Effects of Pine and Hardwood Basal Areas After Uneven-Aged Silvicultural Treatments on Wildlife Habitat

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ABSTRACT: *Uneven-aged management (UEAM) is becoming increasingly popular in the southeastern United States. However, effects of UEAM on wildlife habitat have not been adequately documented. We examined response of habitat within stands of varying levels of pine and hardwood basal area under an uneven-aged management regime in southern Mississippi. Summer and winter trends in understory biomass were similar across treatments. Time since disturbance influenced plant productivity. Stands with lower basal areas tended to have higher browse production, denser and higher vertical habitat structure, more woody, vine, and fern biomass, greater total biomass, and higher plant species diversity and richness. Pine basal area had little influence on browse production relative to effects of hardwood basal area. Although stands with higher basal area had less biomass, a higher proportion of biomass was composed of preferred browse. We recommend that forest managers create stands of varying levels of pine and hardwood basal areas to provide for diverse needs of many wildlife species. South. J. Appl. For. 23(3):151–157.*

Increasingly, forest managers, especially nonindustrial landowners (Farrar 1984), are beginning to use uneven-aged management (UEAM). Current trends on federal lands are toward an increase in UEAM acreage (Guldin 1996). Benefits of UEAM include providing a diverse habitat for wildlife, enhancing biodiversity, potentially increasing habitat quality, increasing recreational opportunities, and aesthetics (Williston 1978, Farrar 1984, Smith 1986, Guldin 1996). In addition, in an Arkansas study, log quality of loblolly pine (*Pinus taeda*) from UEAM was either better or comparable to pine logs from even-aged management (Guldin and Fitzpatrick 1991).

A UEAM system provides a blend of successional habitats more similar to presettlement stands than even-aged systems, creates a diverse vertical stand structure, and maintains a continuous forest cover over time (Guldin 1996). In the South, UEAM is being used to manage for sensitive species, such as Bachman's sparrow (*Aimophila aestivalis*), fox squirrel (*Sciurus niger*), gopher tortoise (*Gopherus polyphemus*), and eastern indigo snake (*Drymarchon coraris couperi*).

Given potential advantages of UEAM under multiple-use management, such systems have been neglected (Tappe et al. 1995, Guldin 1996). Little work has quantified effects of varying levels of hardwood retention within pine/hardwood UEAM systems on wildlife habitat. Tappe et al. (1995) examined effects of four levels of pine basal area on herbaceous cover characteristics. More information is needed to determine how differing amounts of hardwood and pine basal areas affect production and diversity of plant species desirable for wildlife. Therefore, our objectives were to (1) compare habitat conditions in mixed pine-hardwood stands that have been harvested using guidelines for single-tree selection and (2) monitor habitat changes over 2 yr as these stands are brought under UEAM, while retaining a specified hardwood component. Because the treated stands were irregularly aged, our findings characterized transitional conditions leading toward an uneven-aged structure.

Study Area

We conducted our study during 1993–1996 in a naturally regenerated second growth pine-hardwood stand located on the Homochitto National Forest in Franklin County, Mississippi. Soils in the study area were Lorman series (Vertic Hapludalfs), which has a silty loam surface horizon and a

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clayey subsurface. The area was located in the Pine Hill physiographic district (Morris 1995). Elevations range from 61 to 79 m above sea level. Study plots were located on the side slopes of an undulating topography, with slopes ranging from 8 to 15%. Aspects were highly variable and occurred in every quarter. Site index averaged 28 m at 50 yr for loblolly pine, 26 m for shortleaf pine (*P. echinata*), and 23 m for red oaks (*Quercus* spp.).

The existing stand had a wide age class distribution with overstory (dbh ≥ 9 cm) pines and hardwoods ranging from 20 to over 100 yr old. However, about one-half of the pines and over one-third of the hardwoods were between 56–65 yr old. Few of the pines and hardwoods were in the younger age classes, indicating that recruitment into the overstory had been suppressed by the prevailing stand conditions. The stand had been periodically thinned in the past, and there was some evidence of prescribed burning. Overstory pine basal areas averaged 18.6 m^2/ha before harvest, with two-thirds shortleaf pine and one-third loblolly pine. The dominance of shortleaf may reflect the past influence of fire. Overstory hardwood basal areas averaged 7.3 m^2/ha; 60% was in mixed oaks (primarily southern red oak, *Q. falcata* and white oak, *Q. alba*), and 23% was in sweetgum (*Liquidambar styraciflua*) and blackgum (*Nyssa sylvatica*).

Methods

Treatment Plots and Habitat Mensuration

Eighteen square 0.65 ha plots were established, each with an interior square 0.20 ha net plot. Treatment basal areas were: 10 m^2/ha (45 ft^2/ac) or 14 m^2/ha (60 ft^2/ac) of overstory pine in combination with 0.0 m^2/ha (0.0 ft^2/ac), 3.5 m^2/ha (15 ft^2/ac), or 7.0 m^2/ha (30 ft^2/ac) of overstory hardwood. Treatments ($n = 6$) were randomly assigned in a completely random design with three replicates for each pine-hardwood combination for a total of 18 plots.

A timber harvest was implemented using the basal area-maximum diameter-quotient technique of single-tree selection (Baker et al. 1996). Guidelines were 10 or 14 m^2/ha for basal area, 60 cm for maximum diameter, and a quotient of 1.2 for 2.5 cm diameter classes. Hardwood retention favored higher quality red and white oaks; these were typically the larger hardwoods. Plots were harvested during dry weather in September and early October, 1990. Logs were skidded tree-length, and no special restrictions were placed on loggers. Silvicultural treatments were uniformly applied to all plots and included: (1) controlled burn during winter of 1988/89, (2) control of nonmerchantable hardwoods (≥ 1.5 cm in dbh) with stem-injected herbicide (Garlon 3A®) during early June, 1991, and (3) control of hardwood sprouts with foliar-applied herbicide (Garlon 4®) during early July, 1991.

Wildlife habitat was evaluated during summer (July/August, 1993 and 1995) and winter (January/February, 1994 and 1996). During summer, we measured understory plant biomass; plant species diversity, richness, and evenness; relative frequency of growth form (e.g., forb, vine, grass, woody); canopy closure; and vertical vegetative cover. During winter, we measured understory plant biomass and vertical vegetative cover. All measurements were confined to the 0.20 ha net plots except for biomass sampling, which was performed adjacent to net measurement plots to minimize disturbance on the permanent plots.

A single 30.5 m line transect was randomly located across each net plot (Canfield 1941) during summer sampling. Plants encountered at every 3 cm along the transect were identified to species. To assess relative frequency, plants were classified as forbs (herbaceous annual and perennial, nonwoody-stemmed plants except for ferns), vines, woody, ferns, sedges, or grasses. We also estimated plant species diversity (Shannon-Weaver), richness, and evenness (Ludwig and Reynolds 1988). Estimates of biomass for understory vegetation (woody, vines, grass, and forbs) were obtained within 12, 1 m^2 circular sampling plots located systematically around edges (3 per edge) of net plots. Estimates were made by plant growth form (forb, desirable and undesirable vine, desirable and undesirable woody, fern, sedge, and grass). Desirable and undesirable designations were based on the usefulness of that portion of the plant as potential browse for white-tailed deer (*Odocoileus virginianus*; Warren and Hurst 1981). For example, large, woody stems of flowering dogwood (*Cornus florida*) were classed as undesirable woody but leaves and small stems (i.e., new growth) were classified as desirable. All vegetation within sampling plots were collected and dried at 70°C for a minimum of 48 hr or until a constant dry weight was obtained; this weight was used to estimate biomass by growth form.

Vertical vegetative cover (structure) was determined using a vegetation profile board (Nudds 1977). A 1.8 m tall by 20 cm wide board was divided into 6, 0.3 m sections, with each section alternately painted blaze orange or white. At plot center, observers knelt 15 m from the vegetation profile board and estimated percentage cover to the nearest 10% for each board section in each cardinal direction. An estimate of canopy closure was obtained by using a spherical densiometer in the four cardinal directions at plot center at chest height.

Data Analyses

Winter and summer measurements were analyzed separately. Canopy closure and vertical vegetative cover were averaged within plots, then arcsine-transformed because they were percentage data (Steel and Torrie 1980). Species richness, diversity, and evenness were estimated for each plot using BASIC programs available from Ludwig and Reynolds (1988). Biomass data for each growth form were analyzed using 2-way analysis of variance (ANOVA), with a year (2 levels) by treatment (6 levels of pine/hardwood basal area) effect, within a completely randomized design with 3 replicates of 12 subsamples/replicate (36 observations/treatment/season; Steel and Torrie 1980).

We tested the null hypothesis that there was no difference in parameters measured among treatments or between years. We rejected the null hypothesis at $\alpha = 0.05$. Fisher's least significant difference procedure was used for mean separation if an overall model effect was detected at $\alpha = 0.05$. Differences in relative frequency were tested using chi-square analysis to test the null hypothesis that frequency of

Table 1. Summer plant biomass collected during summer within different uneven-aged management treatments, Homochitto National Forest, MS, 1993 and 1995. Woody and vine growth was characterized as desirable or undesirable as browse.

	Management treatment		Growth type								
Year	Residual pine basal area	Residual hardwood basal area	Sedge	Desired woody	Undesired woody	Desired vine	Undesired vine	Grass	Forb	Fern	Total
	(m²/ha)		(g/m²)								
1993	10	0	6 (1)*	19 (5)	123 (19)	33 (4)	3 (1)	54 (6)	24 (7)	14 (4)	275 (24)
	10	3.5	7 (2)	9 (2)	43 (7)	18 (4)	3 (1)	52 (7)	9 (4)	2 (1)	143 (15)
	10	7	7 (1)	6 (2)	35 (7)	12 (3)	1 (1)	56 (6)	5 (1)	3 (2)	124 (12)
	14	0	5 (1)	13 (4)	80 (16)	18 (3)	0 (0)	51 (8)	13 (3)	10 (4)	189 (22)
	14	3.5	7 (2)	2 (1)	18 (4)	14 (3)	2 (1)	54 (10)	8 (2)	3 (1)	107 (14)
	14	7	3 (1)	3 (1)	11 (3)	6 (2)	1 (1)	40 (5)	3 (1)	1 (1)	70 (7)
1995	10	0	9 (5)	28 (5)	153 (21)	55 (7)	11 (3)	23 (3)	12 (3)	10 (3)	301 (21)
	10	3.5	4 (1)	30 (6)	118 (17)	30 (3)	8 (3)	35 (5)	12 (2)	4 (2)	236 (21)
	10	7	5 (1)	14 (3)	87 (16)	21 (3)	87 (2)	34 (4)	9 (2)	2 (1)	179 (18)
	14	0	2 (1)	23 (6)	125 (18)	41 (5)	10 (2)	29 (4)	10 (2)	19 (6)	260 (21)
	14	3.5	4 (1)	6 (2)	62 (15)	23 (3)	5 (2)	41 (5)	14 (3)	3 (1)	159 (16)
	14	7	3 (1)	6 (2)	32 (4)	19 (3)	5 (1)	36 (4)	6 (1)	3 (2)	110 (8)

* Mean and standard error (in parentheses).

growth forms did not differ among treatments. Confidence intervals (95%) were used to determine where significant differences occurred.

Results

Summer Biomass

There was no treatment by year interaction for any growth form (forb, vine, etc.) with respect to mean biomass ($P > 0.30$; Table 1). We detected no significant differences among treatments or between years for sedge ($P = 0.613$ for treatment and 0.453 for year) and forb ($P = 0.095$ for treatment and $P = 0.935$ for year). A significant year effect, but not a significant treatment effect, was observed for undesirable vine ($P = 0.301$ for treatment and $P < 0.001$ for year; significantly higher in second year; Table 1) and grass ($P = 0.915$ for treatment and $P = 0.006$ for year; significantly higher in first year; Table 1). Mean fern biomass had a significant treatment effect ($P < 0.001$ for treatment and $P = 0.499$ for year). Both a treatment effect and a year effect were observed for desirable woody ($P < 0.001$ for treatment and $P = 0.002$ for year), undesirable woody ($P < 0.001$ for treatment and $P = 0.002$ for year), desirable vine ($P < 0.001$ for treatment and $P < 0.001$ for year), and total biomass ($P < 0.001$ for treatment and $P < 0.001$ for year).

Greater mean biomass ($P < 0.05$) occurred during 1995 for desirable woody, undesirable woody, desirable vine, undesirable vine, and total. Mean biomass of grass was higher ($P < 0.05$) during 1993 than 1995. Mean biomass generally was highest in the 10/0 (pine/hardwood basal area in m^2/ha) and 14/0 treatments and lowest in the 10/7 and 14/7 treatments for desirable vine and fern (Table 2). For undesirable woody and total biomass, highest biomass occurred in the 14/0 and 10/0 treatments and lowest in the 14/3.5 and 14/7 treatments. Desirable woody vegetation had the greatest mean biomass in 10/0 and 10/3.5 treatments and lowest biomass in 14/3.5 and 14/7.

Winter Biomass

The treatment by year interaction was not significant with respect to mean biomass (Table 3) for any growth form ($P > 0.25$). Although treatment differences were not significantly different, we found significant differences between years for sedge ($P = 0.598$ for treatment and $P < 0.001$ for year), desirable woody ($P = 0.062$ for treatment and $P = 0.049$ for year) and undesirable vine ($P < 0.129$ for treatment and $P = 0.003$ for year). Differences among treatments and between years were significant for undesirable woody vegetation ($P < 0.001$ for treatment and $P = 0.038$ for year) and total biomass ($P < 0.001$ for treatment and $P = 0.019$ for year). A treatment effect, but no signifi-

Table 2. Combined means (1993 and 1995) for summer biomass (g/m²) for six different uneven-aged management treatments, Homochitto National Forest, MS. Means within a column with the same letter are not significantly different ($P \geq 0.05$). Woody and vine growth were classified based on desirability as browse.

Management treatment						
Residual pine basal area	Residual hardwood basal area	Desirable woody	Undesirable woody	Desirable vine	Fern	Total
(m²/ha)		(g/m²)				
10	0	24^{a}	138^{a}	44^{a}	12^{a}	288^{a}
10	3.5	20^{a}	81^{bc}	21^{c}	3^{b}	190^{c}
10	7	10^{b}	61^{cd}	17^{cd}	2^{b}	152^{d}
14	0	18^{a}	103^{b}	30^{b}	15^{a}	224^{b}
14	3.5	4^{b}	40^{de}	18^{cd}	3^{b}	133^{d}
14	7	5^{b}	22^{e}	13^{d}	2^{b}	90^{e}

Table 3. Winter plant biomass within different uneven-aged management treatments, Homochitto National Forest, MS, 1994 and 1996. Woody vegetation and vines classified by desirability as white-tailed deer browse.

	Management treatment		Growth type								
Year	Residual pine basal area	Residual hardwood basal area	Sedge	Desired woody	Undesired woody	Desired vine	Undesired vine	Grass	Forb	Fern	Total
	·········(m^2/ha)········		······································(g/m^2)······································								
1994	10	0	9 (1)*	6 (1)	79 (14)	11 (2)	10 (4)	5 (1)	2 (1)	0.3 (0.2)	122 (15)
	10	3.5	5 (1)	2 (1)	43 (11)	7 (1)	0.3 (0.3)	6 (2)	2 (1)	2 (2)	72 (12)
	10	7	6 (1)	5 (2)	42 (8)	5 (1)	4 (2)	5 (2)	1 (0.4)	0.01 (0.01)	68 (10)
	14	0	4 (1)	9 (2)	95 (17)	16 (2)	3 (1)	6 (2)	2 (1)	1 (1)	137 (17)
	14	3.5	5 (1)	3 (1)	15 (3)	8 (2)	2 (1)	7 (3)	1 (0.4)	1 (0.4)	42 (6)
	14	7	6 (1)	3 (1)	12 (4)	4 (1)	1 (1)	8 (2)	1 (1)	1 (1)	42 (7)
1996	10	0	1 (1)	12 (5)	120 (24)	17 (4)	10 (2)	4 (1)	3 (1)	1 (1)	167 (26)
	10	3.5	4 (2)	9 (2)	78 (10)	11 (2)	12 (3)	3 (1)	1 (1)	1 (0.4)	120 (13)
	10	7	2 (1)	4 (2)	58 (10)	4 (1)	7 (2)	4 (1)	1 (0.3)	0.01 (0.01)	80 (10)
	14	0	1 (0.04)	11 (3)	92 (17)	15 (2)	12 (3)	5 (1)	4 (1)	2 (1)	142 (18)
	14	3.5	3 (1)	6 (2)	52 (13)	9 (2)	8 (2)	4 (1)	2 (1)	2 (1)	87 (13)
	14	7	3 (1)	3 (1)	19 (4)	4 (1)	2 (1)	3 (1)	1 (0.4)	2 (1)	37 (5)

* Mean and standard error (in parentheses).

cant year effect, was observed for desirable vine ($P < 0.001$ for treatment and $P = 0.356$ for year). We found no significant differences among treatments or between years for grass ($P = 0.980$ for treatment and $P = 0.082$ for year), forbs ($P = 0.083$ for treatment and $P = 0.238$ for year), and fern ($P = 0.397$ for treatment and $P = 0.568$ for year).

Significantly higher ($P < 0.05$) mean biomass occurred in 1996 for desirable woody, undesirable woody, undesirable vine, and total biomass. Mean biomass of sedge was significantly higher ($P < 0.05$) during 1994. For all growth forms with a significant treatment effect, the 14/0 and 10/0 treatments consistently had the highest mean biomass. Lowest mean biomass was in the 14/7 and 14/3.5 treatments for undesirable woody and total biomass and in the 14/7 and 10/7 treatments for desirable vine (Table 4).

Diversity, Evenness and Richness Indices

Evenness did not significantly differ ($P = 0.214$) among treatments or between years (Table 5). There was a significant treatment by year interaction for both diversity ($P = 0.012$) and richness ($P = 0.004$), necessitating within year ANOVAs. During 1993, both richness ($P < 0.001$) and diversity ($P < 0.001$) differed among treatments. However, during 1995, neither richness ($P = 0.984$) nor diversity ($P = 0.484$) differed among treatments. During 1993, the 14/0 and 10/0 treatments had the highest richness indices. However, 10/0 did not differ from 10/3.5 nor 14/3.5 with respect to mean species richness. Lowest richness occurred in the 14/7 and 10/7 treatments. Also during 1993, highest mean diversity indices were in the 14/0, 10/0, and 10/3.5 treatments, which were significantly higher ($P < 0.05$) than mean diversity of the 14/3.5, 14/7, and 10/7 treatments.

Table 4. Combined means (1994 and 1996) for winter biomass (g/m^2) for six different uneven-aged management treatments, Homochitto National Forest, MS. Means within a column with the same letter are not significantly different ($P \geq 0.05$). Desirability of woody and vine browse based on preferences by white-tailed deer.

Management treatment				
Residual pine basal area	Residual hardwood basal area	Undesirable woody	Desirable vine	Total
·········(m^2/ha)········		··················(g/m^2)··················		
10	0	99^a	14^a	145^a
10	3.5	60^b	9^b	94^b
10	7	50^{bc}	5^c	74^{bc}
14	0	94^a	16^a	140^a
14	3.5	34^{cd}	9^b	65^c
14	7	16^d	4^c	37^d

Vertical Vegetative Cover and Canopy Cover

There was no significant interaction between year and treatment with respect to mean vertical cover during summer ($P = 0.481$) nor winter ($P = 0.070$). Vertical cover differed by year and treatment during summer and winter ($P < 0.001$). During summer, the 10/0 and 14/0 treatments had the highest amount of vertical cover and the 14/7 and 10/7 treatments had the lowest amount of vertical cover (Table 6). A similar pattern was observed during winter (Table 6). Vertical cover was higher during 1995 than 1993 for summer and was higher during 1996 than 1994 for winter. We detected no significant interaction between year and treatment with respect to mean canopy cover ($P = 0.75$). A significant difference was found among treatments ($P < 0.001$) and between years ($P = 0.02$). A higher percentage of canopy cover occurred in 1995 treatments than 1993 treatments ($P < 0.05$). As would be expected, the 14/7 and 14/3.5 treatments had the highest mean canopy cover and 14/0 and 10/0 had the lowest mean canopy cover (Table 6).

Frequency of Occurrence

All growth forms, except forbs during 1995 ($P = 0.60$), differed significantly ($P < 0.05$) among treatments with respect to frequency of occurrence (Table 7). For woody vegetation during 1993 and 1995, the 14/0 and 10/0 basal areas tended to have the highest frequency whereas the 14/7 and 10/7 treatments tended to have the least frequency of woody vegetation. The 0 m^2/ha and 3.5 m^2/ha hardwood basal area treatments tended to have the highest frequency of vine with the 10/7 and 14/7 treatments having the lowest frequency of vine growth. This also was consistent between

Table 5. Habitat response to uneven-aged management treatments, by year and season (winter was January–February, summer was July–August), Homochitto National Forest, Mississippi, 1993–1996.

		Management treatment		Measurement of habitat response				
Year	Season	Residual pine basal area	Residual hardwood basal area	Canopy closure (%)	Vertical vegetative cover	Shannon's Diversity Index	Richness	Evenness
		............(m^2/ha)............						
1993	Summer	10	0	56 (8)*	56 (12)	2.59 (0.2)	4.60 (0.4)	0.72 (0.1)
		10	3.5	79 (3)	21 (9)	2.44 (0.3)	4.45 (0.1)	0.68 (0.2)
		10	7	80 (2)	27 (12)	1.91 (0.2)	3.00 (0.4)	0.64 (0.1)
		14	0	57 (10)	41 (6)	2.69 (0.1)	5.45 (0.9)	0.64 (0.01)
		14	3.5	81 (6)	19 (7)	2.07 (0.08)	4.24 (0.7)	0.59 (0.1)
		14	7	89 (2)	17 (4)	1.94 (0.2)	3.04 (0.1)	0.62 (0.02)
1994	Winter	10	0		71 (15)			
		10	3.5		33 (3)			
		10	7		27 (3)			
		14	0		66 (9)			
		14	3.5		36 (9)			
		14	7		23 (3)			
1995	Summer	10	0	62 (7)	94 (4)	2.54 (0.1)	4.39 (0.5)	0.72 (0.1)
		10	3.5	84 (6)	55 (4)	2.61 (0.1)	4.54 (0.4)	0.79 (0.1)
		10	7	82 (1)	36 (13)	2.41 (0.04)	4.48 (0.6)	0.64 (0.1)
		14	0	76 (4)	62 (13)	2.66 (0.2)	4.63 (0.1)	0.80 (0.1)
		14	3.5	90 (1)	50 (5)	2.56 (0.2)	4.36 (0.4)	0.74 (0.2)
		14	7	94 (2)	10 (4)	2.51 (0.2)	4.45 (0.1)	0.68 (0.2)
1996	Winter	10	0		99 (0.4)			
		10	3.5		71 (3)			
		10	7		45 (11)			
		14	0		93 (4)			
		14	3.5		52 (16)			
		14	7		41 (12)			

* Mean and standard error (in parentheses).

years. Sedges and grasses were most frequent in the 7 m^2/ha and 3.5 m^2/ha hardwood basal area treatments and less frequent in the 10/0 and 14/0 treatments; this was consistent between years. During 1993, forbs were most frequent in the 14/0 treatment and least frequent in the 10/7 treatment; forbs did not differ among treatments during 1995. Ferns displayed slightly different frequency patterns between years. During 1993, fern frequency was highest in the 14/0, 14/7, 10/0, and 10/3.5 treatments and lowest in the 10/7 treatment. During 1995, ferns were highest in the 10/0 treatment and lowest in the 10/7 treatment.

Discussion

Production of browse, amount of biomass, plant species diversity, and stand structure have strong influences on wildlife habitat within UEAM. As demonstrated by our data, these factors are influenced by time since disturbance, season of year, and by residual basal area of pine and hardwood retained after timber harvest. Recognition of relationships between residual basal areas and wildlife habitat can allow forest managers to plan for a diversity of habitats to meet the needs of many wildlife species while meeting timber harvest and regeneration goals.

Table 6. Means for vertical vegetative cover (summer and winter) and percentage of canopy cover (summer only), Homochitto National Forest, MS, 1993–1996. Means within a column with the same letter are not significantly different ($P \geq 0.05$).

Management treatment		Vertical vegetative cover		
Residual pine basal area	Residual hardwood basal area	Summer	Winter	Canopy cover
.........(m^2/ha).........				
10	0	73 a	64 a	50 c
10	3.5	46 b	37 bc	65 b
10	7	37 b	33 cd	64 b
14	0	66 a	46 b	55 c
14	3.5	41 b	35 bc	68 ab
14	7	34 b	21 d	74 a

Vegetation Relationships

Biomass trends between years indicated that, during the second year, production was higher for woody vegetation, vines, and total biomass, but lower for grasses. Guldin (1996) speculated that biomass production in uneven-aged stands declined after initial disturbance (i.e., timber harvest), but increased substantially during the next 2 yr. Our results support this trend.

Our results indicated that, within UEAM, although increasing pine basal area contributed to a reduction in browse (i.e., desirable vine, desirable woody, and forb biomass) availability, hardwood basal area had a greater effect on understory and midstory habitat characteristics. In most of the mean separation procedures for biomass of growth forms, stands with similar hardwood basal areas either did not differ significantly or were ranked similarly. We believe pine basal area, especially at 14 m^2/ha, did have an appreciable effect on reducing browse production, although secondary in importance to hardwood basal area.

Results of other studies support our contention. In Arkansas, Tappe et al. (1995) determined four levels (9,

Table 7. Frequency of occurrence and 95% confidence intervals (CI) for plant growth types from line intercept data collected during summer within different uneven-aged management treatments, Homochitto National Forest, MS, 1993 and 1995. Treatments within a column with the same letter are not significantly different ($P \geq 0.05$). Years were analyzed separately.

	Residual	Residual	Growth type											
	pine	hardwood	Woody		Vine		Sedge		Grass		Forb		Fern	
Year	basal area	basal area	Freq.	CI	Freq.	CI	Freq.	CI	Freq.	CI	Freq.	CI	Freq.	CI
	·······(m^2/ha)······													
1993	10	0	24 a	19–29	25 a	18–32	10 b	4–15	8 c	6–11	21 a	13–30	18 a	9–26
	10	3.5	23 a	18–28	17 ab	11–23	11 b	5–17	17 b	13–20	16 abc	8–24	15 a	7–23
	10	7	9 b	6–12	12 b	7–17	18 ab	11–26	20 ab	16–23	6 c	1–12	1 b	0–3
	14	0	27 a	22–32	16 ab	10–22	9 b	4–15	11 c	8–13	31 a	21–41	37 a	26–48
	14	3.5	9 b	6–11	18 ab	12–24	23 ab	15–31	20 ab	17–23	16 abc	8–24	8 ab	2–14
	14	7	8 b	5–11	12 b	7–17	29 a	21–38	25 a	22–29	9 bc	3–16	22 a	13–32
1995	10	0	27 a	23–31	20 a	15–25	3 b	0–12	7 b	4–10	14 a	5–24	59 a	48–70
	10	3.5	15 bc	12–18	20 a	15–25	13 ab	0–29	17 ab	12–21	25 a	13–37	14 b	6–21
	10	7	10 bc	7–13	14 ab	10–18	20 ab	0–40	21 ab	16–26	12 a	3–20	0 c	0–0
	14	0	21 ab	17–25	17 ab	13–22	0.0 b	0–0	6 b	3–9	10 a	2–18	8 b	2–14
	14	3.5	17 b	14–21	19 a	15–24	26 a	4–47	24 a	19–29	19 a	9–30	17 b	8–25
	14	7	11 bc	8–14	10 b	6–13	39 a	15–63	25 a	20–30	20 a	9–31	3 bc	0–6

14, 18, and 23 m^2/ha) of uneven-aged loblolly and shortleaf pine basal areas provided similar wildlife habitat with respect to understory plant diversity. In Louisiana, Blair and Feduccia (1977) noted browse production was inversely related to hardwood basal area, but not to pine basal area. Hardwoods apparently suppress browse production more than pines. Shelton and Murphy (1997) determined hardwoods in the Ouachita Mountains of Arkansas produced about twice as much shade per unit of basal area as did pines. Although Wolters et al. (1982) concluded browse, herbage, and total forage declined with increasing pine basal area, they also recognized shrub and hardwood crown cover could be a greater limiting factor on browse production than pine basal area. Their results in Louisiana are supported by those of Blair (1968) in Louisiana and Schuster and Halls (1963) in Texas. In Appalachian hardwoods, Beck (1983) concluded thinning of hardwoods increased browse production. Blair and Enghardt (1976) determined forage growth in Louisiana was determined by pine basal area in young (< 20 yr) pine stands but in older, thinned stands, hardwoods and shrubs limited browse production.

Wildlife Habitat Considerations

Lower basal areas, especially for hardwoods, and concomitant reduction in canopy cover, resulted in denser and higher vertical habitat structure, more woody vegetation, greater fern biomass, greater total biomass, more abundant browse, and higher species diversity and richness. Numerous studies have reached the same general conclusions regarding these relationships (Ehreneich and Crosby 1960, Patton and McGinnis 1964, Halls 1970, Blair and Enghardt 1976, Blair and Feduccia 1977, Beck 1983, Crawford 1984). These habitat conditions are ideal for numerous species, such as white-tailed deer, small mammals, rabbits (*Sylvilagus* spp.), bobcats (*Lynx rufus*), snakes, lizards and songbirds associated with early succession and/or thick cover [e.g., indigo bunting (*Passerina cyanea*), rufous-sided towhee (*Pipilo erythrophthalmus*)]. Higher plant species diversity provides multiple foraging and cover opportunities for wildlife. Also, a higher vertical habitat component provides more niches for a greater diversity of songbirds (MacArthur and MacArthur 1961).

Although treatments with higher hardwood basal area reduced plant biomass and amount of browse, these stands also provide valuable habitat. As hardwood basal area increased, proportion of biomass that was desirable woody vegetation was maintained while percentage that was undesirable decreased precipitously. Therefore, although less total biomass was available in higher basal area stands, there was a greater proportion of preferred wildlife plant species. In addition, higher hardwood retention would necessarily result in higher production of hard mast, a critical winter food for many wildlife species. The open midstory and understory and closed canopy typical of the higher basal area stands is preferred by many species, such as wild turkey (*Meleagris gallopavo*), fox squirrels, salamanders, and many songbirds.

Some species, such as white-tailed deer and northern bobwhite (*Colinus virginianus*), require a diversity of habitat types to optimize habitat quality. Many wildlife species are either dependent on, or prefer to associate with, edges between different habitat types. When developing habitat plans, it is important to recognize the need for a diversity of habitat types. Based on our results, a diversity of stand conditions can be created by manipulating residual basal areas, especially of hardwoods, within UEAM. Forest managers wanting to maximize habitat diversity may consider leaving different levels of pine and hardwood basal areas in adjacent management units. Such diversity would be beneficial to most wildlife species.

Management Considerations

Although the lower basal area treatments potentially provided important habitat needs for many species (see above), the higher biomass of woody vegetation with lower hardwood retention may have adverse long-term effects on growth of herbaceous vegetation. Treatment plots with low hardwood basal area in our study already had a dense layer of pine regeneration established. Over time, stands with low hardwood retention may increase pine seedling recruitment and subsequent establishment of a dense regeneration layer. While this dense regeneration layer exists, it would effectively shade out desirable wildlife plant species and reduce plant species diversity, thus reducing overall habitat quality of the stand. Until the regeneration layer grows out of this stage, periodic applications of herbicides may prove effective in increasing wildlife values of such stands, and prescribed burning may have a limited applicability in UEAM (Cain 1994).

Conversely, lower hardwood retention would make establishment of pine regeneration easier for forest managers, although overall habitat quality for wildlife would likely be reduced. Because successful UEAM of loblolly and shortleaf pine requires periodic regeneration, the long-term sustainability of pine timber harvests is doubtful at the higher hardwood retention levels tested in this study. Current guidelines for pine stands under single-tree selection recommend retaining no more than 1–3 m^2/ha of hardwood basal area when after-harvest pine basal areas are 10–13 m^2/ha (Baker et al. 1996). A compromise to the needs of wildlife and the need for regeneration may be that a substantial hardwood component can be retained in stands along drainages or in clumps and clusters with a lower hardwood component maintained throughout most of the stand to encourage pine regeneration. Group selection, another uneven-aged option, also may be favorable in managing mixed pine-hardwood stands (Murphy et al. 1993).

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