	Spacing 20 ft	16.7 (3.2)	0.0 – 58.0	64
	Spacing 14 ft	19.9 (2.8)	0.0 – 65.1	15
	Debris piled	17.5 (3.0)	0.0 – 65.1	40
	Debris scattered	18.1 (3.1)	0.0 – 58.0	39
	Interaction 14 ft spacing/piled debris	30.6 (3.6)	0.0 – 65.1	10
	Interaction 14 ft spacing/scattered debris	9.3 (2.0)	0.0 – 14.5	5
	Interaction 20 ft spacing/piled debris	12.3 (2.8)	0.0 – 32.8	29
	Interaction 20 ft spacing/scattered debris	24.0 (3.9)	0.0 – 58.0	35
	Winter season	37.1 (5.2)	0.0 – 65.1	50
	Summer season	4.0 (1.5)	0.0 – 11.0	29
	Northern sites	4.5 (1.8)	0.0 – 6.0	17
	Southern sites	20.4 (3.3)	0.0 – 65.1	62
2007	Spacing 20 ft	11.4 (3.0)	0.0 – 27.9	140
	Spacing 14 ft	19.9 (2.8)	0.0 – 41.8	102
	Debris piled	17.4 (3.4)	0.0 – 41.8	123
	Debris scattered	10.5 (2.7)	0.0 – 33.7	119
	Interaction 14 ft spacing/piled debris	21.5 (3.6)	0.0 – 41.8	39
	Interaction 14 ft spacing/scattered debris	11.5 (2.6)	0.0 – 33.7	62
	Interaction 20 ft spacing/piled debris	13.3 (3.2)	0.0 – 27.9	83
	Interaction 20 ft spacing/scattered debris	9.6 (2.8)	0.0 – 13.0	58
	Winter season	13.3 (2.7)	0.0 – 41.8	34
	Summer season	14.4 (3.3)	0.0 – 33.7	208
	Northern sites	11.1 (2.8)	0.0 – 26.7	86
	Southern sites	16.9 (3.3)	0.0 – 41.8	156

Table 3.5. Mean density estimates (ha), asymptotic standard errors (SE), and total captures (*n*) of house mouse related to row spacing and distribution of logging debris on 4 sites in Louisiana, 2006-2007.

		Density Estimates (ha)		
Year	Treatment	Mean (SE)	Range	*n*
2006	Spacing 20 ft	13.8 (2.4)	0.0 – 41.2	61
	Spacing 14 ft	7.9 (2.1)	0.0 – 63.2	70
	Debris piled	9.4 (2.1)	0.0 – 63.2	90
	Debris scattered	14.0 (2.6)	0.0 – 29.7	41
	Interaction 14 ft spacing/piled debris	6.6 (1.9)	0.0 – 63.2	39
	Interaction 14 ft spacing/scattered debris	8.7 (2.3)	0.0 – 29.7	31
	Interaction 20 ft spacing/piled debris	10.5 (2.2)	0.0 – 41.2	52
	Interaction 20 ft spacing/scattered debris	19.3 (2.9)	0.0 – 27.1	9
	Winter season	16.1 (2.7)	0.0 – 41.2	54
	Summer season	4.1 (1.7)	0.0 – 63.2	77
	Northern sites	0.0 (0.0)	0.0 – 10.5	8
	Southern sites	13.6 (2.7)	0.0 – 63.2	123
2007	Spacing 20 ft	9.8 (2.6)	0.0 – 135.5	163
	Spacing 14 ft	14.1 (2.9)	0.0 – 191.1	278
	Debris piled	15.0 (3.1)	0.0 – 191.1	194
	Debris scattered	8.8 (2.4)	0.0 – 140.0	247
	Interaction 14 ft spacing/piled debris	18.4 (3.4)	0.0 – 191.1	105
	Interaction 14 ft spacing/scattered debris	9.9 (2.3)	0.0 – 140.0	174
	Interaction 20 ft spacing/piled debris	11.7 (2.9)	0.0 – 135.5	89
	Interaction 20 ft spacing/scattered debris	7.4 (2.4)	0.0 – 123.8	73
	Winter season	8.7 (2.1)	0.0 – 191.1	224
	Summer season	16.7 (3.7)	0.0 – 123.8	217
	Northern sites	2.8 (0.7)	0.0 – 20.5	16
	Southern sites	13.8 (3.1)	0.0 – 191.1	425

In year 2, we found 45% greater densities of *Peromyscus* spp. in areas with 14 ft spacing and piled debris than in 14 ft spacing with scattered debris. Densities of cotton rats were similar across all treatments, but tended to be greater (31%) in areas with 14 ft spacing than in 20 ft and in piled debris than in scattered (39%). Densities of house mice were 31% greater in areas with 14 ft spacing than in 20 ft and 42% greater in piled debris than scattered.

<u>Hispid Cotton Rat</u>

Although density estimates for cotton rat ranged from 0 (SE = 0) to 65.1 (SE = 40.4) individuals per ha (Table 3.4), variances and covariances of density estimates must be taken into account for inferences to be drawn and patterns to be observed. The most parsimonious weighted regression model (Akaike weight 0.31) included effects of season within year (year/season) and row spacing (Table 3.6). However, the second best model had a score of 0.19 and was equally plausible. Therefore, for ease of interpretation we chose to make inferences based on the row spacing model, although we recognize that inferences should be interpreted with the understanding that none of the models performed particularly well. Based on the row spacing model, greater cotton rat densities occurred in areas with 14 ft row spacing (Table 3.7).

<u>*Peromyscus* spp.</u>

Density estimates for *Peromyscus* spp. ranged from 0 (SE = 0) to 70.2 (SE = 12.9) individuals per ha (Table 3.3). From the top-ranked weighted regression model (Akaike weight 0.47), we found that site was the important factor in predicting densities of *Peromyscus* spp. (Table 3.8). Whereas the top 3 models were equally plausible, we chose to use the first model for interpretation based on observations in the field that *Peromyscus* spp. were skewed toward northern sites. Because the location of our sites was more influential on *Peromyscus* densities than treatment, we chose to use the first model for interpretation. Based on this model, greater

Table 3.6. Model selection results[a] from weighted regression analysis of row spacing and distribution of logging debris effects on cotton rat densities in north and south Louisiana, 2006-2007.

Model	AIC_c	ΔAIC_c	w_i	K
Density{year/season+spacing}	49.712	0.000	0.31	5
Density{spacing}	50.655	0.944	0.19	2
Density{year/season}	50.842	1.131	0.18	4
Density{constant}	51.528	1.816	0.13	1
Density{year/season+debris}	52.953	3.241	0.06	5

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥5% of the w_i.

Table 3.7. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of row spacing and distribution of logging debris effects on cotton rat densities in north and south Louisiana, 2006-2007.

Variable	Level	Effect size[a]	95% CI
Intercept	–	1.25	-0.59 – 2.84
Spacing	Difference 20 ft, 14 ft	0.48	-0.43 – 1.39
Debris	Difference piled, scattered	0.03	-0.09 – 0.15
Treatment interactions[b]	Difference 14P, 20S	-0.04	-0.15 – 0.07
	Difference 14S, 20S	-0.04	-0.14 – 0.06
	Difference 20P, 20S	0.01	-0.05 – 0.06
Site	Difference A, D	0.01	-0.04 – 0.06
	Difference B, D	0.01	-0.05 – 0.07
	Difference C, D	0.03	-0.05 – 0.10
Year/season[c]	Difference W06, S07	-1.15	-3.53 – 1.23
	Difference S06, S07	-0.87	-2.51 – 0.77
	Difference W07, S07	-1.24	-3.89 – 1.41

[a]Effect sizes are presented as sum to zero and are only relevant to effects within their variable group.

[b]14P = 14 ft spacing/piled debris, 14S = 14 ft spacing/scattered debris, 20P = 20 ft spacing/piled debris, 20S = 20 ft spacing/scattered debris.

[c]W06 = winter 2006, S06 = summer 2006, W07 = winter 2007, S07 = summer 2007.

Table 3.8. Model selection results[a] from weighted regression analysis of row spacing and distribution of logging debris effects on *Peromyscus* densities in north and south Louisiana, 2006-2007.

Model	AIC_c	ΔAIC_c	w_i	K
Density{site}	71.218	0.000	0.47	4
Density{site+spacing}	72.524	1.306	0.25	5
Density{site+debris}	72.877	1.659	0.21	5
Density{site+trt. intx.}	75.753	4.535	0.05	7
Density{site+year/season}	78.344	7.126	0.01	7

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥1% of the w_i.

densities of *Peromyscus* occurred on sites in north Louisiana, and treatments did not influence densities of *Peromyscus* (Table 3.9).

House Mouse

Density estimates for house mouse ranged from 0 (SE = 0) to 191.1 (SE = 497.7) individuals per ha (Table 3.5). The most parsimonious weighted regression model (Akaike weight 0.47) included effects of site, year/season, and treatment interaction (Table 3.10). However, the second best model had a score of 0.31 and was equally plausible with fewer parameters, although none of the models performed particularly well. Because the second model was simpler, we chose to use it for interpretation. We observed greater densities of house mice at sites A and C during summer of year 1, and within 14 ft row spacing units regardless of the distribution of debris, and within 20 ft row spacing units with piled debris (Table 3.11). In essence, house mouse densities were greatest at sites A and C during the first growing season of our study across all treatments except 20 ft row spacing where debris was scattered. We suspect this exception has little biological relevance.

Vegetation Effects

Data for cotton rat and house mouse were used from 2007 only since capture probabilities were too low in 2006. In 2007, we found greater densities of cotton rats in sites with more woody vegetation and vines and lower densities in sites with forbs, grass, and yaupon (Table 3.12). We detected greater densities of house mice in sites with woody vegetation, grasses, and vines and lower densities in sites with forbs and yaupon (Table 3.13). In 2006, we found greater densities of *Peromyscus* spp. in sites with forbs, woody vegetation, and yaupon and lower densities in sites with grass and bare ground (Table 3.14). In 2007, we detected greater densities

Table 3.9. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of row spacing and distribution of logging debris effects on *Peromyscus* densities in north and south Louisiana, 2006-2007.

Variable	Level	Effect size[a]	95% CI
Intercept	–	5.25	3.27 – 7.23
Spacing	Difference 20 ft, 14 ft	-0.19	-0.70 – 0.32
Debris	Difference piled, scattered	0.13	-0.25 – 0.50
Treatment interactions[b]	Difference 14P, 20S	0.08	-0.11 – 0.27
	Difference 14S, 20S	0.01	-0.10 – 0.11
	Difference 20P, 20S	0.01	-0.09 – 0.09
Site	Difference A, D	-2.32	-4.54 – -0.10
	Difference B, D	-3.23	-5.49 – -0.96
	Difference C, D	-5.15	-7.42 – -2.88
Year/season[c]	Difference W06, S07	-0.01	-0.06 – 0.05
	Difference S06, S07	-0.01	-0.08 – 0.05
	Difference W07, S07	-0.01	-0.09 – 0.06

[a]Effect sizes are presented as sum to zero and are only relevant to effects within their variable group.
[b]14P = 14 ft spacing/piled debris, 14S = 14 ft spacing/scattered debris, 20P = 20 ft spacing/piled debris, 20S = 20 ft spacing/scattered debris.
[c]W06 = winter 2006, S06 = summer 2006, W07 = winter 2007, S07 = summer 2007.

Table 3.10. Model selection results[a] from weighted regression analysis of row spacing and distribution of logging debris effects on house mouse densities in north and south Louisiana, 2006-2007.

Model	AIC_c	ΔAIC_c	w_i	*K*
Density{site+year/season+trt. intx.}	-222.748	0.000	0.47	10
Density{site+year/season+spacing}	-221.910	0.837	0.31	8
Density{year/season+spacing}	-218.856	3.892	0.07	5
Density{site+year/season}	-217.906	4.841	0.04	7
Density{rep}	-216.932	5.816	0.03	4

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (*K*) for models with ≥5% of the w_i.

Table 3.11. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of row spacing and distribution of logging debris effects on house mouse densities in north and south Louisiana, 2006-2007.

Variable	Level	Effect size[a]	95% CI
Intercept	–	-0.64	-3.64 – 2.35
Spacing	Difference 20 ft, 14 ft	-0.54	-1.70 – 0.61
Debris	Difference piled, scattered	-0.02	-0.09 – 0.05
Treatment interactions[b]	Difference 14P, 20S	0.54	-1.05 – 2.13
	Difference 14S, 20S	1.40	-2.20 – 5.00
	Difference 20P, 20S	0.75	-0.95 – 2.44
Site	Difference A, D	0.28	-1.99 – 2.55
	Difference B, D	-0.15	-1.43 – 1.13
	Difference C, D	2.43	-0.61 – 5.48
Year/season[c]	Difference W06, S07	-1.04	-2.74 – 0.67
	Difference S06, S07	1.74	-0.21 – 3.68
	Difference W07, S07	-0.72	-2.54 – 1.10

[a]Effect sizes are presented as sum to zero and are only relevant to effects within their variable group.
[b]14P = 14 ft spacing/piled debris, 14S = 14 ft spacing/scattered debris, 20P = 20 ft spacing/piled debris, 20S = 20 ft spacing/scattered debris.
[c]W06 = winter 2006, S06 = summer 2006, W07 = winter 2007, S07 = summer 2007.

Table 3.12. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of vegetation effects on cotton rat densities in north and south Louisiana, 2007[a].

Model variable[b]	Effect size	95% CI
PC1	1.12	-3.91 – 6.16
PC2	-1.41	-6.39 – 3.57
PC3	5.15	0.07 – 10.22
PC4	-6.17	-11.62 – -0.72
PC5	-4.07	-8.85 – 0.71

[a]Data were used from 2007 only since capture probabilities were too low in 2006.
[b]2007 components: PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

Table 3.13. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of vegetation effects on house mouse densities in north and south Louisiana, 2007[a].

Model variable[b]	Effect size	95% CI
PC1	2.17	-8.17 – 12.52
PC2	-29.28	-47.71 – -10.86
PC3	26.89	12.61 – 41.18
PC4	6.27	-3.67 – 16.21
PC5	-1.52	-9.29 – 6.24

[a]Data were used from 2007 only since capture probabilities were too low in 2006.
[b]2007 components: PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

Table 3.14. Model-averaged effect sizes and 95% confidence intervals from weighted regression analysis of vegetation effects on *Peromyscus* densities in north and south Louisiana, 2006-2007.

Year	Model variable	Effect size	95% CI
2006[a]	PC1	-2.25	-6.07 – 1.57
	PC2	1.77	-0.56 – 4.10
	PC3	0.34	-1.47 – 2.14
	PC4	0.80	-0.41 – 2.02
2007[b]	PC1	-3.47	-8.61 – 1.66
	PC2	3.66	-1.39 – 8.72
	PC3	-6.61	-11.77 – -1.46
	PC4	0.82	-4.73 – 6.37
	PC5	-0.14	-5.00 – 4.72

[a]2006 components: PC1 = grass and bare ground, PC2 = forbs, PC3 = woody, PC4 = yaupon.
[b]2007 components: PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

of *Peromyscus* spp. in sites with forbs and grasses and lower densities in sites with woody vegetation, vines, and yaupon.

In 2006, principal component analysis over 15 variables resulted in 4 orthogonal factors that explained 82% of the variance. Principal component analysis over the same variables in 2007 resulted in 5 orthogonal factors that explained 84% of the variance. A summary of the principal components analysis and list of principal components are presented in Tables 2.2, 2.3, and 2.7 in Chapter 2.

Hispid Cotton Rat

In 2007, we detected greater cotton rat densities in sites with woody vegetation and vines, whereas densities were lower in sites with forbs, grass, and yaupon. The most parsimonious model was the global model (Akaike weight 0.75) (Table 3.15). Since cotton rats exhibited positive and negative associations with all the variables we measured, it was difficult to draw conclusive inferences from the global model. Other factors may have influenced our data outside of those we measured. The third model had an Akaike score of 0.10 and was equally plausible, so we interpreted this model with the understanding that inferences would be weak given the poor performance of the model. Based on this model, greater densities of cotton rats occurred in areas with denser woody vegetation and vines (Table 3.12).

Peromyscus spp.

In 2006, *Peromyscus* were more abundant in areas with forbs, woody vegetation, and yaupon and less abundant in areas with grasses and bare ground. The most parsimonious model measured effects without PC3 (Akaike weight 0.33) (Table 3.16), whereas the third model had a score of 0.16 and was equally plausible. Based on our observations in the field that in year 1 forbs typically occurred where *Peromyscus* were captured, we chose the third model for

Table 3.15. Model selection results[a] from weighted regression analysis of vegetation effects on cotton rat densities in north and south Louisiana, 2007[b].

Model[c]	AIC_c	ΔAIC_c	w_i	K
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4+PC5}	72.2	0.00	0.75	8
Density {debris+spacing+debris*spacing+PC2+PC3+PC4+PC5}	76.0	3.80	0.11	7
Density {debris+spacing+debris*spacing+PC1+PC3+PC4+PC5}	76.2	4.00	0.10	7

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥5% of the w_i.

[b]Data were used from 2007 only since capture probabilities were too low in 2006.

[c]PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

Table 3.16. Model selection results[a] from weighted regression analysis of vegetation effects on *Peromyscus* spp. densities in north and south Louisiana, 2006-2007.

2006 Models[b]	AIC_c	ΔAIC_c	w_i	K
Density {debris+spacing+debris*spacing+PC1+PC2+PC4}	57.4	0.00	0.33	6
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4}	57.8	0.40	0.27	7
Density {debris+spacing+debris*spacing+PC1+PC2}	58.9	1.5	0.16	6
Density {debris+spacing+debris*spacing+PC1+PC2+PC3}	61.0	3.6	0.06	
Density {debris+spacing+debris*spacing+PC1+PC3+PC4}	61.0	3.6	0.06	6
2007 Models[c]	AIC_c	ΔAIC_c	w_i	K
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4+PC5}	72.4	0.00	0.70	8
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4}	75.9	3.50	0.12	7
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC5}	76.3	3.90	0.10	7

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥5% of the w_i.

[b]PC1 = grass and bare ground, PC2 = forbs, PC3 = woody, PC4 = yaupon.

[c]PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

interpretation. We detected greater densities of *Peromyscus* in areas with forbs, woody vegetation, and yaupon (Table 3.14).

In 2007, we detected greater densities of *Peromyscus* spp. in sites with forbs and grasses and lower densities in areas with woody vegetation, vines, and yaupon. The most parsimonious model was the global model (Akaike weight 0.70) (Table 3.16). Although the selected models were equivocal, none were strong enough to draw inferences. Therefore, we used the global model for interpretation. Based on this model, we detected greater densities of *Peromyscus* in areas with forbs and grasses (Table 3.14), but recognize that this model could simply be the best of several poorly performing models.

House Mouse

In 2007, house mice were more abundant in areas with woody vegetation, grasses, and vines and less abundant in areas with forbs and yaupon. The most parsimonious model was the global model (Akaike weight 0.75) (Table 3.17). Although the selected models were equivocal, none were strong enough to draw inferences. Therefore, we used the global model for interpretation. Based on this model, we found greater densities of house mice in areas with woody vegetation, grasses, and vines (Table 3.13). Similarly, we temper our conclusions with the understanding that the global model may simply be the best of several poor models for evaluating relationships between captures of house mice and vegetation characteristics.

Discussion

Small mammals in managed forests reflect the compositional and structural diversity of resulting vegetation (Sullivan et al. 2001). Sullivan and Sullivan (2001) demonstrated that small mammal density was greater in harvested stands than in unharvested stands because of vegetation abundance and diversity. Understory vegetation resulting from site preparation

Table 3.17. Model selection results[a] from weighted regression analysis of vegetation effects on house mouse densities in north and south Louisiana, 2007[b].

Model[c]	AIC_c	ΔAIC_c	w_i	*K*
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4+PC5}	80.4	0.00	0.75	8
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC4}	84.5	4.1	0.10	7
Density {debris+spacing+debris*spacing+PC2+PC3+PC4+PC5}	85.0	4.6	0.08	7
Density {debris+spacing+debris*spacing+PC1+PC2+PC3+PC5}	85.5	5.1	0.06	7

[a]Results include Akaike's Information Criterion corrected for small sample size (AIC_c), relative AIC_c (ΔAIC_c), Akaike weight (w_i), and number of parameters (K) for models with ≥5% of the w_i.

[b]Data were used from 2007 only since capture probabilities were too low in 2006.

[c]PC1 = woody, PC2 = forbs, PC3 = vines, PC4 = grass, PC5 = yaupon.

treatments are a leading predictor of wildlife diversity (Lopez and Moro 1997, Humphrey et al., 1999). As forest stands age, small mammal abundance and diversity increase in response to greater plant abundance and diversity (Hartley 2002). Small mammal captures in site preparation treatments are directly associated with vegetation valuable as food or cover.

<u>Cotton Rat</u>

In year one, we found greatest densities of cotton rats in treatments with 14 ft spacing. Cotton rats are grassland specialists with a diet consisting of seeds and grains (O'Connell and Miller 1994). Habitat associations of cotton rats include abundant herbaceous vegetation resulting from intense disturbance (Perry and Thill 2005). Some common herbaceous plants we found were dogfennel (*Eupatorium capillifolium*), croton (*Croton* spp.), and dock (*Rumex* spp.). Dogfennel is likely used for cover and browse, whereas croton and dock are important seed producers (Miller and Miller 1999). Grass was predominant in all treatments during year one, as we encountered mostly pioneer species that commonly appear in the first few years following silvicultural disturbance. Cotton rats forage on various grasses (Fleharty and Olson 1969), and those we encountered were primarily bluestem grasses (*Andropogon* spp.), rosette grasses (*Dicanthelium* spp.), and paspalum grasses (*Paspalum* spp.). Cotton rats rely on the clumped structure of bluestems for nesting and prey on the stems for food, whereas rosette grasses and paspalums are important seed-producers (Miller and Miller 1999).

By year 2, cotton rats were more abundant in treatments with 14 ft spacing. Areas with 14 ft spacing were characterized by persistent grasses and greater woody vegetation, which increased in all treatments. Mengak and Guynn (2003) suggested that cotton rats adapt to stages of succession and use woody vegetation as woody encroachment increases. In addition to association with vegetation for food and cover, vegetation height and density also are important

habitat components for cotton rats (Fleharty and Mares 1973, Goertz 1964, Langley and Shure 1980). In year 2, we found greater densities of cotton rats in treatments with woody vegetation, grass, and vines. Densities of cotton rats were lower in areas with bare ground because dense vegetation was needed for thermal cover, nest sites, and protective cover (Manning and Edge 2008). Beneficial shrubs on our sites included baccharis (*Baccharis* spp.) and American beautyberry (*Callicarpa americana*). We found woody plants such as blackberries (*Rubus* spp.), blueberries (*Vaccinium* spp.), and mast-producing tree species. Bowne et al. (1999) elaborated on the importance of low trees and tall shrubs as cotton rat habitat requirements. Cotton rats have been considered precursors to northern bobwhite (*Colinus virginianus*) because of similar habitat associations (Hiller et al. 2007). Bobwhite use mixed shrub cover and grasses as food and nesting resources (Hiller et al. 2007). Vegetation structure diversity is important for both cotton rat and bobwhite for travel, cover, and nesting (Bowne et al. 1999). Similar to cotton rat, bobwhite use landscapes with moderate amounts of grasses and abundant woody edge (Roseberry and Sudkamp 1998).

Cotton rat densities were greater in treatments with piled debris in both years. Piles can provide critical habitat for species that persist within them (Friend 1982, Lindenmayer et al. 1998) by stimulating growth of sensitive plant species (Bell and Newmaster 2002, Pharo et al. 2004) and providing thermal and protective cover and daytime refugia (McCay 2000). Stands with piled debris were dominated by vines, particularly blackberries and morningglory (*Ipomoea* spp.) on piled sites. Cotton rats likely used morningglory for cover and blackberries as seed-producing forage (Miller and Miller 1999, Manson and Stiles 1998).

***Peromyscus* Species**

In 2006 and 2007, densities of *Peromyscus* spp. were not related to either row spacing or debris treatments. *Peromyscus* are opportunistic habitat generalists whose diet consists of seeds, insect larvae, and animal matter (Whitaker 1966). *Peromyscus* typically inhabit open landscapes with brushy, grass-dominated vegetation and woody structure (Perry and Thill 2005, O'Connell and Miller 1994). As a semi-arboreal species, *Peromyscus* need downed woody debris for traveling, foraging, and nesting (Bowman et al. 2000), and require vegetation structural diversity that mimics arboreal refugia (Buckner and Shure 1985).

We detected greater densities of *Peromyscus* spp. in treatments with forbs, woody vegetation, and yaupon in year one, whereas densities were lower in areas with grasses. Mengak and Guynn (2003) documented similar preferences in cotton mice (*Peromyscus gossypinus*) using woody material and downed debris and avoiding heavy mats of grass. Sites with forbs, woody vegetation, and yaupon were primarily characteristic of the northern sites where we observed greatest densities of *Peromyscus*. *Peromyscus* spp. were associated with more grasses and less woody vegetation in the second year, probably in response to the decrease in grass density throughout all treatments and the increase in woody vegetation across all sites.

House Mouse

We found greater densities of house mice in treatments with 14 ft spacing. As common first invaders of disturbed sites, house mice are grassland specialists and have a diet consisting of seeds, insect larvae, and animal material (Whitaker 1966). Increased invertebrate density from herbaceous establishment and persistent grasses in treatments with 14 ft spacing could have encouraged house mouse use (Perry and Thill 2005). In year two, we found greater densities of house mice in areas with vegetation that included woody material, grass, and vines, whereas

densities were lower in treatments dominated by forbs, bare ground, and yaupon. Mitchell et al. (1995) documented a strong association of house mice with herbaceous cover. We found grasses (bluestem, rosette, and paspalums), forbs (dogfennel, croton, and dock), and woody material (blackberries, shrubs, and mast-producing trees) throughout treatments with 14 ft spacing. Vegetation specific to 14 ft spacing likely satisfied the requirement of house mouse for dense cover, absence of bare ground, nest sites, and thermal and protective cover (Briese and Smith 1974, Manning and Edge 2008). We found greater densities of house mice in site A in the north and site C in the south. Both of these areas contained preferred habitat components of house mouse.

Densities of house mice were greater in areas with piled debris. Piles can create microhabitats for daytime refugia (Perry and Thill 2005, McCay 2000). Vegetation in treatments with piled debris included vines, wherein we detected greater densities of house mouse in year 2. Vines were primarily blackberries and morningglory (*Ipomoea* spp.), and similar to cotton rats, we suspect that house mice were associated with blackberries because of foraging opportunities.

Our capture probability for house mice was low for 2006. Capture probability is the probability of being captured at least once given that the individual was present in the trapping area. Our detection probability during the 7-day trapping periods of 2006 was only around 50%. Densities were likely more related to other parameters we did not analyze, such as plant diversity. The clumped distribution we noted in house mice captures might have attributed to our low detection. House mice may have been forming micropopulations at areas of high resource availability. Factors contributing to clumped distribution probably were close proximity to undisturbed forest edges and to piles. Hansson (1992) observed the relationship of species compositions on clearcuts to compositions in adjoining forests. Abundance and diversity of

vegetation at forest edges afford small mammals more opportunities to find primary habitat components (Osbourne et al. 2005). Because piles stimulate residual forest patches (Newmaster et al. 2007), house mice frequent piles for structural cover and patchy distributions of resources (Hartley 2002).

Management Implications

Densities of small mammals are closely linked to regeneration techniques and silvicultural management. Our research demonstrates that of the 2 small mammal species that were affected by treatment (house mouse and cotton rat), 14 ft spacing and piled debris tended to be positively associated with density. *Peromyscus* spp. readily adapted to all treatments. If managers are interested in optimizing densities of these species, a 14ft row spacing would be preferable over 20 ft. Likewise, piling debris rather than distributing it across the site would further ensure greater densities of small mammals.

CHAPTER 4. CONCLUSION

Mechanical site preparation affects resulting vegetation composition and structure. Early successional vegetation can be managed through intensive forest management. Our research demonstrates that wider row spacing may stimulate growth of herbaceous forbs initially. However, soil disturbance lends itself to woody encroachment in the future. We found that areas where downed woody debris is retained are more productive than those where the soil is scarified and debris is piled. We recommend forest managers use wider row spacing combined with woody vegetation control. We further suggest retaining downed woody debris to preserve soil nutrients and stimulate quality microsites for soil seed banks.

Densities of small mammals are closely linked to regeneration techniques and silvicultural management. Our research demonstrates that of the two small mammal species that were affected by treatment (house mouse and cotton rat), 14 ft spacing and piled debris were important. Since *Peromyscus* spp. adapted to all treatments, we recommend using narrow row spacing and piled debris if suitable habitat for house mouse, cotton rat, and *Peromyscus* spp. is the management goal. These strategies provide suitable habitat components required by small mammal species.

LITERATURE CITED

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267-281 in B.N. Petrov and F. Csaki, editors. Second international symposium on information theory. Akademiai Kiado, Budapest, Hungary.

Alig, R.J., H.A. Knight, and R.A. Birdsey. 1986. Recent area changes in southern forest ownerships and cover types. Res. Pap. SE-260. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 10 pp.

Allen, H.L. and S. Lein. 1998. Effects of site preparation, early fertilization, and weed control on 14-year-old loblolly pine. Proceedings of the Southern Weed Science Society 51:104-110.

Archibold, O.W., C. Acton, and E.A. Ripley. 2000. Effect of site preparation on soil properties and vegetation cover, and the growth and survival of white spruce (Picea glauca) seedlings, in Saskatchewan. Forest Ecology and Management 131:127-141.

Balandier, P., C. Collet, J.H. Miller, P.E. Reynolds, and S.M. Zedaker. 2006. Designing forest vegetation management strategies based on the mechanisms and dynamics of crop tree competition by neighbouring vegetation. Forestry 79:3-27.

Baldwin, V.C. and Q.V. Cao. 1999. Modeling forest timber productivity in the south: Where are we today? Paper presented at the Tenth Biennial Southern Silvicultural Research Conference, Shreveport, LA, February 16, 1999.

Barnum, S.A., C.J. Manville, J.R. Tester, and W.J. Carmen. 1992. Path selection by *Peromyscus leucopus* in the presence and absence of vegetative cover. Journal of Mammalogy 73:797-801.

Baumgartner, L.L. 1940. Trapping, handling, and marking fox squirrels. Journal of Wildlife Management 4:444-450.

Bell, F.W. and S.G. Newmaster. 2002. Clearcutting and conifer release alternatives affect floral richness, abundance and diversity. Part I: seed bearing plants. Canadian Journal of Forestry Research 32:1180-1191.

Bellows A.S., J.F. Pagels, and J.C. Mitchell. 2001. Macrohabitat and microhabitat affinities of small mammals in a fragmented landscape on the upper coastal plain of Virginia. American Midland Naturalist 146:345-360.

Bock, M.D. and K.C.J. Van Rees. 2002. Mechanical site preparation impacts on soil properties and vegetation communities in the Northwest Territories. Canadian Journal of Forest Research 32:1381-1392.

Bowman, J.C., D. Sleep, G.J. Forbes, and M. Edwards. 2000. The association of small mammals with coarse woody debris at log and stand scales. Forest Ecology and Management 129:119-124.

Briese, L.A. and M.H. Smith. 1974. Seasonal abundance and movement of nine species of small mammals. Journal of Mammalogy 55:615-629.

Bowne, D.R., J.D. Peles, and G.W. Barrett. 1999. Effects of landscape spatial structure on movement patterns of the hispid cotton rat (Sigmodon hispidus). Landscape Ecology 14:53-65.

Buckner, C.A. and D.J. Shure. 1985. The response of Peromyscus to forest opening size in the Southern Applachian Mountains. Journal of Mammalogy 66:299-307.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.

Burnham, K.P. and D.R. Anderson. 2004. Multimodel inference: understanding AIC and BIC in model selection. Sociological Methods and Research 33:261-304.

Cain, M.D. 1991. The influence of woody and herbaceous competition on early growth of naturally regenerated loblolly and shortleaf pines. Southern Journal of Applied Forestry 15:179-185.

Cain, M.D. and M.G. Shelton. 2003. Fire effects on germination of seeds from Rhus and Rubus: competitors to pine during natural regeneration. New Forests 26:51-64.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388-394.

Cole, B. 2006. Map Resources. http://geology.com/state-map/louisiana.shtml.

Converse, S.J., G.C. White, and W.M. Block. 2006. Small mammal responses to thinning and wildfire in ponderosa pine-dominated forests of the southwestern United States. Journal of Wildlife Management 70:1711-1722.

Cox, C. 2000. Herbicide factsheet: triclopyr. Journal of Pesticide Reform 20(4):12-18.

Daubenmire, R.K. 1959. A canopy coverage method of vegetational analysis. Northwest Science 35:43-64.

Dimmick, R.W., M.J. Gudlin, and D.F. McKenzie. 2002. The Northern Bobwhite Conservation Initiative. Miscellaneous publication of the Southeast Eassociation of Fish and Wildlife Agencies, South Carolina. 96 pages.

Draper, N.R. and H. Smith. 1998. Applied regression analysis. Third edition. John Wiley and Sons, New York, New York, USA.

Fleharty, E.D. and M.A. Mares. 1973. Habitat preference and spatial relations of Sigmodon hispidus on a remnant prairie in west-central Kansas. Southwestern Naturalist 18:21-29.

Fleharty, E.D. and L.E. Olson. 1969. Summer food habits of Microtus ochrogaster and Sigmodon hispidus. Journal of Mammalogy 50:475-486.

Franklin, A.B. 1997. Factors affecting temporal and spatial variation in northern spotted owl populations in northwest California. Dissertation. Colorado State University, Fort Collins, CO, USA.

Friend, G.R. 1982. Bird populations in exotic pine plantations and indigenous eucalypt forests in Gippsland, Victoria. Emu 82:80-91

George, J.L. 1960. Some primary and secondary effects of herbicides on wildlife. Pages 40-73 in McDermott, R.E. and W.R. Byrnes, eds. Herbicides and Their Use in Forestry. Proceedings Forestry Symposium.

Goertz, J.W. 1964. The influence of habitat quality upon cotton rat populations. Ecological Monograph 34:359-381.

Gresham, C.A. 2002. Sustainability of intensive loblolly pine plantation management in the South Carolina coastal plain, USA. Forest Ecology and Management 155:69-80.

Haeussler, S., L. Bedford, J.O. Boateng, and A. MacKinnon. 1999. Plant community responses to mechnical site preparation in northern interior British Columbia. Canadian Journal of Forestry Research 29:1084-1100.

Hanski, I. 1987. Pine sawfly population dynamics: patterns, processes, problems. Oikos 50:327-335.

Hansson, L. 1992. Small mammal communities on clearcuts in a latitudinal gradient. Acta Oecologica 13:687-699.

Hardy, C.C. 1996. Guidelines for estimating volume, biomass, and smoke production for piled slash. Gen. Tech. Rep. PNW-GTR-364. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr., and K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15:133-302.

Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. Forest Ecology and Management 155:81-95.

Hautala, H., J. Jalonen, S. Laaka-Lindberg, and I. Vanha-Majamaa. 2004. Impacts of retention felling on coarse woody debris (CWD) in mature boreal spruce forests in Finland. Biodiversity and Conservation 13:1541-1554.

Haywood, J.D. 2005. Influence of precommercial thinning and fertilization on total stem volume and lower stem form of loblolly pine. Southern Journal of Applied Forestry 29:215-220.

Hiller, T.L., F.S. Guthery, A.R. Rybak, S.D. Fuhlendorf, S.G. Smith, W.H. Puckett, and R.A. Baker. 2007. Management implications of cover selection data: Northern bobwhite example. Journal of Wildlife Management 71:195-201.

Huggins, R. M. 1989. On the statistical analysis of capture experiments. Biometrika 76:133-140.

Huggins, R.M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. Biometrics 47:725-732.

Humphrey, J.W., Hawes, C., Peace, A.J., Ferris-Koan, R., Jukes, M.R. 1999. Relationships between insect diversity and habitat characteristics in plantation forests. Forest Ecology and Management 113:11-21.

Hurvich, C.M. and C.L. Tsai. 1989. Regression and time series model selection in small samples. Biometrika 76:297-307.

Jackson, D.A. 1993. Stopping rules in principal components analysis: A comparison of heuristic and statistical approaches. Ecology 74:2204-2214.

Johnson, R.A. and D.W. Wichern. 2001. Applied Multivariate Statistical Analysis, 5th edition. Prentice Hall.

Jones, J.D.J. and M.J. Chamberlain. 2004. Efficacy of herbicides and fire to improve vegetative conditions for northern bobwhites in mature pine forests. Wildlife Society Bulletin 32:1-8.

Kline, J.D., B.J. Butler, and R.J. Alig. 2002. Tree planting in the South: What does the future hold? Southern Journal of Applied Forestry 26:99-107.

Knowe, S.E., B.D. Shiver, and W.N. Kline. 1992. Fourth-year response of loblolly pine following chemical and mechanical site preparation in the Georgia Piedmont. Southern Journal of Applied Forestry 16:99-105.

Langley, A.K. and D.J. Shure. 1980. The effects of loblolly pine plantations on small mammal populations. American Midland Naturalist 103:59-65.

Larson, D.A. 1992. Analysis of variance with just summary statistics as input. American Statistical Association 46:151-152.

Lauer, D.K., G.R. Glover, and D.H. Gjerstad. 1993. Comparison of duration and method of herbaceous weed control on loblolly pine response through midrotation. Canadian Journal of Forest Research 23:2116-2125.

Lauer, D.K. and B.R. Zutter. 2001. Vegetation cover response and second-year loblolly and slash pine response following bedding and pre- and postplant herbicide applications in Florida. Southern Journal of Applied Forestry 25:75-83.

Lindenmayer, D.B., M.L. Pope, R.B. Cunningham, C.F. Donnelly, and H.A. Nix. 1998. Conserving biodiversity in intensively-managed exotic softwood plantations in Australia: preliminary results from a landscape scale fragmentation experiment, Abstract. In: Gustafsson, L., J.O. Weslien, C.H. Palmer, and L. Sennerby-Forsse (Eds.), Biodiversity in Managed Forests—Concepts and Solutions, Sweden 1997. Report 1/98. The Forestry Research Institute of Sweden, Uppsala.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for mixed models. SAS Institute Inc., Cary, North Carolina, USA.

Loeb, S.C. 1999. Responses of small mammals to coarse woody debris in a southeastern pine forest. Journal of Mammalogy 80:460-471.

Lopez, G. and M.J. Moro. 1997. Birds of Aleppo pine plantations in southeast Spain in relation to vegetation composition and structure. Journal of Applied Ecology 34:1257-1272.

Lukacs, P.M., W.L. Thompson, W.L. Kendall, W.R. Gould, P.F. Doherty, K.P. Burnham, and D.R. Anderson. 2007. Concerns regarding a call for pluralism of information theory and hypothesis testing. Journal of Applied Ecology 44:456-460.

Manning, J.A. and W.D. Edge. 2008. Small mammal responses to fine woody debris and forest fuel reduction in southwest Oregon. Journal of Wildlife Management 72:625-632.

Manson, R.H. and E.W. Stiles. 1998. Links between microhabitat preferences and seed predation by small mammals in old fields. Oikos 82:37-50.

McCay. T.S. 2000. Use of woody debris by cotton mice (Peromyscus gossypinus) in a Southeastern pine forest. Journal of Mammalogy 81:527-535.

Mengak, M.T. and D.C. Guynn Jr. 2003. Small mammal microhabitat use on young loblolly pine regeneration areas. Forest Ecology and Management 173:309-317.

Miller, J.H. 1980. Competition after windrowing or single-roller chopping for site preparation in the Southern Piedmont. Proceedings of the Southern Weed Science Society 33:139-145.

Miller, J.H. and K.V. Miller. 1999. Forest plants of the southeast and their wildlife uses. Craftmaster Printers, Inc., Auburn, Alabama, USA. 454 pages.

Miller, D.A., R.E. Thill, M.A. Melchiors, T.B. Wigley, and P.A. Tappe. 2004. Small mammal communities of streamside management zones in intensively managed pine forests of Arkansas. Forest Ecology and Management 203:381-393.

Miller, J.H., B.R. Zutter, S.M. Zedaker, M.B. Edwards, J.D. Haywood, and R.A. Newbold. 1991. A regional study on the influence of woody and herbaceous competition on early pine growth. Southern Journal of Applied Forestry 15:169-179.

Mitchell, M.S., K.S. Karriker, E.J. Jones, and R.A. Lancia. 1995. Small mammal communities associated with pine plantation management of pocosins. Journal of Wildlife Management 59:875-881.

Morris, L.A., W.L. Pritchett, and B.F. Swindel. 1983. Displacement of nutrients into windrows during site preparation of a flatwood forest. Soil Science Society American Journal 47:591-594.

Newmaster, S.G., W.C. Parker, F.W. Bell, and J.M. Paterson. 2007. Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut. Forest Ecology and Management 246:196-207.

O'Connell, W.E. and K.V. Miller. 1994. Site preparation influences on vegetative composition and avian and small mammal communities in the South Carolina upper coastal plain. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 48:321-330.

Osbourne, J.D. and J.T. Anderson. 2002. Small mammal response to coarse woody debris in the central Appalachians. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 56:198-209.

Osbourne, J.D., J.T. Anderson, and A.B. Spurgeon. 2005. Effects of habitat on small-mammal diversity and abundance in West Virginia. Wildlife Society Bulletin 33:814-822.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62:1-135.

Peltzer, D.A., M.L. Bast, S.D. Wilson, and A.K. Gerry. 2000. Plant diversity and tree responses following contrasting disturbances in boreal forest. Forest Ecology and Management 127:191-203.

Perry, R.W. and R.E. Thill. 2005. Small mammal responses to pine regeneration treatments in the Ouachita Mountains of Arkansas and Oklahoma, USA. Forest Ecology and Management 219:81-94.

Pharo, E.J., D.B. Lindemayer, and N. Taws. 2004. The effects of large-scale fragmentation on bryophytes in temperate forests. Journal of Applied Ecology 41:910-921.

Prisley, S.P. and A.J. Malmquist. 2002. Impacts of rotation age changes on growth/removals ratios. Southern Journal of Applied Forestry 26:72-77.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Roseberry, J.L. and S.D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895-902.

SAS version 9.1.3. Service Pak 4. Copyright 2002-2003 by SAS Institute Inc., Cary, NC, USA.

Schabenberger, L.E. and S.M. Zedaker. 1999. Relationships between loblolly pine yield and woody plant diversity in Virginia Piedmont plantations. Canadian Journal of Forest Research 29:1065-1072.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Second edition. Charles Griffin, London, United Kingdom.

Shiver, B.D. and S.W. Martin. 2002. Twelve-year results of a loblolly pine site preparation study in the Piedmont and upper coastal plain of South Carolina, Georgia, and Alabama. Southern Journal of Applied Forestry 26:32-36.

Siitonen, J. 2001. Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecological Bulletins 49:11-41.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions [Online WWW]. Available URL: http://soils.usda.gov/technical/classification/osd/index.html [Accessed 10 February 2004]. USDA-NRCS, Lincoln, NE

Sparling, V.A. 1996. Effects of chemical and mechanical site preparations on the habitat and abundance of birds and small mammal in the upper coastal plain of South Carolina. M.S. Thesis. University of Georgia, Athens, USA.

Sullivan, T.P. and D.S. Sullivan. 2001. Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. Journal of Applied Ecology 38:1234-1252.

Sullivan, T.P., D.S. Sullivan, and P.M.F. Lindgren. 2001. Stand structure and small mammals in young lodgepole pine forest: 10-year results after thinning. Ecological Applications 11:1151-1173.

Sustainable Forestry Initiative Inc., 2005. Sustainable Forestry Initiative (SFI) Standard, 2005–2009 ed. American Forest and Paper Association, Washington, D.C., USA.

Taylor, A. 2008. Breeding bird communities in early successional Louisiana pine plantations. M.S. Thesis. Louisiana State University, Baton Rouge, USA.

Thevenet, A., A. Citterio, and H. Piegay. 1998. A new methodology for the assessment of large woody debris accumulations on highly modified rivers (example of two French Piedmont rivers). Regulated Rivers: Research & Management 14:467-483.

Trani, M.K., R.T. Brooks, T.L. Schmidt, V.A. Rudis, and C.M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29:413-424.

USDA. 1997. Loblolly pine: the ecology and culture of loblolly pine (*Pinus taeda*) / Robert P. Schultz. USDA Agricultural Handbook No. 713.

USDA Forest Service. 2002. National forest inventory and analysis data base retrieval system. <http://www.ncrs.fs.fed.us/4801/FIADB/rpa_tabler/2002_rpa_draft_tables.htm>

USDA, NRCS. 2008. The PLANTS Database (http://plants.usda.gov, 27 June 2008). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Venables, W.N., D.M. Smith, and the R Development Core Team. 2006. Program R: An Introduction to R. Release 2.4.1. Available online at: http://www.r-project.org/.

Vlosky, R.P. and N.P. Chance. 1995. Louisiana's forests and forest products industries. In press.

Weyerhaeuser Company. Weyerhaeuser company investor guide. Mobular Technologies, 2004.

Whitaker, J.O. 1966. Food of Mus musculus, Peromyscus maniculatus bairdi and Peromyscus leucopus in Vigo County, Indiana. Journal of Mammalogy 47:473-486.

White, G.C. and K.P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study (Supplement) 46:120-139.

Wilson, K.R. and D.R. Anderson. 1985. Evaluation of two density estimators of small mammal population size. Journal of Mammalogy 66:13-21.

Zeide, B. and D. Sharer. 2000. Good forestry at a glance: a guide for managing even-aged loblolly pine stands. Arkansas Forest Resources Center Series 003. 19 pp.

Zollner P.A. and K.J. Crane. 2003. Influence of canopy closure and shrub coverage on travel along coarse woody debris by Eastern chipmunks (*Tamias striatus*). American Midland Naturalist 150:151-157.

APPENDIX 1. PLANT SPECIES RECORDED FROM LINE INTERCEPTS

Genus and/or species	Common name
Acer rubrum	Red maple
Ambrosia artemisiifolia	Ragweed
Ampelopsis arborea	Peppervine
Andropogon spp.	Bluestem grasses
Asimina triloba	Pawpaw
Aster spp.	Asters
Athyrium filix-femina	Common ladyfern
Baccharis spp.	Baccharis
Callicarpa americana	American beautyberry
Carya spp.	Hickories
Celtis laevigata	Sugarberry
Centrosema spp.	Butterfly peas
Cephalanthus occidentalis	Common buttonbush
Cestrum spp.	Jessamines
Chamaecrista fasciculata	Partridge pea
Cirsium spp.	Thistles
Clitoria spp.	Pigeonwings
Crataegus spp.	Hawthorns
Conyza canadensis	Canadian horseweed
Croton spp.	Croton
Cyperus esculentus	Yellow nutsedge
Dichanthelium spp.	Rosette grasses
Diodia spp.	Buttonweeds
Diospyros virginiana	Common persimmon
Eupatorium capillifolium	Dogfennel
Euphorbia spp.	Spurges
Hamamelis virginiana	American witchhazel

APPENDIX 1 (continued).

Genus and/or species	Common name
Hypericum gentianoides	Pineweed
Ilex opaca	American holly
Ilex vomitoria	Yaupon
Ipomoea spp.	Morning glorys
Kummerowia striata	Japanese clover
Lespedeza spp.	Lespedezas
Ligustrum spp.	Privets
Liquidambar styraciflua	Sweetgum
Ludwigia spp.	Primroses
Lygodium japonicum	Japanese climbing fern
Morella cerifera	Wax myrtle
Ostrya virginiana	Hophornbeam
Panicum spp.	Panicgrasses
Parthenocissus quinquefolia	Virginia creeper
Paspalum spp.	Paspalum grasses
Passiflora spp.	Passionflowers
Phytolacca spp.	Pokeweeds
Pinus taeda	Loblolly pine
Platanus occidentalis	American sycamore
Prunus spp.	Cherries
Pseudognaphalium obtusifolium	Rabbit-tobacco
Quercus spp.	Oaks
Rhus spp.	Sumacs
Rhyncosia spp.	Snoutbeans
Rubus spp.	Blackberries
Rumex spp.	Dock

APPENDIX 1 (continued).

Genus and/or species	Common name
Sassafras albidum	Sassafras
Sesbania cannabina	Sesbania
Smiliax spp.	Greenbriars
Solanum carolinense	Carolina horsenettle
Solidago spp.	Goldenrods
Symeria paniculata	Water grape
Toxicodendron pubescens	Atlantic poison oak
Toxicodendron radicans	Eastern poison ivy
Triadica sebifera	Chinese tallow
Trifolium spp.	Clovers
Vaccinium spp.	Blueberries
Viburnum dentatum	Southern arrowwood
Vitis spp.	Grapes
Wisteria spp.	Wisterias

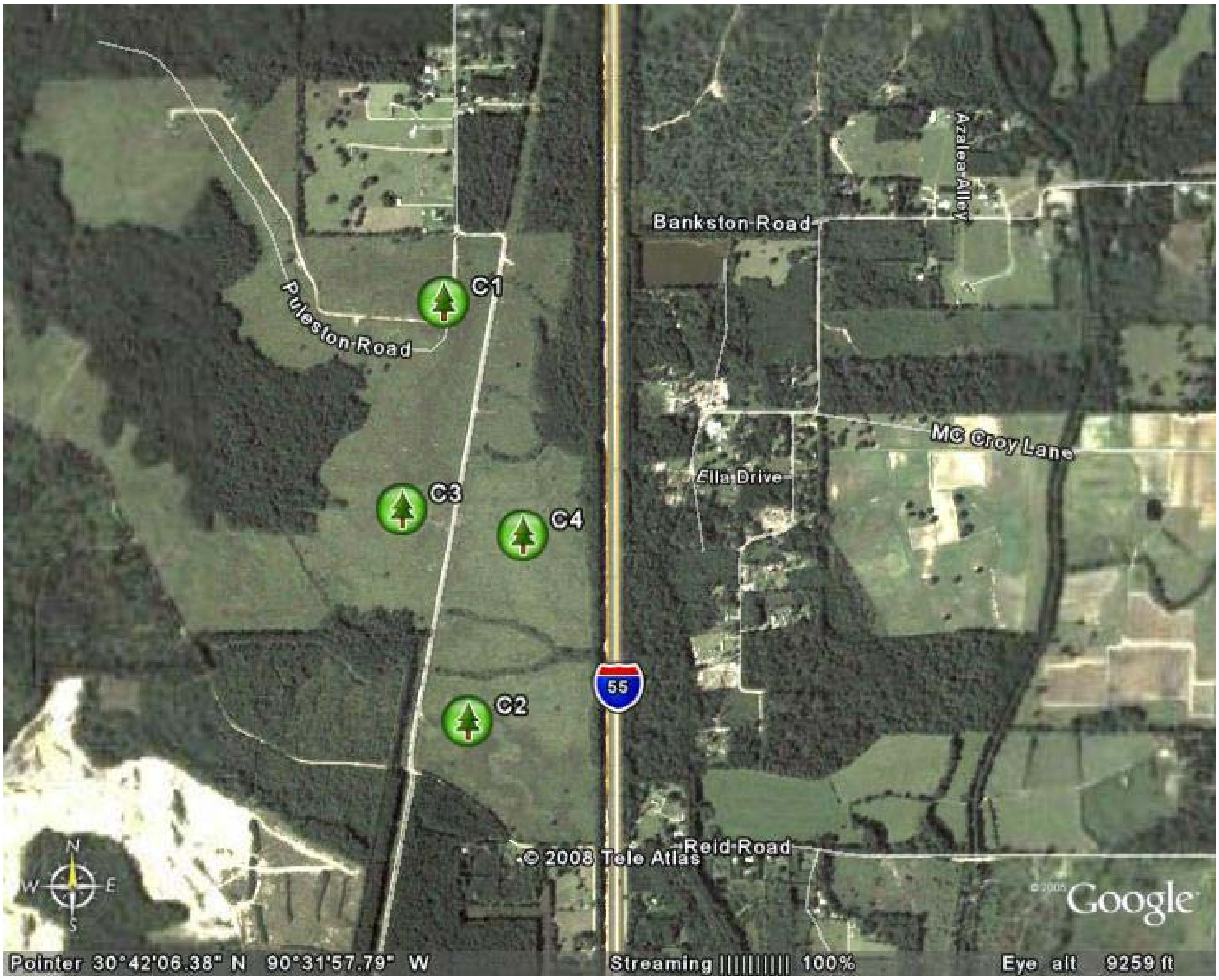
APPENDIX 2. AERIAL PLOT PHOTOS

Appendix 2. Aerial photo of plots on site A. A1 = 14 ft spacing, piled debris; A2 = 14 ft spacing, scattered debris; A3 = 20 ft spacing, scattered debris; A4 = 20 ft spacing, piled debris.

APPENDIX 2 (continued).

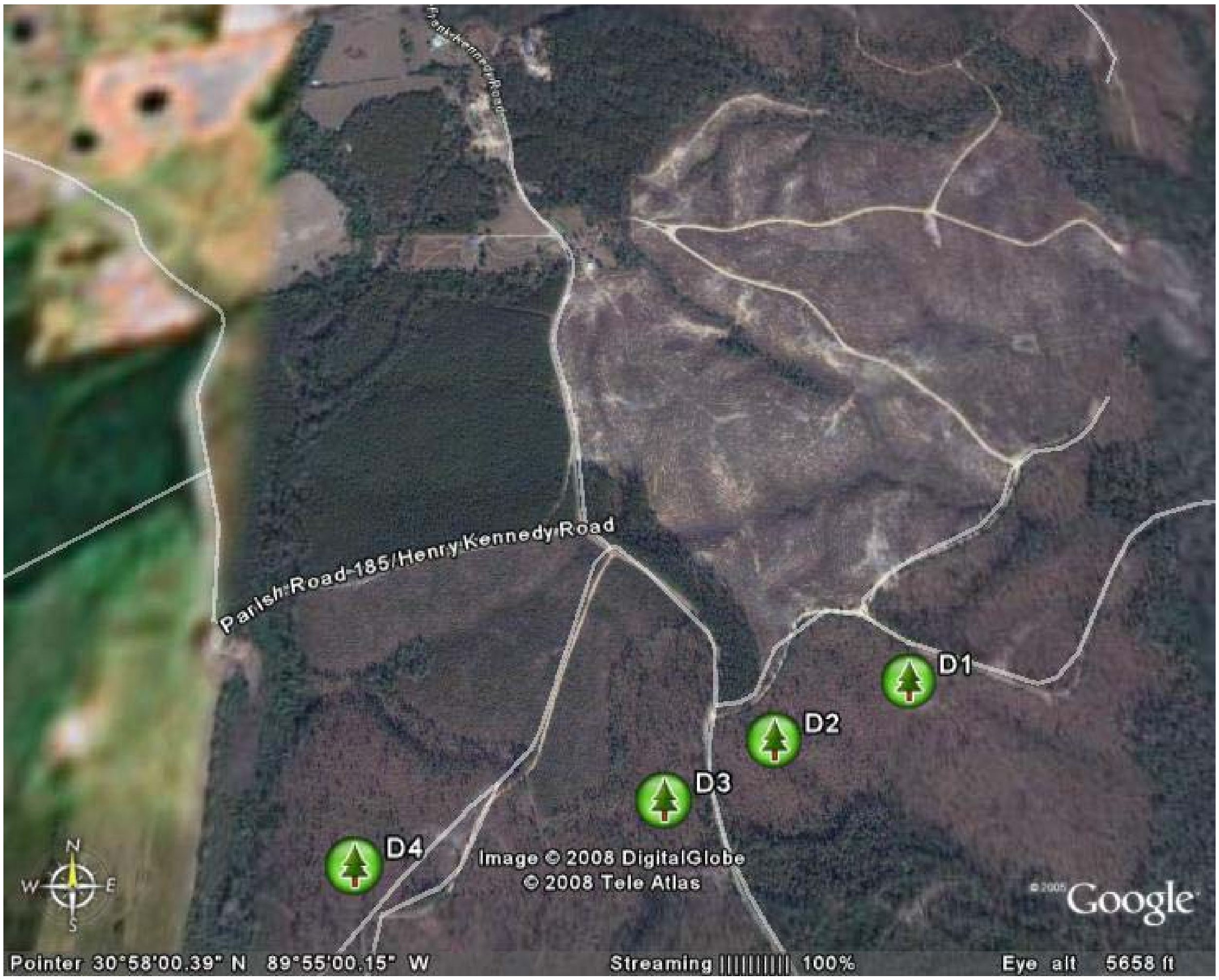
Appendix 2. Aerial photo of plots on site B. B1 = 14 ft spacing, scattered debris; B2 = 14 ft spacing, piled debris; B3 = 20 ft spacing, scattered debris; B4 = 20 ft spacing, piled debris.

APPENDIX 2 (continued).



Appendix 2. Aerial photo of plots on site C. C1 = 20 ft spacing, piled debris; C2 = 20 ft spacing, scattered debris; C3 = 14 ft spacing, scattered debris; C4 = 14 ft spacing, piled debris.

APPENDIX 2 (continued).



Appendix 2. Aerial photo of plots on site D. D1 = 14 ft spacing, piled debris; D2 = 14 ft spacing, scattered debris; D3 = 20 ft spacing, scattered debris; D4 = 20 ft spacing, piled debris.

APPENDIX 3. PHOTOS OF DEBRIS ARRANGEMENTS

Example of scattered debris arrangement.

APPENDIX 3 (continued).

Example of piled debris arrangement.

VITA

Anne Bechard was born in Memphis, Tennessee, in 1970. At the age of 14, she moved on her own to Boston, Massachusetts, to live at the convent of the Daughters of St. Paul. As a Postulant in religious training, she immersed herself in the mission of the Order, which was to share Christian life through the media. During her 6-year stay, she worked with book-binding machinery, became an experienced typesetter, and furthered her musical training in the audiovisual and sound studio. Anne graduated from the Daughters of St. Paul High School while in residence there, then moved back to Memphis in 1990. She worked as a typesetter, copyeditor, and continuing medical education director for several years at the *Journal of Clinical Psychiatry*. In 2001, she moved to Knoxville, Tennessee, to attend University of Tennessee. After graduating with a Bachelor of Science in Wildlife and Fisheries Science, she was offered a graduate assistantship at Louisiana State University, where she anticipates graduating with a Master of Science in wildlife degree in December 2008.