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Effects of row spacing and debris distribution on small mammal and vegetation communities in newly established loblolly pine plantations, Louisiana

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EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON SMALL MAMMAL AND VEGETATION COMMUNITIES IN NEWLY ESTABLISHED LOBLOLLY PINE PLANTATIONS, LOUISIANA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
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in

The School of Renewable Natural Resources

by
Joshua Lee Grace
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ABSTRACT

Commercial pine (*Pinus* spp.) forests in the southeastern United States are key to providing fiber for global wood supply needs. Concern has arisen over possible effects of intensive forest management techniques, including row spacing and distribution of woody debris after logging, on plant and wildlife communities. Therefore, we quantified response of plant and small mammal communities in replanted loblolly pine (*P. taeda*) stands to mechanical site preparation including 2 levels of row spacing and 2 methods of distributing woody debris following harvest in north and southeastern Louisiana, USA. Sites (*n*=16) were prepared with a combination of row spacing between planting beds (4.3 m and 6.1 m) and distribution of logging debris (piled and scattered). We examined vegetation using various sampling methods, and used mark-recapture techniques to assess small mammal communities in each of 4 replicate stands for 4 years post-treatment. Site preparation involving wider row spacing generally did not affect vegetation structure and composition; or relative abundance and diversity of small mammals. Piling debris in specific locales throughout the stand reduced non-pine woody vegetation, but did not affect small mammal communities. However, the increased woody growth associated with scattering debris throughout the stand resulted in higher lactation-level carrying capacity estimates for white-tailed deer (*Odocoileus virginianus*); due to importance of semi-woody browse to deer in Louisiana. We suggest that row spacing may not be a significant factor when planning implementation of site preparation techniques relative to small mammals and deer browse production. We suspect further research examining later stages of succession and stand development may provide further insight into the tradeoffs between increased woody growth associated with scattering debris and the potential benefits that may result from reducing woody growth by piling debris into certain locales throughout the stand.

CHAPTER 1. INTRODUCTION

Overview

The forest products industry is economically important in Louisiana, where greater than 48% of land is used for timber production (Vlosky and Chance 1996). The southeastern United States is includes approximately 12 million ha of pine plantations (Ince 2001) and these forests comprise 15% of global wood fiber (Wear and Greis 2002, Siry et al. 2006). Changing technology, along with a rising world-wide desire to conserve natural resources, has prompted forest industries to adapt new management techniques. Forest certification programs, such as the Sustainable Forestry Initiative (SFI) have encouraged forest management techniques based on conserving biodiversity, wildlife habitat, species at risk, and protection of water quality (Sustainable Forestry Initiative Inc. 2005). Many timber companies have adopted similar, internally-driven, sustainable forest management strategies.

Timber industries focused on managing softwood (e.g., pine) in the southeastern United States primarily use plantation silviculture. Plantation silviculture relies on intensive management of even-aged stands and typically results in short rotation lengths (Gresham 2002). Intensive management of these stands involves manipulating site resources, tree genetics, and stand demographics to optimize tree growth. Plantation silviculture is most successful when maintaining a positive economic return on investment through enhanced site productivity and environmental quality (Vance et al. 2010). Mechanical and chemical site treatments are used to increase pine productivity in intensively managed stands, and raised beds are commonly used to elevate seedlings above the water table and increase access to light, nutrients, and water (Morris and Lowery 1998). Other mechanical site preparation techniques include clearing, raking, chopping, disking and ripping, and burning. Chemical treatments such as herbicides and fertilizers also provide seedlings with a competitive advantage (Miller et al. 1999).

Although mechanical and chemical treatments increase timber yield, they have varying effects on development and composition of the understory (Carnus et al. 2006, Iglay et al. 2010b, Lane *in press*). Clearly, site treatments can affect successional trajectories of plant communities, and hence, species of flora and fauna inhabiting forest stands. A goal of sustainable forest management is to minimize deleterious effects to wildlife from site preparation. Thus, effects of silvicultural treatments on plant and wildlife communities are of interest to forest products companies and natural resource managers alike (Miller and Miller 2004).

Weyerhaeuser Company (WeyCo) has a long history of forest stewardship and environmental management programs, including managing within the SFI standards. WeyCo is the largest industrial landowner in Louisiana and is particularly interested in continuous improvement via research and technological innovation, including understanding the effects of stand establishment treatments on vegetation and wildlife communities. Common stand establishment practices throughout private timberlands in the southeast include creating rows of elevated seed beds, in which logging debris is left in the area between beds (Edwards 2004, Lane 2010). Different variations of site treatment may maximize both timber yield and wildlife habitat. For example, WeyCo currently plants on 6.1 m (20 ft.) row spacing and logging debris is scattered throughout the stand. Variation in row spacing or debris distribution may be more beneficial to both timber yield and wildlife habitat.

Row spacing has economic and biological implications that WeyCo strives to balance. It is believed that wider row spacing creates differences in canopy cover that may affect vegetation succession, and composition and diversity of plants growing between rows of planted seedlings.

Delayed canopy closure may benefit wildlife that us early successional plant communities. The time between tree harvest and canopy closure is often characterized by abundant white-tailed deer *(Odocoileus virginanus)* forage (Johnson 1987, Blair and Enghart 1977, Miller et al. 1999, Jones et al. 2009). Northern bobwhite *(Colinus virginianus)* is a species of concern throughout the southeast and its populations are inextricably linked to quality of early successional plant communities (Brennan 1991, Howell et al. 2009). Likewise, the gopher tortoise *(Gopherus polyphemus)* is a federally-listed threatened species and uses early successional understory plant communities in upland pine forests (Diemer 1986). From a forest production standpoint, wider row spacing provides more space for individual tree growth and can improve timber quality and quantity. Improving timber quality can benefit future growth and yield of commercial species (Baldwin and Cao 1999). Row spacing also may determine the rate and amount of woody encroachment, a factor important for pine production (Jagodzinski 2009).

Coarse woody debris (CWD) includes standing or fallen dead wood and is considered a manageable ecosystem component (McMinn and Crossley 1996). Coarse woody debris has many ecological functions within ecosystems and is crucial for providing habitat for many species (Elton 1966, Harmon and Franklin 1986). For instance, CWD creates travel corridors, and provides protection, denning, hunting, resting, and breeding habitat to small mammals and many other species (Harmon et al. 1986, Thompson et al 2003). Debris distribution can impact vegetation structure and the creation of microhabitats throughout the stand, affecting mammal communities. Debris piling is used to facilitate drainage and decrease vegetation encroachment (Zeide and Sharer 2000). Research involving CWD has predominantly focused on volume within stands of middle to old growth (Carey and Johnson 1995). Little information pertaining to CWD in newly harvested pine stands exists and there is a notable lack of research involving effects of

CWD arrangement on small mammal communities. Understanding effects of CWD on animal and plant communities in loblolly pine forests is particularly important due to the predominance of this forest type in the southeast (McMinn and Crossley 1996).

Objectives

This research examined relationships of row spacing and distribution of logging debris, on small mammal communities and vegetation composition within recently regenerated loblolly pine stands owned by WeyCo in Louisiana, United States. The treatment response of vegetation communities is particularly important in regards to habitat and feeding needs of various wildlife species.

Specific research objectives included:

- Assessing plant communities relative to row spacing and distribution of logging debris through time
- Evaluating small mammal community response to different row spacing patterns and distribution of logging debris, both temporally and spatially
- Comparing effects of row spacing and distribution of logging debris on forage production and nutritional carrying capacity for white-tailed deer (hereafter deer).

Study Area

We conducted semiannual field sampling during the growing seasons of 4 years (2006, 2007, 2009, and 2010) on 4 study sites located in 2 areas of north-central Louisiana (sites A and B) and 2 areas of southeast Louisiana (sites C and D) (Figure 1.1).

The north-central Louisiana sites were in Winn and Jackson parishes approximately 27 km from Jonesboro (32°2’N, 92°6’W). Mean annual rainfall was 151 cm, and average

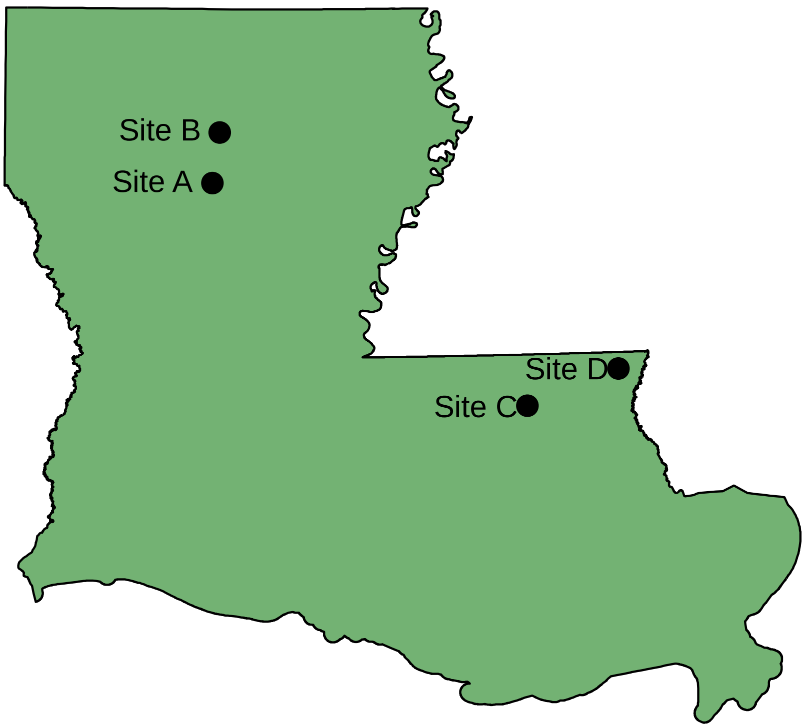

Figure 1.1. Location of 4 study sites chosen to investigate the effects of site preparation including variation in row spacing and distribution of logging debris on small mammal and vegetation communities in Louisiana, USA, 2006-2010.

January low and July high temperatures were 0.5 and 33°C, respectively (National Oceanic and Atmosphere Administration 2011). Soil type was a fine sandy loam (Natural Resources Conservation Service 2009). Elevation ranged from 35-60 m above sea level. Southeast Louisiana sites were in Tangipahoa and Washington parishes approximately 42 km from Franklinton (30°8’N, 90°1’W). Mean annual rainfall was 163 cm and January low and July high temperatures were 3.3 and 33°C, respectively. Soil type was a very fine sandy loam (Natural

Resources Conservation Service 2009). Elevation ranged from 30 to 77 m above sea level. All sites were predominantly upland pine ecosystems with interspersed streamside management zones (SMZ's).

All sites were owned by WeyCo and the primary land use of each study site was intensive management of loblolly pine (*Pinus taeda*) stands. The primary target product was sawtimber with fiber removed during silvicultural thinning. Sites were harvested using clear cutting in 2005 and replanted in 2006. All stands were >20 years old prior to harvest. Replanting involved standard and experimental treatments, on which this research was focused. All sites received a banded application of Arsenal® AC (4 oz/ac, BASF Corp. Research Triangle Park, NC) and Oust Extra® (2.5 oz/ac, DuPont™ Crop Protection, Wilmington, DE) within the first growing season. Sites received a hardwood release treatment of Arsenal® AC (12 oz/ac) in years 2 or 3 post-planting.

Four plots (experimental units) of 10.1 ha were designated within each site, with each site encompassing approximately 60.7 ha. Experimental units in each site were randomly assigned row spacing treatments. Two units (20.2 ha) were assigned 4.3 m spacing and 2 units were assigned 6.1 m spacing. Each row-spacing width received 2 different treatments involving distribution of logging debris after harvesting. One treatment consisted of the standard approach used by WeyCo where debris is scattered throughout the stand following harvest. The second treatment involved piling debris into 5 large piles located throughout the stand. The resulting study design was a randomized complete block design including 4, 10.1 ha experimental units at 4 sites (Figure 1.2). The treatment combination of 6.1 m spacing and scattered debris arrangement is the standard approach used by WeyCo.

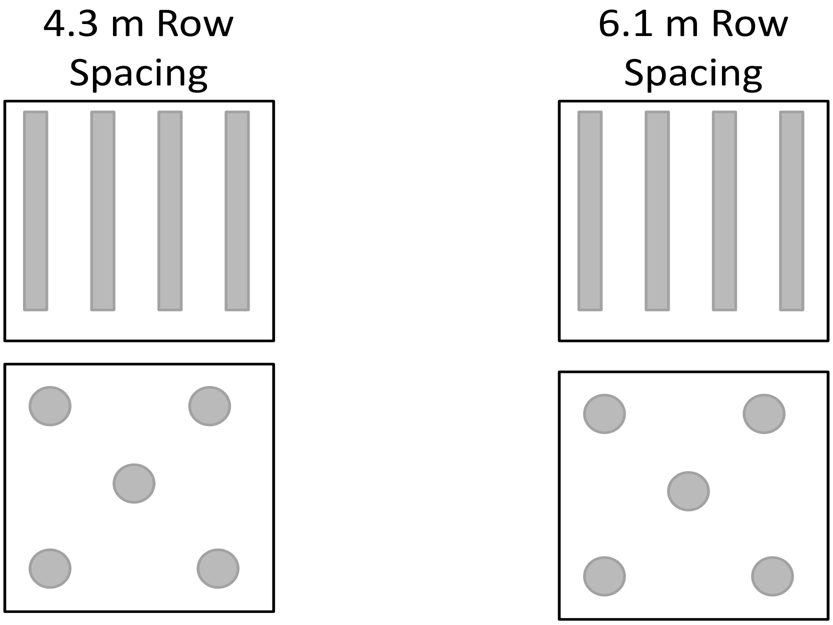

Figure 1.2.Treatment combination of row spacing (4.3 m and 6.1 m) and distribution of logging debris (piled and scattered) applied to 4 sites in north and southeastern Louisiana, USA, 2006-2010.

CHAPTER II. EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON VEGETATION COMMUNITIES IN NEWLY ESTABLISHED LOBLOLLY-PINE PLANTATIONS IN LOUISIANA

Introduction

Commercial pine forests in the southeastern United States are an important source of global wood supply (Siry et al. 2006). Increasing demand has resulted in intensive management regimes that increase wood forest productivity in southern managed forests (Wagner et al. 2004). A goal of intensive management is to reduce competition with pine seedlings and shorten rotation lengths. Forest managers often use mechanical and chemical site preparation to facilitate planting and increase growth rate and quality of loblolly pine (Gresham 2002). However, forest ecosystems contain considerable terrestrial biological diversity, making it necessary to manage forest land for productivity and sustainability of the ecosystem (Carnus et al. 2006); this is evidenced by the increasing use of forest certification systems (e.g. Miller et al. 2009). Increasing concern for sustainability requires an understanding of how site preparation techniques affect flora and fauna communities. Therefore, vegetation response to silvicultural treatments is of interest to forest landowners and natural resource managers alike (Miller and Miller 2004).

Research examining effects of site preparation on floristic diversity within intensively managed forests is limited (see Miller and Miller 2004, Jones 2008, Lane 2010), prompting Miller and Miller (2004) to encourage further research examining silvicultural treatment effects on plant communities. Previous work has focused on chemical site treatments alone, or in combination with a mechanical treatment such as prescribed burning (Miller and Miller 2004, Jeffries 2002, Miller and Chamberlain 2008). However, research examining mechanical site preparation, including stand structure (row spacing) and distribution of logging debris, is lacking.

Wider row spacing is assumed to increase sunlight exposure, and increase access to nutrients, thus enhancing establishment of semi-woody and herbaceous understory species (Osbourne and Anderson 2002). Additionally, wider rows may delay time to canopy closure of pines, thus increasing time stands provide early successional habitat conditions. Extending early seral stages benefits wildlife species that thrive in early successional habitat. However, extended time to canopy closure could potentially promote woody encroachment, increasing resource competition and reducing growth and yield of pine trees (Haywood 1994, Miller et al. 1995).

Logging debris has significant impacts on microhabitat and availability of nutrients to plants (Harmon et al. 1986). Research efforts have focused extensively on effects of logging debris volume on plant and wildlife communities in mature forests (Loeb 1999, Mengak and Guynn 2003). Relatively little research has examined the relationship between plant communities and debris placement in recently established stands. Because understanding components of site preparation, such as row spacing and woody debris distribution, is critical to successfully managing for forest productivity and sustainability, we examined plant community response following site preparation with experimental row spacing and distribution of logging debris within intensively managed pine stands in Louisiana, USA.

Methods

Study Area

We studied plant communities in four, early-rotation, loblolly pine plantations of approximately 60.7 ha each. Sites were owned and managed by WeyCo and harvested using clear cutting in 2005 and replanted during winter 2006. All stands were >20 years old prior to harvest. Replanting involved standard row spacing debris distribution techniques as well as experimental techniques on which this research was focused. Study sites were located in 2 areas of north-central Louisiana (Winn and Jackson parishes) and 2 areas of southeast Louisiana (Tangipahoa and Washington parishes) (See Figure 1.1, Chapter 1). Mean annual rainfall ranged from 150.62 - 163.10 cm and average January low and July high temperatures were 3.3 and 33° C, respectively (National Oceanic and Atmosphere Administration 2011). Elevation ranged from 30 to 77 m above sea level. All sites received a banded application of Arsenal® AC (4 oz/ac, BASF Corp. Research Triangle Park, NC) and Oust Extra® (2.5 oz/ac, DuPont™ Crop Protection, Wilmington, DE) within the first growing season. Sites received a hardwood release treatment of Arsenal® AC (12 oz/ac) in years 2 or 3 post-planting. The site located in Tangipahoa parish received the hardwood release treatment in fall prior to 2010 sampling, following standard operating procedures for substantial woody growth of non-pine species. The sites were predominantly upland pine forests with interspersed streamside management zones (SMZs). Dominant woody and semi-woody species generally included loblolly pine, red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), black cherry (*Prunus serotina*) and brambles (*Rubus* spp.). Dominant grasses included bluestems (*Andropogon* spp.), rosette grasses (*Dicanthelium* spp.) and paspalum grasses (*Paspalum* spp.) among others (Miller and Miller 2009, USDA Plants Database 2009).

Data Collection and Analysis

We established 4, 10.1 ha plots (stands) within each site ($n = 4$) to which we randomly assigned a treatment combination. Treatments included 2 row spacing widths (4.3 m and 6.1 m) and 2 debris distributions (scattered and piled). Scattered debris distribution consisted of the standard approach used by WeyCo; scattering logging debris between rows throughout the stand (Bechard 2008). The second debris treatment involved piling logging debris into 5 large piles located throughout the stand. The resulting design represented a randomized complete block design consisting of 4 stands within each site, representing one of 4 treatment combinations.

We collected vegetation data annually during the growing seasons (June –July) of 2006, 2007, 2009, and 2010. We systematically established 5 circular sampling plots (0.04 ha) on a diagonal transect in each stand to account for possible differences in aspect, slope, and microclimate. Distance between sampling plots depended on the size of each stand and our ability to sample the entire 10.1 ha stand. In each sampling plot, we measured vegetation composition, vertical obstruction, and average and maximum vegetation height (m) at the center and 10 m in each cardinal direction from the center of the sampling plot following methods outlined by Bechard (2008). We measured vegetation composition by visually estimating percentage cover of 7 vegetation categories (grass, forbs, woody, vine, debris, bare ground, and fern) in a 1 m^2 Daubenmire frame (Daubenmire 1959). We measured vertical obstruction and average and maximum vegetation height visually using a 1 m Robel pole with 0.1 m increments (Robel 1970). We measured plant diversity using the line intercept method by counting proportion of individual species/genera intersecting a 10 m transect (Canfield 1941). We estimated species richness by totaling number of different plant species occurring across transects within each stand. We estimated plant species diversity in each stand using the Shannon-Weaver index (Ludwig and Reynolds 1988, Miller and Chamberlain 2008). We excluded debris and bare ground from species richness and diversity estimates. We designated 6 plant species or groups as important based on wildlife value or interest to timber management; sweetgum, beautyberry (*Callicarpa americana*), goldenrod (*Solidago* spp.), bluestem, brambles and yaupon (*Ilex vomitoria*). We determined an absolute count of woody stems in each sampling plot to provide mid- and overstory species composition. We identified plants to genus or species as needed using Miller and Miller (1999) and the USDA Plant Index (2009).

We used mean response of each variable across transects for 4 years, with stands as the experimental units (*n* = 16), to quantify response variables. Because structural and compositional vegetation data were assumed to be highly correlated, we conducted a principal component analysis (PCA) to reorganize vegetation composition, stem counts, vertical obstruction and height data into components (PROC FACTOR; SAS Institute 2009). We analyzed scree plots and eigenvalues >1 to determine number of principal components to retain (*n* = 4; see Results). We used VARIMAX rotation to simplify interpretation of the factors (Jackson 1993). We designated principal components (PC) according to which variables loaded highly upon them (Table 2.1). Woody vegetation variables primarily loaded highly on PC1; therefore, we distinguished PC1 as the woody component. Grass and debris cover explained much of the variance in PC2. Principal component 3 was considered as a yaupon component whereas PC4 accounted for forbs.

We used a mixed model analysis of variance (ANOVA) blocked on site to test for main effects of year, treatment, and year by treatment interactions for each principal component individually (PROC MIXED; SAS Institute 2009). We tested the null hypothesis that the principal components did not differ among years or treatments. If significant year effects occurred, we used least-squared means with Tukey-Kramer correction for multiple comparisons.

To quantify effects of year and treatment, and their interaction, on species diversity, we used repeated measures mixed model analyses of variance (ANOVA) with year and treatment as main effects, year as a repeated measure and stand as the subject (PROC MIXED; SAS Institute 2009). When a statistical difference was detected among years, we used least squared means with

Bonferonni corrections for multiple comparisons to determine where differences occurred. We tested the null hypothesis that species richness, species diversity and relative abundance of 6 plant species/groups did not differ among years or treatments.

Results

Vegetation Structure and Composition

We documented 124 plant species or genera (12 grass, 45 woody tree or shrub, 6 vine, and 61 forbs) in sampling plots (*n*=64) among all sites. Dominant grass species on our sites included bluestem and rosette grasses whereas forbs included common ragweed (*Ambrosia artemisiifolia*), goldenrod, woolly croton (*Croton capitatus*), bonesets (*Eupatorium* spp.) and asters (*Aster* spp.). Our sites were characterized by dominant woody mid-story species including yaupon, Eastern baccharis (*Baccharis halimifolia*), beautyberry, and winged sumac (*Rhus copallina*). Abundant vines included brambles and greenbriars (*Smilax* spp.).

Based on eigenvalues ≥1 and scree plot analysis, 4 principal components were retained for analysis of vegetation structure and composition data, accounting for 67% of the variance (Table 2.1). In interpreting the rotated factor pattern, a variable loaded on a given component if the factor loading was $^{\pm}$ 0.60 or greater for that component (Table 2.2.). There were no significant (*P*_>0.05) second or third order interactions for any comparisons.

Principal component one (percent cover woody vegetation, hardwood stem count, vegetation height) differed between debris treatments and among years (Tables 2.2, 2.3). Absolute hardwood stem counts were greater in scattered debris (35.05 ± 2.98) than in piled debris (31.47 ± 3.49) and hardwood stems generally increased from 2006 to 2010. Hardwood stems were greater in 2009 and 2010 (Table 2.3; $t_{41.6} = {}^{-}8.83$ - ${}^{-}2.30$, $P < 0.001$) than 2006 and 2007. Percentage cover of woody vegetation differed between debris treatments, but was likely biologically insignificant due to minor differences between means. Among years, woody cover was more abundant in 2009 and 2010 (Table 2.3; $t_{41.8}$ = ¯7.59 - 6.74, *P* <0.001) than 2006 and 2007 (Table 2.3).

Minimum, maximum and average vegetation height differed between debris treatments and among years (Table 2.2). Average vegetation height was greater in scattered debris (0.65 m ± 0.03) than in piled debris (0.52 m ± 0.02) and was greater in 2009 and 2010 (Table 2.3; $t_{41.8}$ = ¯6.74 – ¯7.59, *P* < 0.001-0.002) than 2006 and 2007 (Table 2.3). Principal component 2 (percent cover grass, percent cover debris) did not differ between treatments or among years (Table 2.2).

Percentage cover of grass and debris were similar across treatments and over time (Table 2.3). Principal component 3 (percent cover of yaupon) differed among debris distribution and among years (Tables 2.1, 2.2).

Table 2.1 Eigenvalues and variance explained by each principal component developed through rotated factor loading of 12 vegetation attributes measured on 4 young, intensively managed loblolly pine stands in north and southeast Louisiana during June – July, 2006-2010.

	Component			
Variables	1	2	3	4
Eigenvalue	4.25	1.63	1.10	1.03
Variance explained	0.35	0.14	0.09	0.09
Percent cover yaupon	0.24	0.01	0.88	0.01
Percent cover fern	0.21	-0.07	-0.06	-0.50
Percent cover vine	0.58	-0.12	0.12	-0.07
Percent cover woody	0.68	0.01	-0.02	-0.24
Percent cover forbs	0.32	-0.04	-0.09	0.80
Percent cover grass	-0.09	0.93	-0.04	-0.09
Percent cover bare ground	-0.48	-0.59	0.36	-0.01
Percent cover debris	-0.13	-0.61	-0.23	-0.21
Hardwood stem count	0.74	0.01	0.40	-0.10
Minimum height (m)	0.85	0.13	0.21	0.12
Maximum height (m)	0.80	0.25	0.09	0.27
Average height (m)	0.83	0.24	-0.07	0.18

*Bold type indicates variables included in that component.

Table 2.2. Test statistics for mixed model analysis of variance (ANOVA) of main effects on principal components used to examine plant community response in regenerating loblolly pine stands site prepared with a combination of row spacing and debris distribution in north and southeast Louisiana, USA, 2006-2010. All tests significant at *P* < 0.05.

	ANOVA results				
Component	Effect	Num DF	Den DF	F-value	*P*-value
PC1	Year	3	41.6	52.78	<0.001
	Row	1	41.7	1.69	0.200
	Debris	1	41.7	6.67	0.013
PC2	Year	3	44.8	1.14	0.344
	Row	1	44.8	0.69	0.411
	Debris	1	44.8	0.45	0.505
PC3	Year	3	44.7	61.65	<0.001
	Row	1	38.3	2.15	0.151
	Debris	1	38.3	9.18	0.004
PC4	Year	3	44.9	4.67	0.010
	Row	1	45.1	3.31	0.080
	Debris	1	45.1	3.62	0.063

Percentage cover of yaupon was greater in piled (4.58 ± 0.77) than scattered debris (3.78 ± 0.62). Yaupon cover was similar in 2006 and 2007 (Table 2.3; $t_{42.2}= {}^{-}2.26$; $P= 0.76$), but generally increased from 2007 to 2010 (Table 2.3; $t_{41.9} = {}^{-}13.69 – {}^{-}5.16$; $P < 0.001 – 0.002$).

Finally, principal component 4 (percent cover forbs) did not differ between treatments, but did differ among years (Table 2.2). Percentage cover of forbs was greater in 2009 (17.53 ± 1.45; $t_{46}= -4.29$, $P < 0.001$) than 2006 (7.10 ± 0.95).

Species Diversity

There were no significant (P =0.05) second or third order interactions for any comparisons. Mean species richness differed among years, but not among treatments (Table 2.4). Species richness generally increased from 2006 to 2010 (Table 2.5; $t_{45} = {}^{-}5.53 - {}^{-}3.42$; $P < 0.001 –$ 0.008), but was similar in 2009 and 2010 (Table 2.5; $\underline{P} \geq 0.05$). Species diversity differed among

Table 2.3. Mean values with associated stand errors (SE) of vegetation attributes explaining four principal components characterizing vegetation structure and percent composition in regenerating loblolly pine stands site prepared with a combination of row spacing (4.3 m, 6.1 m) and debris distributions (S, P) across sites in north and southeastern Louisiana, USA, 2006-2010.

		Mean (SE)								
Year	Treatment	Hardwood Stems	Min. Height (m)	Max. Height (m)	Avg. Height (m)	Yaupon (%)	Woody (%)	Forbs (%)	Grass (%)	Debris (%)
2006	4.3S	6.36 (2.13)	0.17 (0.03)	0.43 (0.07)	0.30 (0.05)	0.02 (0.02)	2.39 (0.91)	5.25 (1.60)	31.14 (7.52)	22.82 (4.98)
	4.3P	6.12 (2.14)	0.23 (0.05)	0.48 (0.07)	0.35 (0.06)	0.00	3.57 (1.66)	9.10 (2.63)	25.35 (7.39)	14.94 (3.71)
	6.1S	9.97 (2.05)	0.21 (0.03)	0.64 (0.06)	0.43 (0.04)	0.00	3.77 (1.10)	8.71 (1.93)	24.77 (5.31)	23.73 (4.07)
	6.1P	6.80 (2.32)	0.17 (0.04)	0.45 (0.07)	0.31 (0.06)	0.00	2.31 (0.93)	5.37 (1.36)	21.17 (5.10)	16.48 (3.27)
2007	4.3S	9.50 (1.91)	0.27 (0.04)	0.71 (0.07)	0.49 (0.05)	0.06 (0.03)	5.57 (1.08)	0.64 (1.58)	26.58 (3.51)	7.95 (2.32)
	4.3P	5.13 (1.08)	0.17 (0.03)	0.75 (0.07)	0.46 (0.04)	0.00	4.25 (0.86)	14.86 (2.84)	28.23 (5.03)	2.74 (1.08)
	6.1S	12.53 (3.41)	0.36 (0.06)	0.92 (0.07)	0.64 (0.06)	0.06 (0.04)	9.21 (1.92)	11.58 (1.86)	27.53 (4.47)	11.66 (3.06)
	6.1P	8.30 (2.32)	0.28 (0.05)	0.65 (0.07)	0.47 (0.05)	0.15 (0.11)	7.80 (2.48)	11.19 (1.92)	25.09 (3.38)	3.66 (1.44)
2009	4.3S	52.90 (6.15)	0.70 (0.08)	1.37 (0.05)	1.01 (0.11)	2.15 (1.06)	13.11 (2.36)	13.20 (1.61)	20.77 (3.18)	13.36 (2.64)
	4.3P	42.35 (11.31)	0.58 (0.08)	1.25 (0.06)	0.66 (0.08)	1.05 (0.62)	6.94 (1.89)	16.15 (2.80)	30.29 (4.06)	2.55 (0.56)

(Table continued)

2010	6.1S	45.00	0.63	1.38	0.90	1.94	7.96	17.91	22.68	12.40
		(6.59)	(0.06)	(0.04)	(0.07)	(1.19)	(1.64)	(2.13)	(3.77)	(2.08)
	6.1P	50.15	0.65	1.36	0.79	0.15	11.77	22.86	26.12	4.96
		(13.13)	(0.06)	(0.04)	(0.09)	(0.15)	(2.83)	(4.16)	(4.87)	(1.11)
	4.3S	92.80	0.96	1.31	0.83	16.20	11.45	13.36	29.25	9.70
		(8.76)	(0.08)	(0.05)	(0.09)	(2.12)	(2.83)	(1.96)	(3.92)	(1.55)
	4.3P	83.85	0.80	1.13	0.63	24.15	10.55	13.75	29.58	4.52
		(11.36)	(0.09)	(0.07)	(0.07)	(3.54)	(1.98)	(2.14)	(3.78)	(1.10)
	6.1S	95.10	1.03	1.36	0.90	16.40	13.35	18.20	21.55	11.50
		(9.66)	(0.06)	(0.04)	(0.05)	(3.12)	(3.28)	(2.66)	(2.32)	(1.75)
	6.1P	92.50	0.84	1.20	0.75	19.06	14.25	23.25	23.20	3.55
		(14.04)	(0.09)	(0.07)	(0.07)	(3.07)	(3.37)	(4.23)	(2.94)	(1.23)

Table 2.4. Test statistics of repeated measures analysis of variance (ANOVA) for main effects on 8 vegetation attributes characterizing species richness, diversity and abundance in regenerating loblolly pine stands prepared with a combination of row spacing and debris distribution in north and southeastern Louisiana, USA, 2006-2010. All tests significant at $P < 0.05$.

	Repeated measures ANOVA results		
	Effect[a]	F-value	*P*-value
Species richness	Year	35.58	<.001
	Row	2.78	0.300
	Debris	1.10	0.103
Species Diversity	Year	24.29	<.001
	Row	1.02	0.319
	Debris	2.11	0.153
Bluestem	Year	1.18	0.328
	Row	0.66	0.524
	Debris	0.00	0.981
Goldenrod	Year	0.68	0.570
	Row	3.45	0.070
	Debris	0.02	0.885
Sweetgum	Year	2.00	0.127
	Row	0.12	0.732
	Debris	0.00	0.987
Beautyberry	Year	7.09	0.001
	Row	2.30	0.137
	Debris	0.00	0.537
Rubus	Year	6.18	0.001
	Row	0.36	0.552
	Debris	1.06	0.310
Yaupon	Year	1.55	0.215
	Row	0.19	0.669
	Debris	4.21	0.046

a. Degrees of freedom (numerator, denominator) are 3, 45for year and year by treatment; 1, 45 for treatment.

years, but not among treatments (Table 2.4). Among years, species diversity increased from 2006 to 2009 Table 2.5; $t_{45} = ¯7.34 - ¯2.82$; $P < 0.001 – 0.043$), but remained similar in 2009 and 2010 (Table 2.5; $P \geq 0.05$).

Mean relative abundance of bluestem and goldenrod did not differ among treatments or among years (Table 2.4). Mean relative abundance of sweetgum differed among years by row spacing (F=3.39, P = 0.026). In 2007, we found greater relative abundance of sweetgum in 6.1 m spacing (Table 2.5; $t_{45} = -2.28$; P= 0.027) than 4.3 m spacing. Stands with 6.1 m spacing had the greatest relative abundance of sweetgum in 2007 (Table 2.5; $t_{45} = -3.03$ – 2.91; P = 0.004). Mean relative abundance of beautyberry differed in 6.1 m spacing among years ($F_{1, 45}$ = 0.21; P = 0.014) and by year, but was not affected by row spacing or debris alone (Table 2.4). Among years, relative abundance of beautyberry was similar in 2006 and 2007 (Table 2.5; $P \geq 0.05$) and increased from 2007 to 2009 ($t_{45} = -3.59$; P = 0.005). Relative abundance of beautyberry generally increased in 6.1 m spacing over time with the greatest abundance in years 2009 and 2010 (Table 2.5; $t_{45} = -4.96$; P <0.001). Mean relative abundance of brambles differed among years but not by treatment (Table 4). Relative abundance of brambles generally increased and was greater in 2010 (Table 2.5; $t_{45} = -4.16$; P = 0.001) than 2006 (Table 2.5). Finally, mean relative abundance of yaupon differed with respect to debris distribution but not by row spacing or across years (Table 2.4). We found a greater relative abundance of yaupon in stands with scattered debris (2.16 % ± 0.01) than those with piled debris (0.01% ± 0.00).

Discussion

Site preparation where logging debris was scattered generally resulted in increased woody vegetation (PC1) as indicated by greater woody cover, more hardwood stems, and increased vegetation height. Scattering debris throughout the stand potentially creates more microhabitats than piling debris in a few, specific, locales. Logging debris functions as seed banks, reservoirs of moisture during droughts, and increased nutrient exchange sites for plants

(Van Lear 1993). Scattered debris presumably would provide conditions favorable for rapid seed germination throughout the stand.

Relative abundance of yaupon was greater in stands with scattered debris, although percentage cover of yaupon was greater in stands with piled debris. This apparent contradiction could be a result of the height of yaupon plants within each treated stand. As mentioned previously, stands with scattered debris had greater vegetation height and woody cover throughout the stand. It is likely that yaupon grew vertically in areas with scattered debris to compete with a greater number of woody plants. Alternatively, lower vegetation height on sites with piled debris suggests yaupon grew more laterally due to less abundant woody cover and vertical competition. Presence of yaupon can have potentially negative effects on vegetation communities due to its ability to dominate understory vegetation, thus reducing species richness and diversity (Moreland 2005, Chamberlain and Miller 2006). We observed an increase in relative abundance of beautyberry over time on sites with 6.1 m spacing. Beautyberry and yaupon share many characteristics and readily compete within the understory. However, beautyberry has a more rapid growth rate than yaupon and is considered a far better plant for wildlife because of its fruit and seed production (USDA Plants Database 2011). It is likely that treatment effects on the overall woody component, and individual species, were limited due to the hardwood release treatment prior to the final growing season on the Tangipahoa parish site. Imazapyr® is known to drastically reduce, and control, broadleaf herbs and woody species upon initial application and during subsequent growing seasons (Iglay 2010, Lane et al. *in press*). We suspect that effect sizes for the woody component would have been greater if this site remained untreated.

Table 2.5. Mean relative abundance (%) and values of species richness and diversity, with associated stand errors (SE), in regenerating loblolly pine stands subjected to combination of row spacing (4.3 m, 6.1 m) and debris distributions (S, P) across sites in north and southeastern Louisiana, 2006-2010.

		Mean (SE)							
Year	Treatment	Species Richness	Species Diversity	Bluestem	Goldenrod	Sweetgum	Beautyberry	Rubus	Yaupon
2006	4.3S	4.05 (0.35)	2.75 (0.31)	20.02 (0.17)	0.02 (0.01)	1.07 (0.01)	0.00	4.03 (0.03)	0.50 (0.00)
	4.3P	3.05 (0.42)	2.10 (0.20)	19.48 (0.19)	0.00	1.92 (0.01)	0.00	4.00 (0.03)	0.20 (0.00)
	6.1S	3.25 (1.65)	2.22 (0.67)	15.92 (0.16)	0.04 (0.04)	0.65 (0.01)	0.00	2.14 (0.01)	0.30 (0.01)
	6.1P	2.70 (0.99)	2.00 (0.37)	14.28 (0.14)	0.03 (0.03)	0.42 (0.00)	0.00	1.19 (0.01)	0.12 (0.00)
2007	4.3S	5.30 (1.14)	3.27 (0.60)	14.43 (0.02)	0.01 (0.00)	0.65 (0.00)	0.75 (0.01)	9.73 (0.07)	2.14 (0.01)
	4.3P	4.05 (0.50)	2.63 (0.18)	20.90 (0.12)	0.01 (0.00)	0.70 (0.01)	0.00)	9.95 (0.06)	0.65 (0.01)
	6.1S	4.80 (0.74)	3.22 (0.71)	15.77 (0.12)	0.04 (0.02)	2.76 (0.00)	0.00	5.50 (0.05)	1.57 (0.01)
	6.1P	4.84 (0.52)	2.95 (0.32)	13.54 (0.10)	0.02 (0.02)	2.19 (0.02)	0.00	8.64 (0.07)	0.44 (0.00)
2009	4.3S	9.75 (1.13)	4.54 (.044)	9.23 (0.05)	0.02 (0.01)	0.50 (0.00)	0.85 (0.01)	10.10 (0.01)	3.06 (0.02)
	4.3P	8.75 (0.38)	4.29 (0.62)	10.40 (0.05)	0.02 (0.00)	0.27 (0.00)	0.07 (0.00)	5.22 (0.02)	2.46 (0.02)
	6.1S	9.40 (1.33)	4.57 (0.70)	8.03 (0.03)	0.02 (0.01)	0.55 (0.00)	4.23 (0.02)	11.24 (0.02)	2.91 (0.02)
	6.1P	10.05 (1.61)	4.46 (0.77)	3.71 (0.01)	0.02 (0.04)	0.72 (0.01)	3.63 (0.03)	6.44 (0.02)	0.37 (0.00)

(Table continued)

2010	4.3S	9.85 (0.66)	5.10 (0.50)	7.09 (0.05)	0.04 (0.02)	1.00 (0.01)	2.06 (0.00)	13.21 (0.03)	2.81 (0.01)
	4.3P	9.85 (1.32)	4.57 (0.29)	9.43 (0.05)	0.02 (0.00)	0.87 (0.01)	1.49 (0.01)	9.50 (0.04)	0.47 (0.00)
	6.1S	8.75 (1.30)	4.31 (0.76)	6.89 (0.04)	0.05 (0.03)	0.60 (0.00)	5.45 (0.03)	11.92 (0.03)	3.98 (0.03)
	6.1P	8.55 (0.53)	4.48 (0.16)	6.32 (0.03)	0.08 (0.06)	0.62 (0.00)	3.53 (0.03)	12.51 (0.00)	0.00 (0.00)

Relative abundance of beautyberry and brambles, percentage cover of forbs, and amount of woody vegetation differed across years. A decrease in percentage cover of forbs and an increase in percent cover of yaupon in 2009 and 2010 reflected simple successional changes as pine seedlings aged and woody vegetation became more prominent. Relative abundance of brambles was not affected by row spacing or debris distribution, but increased throughout the course of the study. Brambles are common in early forest plantations and may persist into later stand rotation in combination with woody control and thinning (Miller and Miller 1999), suggesting mechanical site preparation techniques would have little effect on establishment of this group of species. Brambles are an important resource in young pine plantations, providing cover and forage for many wildlife species throughout the southeast. Specifically, brambles are considered to be among the most important forage plants for white-tailed deer (*Odocoileus virginianus*; Askins 2001, Moreland 2005) and also provide forage and habitat for numerous small mammal and bird species (Miller and Miller 1999). Notably, relative abundance of goldenrod did not differ among treatments or years despite the reduction of woody vegetation in stands with piled debris. Presumably, reducing woody species would promote understory species such as goldenrod but this was not the case in our study. Basal rosettes are commonly consumed by wild turkey (*Meleagris gallopavo*) during winter months whereas many species of birds consume goldenrod seeds. Browsing by white-tailed deer may occur before flowering at a high rate in Louisiana (Miller and Miller 1999, Moreland 2005). Goldenrod was among the most abundant species on our sites, and given the abundance of only a few understory species, we would expect it to be a key forage and cover species for wildlife inhabiting sites similar to those we studied.

Species richness and diversity was not affected by row spacing or distribution of logging debris. In a similar study examining the effects of row spacing on vegetation in North Carolina, USA, Lane (2010) also observed that mechanical site preparation involving row spacing had little effect on species richness and diversity. However, we did find that species richness generally increased through time before stabilizing in 2010 likely due to successional changes as canopy closure increased throughout study plots. We found species diversity increased from 2006 to 2007 but remained similar across the remaining years of the study. Herbaceous vegetation has been found to establish quickly in mechanically prepared sites (Miller et al. 1995, O'Connell and Miller 1994), likely accounting for an initial increase in species diversity. Previous research has shown few differences in species diversity during initial years following mechanical site preparation (Hurst et al. 1994, O'Connell and Miller 1994), consistent with our findings, as species diversity remained similar following initial establishment.

Management Implications

Our findings demonstrate that distributing debris in larger piles throughout the stand decreased the overall woody component of the stand, including vegetation height. Average and minimum vegetation height is representative of mid and understory vegetation, suggesting that stands with piled logging debris had reduced height of non-pine vegetation. From an industrial forest standpoint, this may prove beneficial in reducing woody encroachment and lowering competition for newly planted pine seedlings. Reducing competing woody vegetation increases quality and timber yields (Baldwin and Cao 1999, Glover and Zutter 1993). Ecologically, woody growth suppression has been shown widely throughout the Southeast to promote the growth of an herbaceous understory (Carnus et al. 2006, Miller et al. 1995). Reducing woody growth may also delay time to canopy closure and extend the more diverse early succession plant communities, benefiting numerous wildlife species (Baker and Hunter 2002, Dickson 1982, Litviatis 2001). However, our findings suggest that species richness and diversity may not be a significant factor when planning the implementation of site preparation involving row spacing and distribution of logging debris. This being said, it is important to realize that wider row spacing generally delays canopy closure and increases species diversity and richness (Baker and Hunter 2002, Melchoirs 1991). Additionally, Lane (2010) determined that site preparation with wide row spacing in coordination with banded herbaceous weed control may provide greater herbaceous plant cover. We suspect research examining later stages of succession and stand development may provide further insight into how row spacing affects canopy closure and species diversity and richness.

CHAPTER III. EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON DEER FORAGE AND CARRYING CAPACITY IN NEWLY ESTABLISHED LOBLOLLY PINE PLANTATIONS IN LOUISIANA, USA

Introduction

The southeastern United States is composed of approximately 12 million ha of pine plantation (Ince 2001). The forest products industry is economically important in the southeast, particularly Louisiana, where greater than 48% of land is used for timber production (Clement and Vlosky 2008). To meet increasing wood supply demands, forest managers have adopted more intensive management regimes to increase timber productivity. Intensive forest management involves management of even-aged stands and results in short rotation length. Mechanical and chemical site preparation techniques are used to facilitate planting and increase the speed and quality of loblolly pine growth (Glover and Zutter 1993, Gresham 2002).

Increasing interest in sustainable forest management necessitates an understanding of how site preparation techniques affect wildlife and plant communities. Site preparation increases timber yield, but has varying effects on development and composition of the understory (Carnus et al. 2006). Many wildlife species are associated with pine plantation understory, particularly early seral stages (Askins 2001, Huntly and Inouye 1987), including white-tailed deer (hereafter, deer, Litvaitis 2001). Deer are an important economic and recreational resource in Louisiana and are considered by many to be a keystone herbivore relative to forest understory vegetation (Waller and Alverson 1997, Rooney 2001, Greenwald et al. 2008). Moreover, it is common practice for commercial forest landowners to lease land for sport hunting, primarily deer hunting (Jones et al. 2004).

The considerable interest in deer throughout the southeast, coupled with the known relationship between deer carrying capacity and vegetation quality (Jones et al. 2009), warrants research to explore effects of site preparation techniques on forage. Research examining effects of site preparation on deer forage and carrying capacity is advancing, but limited to primarily chemical or few mechanical treatments (e.g. prescribed fire [Chamberlain and Miller 2006, Mixon et al. 2008, Iglay et al. 2010b]). Research examining effects of mechanical site preparation, including stand structure (row spacing) and the distribution of logging debris, on forage quality for deer is lacking. Logging debris has significant impacts on microhabitat and availability of nutrients to plants (Harmon et al. 1986) and distribution of debris within a stand can affect seed germination of forage species (Van Lear 1993). Wider row spacing is assumed to create differences in canopy cover which may affect vegetation succession and plant communities growing between rows of pine seedlings. The period between planting and canopy closure provides abundant deer forage (Askins 2001, Fuller and Gill 2001). To understand the implications of site preparation on deer forage production, we examined effects of site preparation with experimental row spacing and distribution of logging debris on forage abundance and nutritional carrying capacity for deer.

Methods

Study Area

We quantified abundance of deer forage plants in 4, early rotation, loblolly pine plantations of approximately 60.7 ha each. Sites were owned by WeyCo and harvested using clear cutting in 2005, and replanted during winter 2006. All stands were >20 years old prior to harvest. Replanting involved standard and experimental treatments on which this research was focused. Study sites were located in 2 areas of north-central Louisiana and 2 areas of southeast

Louisiana (Figure 1.1, Chapter 1). Mean annual rainfall ranged from 150.62-163.10 cm and average January low and July high temperatures were 0.5-3.3 and 33° C, respectively. Elevation ranged from 30 to 77 m above sea level. All sites received a banded application of Arsenal® AC (4 oz/ac, BASF Corp. Research Triangle Park, NC) and Oust Extra® (2.5 oz/ac, DuPont™ Crop Protection, Wilmington, DE) within the first growing season. Sites received a hardwood release treatment of Arsenal® AC (12 oz/ac) in years 2 or 3 post-planting. The site located in Tangipahoa parish received the hardwood release treatment in fall prior to 2010 sampling, following standard operating procedures for substantial woody growth of non-pine species. The sites were predominantly upland pine ecosystems with interspersed stream management zones (SMZs). Dominant woody and semi-woody species generally included loblolly pine, red maple *(Acer rubrum)*, sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), black cherry (*Prunus serotina*) and blackberry *(Rubus* spp.). Dominant grasses included bluestems *(Andropogon* spp.), rosette grasses (*Dicanthelium* spp.) and paspalum grasses (*Paspalum* spp.) among others (See Chapter 2, Miller and Miller 2009). All sites received a banded application of Arsenal AC (4 oz/ac) and Oust Extra (2.5 oz/ac) within the first growing season. Sites received a release treatment of Arsenal AC (12 oz/ac) in years 2-3 post planting.

Data Collection and Analysis

We established 4, 10.1 ha plots (stands) within each site (*n*=4) to which we randomly assigned treatments. Treatments included 2 row spacing widths (4.3 m and 6.1 m) and 2 debris distributions (scattered and piled). Scattered debris distribution consisted of the standard approach used by WeyCo; scattering logging debris between rows throughout the stand (Bechard 2008). The second debris treatment involved piling logging debris into 5 large piles isolated throughout the stand. The resulting design represented a randomized complete block design consisting of 4 stands within each site, representing one of 4 treatment combinations (Figure 1.2, Chapter 1).

We used standard methods for estimating deer forage which involved collecting vegetation data annually during the growing seasons (Jun-Jul) of 2009 and 2010 (representing years 4 and 5 in the stand rotation). We placed 10, 1-m^2, Daubenmire frames at equal distance on a diagonal transect across each plot (Daubenmire 1959). We clipped all succulent plant material $\leq$ 1.5 m above ground and identified species/genera (hereafter, species). We composed a list of potential moderate and high quality deer forages (Miller and Miller 1999, Moreland 2005). Clippings were kept frozen until they were oven-dried at a temperature of 70° C for 72 hours (Chamberlain and Miller 2006). We measured dry-weight biomass to the nearest gram and determined total production (kg/ha) for all species (n=95) and preferred forage species (n=36). We selected 5 individual forage species for analysis, along with total and preferred forage, because of their abundance or importance to deer on our study sites [brambles (*Rubus* spp.) ragweed (*Ambrosia* spp.), goldenrod (*Solidago* spp.), greenbriar (*Smilax* spp.), and wild grape (*Vitis* spp.); Moreland 2005].

Three samples of each preferred forage species were analyzed by the Southeast Research Station operated by the Louisiana State University Agricultural Center for crude protein (CP) on a dry matter basis using the Kjeldahl procedure (Jurgens 2002). We report all nutritional values on a dry matter basis (kg/ha). We estimated carrying capacity (deer-days/ha) using the explicit nutritional constraints model (Hobbs and Swift 1985). We assumed a daily dry matter intake of 1,360 g (Edwards et al. 2004), which is within the range of intake rates of deer in the southern United States (Fowler et al. 1967, Asleson et al. 1996, Campbell and Hewitt 2005). For each stand, we calculated a measure of nutritional carrying capacity (CC) based on lactation demands for CP. Because our sites contained adequate biomass to meet lactation requirements in all stands, we set target diet quality at 14% CP to support a lactating female with one fawn (Asleson et al. 1996, Verme and Ullrey 1984). Lactating females experience the greatest nutritional demands among adult deer during the growing season (Jacobson et al. 1979), so lactation level requirements should be sufficient to support antler growth in males (Asleson et al. 1996). Although secondary compounds, such as condensed proteins, have potential effects on protein digestibility (Hanley et al. 1992), we assumed CP content of forage species accurately compared relative plant quality among treatments.

We used mean response of each variable across transects, with stands as experimental units (n = 16, for 2 years), to quantify response variables. We used repeated measures, mixed model analysis of variance (ANOVA) to test for main effects of year, treatment, and year by treatment interactions on total forage production, production of preferred forage species, production of the 5 individual species, and 14% CP CC estimates, individually (PROC MIXED; SAS Institute 2009). We specified year as a repeated measure with subject equal to site × row × debris and treated site as a random variable to account for geographical differences and variation in timing of herbicide application. For each analysis we selected the covariance structure using Akaike's Information Criterion corrected for small sample size. When a statistical difference was detected among years, we used least squared means with Bonferonni corrections for multiple comparisons to determine where differences occurred. We tested the null hypothesis that 14% CP CC estimates and forage production for total, preferred, and 5 dominant species did not differ between years or treatments.

Results

Mean total biomass of plants sampled in 2009 and 2010 was 6119 kg/ha (SD=353) and 8598 kg/ha (SD=601), respectively. Species with the greatest biomass included goldenrod (3784 kg/ha), brambles (3370 kg/ha), bluestem (2757 kg/ha) and rosette grass (1933 kg/ha). There were no significant year × treatment interactions for any comparisons. Total forage biomass did not differ between treatments or among years (Table 3.1). Preferred forage biomass differed among

Table 3.1. Results of repeated measures analysis of variance (ANOVA) for year (2 levels) and treatment (prepared with a combination of row spacing and debris distribution) for mean biomass (kg/ha) of selected plant species or species groups in loblolly pine plantations in north and southeastern Louisiana, 2009-2010.

	Repeated measures ANOVA results		
Variable	Effect[a]	*F*-value	*P*-value
Total forage	Row	2.43	0.1337
	Debris	0.36	0.5537
	Year	0.29	0.3116
Preferred forage	Row	2.64	0.1189
	Debris	2.4	0.1363
	Year	7.82	0.0108
Ragweed	Row	0.14	0.7119
	Debris	4.85	0.039
	Year	0.28	0.6004
Greenbriar	Row	1.86	0.1867
	Debris	1.41	0.2477
	Year	0.2	0.659
Goldenrod	Row	0.24	0.6285
	Debris	0.26	0.6141
	Year	6.4	0.0195
Brambles	Row	0.37	0.5497
	Debris	5.03	0.0358
	Year	0.33	0.2323
Vitis spp.	Row	0.55	0.4653
	Debris	5.73	0.0261
	Year	0.15	0.7028

a. Degrees freedom (numerator, denominator) are 1, 21.

years but not among treatments (Table 3.1). More preferred forage plants occurred in 2010 (551.94 kg/ha ± 70.63; t21 = ¯2.80; P= 0.012) than 2009 (390.60 kg/ha ± 55.88). Biomass of ragweed was affected by distribution of logging debris but not by row spacing or year (Table 3.1). We found greater biomass of ragweed on sites with piled debris (48.85 kg/ha ± 36.00) than scattered (6.76 kg/ha ± 4.74). Biomass of goldenrod differed by year but not by treatment, with greater biomass in 2010 (184.50 kg/ha ± 69.25; t_{21}= ¯2.53; *P*= 0.019) than 2009 (32.23 kg/ha ± 5.47; Table 3.1). Biomass of brambles was affected by distribution of debris but not row spacing or year (Table 3.1), with greater biomass in scattered debris (114.92 kg/ha ± 19.32) than piled (7.82 kg/ha ± 5.47). Biomass of *Vitis* spp. was greater in stands with scattered (14.33 kg/ha ± 8.12) than piled debris (1.08 kg/ha ± 0.93), but was not affected by row spacing or year (Table 3.1).

We analyzed protein content of 33 preferred deer forage species collected across all treatment plots and years (Table 3.2). Crude protein values ranged from 2.47% to 16.34% (Table 3.2). Lactation-level CC differed between row and debris combination, but not among single treatments or years (Table 3.3). We found CC to be greater in stands with 14 ft row spacing and scattered debris (89.91 deer-days/ha ± 13.23; *F*= 6.28; *P*= 0.021) than those with piled debris (73.82 deer-days/ha ± 43.85). Carrying capacity estimates were generally greater in 4.3 m row spacing compared to 6.1 m (Table 3.3).

Discussion

All stands received similar chemical site preparation and we assumed the effects on plant communities were similar among stands. Early plant succession following stand establishment and site preparation is often characterized by a quick recovery of vegetation (Edwards 2004,

Table 3.2. Mean total biomass (kg/ha) of total and preferred forage, and biomass (kg/ha) and crude protein (CP, %) of forage species used for lactation-level (14% CP) white-tailed deer carrying capacity estimates in intensively managed loblolly pine plantations treated with mechanical site preparation techniques in north and southeastern Louisiana, USA, 2009-2010.

	Biomass						
Species	14 ft Spacing	20 ft Spacing	Piled Debris	Scattered debris	2009	2010	CP
Total forage	736.69	922.83	857.22	802.30	889.92	769.60	
Preferred forage	378.23	564.31	542.41	400.03	390.60	551.93	
Aster (*Asteraceae* spp.)	277.9	278.24	355.82	200.32	528.28	27.86	5.60
American beautyberry (*Callicarpa americana)*	125.04	784.45	452.64	456.85	333.96	575.53	8.59
Boneset (*Eupatorium leucolepis*)	174.71	270.4	283.75	161.36	264.52	180.59	9.35
Bracken fern (*Pteridium aquilinum*)	52.21	10.55	10.55	52.21	0	62.76	7.24
Brambles (*Rubus* spp.)	1795.65	1573.49	1530.41	1838.73	1772.68	1596.46	12.46
Butterfly pea (*Clitoria mariana*)	4.73	0.43	3.47	1.69	3.90	1.26	9.08
Chinese privet (*Ligustrum sinense*)	0	11.30	11.30	0	11.30	0	4.53
Common ragweed (*Ambrosia artemisiifolia)*	150.35	659.43	701.57	108.21	720.50	89.28	11.04
Daisy fleabane (*Erigeron strigosus*)	0	3.30	3.30	0	0	3.30	10.28
Deerberry (*Vaccinium stamineum*)	43.50	12.94	9.27	47.17	28.40	28.04	9.06
Goldenrod (*Solidago* spp)	976.59	2507.04	2678.20	805.43	531.71	2951.92	8.50
Grape (*Vitis* spp.)	151.85	94.68	17.29	229.24	55.90	191.04	5.68
Greenbriar (*Smilax* spp.)	233.23	169.61	191.30	210.91	179.56	223.28	8.10
Japanese honeysuckle (*Lonicera japonica*)	3.94	10.42	1.10	13.25	10.34	4.01	11.91
Meadowbeauty (*Rhexia virginica*)	22.63	1.33	22.63	1.33	0	23.96	6.37
Oaks (*Quercus* spp.)	0	13.67	0	13.67	13.67	0	8.64
Partridge pea (*Chamaecrista* spp.)	0.35	1.95	0.03	2.27	1.85	0.45	16.34
Pencil flower (*Stylosanthus biflora*)	0.23	0.66	0.66	0.23	0.82	0.07	10.13
Persimmon (*Diospyrus virginiana*)	119.73	0	119.73	0	60.71	59.02	5.83

(Table continued)

Red maple (*Acer rubrum*)	108.71	101.74	4.71	205.74	20.53	189.92	10.60
Rosette grass (*Dicanthelium* spp.)	825.45	1107.57	1267.22	665.8	675.09	1257.93	8.60
Rush (*Juncus* spp.)	185.85	240.13	327.71	98.27	274.42	151.56	8.87
Smooth tickclover (*Desmodium laevigatum*)	18.26	50.98	19.76	49.48	14.06	55.18	9.96
Spurred butterfly pea (*Callicarpa americana*)	3.42	3.92	5.39	1.95	5.74	1.60	13.02
Swamp sunflower (*Helianthus angustifolius*)	511.15	488.3	598.82	400.63	353.89	645.56	8.06
Trailing lespedeza (*Lespedeza procumbens*)	9.14	85.07	10.16	84.05	55.98	38.23	2.47
Virginia buttonweed (*Diodia virginiana*)	25.41	33.42	31.06	27.77	0	58.83	9.95
White titi (*Cyrilla racemiflora*)	0	9.30	0	9.30	9.30	0	13.72
Winged sumac (*Rhus copallinum*)	108.71	101.74	4.71	205.74	20.53	189.92	10.60
Witch hazel (*Hamamelis virginiana*)	0	62.97	22.27	40.70	40.7	22.27	9.47
Yaupon (*Ilex vomitoria*)	52.16	54.24	18.44	87.96	35.46	70.94	5.32
Yellow jessamine (*Gelsemium sempervirens*)	47.64	79.85	72.07	55.42	54.97	72.52	10.66
Yellow woodsorrel (*Oxalis stricta*)	0.15	1.43	1.13	0.45	0	1.576	12.40

Table 3.3. Mean nutritional carrying capacity (deer-days/ha) (with appropriate standard error) based on a mean diet quality of 14% crude protein and results of repeated measures analysis of variance (ANOVA) for year (2 levels) and treatment (prepared with a combination of row spacing and debris distribution) in 4-5-year-old loblolly pine plantations in north and southeastern Louisiana, 2009-2010.

	Treatment				Repeated measures ANOVA results		
Year	14 ft spacing	20 ft spacing	Piled debris	Scattered debris	Effect[a]	F-value	P-value
2009	85.31	73.50	88.64	70.16	Row	0.01	0.9188
	(41.44)	(41.49)	(47.51)	(34.16)	Debris	4.19	0.0534
					Year	1.38	0.2533
2010	78.42	67.92	49.22	97.12			
	(41.49)	(10.76)	(15.20)	(11.15)			

a. Degrees of freedom (numerator, denominator) are 1, 21.

Miller et al. 1995, Miller and Chamberlain 2008). Plant communities tend to increase in species richness and diversity in the initial 2-3 years post planting, then decrease or remain constant as canopy closure increases (Baker and Hunter 2002, Edwards 2004, Miller et al. 1995). We documented similar patterns on our study sites, but with an increase in species diversity and richness through year 5 post-harvest (Bechard 2008; see Chapter 2). We assumed deer forage and carrying capacity estimates would peak during these years as well.

Although total biomass for all forage species was not affected by treatments or time, biomass of preferred forage species was greater in 2010. This corresponds with an increase in abundance of forbs and brambles on study sites in 2010. As stated previously, goldenrod and brambles comprised the greatest biomass among all species sampled on our sites with relatively high CP percentages (Table 3.3).

Brambles are a valuable forage species in recently established pine plantations, providing foliage from early spring to late fall (Miller and Miller 1999, Askins 2001). Goldenrod is a preferred spring and summer forage, typically inhabiting disturbed soils of new plantations during initial years (Miller and Miller 1999). Spring and summer forages promote body growth, lactation demands, and replenish fat stores necessary for winter survival (Moen 1978, Wallmo et al. 1977). Increasing biomass of these species through the 5 years of stand establishment undoubtedly benefits deer and suggests that preferred forage may increase beyond the initial 2-3 years post-planting as demonstrated in other studies (Hurst and Warren 1980, Felix et al. 1986).

Site preparation where logging debris was scattered generally resulted in increased woody vegetation throughout our study sites (Bechard 2008, see Chapter 2). Logging debris is a valuable resource in new pine plantations, providing favorable conditions for rapid regeneration of plants and woody regeneration (Van Lear 1993). Scattered debris increased biomass of brambles and *Vitis* spp.. Notably, common ragweed was greater where logging debris was piled rather than scattered, likely a result of increased sunlight penetration due to reduced canopy (Blair and Enghart 1976). Alternatively, greater ragweed biomass may be attributed to additional soil disturbance associated with pushing debris into piles, along with the species' tendency to successfully establish in disturbed soils (Miller and Miller 1999, Moreland 2005). Ragweed is a preferred spring/summer forage species in southeastern forests and is a critical early inhabitant of new plantations (Miller and Miller 1999).

Lactation-level CC estimates ranged from 0.12 deer-days/ha to 360 deer-days/ha and CC was greater in 4.3 m spacing with scattered debris distribution. Suppressing woody growth promotes herbaceous understory and generally increases preferred deer forage and CC estimates (Carnus et al 2006, Chamberlain and Miller 2006, Iglay et al. 2010a, Peitz et al. 1999). Woody and semi-woody plant species including greenbriar, brambles, blueberry (*Vaccinium* spp.) and wild grape, are considered to be among the most, if not the most, important forage groups for deer throughout the southeast (Harlow and Guynn 1987, Moreland 2005). Specifically, brambles have been found to dominate bite counts, and fecal and stomach samples from deer in young loblolly-pine plantations of Louisiana and eastern Texas (Lay 1965, Thill 1984). In our study, high protein woody and semi-woody species contributed to 88% of CC estimates. Contribution of forage grasses and forbs was limited by their low CP content. Unlike similar studies conducted in more fertile soil regions of the southeast (e.g. Iglay et al. 2010a, Jones et al. 2009, Mixon et al. 2008), we documented fewer total forage species and fewer species with >14% CP. The explicit nutritional constraints model estimates the maximum number of deer that can obtain a diet of 14% CP based on the primary assumption that herbivores will select higher quality forage items in preference to lower ones (Hobbs and Swift 1985). Estimates rely on determining number of forage species that can be mixed to achieve a target diet quality less than the desired nutritional constraint. The extreme variation ranges of CC can be attributed to certain estimates being based on a mixture of a few high protein forages in low amounts. A lack of forage species with >14% CP on our sites suggests that CC may be underestimated in stands where target diet quality was achieved by a few high quality species and not abundant forage of species with moderate CP levels (e.g., *Rubus* spp.). Presumably, the stands sampled in our study should support greater deer-day/ha estimates given that it is unlikely deer will limit foraging to only a few species if additional forage species are present.

Although Imazapyr® is known to drastically reduce, and control, broadleaf herbs and woody species (Iglay 2010, Lane et al. *in press*), brambles are relatively resistant to the treatment. Because of their importance to CC estimates in our study, and deer diets throughout out Louisiana, release treatments conducted after planting likely only minimally affected CC estimates and biomass of preferred species in our analyses.

Management Implications

Intensive forest management presents public and private land managers with a unique opportunity to manage for early successional habitat. Balancing greater timber yields and quality deer habitat will continue to grow in importance given the vast area of timber plantations and frequency with which these forests are leased for sport hunting. Our findings suggest that site preparation using wider row spacing (6.1 m) in north and southeastern Louisiana may increase biomass of particular forage species, but does not impact preferred deer browse or total forage production in years 4 and 5 post-establishment. However, it is important to recognize that wider row spacing generally delays canopy closure, extending the more diverse early-seral stages (Dickson 1982, Melchoirs 1991). Although wider spacing may not affect deer forage, countless other wildlife species may benefit including small mammals, northern bobwhite (*Colinus virginianus*) and various early-successional bird species. Lane (2010) also suggested wider row spacing may have confounding effects in various treatment combinations. Further research examining commercial pine yields and successional changes associated with wider spacing will aide in determining whether it is a desired approach.

Our findings also illustrate that scattering debris throughout new plantations, rather than piling in specific locales, increase semi-woody vines and lactation-level CC estimates, particularly within narrower row spacing. The importance of semi-woody vines, primarily brambles, and woody species to deer diets in Louisiana suggests that scattered debris distribution may be highly beneficial to forage production. However, an increased woody component could come at the cost of decreased time to canopy closure and a shorter, less diverse understory (Baker and Hunter 2002, Miller and Miller 2004).

CHAPTER IV. EFFECTS OF ROW SPACING AND DEBRIS DISTRIBUTION ON SMALL MAMMAL COMMUNITIES IN NEWLY ESTABLISHED COMMERCIAL PINE STANDS IN LOUISIANA, USA

Introduction

The southeastern United States is composed of approximately 12 million hectares of pine plantation and provides 15% of global wood fiber needs (Ince 2001, Siry et al. 2006). Growing demand for global wood supplies has prompted forest managers to increase yields by implementing more intensive management regimes. Use of mechanical site preparation is often used to facilitate planting and increase loblolly pine production throughout the southeastern United States (Gresham 2002, Glover and Zutter 1993). Although various site preparation techniques increase timber yields, they have varying effects on understory development, wildlife habitat, and biodiversity (Carnus et al. 2006, Edwards 2004, Hayes et al. 2005). A current and future goal of forest management is to minimize harmful effects of mechanical site preparation to wildlife.

Many wildlife species are associated with pine plantation understory, particularly the diverse early seral stages of stand establishment (Dickson 1982, Huntly and Inouye 1987). A variety of herbivorous rodents and soricid insectivores depend on early successional vegetation for food, shelter, nesting and travel corridors (Humphrey et al. 1999, Perry and Thill 2005). Small mammals may be used as potential indicators of health and sustainable forest management as their populations change during vegetation succession (Huntly and Inouye 1987, Carey and Harrington 2001). Thus, small mammal populations may reflect direct impacts of early site preparation in young pine plantations (Humphrey et al. 1999). Presence of small mammals increases overall plant and wildlife species richness and diversity by providing a prey base for other wildlife species, and they play a critical role in seed dispersal (Fredriani et al. 2000).

Therefore, understanding response of small mammal populations to silvicultural treatments is necessary to further sustainable forest management.

A variety of research examining small mammal communities in relation to forest management techniques exists (see Langley and Shure 1980, Miller and Chapman 1995). Previous work has predominantly focused on varying aspects of understory structure, coarse woody debris (CWD) volume, and clear cutting in stands of middle to old growth (Huntly and Inouye 1987, Carey and Johnson 1995). Few studies have researched the effects of mechanical site preparation such as stand structure (row spacing) and arrangement, rather than volume, of CWD throughout the stand on small mammal communities (See Lane 2010). Wider row spacing is assumed to create differences in canopy cover which may affect vegetation succession and plant communities growing between rows of pine seedlings, directly impacting small mammal communities. Coarse woody debris (CWD) has many ecological functions within ecosystems and is crucial for providing habitat for many species (Elton 1966, Harmon and Franklin 1986). Debris distribution can impact vegetation structure and creation of microhabitats throughout the stand, affecting small mammal densities. Because small mammal communities are directly impacted by forest-floor processes and are ecologically important, we examined small mammal community response following site preparation with experimental row spacing and logging debris distribution techniques in Louisiana, USA.

Methods

Study Area

We studied small mammal communities in 4, early-rotation, loblolly pine plantations of approximately 60.7 ha. Sites were owned by WeyCo and harvested using clear cutting in 2005 and replanted in 2006. All stands were >20 years old prior to harvest. Replanting involved standard and experimental treatments on which this research was focused. Study sites were located in 2 areas of north-central Louisiana and 2 areas of southeast Louisiana (Figure 1.1, Chapter 1). Mean annual rainfall ranged from 150.62-163.10 cm and average January low and July high temperatures were 0.5-3.3 and 33° C, respectively. Elevation ranged from 30 to 77 m above sea level. All sites received a banded application of Arsenal® AC (4 oz/ac, BASF Corp. Research Triangle Park, NC) and Oust Extra® (2.5 oz/ac, DuPont™ Crop Protection, Wilmington, DE) within the first growing season. Sites received a hardwood release treatment of Arsenal® AC (12 oz/ac) in years 2 or 3 post-planting. The site located in Tangipahoa parish received the hardwood release treatment in fall prior to 2010 sampling, following standard operating procedures for substantial woody growth of non-pine species. The sites were predominantly upland pine ecosystems with interspersed stream management zones (SMZs). Dominant woody species generally included loblolly pine, red maple *(Acer rubrum)*, sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), black cherry (*Prunus serotina*) and blackberry *(Rubus* spp.). Dominant grasses included bluestems *(Andropogon* spp.), rosette grasses (*Dicanthelium* spp.) and paspalum grasses (*Paspalum* spp.) among others (Miller and Miller 2009, USDA Plants Database 2009).

Data Collection and Analysis

We established 4, 10.1 ha plots (stands, *n*=16) within each site (*n*=4) to which we randomly assigned treatment. Treatments included row spacing widths (4.1 m and 6.1 m) and debris distributions (scattered and piled). Scattered debris distribution consisted of the standard approach used by WeyCo; scattering logging debris between rows throughout the stand (Bechard 2008). The second debris treatment involved piling debris into 5 large piles isolated throughout the stand. The resulting design represented a randomized complete block design consisting of 4 stands within each site, representing one of 4 treatment combinations (see Figure 1.2, Chapter 1).

We conducted live trapping of small mammals bi-annually during winter (January-February) and summer (June-July) in each stand during 2006, 2007, 2009, and 2010. Trapping did not occur in 2008, however, we will refer to 2008 as year 3 post-planting. A bi-annual sampling regime was necessary because of annual population cycles experienced by small mammals (Krebs and Myers 1974). Within each stand, 25 Sherman live-traps were distributed systematically in a 60 x 60 m grid, with 15 m between each trap (Bechard 2008). Traps were baited with peanut butter and oats, and cotton balls were placed in traps to aide in thermoregulation. Cardboard pieces (22 x 28 cm) were placed over the traps to protect against heat during summer trapping. During periods of warmer temperature, the contact insecticide bifenthrin (Talstar ™, FMC Corp., Middleton, NY) was distributed around each trapping area as needed to prevent fatalities due to fire ants (*Solenopsis invicta*, Bechard 2008). We checked traps in the morning for 7 consecutive days in each stand. Once captured, each specimen was identified by species, sexed, aged and weighed (g), and marked using toe-clipping to provide a unique identification upon recapture. All sampling techniques were approved by the Louisiana State University Agricultural Institutional Animal Care and Use Committee (Protocol Number A2007-01).

We calculated relative abundance of species for each site across years (total captures/100 trap nights). We used number of total individuals sampled in each year, with stands as experimental units (*n*=16), to estimate mean Shannon H’ diversity indices and mean species richness. To quantify effects of year and treatment, and their interactions, on species diversity and richness, we used mixed model analysis of variance (ANOVA) with year and treatment as main effects and site as a block (PROC MIXED; SAS Institute 2009). When statistical difference was detected among years, we used least squared with Bonferroni corrections for multiple comparisons to determine where differences occurred. We tested the null hypothesis that species diversity, richness, and capture rates did not differ between years or treatments.

Results

We captured 1,697 individual small mammals representing 5 dominant species during 23,800 trap nights during 2006-2010. Species included house mouse (*Mus musculus*, *n*=308), hispid cotton rat (*Sigmodon hispidus*, *n*=347), marsh rice rat (*Oryzomys palustris*, *n*=95), harvest mice (*Reithrodontomys* spp.*n*=197), and *Peromyscus* species (*n*=760). Genus *Peromyscus* spp. was grouped (*P. gossypinus, P. nuttalli, P. leucopus)* to minimize observer bias and misidentification due to frequent hybridization among species (Osbourne and Anderson 2002). Genus *Reithrodontomys* spp. was also grouped to minimize misidentification of Eastern harvest mouse (*Reithrodontomys humulis*) and Fulvous harvest mouse (*Reighrodontomys fulvescens*). Incidental species captured included longtail weasel (*Mustela frenata*, *n*=1), least shrew (*Cryptotis parva, n*=4), and shorttail shrew (*Blarina brevicauda*, *n*=1). Age classes across dominant species were predominantly sub adult or adult and the proportion of males captured was greater than females in all species (Table 4.1).

Table 4.1. Proportion of sex and age class for dominant small mammal species (*n* = 5) captured and marked across 4 sites in north and southeast Louisiana, 2006-2010.

		Sex		Age Class		
Species	*n*	Male	Female	Juvenile	Sub adult	Adult
House Mouse	308	0.63	0.36	0.26	0.41	0.33
*Peromyscus*spp.	760	0.60	0.40	0.28	0.34	0.38
Reithrodontomys spp.	197	0.52	0.48	0.20	0.36	0.44
Hispid Cotton Rat	347	0.51	0.49	0.14	0.44	0.42
Marsh Rice Rat	95	0.64	0.36	0.10	0.49	0.41

Table 4.2. Mean small mammal species richness and Shannon H’ diversity index (with appropriate stand error) and results of analysis of variance (ANOVA) for year (4 levels) and treatment (prepared with a combination of row spacing and debris distribution) in 4, 5 year-old loblolly pine plantations in north and southeastern Louisiana, 2006-2010.

	Year[b]				ANOVA Results		
Variable	2006	2007	2009	2010	Effect[a]	*F*-value	*P*-value
Species Diversity	1.82	2.15	1.98	1.65	Row	1.44	0.237
	(0.12)	(0.10)	(0.16)	(0.15)	Debris	1.60	0.212
					Year	2.68	0.058
Species Richness	2.22	2.69	2.22	1.97	Row	0.45	0.507
	(0.16)	(0.12)	(0.21)	(0.13)	Debris	0.23	0.635
					Year	3.38	0.027

a. Degrees of freedom are 1, 45 (numerator, denominator) for treatment and 3, 45 (numerator, denominator) for year.
b. Mean values for stand (*n*= 16)

There were no significant (P=0.05) third order interactions for any comparisons. Species richness differed among years but not among treatments (Table 4.2). Species richness increased from 2006-2007 and decreased from 2007-2010, with greatest richness in 2007 (2.69 ±0.12; t_{45}= 2.03-3.11; P= 0.003-0.048; Table 4.3). Species diversity did not differ among treatments (Table 4.2), but generally increased from 2006-2009 before decreasing through the remainder of the study (Table 4.3). House mouse captures were greater in 2007 (5.94 ± 1.98; $t_{45} \leq 3.99$; $P \leq 0.003$) than 2009 (1.00 ± 0.30) and 2010 (1.00 ± 0.26), decreasing by 93%. *Peromyscus* spp. were also more abundant in 2007 (8.97 ± 1.50; t_{45} = 4.50; P = 0.001) than following years, experiencing a 68% decline in captures (Figure 4.1). Harvest mice increased in abundance throughout the study (Figure 4.1), with the greatest number of captures in 2010 (3.03 ± 0.59, t_{45} = ¯3.20; P= 0.015). Capture rates of marsh rice rats did not fluctuate across years, whereas captures of hispid cotton rats were greatest in 2007 (6.60 ± 1.44; t_{45} = ¯3.35 – 4.04; $P \leq 0.010$) and experienced a 67% decline from 2007-2010. Total small mammal captures did not differ among treatments but did differ among years ($F_{3,45}$ = 12.80, $P < 0.001$), with the more total captures in 2007 (22.91 ± 2.48,

t_{45}= $^{-}$4.71-5.74, P= 0.001). Subsequently, relative abundance (# of marked individuals/100 trap nights) of small mammals increased from 2006-2007 before decreasing throughout the remainder of the study (Figure 4.1).

Discussion

Small mammals respond directly to various site preparation techniques used in intensive timber management. Early successional vegetation communities found in newly established pine plantations support many species of small mammals (Huntly and Inouye 1987). Previous studies have found mechanical site preparation to have short-lived affects on small mammal communities (O’Connell and Miller 1994, Lane 2010).

In a similar study in North Carolina, Lane (2010) found that treatment combinations involving strip sheering (pushing debris between beds) resulted in increased capture rates during the first 2 years following treatment. Small mammal communities are positively associated with increasing amounts and availability of coarse woody debris (CWD; Barry and Francq 1980, Carey and Johnson 1995, Bellows et al. 2001), thus scattered debris would presumably have a positive impact on small mammal communities. However, we found that site preparation involving distribution of logging debris had no impact on small mammal capture rates, or species richness and diversity.

Site preparation involving row spacing did not affect small mammal capture rates or species richness and diversity. Lane (2010) observed similar results with wide row spacing (6.1 m) and small mammal species in North Carolina, attributing the majority of their results to confounding treatments. Wide row spacing is generally thought to delay canopy closure and extend the period of early successional habitat critical to most small mammals (Atkeson and

Johnson 1979). On our study sites, row spacing did not substantially influence vegetation communities, and small mammal species declined irrespective of tree spacing after years 2 and 3 post-planting.

Small mammal communities have been found to generally increase in abundance, species richness, and species diversity in response to greater plant abundance and diversity (Hartley 2002), before decreasing as plant succession enters later seral stages (Atkeson and Johnson 1979, Lane 2010). We found similar successional patterns in our study as illustrated by Figure 4.1. Small mammal species colonized our study sites quickly and relative abundance peaked in years 2 and 3 post-planting, coinciding with increasing woody growth and progression of plant succession within stands (see Chapter 2). Captures of house mice, hispid cotton rats, and *Peromyscus* spp. were greatest in 2007. House mice and hispid cotton rats are common early colonizers in young plantations and are associated with abundant herbaceous vegetation (Langley and Shure 1980, Clark et al. 1985). Site preparation that promotes growth of herbaceous vegetation will likely benefit these 2 species, and their sharp decline after year 2007 in our study was likely due to simple succession in vegetation communities. *Peromyscus* spp. is opportunistic habitat generalists that typically inhabit open areas, but depend on woody debris for traveling, foraging, and nesting (Bowman et al. 2000). Although *Peromyscus* spp. was the most abundant species captured throughout our study, we did not find any associations between capture rates and debris treatments. Notably, *Reithrodontomys* spp. capture rates increased throughout the study, having the greatest relative abundance in 2010. *Reithrodontomys* spp is typically a pioneer species that uses early successional communities rich in grasses and forbs (Bellows et al. 2001).

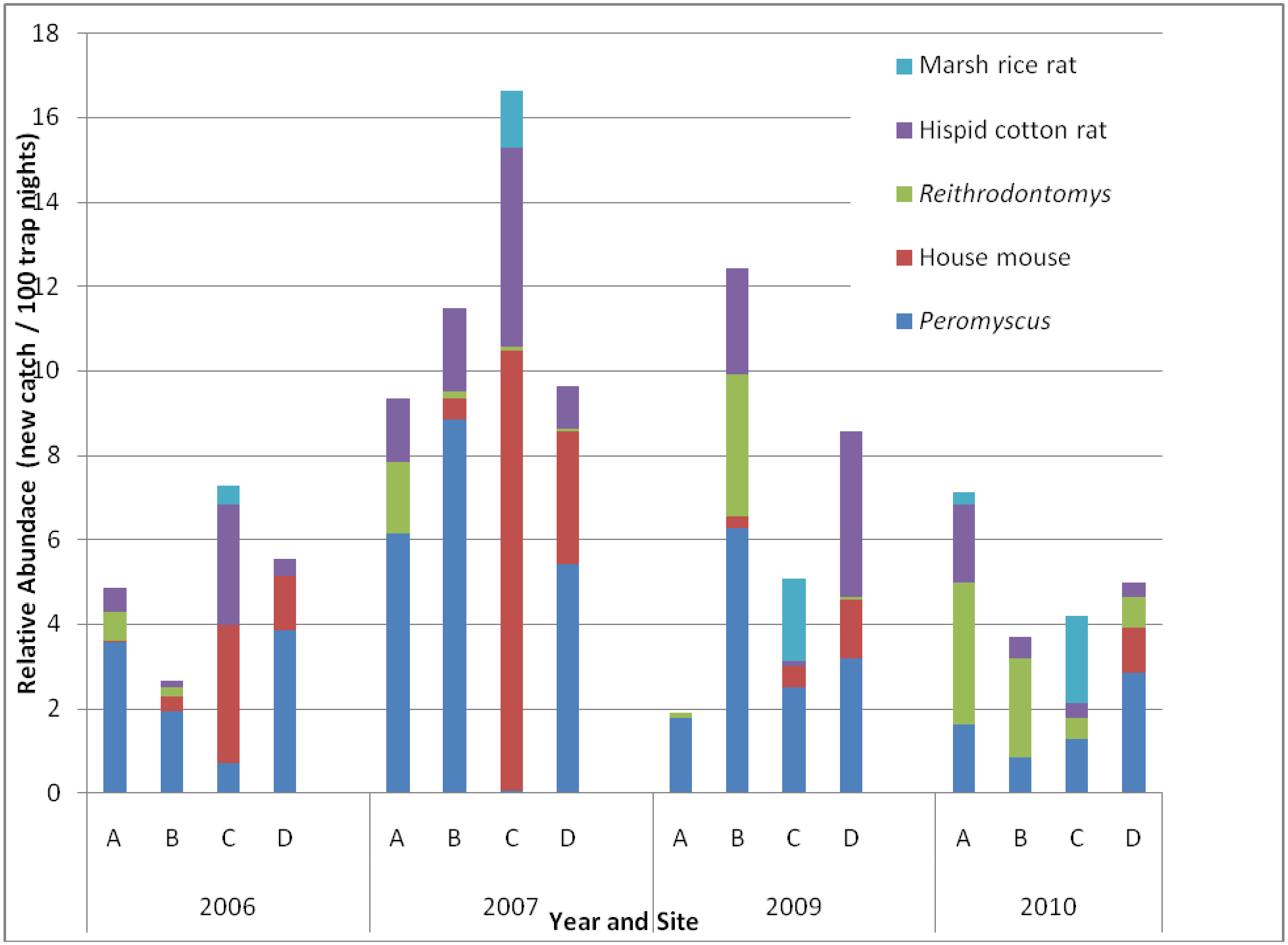

Figure 4.1. Relative abundance (marked individual/100 trap nights) of dominant species (*n*=5) captured across 4 sites in north and southeast Louisiana, 2006-2010.

Harvest mice were more abundant in 2009 and 2010, suggesting they responded to increasing plant richness and diversity found on our study sites through those years (see Chapter 2). Marsh rice rats were the least abundant species captured in our study and were predominantly found in one site (Tangipahoa Parish), which was consistently wetter than any other site.

Succession of small mammal communities within our study sites generally resembled succession commonly found in forest plantations and disturbed sites (Langley and Shure 1980, Lane 2010). Species such as house mouse, *Peromyscus* spp. and hispid cotton rats colonized our sites rapidly after planting and site preparation. Harvest mice, however, consistently increased in abundance throughout time as vegetation communities became more rich and diverse. Small mammals peaked in years 2 and 3 and decreased in following years, similar to results observed by Lane (2010).

Management Implications

Intensive forest management presents public and private land managers with a unique opportunity to manage for early successional habitat. Balancing greater timber yields and quality wildlife habitat will continue to grow in importance, given the importance of commercial timber industry throughout the southeast. Our findings suggest that site preparation involving row spacing in north and southeastern Louisiana does not have notable impacts on small mammal communities. However, it is important to recognize that wider row spacing generally delays canopy closure, extending the more diverse early-seral stages in which small mammals depend on (Dickson 1982, Melchoirs 1991). Although wider spacing may not directly affect small mammal communities, countless other wildlife species may benefit in possible delay in canopy cover. Further research examining commercial pine yields and successional changes associated with wider spacing will aide in determining whether it is a desired approach.

Our findings also illustrate that debris distribution throughout pine plantations may not affect small mammal communities in young pine plantations. However, many small mammal species are dependent on woody debris and site preparation involving scattering debris between pine rows may benefit small mammals in years beyond the scope of this research. This being said, an increased woody component could come at the cost of decreased time to canopy closure and a shorter, less diverse understory (Baker and Hunter 2002, Miller and Miller 2004). Therefore, we suggest further research examining debris distribution in middle-aged pine plantations may provide information on the effects of distribution to certain small mammal species.

CHAPTER V. CONCLUSIONS

We observed that site preparation involving wider row spacing (6.1 m) affected specific plant species, but generally did not impact vegetation structure or small mammal communities. This being said, it is important to realize that wider row spacing generally delays canopy closure and increases species diversity and richness of a more herbaceous understory (Baker and Hunter 2002, Melchoirs 1991). We suspect research examining later stages of succession and stand development may provide further insight into how row spacing affects canopy closure and vegetation structure and composition.

We also observed that scattering debris throughout new plantations, rather than piling in specific locales, increased semi-woody vines and lactation-level CC estimates, particularly within narrower row spacing. The importance of semi-woody vines, primarily brambles, and woody species to deer diets in Louisiana suggests that scattered debris distribution may be highly beneficial to forage production. However, our findings illustrate that distributing debris in larger piles throughout the stand decreased the overall woody component of the stand, including vegetation height. Our study suggests that when preparing sites in north and southeastern Louisiana, tradeoffs exist between reducing competing woody vegetation in order to increase quality and timber yields (Baldwin and Cao 1999, Glover and Zutter 1993), and providing semi-woody forage species that are key to greater deer CC.

LITERATURE CITED

Askins, R. A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin. 29:407-412.

Asleson, M. A., E. C. Hellgren, and L. W. Varner. 1996. Nitrogen requirements for antler growth and maintenance in white-tailed deer. Journal of Wildlife Management 60:744-752.

Atkeson, T. D. and A. S. Johnson. 1979. Succession of small mammals on pine plantations in the Georgia Piedmont. American Midland Naturalist 101:385-392.

Baker, J. C. and W. C. Hunter. 2002. Effects of forest management on terrestrial ecosystems. Pages 91-112 in D. N. Wear and J. G. Greis, editors. Southern Forest Resource Assessment. General Technical Report SRS-53. USDA Forest Service, Southern Research Station, Ashville, NC.

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.

Barry, R. E., Jr., and E. N. Francq. 1980. Orientation to landmarks within the preferred habitat by *Peromyscus leucopus*. Journal of Mammalogy 61:292-303.

Bechard, A. 2008. Influence of row spacing and debris distribution on vegetation and small mammals in Louisiana pine plantations. Thesis. Louisiana State University, Baton Rouge, Louisiana, USA.

Bellows, A. S., Pagels, J. F., Mitchell, J. C. 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.

Blair, R. L., and L. E. Brunett. 1977. Deer habitat potential of Pine-Hardwood forests in Louisiana. Research Paper SO-136, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA.

Blair, R. M., and H. G. Enghart. 1976. Deer forage and overstory dynamics in a loblolly pine plantation. Journal of Rangeland Management 29:104-108.

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

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin. 19:544-555.

Campbell, T. A., and D. G. Hewitt. 2005. Nutritional value of guajillo as a component of male white-tailed deer diets. Rangeland Ecology and Management 58:58-64.

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

Carey, A. B. and C. A. Harrington. 2001. Small mammals in young forests: implications for management for sustainability. Forest Ecology and Management. 154:289-309.

Carey, A. B. and M. L. Johnson. 1995. Small mammals in managed, naturally young , and old-growth forests. Ecological Applications. 5(2):336-352.

Carnus, J. M., J. A. Parrotta, E. G. Brockerhoff, M. Arbez, H. Jactel, A. Kremer, D. Lamb, K. O'Hara, and B. Walters. 2006. Planted forests and biodiversity. Journal of Forestry 104:65-77.

Chamberlain, M. J., and D. A. Miller. 2006. Effects of two site preparation techniques on biomass of forage plants for white-tailed deer in eastern Louisiana. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 60:64–69.

Clark, M. K., Lee, D. S., Funderburg, J. B. Jr. 1985. The mammal fauna of Carolina bays, pocosins, and associated communities in North Carolina: an overview. Brimleyana 11:1-38.

Clement, C. E., and R. P. Vlosky. 2008. A comparison of the primary and secondary wood products sectors in Louisiana. Working Paper #84. Louisiana Forest Products Development Center. Louisiana State University Ag Center. Louisiana State University. Baton Rouge, LA. p. 1-18.

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

Diemer, J. E. 1986. The ecology and management of the Gopher Tortoise in the Southeastern United States. Herpetologica. 42:125-133.

Dickson, J. G. 1982. Impact of forestry practices on wildlife in southern pine forests. Proceedings of the 1981 convention of the society of American foresters 224-230.

Edwards, S. L. 2004. Effects of intensive plantation management on wildlife habitat quality in southern Mississippi. Thesis, Mississippi State University, Mississippi State.

Edwards, S. L., S. Demarais, B. Watkins, and B. Strickland. 2004. White-tailed deer forage production in managed and unmanaged pine stands and summer food plots in Mississippi. Wildlife Society Bulletin 32:739-745.

Elton, C. S. 1966. Dying and dead wood. Pages 283-292 in The pattern of animal communities, John Wiley & Sons, New York, USA.

Fowler, J. F., J. D. Newsom, and H. L. Short. 1967. Seasonal variation in good consumption and weight gain in male and female white-tailed deer. Proceedings of the Southeastern Association of Game and Fish Commissioners 21:24-32.

Fedriani, J. M., T. K. Fuller, R. M. Sauvajot, and E. C. York. 2000. Competition and intraguild predation among three sympatric carnivores. Oecologia 125:258-270.

Felix, A. C, III, T. L. Sharik, and B. S. McGinnes. 1986. Effects of pine conversion on food plants of Northern bobwhite quail, Eastern wild turkey, and white-tailed deer in the Virginia Piedmont. Southern Journal of Applied Forestry 10:47-52.

Fuller R. J. and R. M. A. Gill 2001. Ecological impacts of increasing numbers of deer in British woodland. Forestry 74:193-99.

Glover, G. R., and B. R. Zutter. 1993. Loblolly Pine and mixed hardwood stand dynamics for 27 years following chemical, mechanical, and manual site preparation. Canadian Journal of Forest Research 23:2126-2132.

Greenwald, K. R., L. J. Petit, and T. A. Waite. 2008. Indirect effects of a keystone herbivore elevate local animal diversity. Journal of Wildlife Management 72:1318-1321.

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.

Hanley, T. A., C. T. Robbins, A. E. Hagerman, and C. McArthur. 1992. Predicting digestible protein and digestible dry matter in tannin-containing forages consumed by ruminants. Ecology 73:537-541.

Harlow, R. F., and D. C. Guynn. 1987. Foods, food habits and food habits analysis studies of white-tailed deer: selected and annotated bibliography. Department of Forest Resources. Clemson University. Clemson, SC.

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.

Harmon, M. E., and J. F. Franklin. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15:133-276.

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

Hayes, J. P., Schoenholtz, S. H., Hartley, M. J., Murphy, G., Powers, R. F., Berg, D., Radosevich, S. R. 2005. Environmental consequences of intensively managed forest plantations in the Pacific Northwest. Journal of Forestry. 103:83-87.

Haywood, J. D. 1994. Tenth-year results of herbaceous weed control in a Loblolly pine plantation. Southern Journal of Applied Forestry 18:105–109.

Hobbs, N. T., and D. M. Swift. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. Journal of Wildlife Management 49:814-822.

Howell, J. E., C. T. Moore, M. J. Conroy, R. G. Hamrick, R. J. Cooper, R. E. Thakston, and J. P. Carroll. 2009. Conservation of northern bobwhite on private lands in Georgia, USA under uncertainly about landscape-level habitat effects. Landscape Ecology. 24:405-418.

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

Huntly, N., and R. S. Inouye. 1987. Small mammal populations of an old-field chronosequence-successional patterns and associations with vegetation. Journal of Mammology 68:739-745.

Hurst, G. A., L. M. Wilson, B. D. Leopold, R. M. Watkins, M. D. Weinstein. 1994. Plant species richness following chemical and mechanical site preparation in Mississippi. Pages 131-133 in J. D. Dolan, and A. Reigal, editors. Proceedings of environmental issues affecting the forestry and forest products industries in the Eastern United States. General Technical Report NE-219. USDA, Forest Service, Northeaster Forest Experiment Station, Baltimore, Maryland.

Hurst, G. A., and R. C. Warren. 1980. Intensive pine plantation management and white-tailed deer habitat. Annual Forestry Symposium 29:90-102.

Iglay, R. B. 2010. Effects of prescribed fire and selective herbicide (Imazapyr) on biodiversity in intensively managed pine stands of Mississippi. Dissertation. Mississippi State University. Starkville, MS.

Iglay, R. B., P. D. Jones, D. A. Miller, S. Demarais, B. D. Leopold, and L. W. Burger Jr. 2010a. Deer carrying capacity in mid-rotation pine plantations of Mississippi. Journal of Wildlife Management 74: 1003-1012.

Iglay, R. B., B. D. Leopold, D. A. Miller, and L. W. Burger Jr. 2010b. Effect of plant community composition on plant response to fire and herbicide treatments. Forest Ecology and Management 260:435-548.

Ince, P. J. 2001. Outlook for sustainable fiber supply though forest management and other developments in the U.S. pulp and paper sector. Proceedings of International Environment Health Safety Conference and Exhibit. Technical Association of the Pulp and Paper Industry. Charlotte, North Carolina, USA.

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

Jacobson, H. A.. D. C. Guynn, Jr., R. N. Griffin, and D. Lewis. 1979. Fecundity of white-tailed deer in Mississippi and periodicity of corpora lutea and lactation. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 33:30-35.

Jagodzinski, A. M., and J. Oleksyn. 2009. Ecological consequences of silviculture at variable stand densities. I. Stand growth and development. Sylwan 153:75-85.

Jeffries, S. B. 2002. Effects of site preparation and vegetation control on the plant communities successional dynamics, and stand structure of a loblolly pine (Pinus taeda) plantation. Dissertation. North Carolina State University. Durham, NC.

Johnson, K. G. 1987. Effects of pine regeneration on vegetation, deer hunting, and harvest. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 41:271-278.

Jones, P. D. 2008. Effects of five different intensities of stand establishment on wildlife habitat quality and tree growth in loblolly pine (Pinus taeda) plantations in southern Mississippi. Dissertation. Mississippi State University, Starkville, MS.

Jones, P. D., S. L. Edwards, and S. Demarais. 2009. White-tailed deer foraging habitat in intensively established loblolly pine plantations. Journal of Wildlife Management 73:488-496.

Jones, W. D., J. C. Jones, I. A. Munn, and S. C. Grado. 2004. Wildlife enterprises on Mississippi private lands. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 58:344-355.

Krebs, C. J. and J. H. Myers. 1974. Population cycles in small mammals. Advances in Ecological Research . 8:268-389.

Lane, V. R. 2010. Plant, small mammal, and bird community responses to a gradient of site preparation intensities in pine plantations in the Coastal Plain of North Carolina. Dissertation, University of Georgia, Athens, USA.

Lane, V. R., K. V. Miller, S. B. Castleberry, D. A. Miller, T. B. Wigley, G. M. Marsh, and R. L. Mihalco. In press. Plant community responses to a gradient of site preparation intensities in pine plantations in the Coastal Plain of North Carolina. Forest Ecology and Management.

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

Lay, D. W. 1965. Fruit utilization by deer in southern forests. Journal of Wildlife Management. 29:370-375.

Litviatis, J.A. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin 29:466-473.

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

Ludwig, J. A. and J. F. Reynolds. 1988. Statistical Ecology. John Wiley & Sons, New York, New York, USA.

McMinn, J. W., and D. A. Crossley, J. R. 1996. Biodiversity and coarse woody debris in southern forests. Proceedings of the workshop on coarse woody debris in southern forests: effects on biodiversity. General Technical Report. SE-94. USDA Forest Service. Southern Research Station, Asheville North Carolina.

Melchiors, M.A. 1991. Wildlife management in southern pine regeneration systems. Pages 391-420 in M.L. Duryea and P.M Dougherty, eds. Forest Regeneration Manual. Kulwer Academic Publishers, The Netherlands.

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, D. A. and M. J. Chamberlain. 2008. Plant community response to burning and herbicide site preparation in eastern Louisiana, USA. Forest Ecology and Management. 255:774-780.

Miller, K.V., and B. R. Chapman. 1995. Responses of vegetation, birds, and small mammals to chemical and mechanical site preparation. Pages 146-148 in, Forest Research Institute Bulletin, Rotorua, New Zealand.

Miller, D. A., T. B. Wigley, and K.V. Miller. 2009. Managed Forests and Conservation of Terrestrial Biodiversity in the Southern United States. Society of the American Foresters 197-203.

Miller, J. H. B. R. Zutter, S. M. Zedaker, M. B. Edwards, and R. A. Newbold. 1995. Early plant succession in loblolly pine plantations as affected by vegetation management. Southern Journal of Applied Forestry 19:109-126.

Miller, J. H., and K. V. Miller. 1999. Forest plants of the Southeast and their wildlife uses. Southern Weed Science Society, Craftmaster Printers, Auburn, Alabama, USA.

Miller, J. H., R. S. Boyd, and M. B. Edwards. 1999. Floristic diversity, stand structure, and composition 11 years after herbicide site preparation. Canadian Journal of Forest Research 29:1073–1083.

Miller, J.H, B.R. Zutter, S.M. Zedaker, M.B. Edwards, and R.A. New hold. 1995. Early plant succession in loblolly pine plantations as affected by vegetation management. Southern Journal of Applied Forestry. 19:109-126.

Miller, K. V., and J. H. Miller. 2004. Forestry herbicide influences on biodiversity and wildlife habitat in southern forests. Wildlife Society Bulletin 32:1049-1060.

Mixon, M. R., S. Demarais, P. D. Jones, B. L. Rude. 2009. Deer forage response to herbicide and fire in mid-rotation pine plantations. Journal of Wildlife Management 73: 663-668.

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. Journal of Wildlife Management 42:715-738.

Moreland, D. A. 2005. A Checklist of the Woody and Herbaceous Deer Food Plants of Louisiana. Louisiana Department of Wildlife and Fisheries, Wildlife Division, Louisiana, USA.

Morris, L. A. and R. R. Lowery. 1988. Influence of site preparation on soil conditions affecting stand establishment and tree growth. Southern Journal of Applied Forestry. 12:170-178.

Natural Resources Conservation Services (NRCS). 2009. Web Soil Survey Map. United States Department of Agriculture. http://websoilsurvey.nrcs.usda.gov/app/. Accessed October 27, 2010.

O’Connell, W. E., and K. V. Miller. 1994. Site preparation influence on vegetative composition and avian and small mammal communities in the South Carolina Upper Coastal Plain. Proceedings of the Southeastern Association of Fish and Wildlife 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.

Peitz, D. G., P. A. Tappe, M. G. Shelton, and M. G. Sams. 1999. Deer browse response to pine-hardwood thinning regimes in southeastern Arkansas. Southern Journal of Applied Forestry 23:16-20.

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.

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.

Rooney, T. P. 2001. Deer impacts on forest ecosystems: a North American perspective. Journal of Forestry 74:201-208.

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

Siry, J. P., W. D. Greene, T. G. Harris, R. L. Izlar, A. K. Hamsley, K. Eason, T. Tye, S. S. Baldwin, and C.Hyldahl. 2006. Wood supply chain efficiency and fiber cost—what can we do better? Forest Products Journal 56:4–10.

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

Thill, R. E. 1984. Deer and cattle diets on Louisiana pine-hardwood sites. Journal of Wildlife Management. 48:788-798.

Thompson, I. D, J. A. Baker, and M. Ter-Mikaelian. 2003. A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. Forest Ecology and Management 177:441-469.

U.S. Department of Agriculture [USDA]. 2009. The PLANTS Database. <http://plants.usda.gov>

Van Lear, D. H. 1993. Dynamics of coarse woody debris in southern forest ecosystems. Biodiversity and coarse woody debris in southern forests. Proceedings of the Workshop on Coarse Woody Debris in Southern Forests: Effects on Biodiversity. Atlanta, Georgia.10-16.

Vance, E. D., D. A. Maguire, and R. S. Zalesny. 2010. Research strategies for increasing productivity of intensively managed forest plantations. Journal of Forestry. 108:183-192.

Verme, L. J., and D. E. Ullrey. 1984. Physiology and nutrition. Pages 91-118 in L.K. Halls, editor. White-tailed deer ecology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Vlosky, R. P. and N. P. Chance. 1996. An analysis of state-level economic development programs targeting the wood products industry. Forest Products Journal 46:23-29.

Wagner, R. G., M. Newton, E. C. Cole, J. H. Miller, and B. D. Shiver. 2004. The role of herbicides for enhancing forest productivity and conserving land for biodiversity in North America. Wildlife Society Bulletin 32:1028-1041.

Waller, D. M., and W. S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildlife Society Bulletin 25:217-226.

Wallmo, O. C., L. H. Carpenter, W. L. Regelin, R. B. Gill, and D. L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30:122-127.

Wear, D. N., and J. G. Greis. 2002. The Southern Forest Resource Assessment: Summary Report. General Technical Report SRS-54. United States Forest Service, Washington, DC, USA.

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.

VITA

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