Effects of Row Spacing and Debris Distribution on Vegetative Communities in Newly Established Loblolly-pine Plantations in Louisiana

Joshua L. Grace, *School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

Michael J. Chamberlain[1], *School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

Darren A. Miller, *Weyerhaeuser Company, Box 2288, Columbus, MS 39704*

Philip C. Stouffer, *School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge, LA 70803*

Abstract: Commercial pine (*Pinus* spp.) forests in the southeastern United States are critical to providing fiber for global wood supply needs. Intensive forest management techniques including row spacing and woody debris distribution can impact plant communities. Therefore, we quantified response of plant communities in replanted *P. taeda* stands to mechanical site preparation at two levels of row spacing (narrow and wide) and two methods of distributing woody debris (piling and scattering) following harvest in Louisiana. Sites were prepared with a combination of row spacing between planting beds ($n = 2$; 4.3 m and 6.1 m) and distribution of logging debris ($n = 2$; piled and scattered). We examined structural, compositional and species-specific characteristics of plant communities in each of four replicate stands for four years post-treatment. We documented 124 genera or species of plants and species richness and Shannon-diversity estimates were similar between site preparation methods. However, species richness and diversity varied among years and were reflective of successional changes. Placing woody debris in large piles throughout the stand appeared to influence stand structure by reducing woody plant growth, whereas scattering debris between rows of seedlings resulted in a more developed woody component. Variation in row spacing affected abundance of some individual species, but did not affect stand structure. Our results demonstrate that mechanical site preparation involving stand structure and distribution of logging debris influences plant communities and may change the trajectory of succession. However, plant species richness and diversity may not be strongly affected by row spacing or debris distribution. Therefore, we suggest that piling debris into isolated locales throughout the stand may increase availability of early successional vegetation through reduction of non-pine woody growth.

Key words: forest management, intensive forestry, Louisiana, *Pinus taeda*, silviculture, site preparation, stand establishment, succession, vegetation community

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Commercial pine (*Pinus* spp.) 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 commercial forest productivity (Wagner et al. 2004). A goal of intensive management is to reduce competition with pine seedlings. Forest managers often use mechanical and chemical site preparation to facilitate planting and increase growth and quality of loblolly pine (*Pinus taeda*; Gresham 2002). However, forest ecosystems contain considerable terrestrial biological diversity requiring managers to consider productivity and sustainability of the ecosystem (Carnus et al. 2006) as 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 floral and faunal communities (Miller and Miller 2004).

Research examining effects of site preparation on floristic diversity within intensively-managed forests is limited and further research is necessary (Miller and Miller 2004). Previous work has focused on chemical site treatments alone or in combination with other treatments such as prescribed burning (Jeffries 2002, Edwards et al. 2006, Miller and Chamberlain 2008). However, research examining mechanical site preparation, including row spacing and distribution of logging debris, is lacking. Wider row spacing is assumed to increase sunlight exposure and access to nutrients, enhancing establishment of semi-woody and herbaceous understory species (Osbourne and Anderson 2002). Additionally, wider rows may delay time to canopy closure, increasing the time stands provide 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 can impact microhabitat and availability of nutrients to plants (Harmon et al. 1986). Although some research has focused extensively on the effects of logging debris volume on

[1] Current Address: Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602

plant and wildlife communities (Loeb 1999, Mengak and Guynn 2003), relatively little research has examined the relationship between placement of logging debris and plant and wildlife communities. Because understanding the effects of site preparation (e.g., row spacing and woody debris distribution) is critical to 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.

Methods

Study Area

Study sites included four, early-rotation, loblolly pine plantations of approximately 60.7 ha each owned and managed by Weyerhaeuser Company. Sites were harvested using clear cutting throughout 2005 and replanted in 2006. Two study sites were located in north-central Louisiana (Winn and Jackson parishes) and two in southeast Louisiana (Tangipahoa and Washington parishes). 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 stands were >20 years old prior to harvest. Spacing of trees was held constant and seed beds were elevated after shearing. All sites received a banded application of Arsenal AC (48ml/ha, BASF Corp. Research Triangle Park, North Carolina) and Oust Extra (30ml/ha, DuPont Crop Protection, Wilmington, Deleware) within the first growing season. Sites received a hardwood release treatment of Arsenal AC (143 ml/ha) in years 2 or 3 post-planting. 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.) (Miller and Miller 1999, USDA Plants Database 2011).

Data Collection and Analysis

We established four 10.1-ha stands within each site ($n = 4$) and randomly assigned a treatment combination. Treatments included two row spacing widths (4.3 m and 6.1 m) and two debris distributions (scattered and piled). Scattered debris distribution consisted of scattering logging debris between rows throughout the stand (Bechard 2008), whereas piled distribution involved piling logging debris into five large piles located throughout the stand. The resulting design represented a randomized complete block design consisting of four experimental stands within each site.

We measured vegetation during June and July of 2006, 2007, 2009, and 2010. We established five circular sampling plots (0.04 ha) on a diagonal transect in each stand ($n = 16$) to account for possible differences in aspect, slope, and microclimate. Distance between sampling plots depended on the size of each 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 seven 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 et. al 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 excluded debris and bare ground from species richness and diversity estimates to provide more accurate results based solely on vegetation abundance. We estimated plant species diversity in each stand using the Shannon-Weaver index (Ludwig and Reynolds 1988). We designated six 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 using Miller and Miller (1999) and the USDA Plant Index (2011).

We used mean response of each variable across transects for four years, with stands as the experimental units ($n = 16$), to quantify response variables. We conducted a principal component analysis (PCA) with VARIMAX rotation of factors to reorganize vegetation composition, stem counts, vertical obstruction, and height data into components (PROC FACTOR; Johnson and Wichern 1988, Jackson 1993, SAS Institute 2009). We analyzed scree plots and eigenvalues >1 to determine number of principal components to retain ($n = 4$).

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 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 six 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) among all sites. Dominant grass species included bluestem and rosette grasses and dominant 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.).

A total of 67% of the variation in vegetation composition, stem counts, vertical obstruction and height data was explained by the first four principal components (Table 1). We designated principal components (PC) according to which variables loaded highly upon them (Table 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 three was considered as a yaupon component, whereas PC4 accounted for forbs. There were no significant ($P \geq 0.05$) 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 (Table 2).

Principal component two (percent cover grass, percent cover debris) was similar between treatments and among years (Table 2). Principal component three (percent cover of yaupon) differed among debris distribution and among years (Table 2). Principal component four (percent cover forbs) was similar between treatments, but did differ among years (Table 2).

Hardwood stems were greater in 2010 (Table 3; $t_{42.6} = -10.81$, $P < 0.001$) than 2006 (Table 3). Percent woody cover was greater in 2010 (Table 3; $t_{41.3} = -8.83$, $P = < 0.001$) than 2007 (Table 3). Percent cover of yaupon was greater in 2010 (Table 3; $t_{37.8} = -12.39$, $P \leq 0.001$) than 2007 (Table 3). Percentage cover of forbs was greater in 2009 (Table 3; $t_{46} = -4.29$, $P < 0.001$) than 2006 (Table 3).

Table 1. Eigenvalues and variance explained by each principal component developed through rotated factor loading of 12 vegetation attributes measured on four young, intensively-managed loblolly pine stands in north and southeastern Louisiana, 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 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 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

Table 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 southeastern Louisiana, 2006–2010.

	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

Species Diversity

Mean species richness differed among years, but not among treatments (Table 4). Species diversity differed among years, but not among treatments (Table 4). Mean relative abundance of bluestem and goldenrod did not differ among treatments or among years (Table 4). Mean relative abundance of beautyberry was not affected by row spacing or debris distribution alone. Mean relative abundance of brambles differed among years but not by treatment (Table 4). Finally, mean relative abundance of yaupon differed with respect to debris distribution but not by row spacing or across years (Table 4).

Species richness was greater in 2009 (Table 5; $t_{45} = -8.68$, $P < 0.001$) than 2006 (Table 5), and was similar in 2009 and 2010 (Table 5;

Table 3. Mean values with associated standard 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 = scattered, P = piled) across sites in north and southeastern Louisiana, 2006–2010.

		Mean (SE)							
Year	**Treat.**	**Hardwood stems**	**Min. height (m)**	**Max. height (m)**	**Avg. height (m)**	**Yaupon (%)**	**Woody (%)**	**Forbs (%)**	**Grass (%)**
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)
	4.3P	6.12 (2.14)	0.23 (0.05)	0.48 (0.07)	0.35 (0.06)	0.00 (0.00)	3.57 (1.66)	9.10 (2.63)	25.35 (7.39)
	6.1S	9.97 (2.05)	0.21 (0.03)	0.64 (0.06)	0.43 (0.04)	0.00 (0.00)	3.77 (1.10)	8.71 (1.93)	24.77 (5.31)
	6.1P	6.80 (2.32)	0.17 (0.04)	0.45 (0.07)	0.31 (0.06)	0.00 (0.00)	2.31 (0.93)	5.37 (1.36)	21.17 (5.10)
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)
	4.3P	5.13 (1.08)	0.17 (0.03)	0.75 (0.07)	0.46 (0.04)	0.00 (0.00)	4.25 (0.86)	14.86 (2.84)	28.23 (5.03)
	6.1S	12.50 (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)
	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)
2009	4.3S	52.90 (6.15)	0.70 (0.08)	1.37 (0.05)	1.01 (0.11)	2.15 (1.06)	13.10 (2.36)	13.20 (1.61)	20.77 (3.18)
	4.3P	42.40 (11.3)	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)
	6.1S	45.00 (6.59)	0.63 (0.06)	1.38 (0.04)	0.90 (0.07)	1.94 (1.19)	7.96 (1.64)	17.91 (2.13)	22.68 (3.77)
	6.1P	50.2 (13.1)	0.65 (0.06)	1.36 (0.04)	0.79 (0.09)	0.15 (0.15)	11.8 (2.83)	22.86 (4.16)	26.12(4.87)
2010	4.3S	92.8 (8.76)	0.96 (0.08)	1.31 (0.05)	0.83 (0.09)	16.20 (2.12)	11.40 (2.83)	13.40 (1.96)	29.25 (3.92)
	4.3P	83.85 (11.36)	0.80 (0.09)	1.13 (0.07)	0.63 (0.07)	24.15 (3.54)	10.55 (1.98)	13.75 (2.14)	29.58 (3.78)
	6.1S	95.10 (9.66)	1.03 (0.06)	1.36 (0.04)	0.90 (0.05)	16.40 (3.12)	13.35 (3.28)	18.20 (2.66)	21.55 (2.32)
	6.1P	92.50 (14.04)	0.84 (0.09)	1.20 (0.07)	0.75 (0.07)	19.06 (3.07)	14.25 (3.37)	23.25 (4.23)	23.20 (2.94)

$P = 1.000$). Species diversity was greater in 2010 (Table 5; $t_{45} = -8.68$, $P < 0.001$) than 2006 (Table 5). Mean relative abundance of beautyberry in 6.1 m spacing was greater in 2009 (Table 5; $t_{45} = -4.96$, $P = 0.003$) than 2007 (Table 5). Relative abundance of brambles increased and was greater in 2010 (Table 5; $t_{45} = -4.16$, $P = 0.001$) than 2006 (Table 5).

Discussion

Site preparation where logging debris was scattered 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 more favorable conditions for rapid seed germination due to less soil disturbance associated with this leaving debris where it lays.

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. 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. The presence of yaupon can have potentially negative effects on

Table 4. Test statistics of repeated measures analysis of variance (ANOVA) for main effects on eight 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, 2006–2010.

	Repeated measures MANOVA 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 freedom (numerator, denominator) are 3, 45 for year and year by treatment; 1, 45 for treatment.

Table 5. Mean values with associated standard errors (SE) of eight vegetation attributes characterizing species richness, diversity, and relative abundance (%) in regenerating loblolly pine stands subjected to combination of row spacing (4.3 m, 6.1 m) and debris distributions (S = scattered, P = piled) 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 (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 (0.00)	1.92 (0.01)	0.00 (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 (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 (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 (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 (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 (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)
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)

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). 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 successional changes as pine seedlings grew 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 the establishment of this group of species. Brambles are considered to be among the most important forage plants for white-tailed deer (*Odocoileus virginianus*; Askins 2001, Moreland 2005) and 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; however, 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, insects, and small mammals depend on goldenrod. Browsing by white-tailed deer may occur before flowering at a high rate in Louisiana (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 species for small mammals and provide cover habitat for species of concern such as bobwhite quail (*Colinus virginianus*) 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, Lane et al. (2011) observed that mechanical site preparation involving row spacing had little effect on species richness and diversity. However, we noticed that species richness increased from 2006–2009 before stabilizing in 2010. This stabilization was likely due to successional changes as woody species became more established and canopy closure increased. Additionally, species diversity increased from 2006 to 2007, but remained similar across the remaining years of the study. Herbaceous vegetation has been shown to establish quickly in mechanically prepared sites (O'Connell and Miller 1994, Miller et al. 1995); however, previous research has shown few differences in species diversity after initial establishment (Hurst et al. 1994, O'Connell and Miller 1994).

Management Implications

Our results 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 was 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 (Glover and Zutter 1993, Baldwin and Cao 1999). Ecologically, woody growth suppression has been shown widely throughout the Southeast to promote the growth of an herbaceous understory (Miller et al. 1995, Carnus et al. 2006). Also, reducing woody growth may delay time to canopy closure and extend the more diverse early succession plant communities, benefiting numerous wildlife species (Dickson 1982, Litvaitis 2001, Baker and Hunter 2002). However, our results indicate 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. Additionally, it is important to realize that wider row spacing generally delays canopy closure and increases species diversity and richness (Melchoirs 1991, Baker and Hunter 2002). Further, 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.

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