White-tailed deer forage production in managed and unmanaged pine stands and summer food plots in Mississippi

Scott L. Edwards, Steve Demarais, Bobby Watkins, and Bronson K. Strickland

Abstract Nutritional habitat quality in unmanaged southeastern forests often is limited because a dense midstory and litter layer impede growth of high-quality, shade-intolerant forage species. Management actions often are designed to improve the quantity of natural forages and to supplement natural forages with agronomic plantings. We evaluated the use of a selective herbicide, prescribed fire, and fertilizer to improve forage production for white-tailed deer (*Odocoileus virginianus*) in naturally regenerated, mature loblolly pine (*Pinus taeda*) stands in north-central Mississippi, treated during 1998–1999. We compared nutritional quality and production of selected forages in treated plots ($n=4$) and untreated plots ($n=4$) during years 2 and 3 post-treatment. We also measured quality and production of cowpeas (*Vigna unguiculata*) produced in food plots ($n=4$). Treatment plots produced an average of 435 kg/ha of leaf biomass and 34 kg/ha of digestible protein; untreated plots averaged 119 kg/ha of leaf biomass and 7 kg/ha of digestible protein. Cowpea food plots produced 545 kg/ha of leaf biomass and 110 kg/ha of digestible protein. Carrying-capacity estimates (deer-days/ha) increased from 7 in untreated plots to 268 in treated plots. Extrapolated over a 10-year economic planning horizon, the cost of producing digestible protein was $8/kg for treated plots and $15/kg for cowpea food plots. Vegetation treatments as described can cost-effectively produce high-quality, natural deer forages.

Key words ARSENAL® herbicide, crude protein, digestible protein, forage, in vitro digestibility, Mississippi, *Odocoileus virginianus*, quality vegetation management, white-tailed deer

Nutritional carrying capacity for deer in unmanaged, pine (*Pinus* spp.)-dominated southeastern forests often is limited by a dense midstory of undesirable woody species and understory litter layers that impede growth of high-quality, shade-intolerant forage species. Conversion of poorly managed forests to stands with an open midstory and a diverse understory is difficult using prescribed burning (Baker 1992) and mechanical hardwood control (e.g., bush hogging). A history of fire suppression and past, often poor forest management practices have made it nearly impossible to convert stands to pre-settlement conditions (Tiedemann et al. 2000) that historically provided high-quality habitat for white-tailed deer (*Odocoileus virginianus*, Dickson 2001). Management actions often are needed to increase production of quality natural forages and to supplement the natural forage base with food plots for optimal deer body growth and antler development.

We applied a combination of vegetation management techniques (i.e., selective herbicide, prescribed fire, and fertilizer) to improve the natural forage base for deer. We treated the sequential

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application of these 3 practices as a single management regime. We hypothesized that this management regime would alter vegetation structure and production. We predicted that eliminating the undesirable, hardwood-dominated midstory would allow more sunlight to reach the forest floor, burning the litter layer would promote establishment of preferred deer forages, and fertilizing would promote forage growth. We evaluated vegetation response to the cumulative effects of these 3 practices used in combination. We compared forage quality (i.e., crude protein and in vitro digestibility), forage quantity (i.e., total biomass, leaf biomass, and digestible protein), and nutritional carrying-capacity estimates in treated and untreated plots. We then compared the cost-effectiveness of this vegetation management option to the establishment of cowpea (*Vigna unguiculata*) food plots.

Study area and methods

Study areas were located in naturally regenerated, mature (45–50-year-old) loblolly pine (*Pinus taeda*) stands on private land in Noxubee County, Mississippi. Treated plots (1 ha, $n=4$) received a herbicide treatment of ARSENAL® Applicators Concentrate (BASF Forestry, Research Triangle Park, N.C.) applied at 1.2 L/ha in October 1998 via skidder using a water solution at 187 L/ha. We burned each plot in March 1999 and applied 222 kg/ha of 0-26-26 fertilizer to each plot in August 1999. Untreated plots (1 ha, $n=4$) were located in adjacent stands of loblolly pine similar in age, basal area, and topography. We arranged paired plots in a complete block design to eliminate any potential plot variability. We planted cowpea food plots (0.4 ha, $n=4$) in April 2000 and April 2001. We limed and fertilized food plots based on soil tests, to levels recommended by Stewart (2000).

We collected leaf samples from randomly selected plants throughout each plot during August 2000 and August 2001 from 12 species with a moderate to high annual deer forage preference rating (Warren and Hurst 1981). We sampled beggar's lice (*Desmodium ciliare*), ragweed (*Ambrosia artemisiifolia*), American beautyberry (*Callicarpa americana*), yellow poplar (*Liriodendron tulipifera*), winged elm (*Ulmus alata*), flowering dogwood (*Cornus florida*), tree sparkleberry (*Vaccinium arboreum*), catbrier (*Smilax bona-nox*), Japanese honeysuckle (*Lonicera japonica*), muscadine (*Vitis rotundifolia*), blackberry (*Rubus argutus*), and Alabama supple-jack (*Berchemia scandens*). Sweetgum (*Liquidambar styraciflua*) has a low preference rating (Warren and Hurst 1981), but was selected because of its prevalence in unmanaged timber stands in the southeastern United States.

We dried leaf samples in a forced-air oven at 60°C for 72 hours, then ground samples in a Wiley mill to a particle size that would pass through a 2-mm screen. We analyzed duplicate samples for nitrogen content to determine percent crude protein (CP) using the Kjeldahl procedure (Helrich 1990) and in vitro dry-matter disappearance (IVDMD) to determine digestibility (Cherney et al. 1997). We calculated a relative estimate of digestible protein production by multiplying a species' leaf biomass production by its CP and IVDMD percentages.

We measured forage production in 4 2-m^2 wire-fence exclosures placed randomly within each of the treated and untreated plots during May 2000 and May 2001 and clipped to ground level during August 2000 and August 2001. We sorted clippings by species for the 13 selected deer forages and by forage class (e.g., browse, forb, grass) for other species. We separated clippings into leaf biomass (e.g., leaves; portions of the plant potentially consumable by deer) and nonconsumable biomass (e.g., stems; portions of the plant not potentially consumable by deer), placed them in paper bags, dried them in a forced-air oven at 60°C for 72 hours, and weighed them to determine dry-matter weight. We randomly placed 4 0.5-m^2 exclosures within each cowpea food plot and clipped and processed them similarly to the natural vegetation.

We calculated mean production (kg/ha, dry-matter basis) of total biomass, leaf biomass, and digestible protein for each forage class, selected species, and cowpeas. We compared means ($P<0.05$) between treated ($n=4$) and untreated ($n=4$) plots and between years ($n=2$) by species, annual preference rating groups, and forage class using repeated-measures ANOVA in SAS Proc MIXED. We modeled the covariance for each hypothesis test and chose the most appropriate structure (e.g., auto-regressive, unstructured, etc.) by minimizing AIC_c (Littell et al. 1996). We separated means using Fisher's least significant difference when a treatment-by-year interaction was detected.

We estimated deer-days of foraging capacity as an index to the treatment effects on nutritional carrying capacity using the explicit nutritional constraints model (Hobbs and Swift 1985). We calculated the amount of forage biomass (kg/ha) of the 12 preferred deer forages that could be mixed to produce a mean diet quality of 12% CP, based on the observed percent CP for each species. We divided this amount by a dry-matter intake of 1.36 kg/day to calculate deer carrying capacity. We chose 12% because CP requirements for adult maintenance range from 4-12% (Holter et al. 1979, Asleson et al. 1996), and a dry-matter intake of 1.36 kg/day has been reported for white-tailed deer (French et al. 1956, Fowler et al. 1967).

We calculated the cost of producing 1 kg of digestible protein for the 12 preferred deer forages within treated and untreated plots during years 2 and 3 post-treatment and within cowpea food plots. A single treatment with a prescribed burn at year 5 post-treatment will maintain the vegetative response for a minimum of 10 years (S. Demarais, Mississippi State University, unpublished data). Therefore, the cost of producing 1 kg of digestible protein was projected over a 10-year economic planning horizon. We determined present values and the interest rate according to Bullard and Straka (1998).

Results

Total biomass ($F_{1,6}=12.23$, $P=0.013$) and leaf biomass ($F_{1,6} = 25.76$, $P = 0.002$) production increased in treated plots compared to untreated plots (Table 1), but did not differ between years ($P > 0.05$). Total browse biomass did not differ ($F_{1,6}= 1.86$, $P=0.221$) between treated and untreated plots, but treated plots produced more browse leaf biomass ($F_{1,6}=12.88$, $P=0.012$). Neither browse total ($F_{1,6}=0.55$, $P=0.488$) nor browse leaf biomass ($F_{1,6}=1.43$, $P=0.277$) differed between years. Forb total biomass differed by treatment ($F_{1,6}=24.17$, $P=0.003$) and year ($F_{1,6}=7.39$, $P=0.035$). Forb leaf biomass was greater in treated plots ($F_{1,6}=22.41$, $P=0.003$). Treated plots produced more total and leaf grass biomass ($F_{1,6}=8.04$, $P=0.030$) than untreated plots.

Leaf biomass production of forage species increased in treated plots (Table 2). The treatment increased leaf biomass production of high-use forages in treated plots ($F_{1,6}=26.52$, $P=0.002$), specifically beggar's lice ($F_{1,6}=7.52$, $P=0.034$), American beautyberry ($F_{1,6}=16.66$, $P=0.007$), and blackberry ($F_{1,6}=10.48$, $P=0.018$).

Crude protein of most selected deer forages did not increase in treated plots, and there was no definitive, treatment-related increase in IVDMD; however, there was an increase in the amount of available digestible protein in treated plots (Table 3).

Table 1. Total and leaf biomass production (kg/ha) by forage class in the understory of loblolly pine stands treated (n = 4) during 1998–1999 or untreated (n = 4) in Noxubee County, Mississippi, 2000–2001.

	Treated		Untreated	
Forage class	$\bar{x}$	SE	$\bar{x}$	SE
Total biomass				
Browse	1,447	231	985	234
Forb [ab]	233	61	7	7
Grass [c]	616	196	28	11
Total [c]	2,296	253	1,020	246
Leaf biomass				
Browse [c]	643	93	265	48
Forb [a]	113	29	3	3
Grass [c]	616	196	28	11
Total [a]	1,372	197	296	57

[a] Treatment effect ($P < 0.01$).
[b] Year effect ($P < 0.05$); $\bar{x}$ (SE), 2000 = 57 (29), 2001 = 182 (74).
[c] Treatment effect ($P < 0.05$).

Table 2. Leaf biomass production (kg/ha) for selected deer forages in the understory of loblolly pine stands treated (n = 4) during 1998–1999 or untreated (n = 4) in Noxubee County, Mississippi, 2000–2001.

		Treated		Untreated	
Species	Rating[a]	$\bar{x}$	SE	$\bar{x}$	SE
Forb					
Beggar's lice[b]	4	31	10	1	1
Ragweed	4	7	4	0	0
Browse (Tree-shrub)					
Sweetgum	1	45	30	35	14
American beautyberry [c]	4	84	20	5	3
Yellow poplar	4	3	3	1	1
Winged elm	4	25	8	25	5
Flowering dogwood	4	0	0	5	3
Tree sparkleberry	4	21	14	0	0
Browse - Vine					
Catbrier	3	1	1	2	2
Japanese honeysuckle	3	22	7	26	6
Muscadine	4	120	37	43	13
Blackberry[b]	4	115	33	1	1
Alabama supple-jack	4	6	3	10	4
Total - moderate use	3	23	7	28	6
Total - high use [c]	4	412	54	91	23

[a] Annual preference rating of 1, seldom eaten; 3, moderate use; 4, high use (Warren and Hurst 1981).
[b] Treatment effect ($P < 0.05$).
[c] Treatment effect ($P < 0.01$).

Table 3. Crude protein (%), in vitro digestibility (%), and available digestible protein (kg/ha) from leaf biomass for selected deer forages in the understory of loblolly pine stands treated (n = 4) during 1998–1999 or untreated (n = 4) in Noxubee County, Mississippi, 2000–2001.

		Crude protein[b]				Digestibility[b]				Digestible protein			
		Treated		Untreated		Treated		Untreated		Treated		Untreated	
Species	Rating[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Forb													
Beggar's lice[c]	4	19.9	1.6	18.0		55.1	11.7	69.1		3.4	1.2	0.1	0.1
Ragweed	4	24.9	4.3			73.8	12.7			1.0	0.5	0.0	0.0
Browse (Tree-shrub)													
Sweetgum[d]	1	10.7	0.7	9.0	0.3	62.6	6.5	69.4	4.7	2.2	1.5	2.4	1.1
American beautyberry[ef]	4	12.1	0.5	12.9	0.6	57.3	3.9	58.7	2.7	6.8	1.8	0.4	0.2
Yellow poplar	4	13.3	1.7	10.0	0.9	66.9	10.3	68.0	8.5	0.3	0.3	0.1	0.1
Winged elm	4	11.7	1.1	10.0	0.3	59.5	13.8	58.3	7.2	1.5	0.5	1.2	0.3
Flowering dogwood	4	7.2		6.8	0.4	85.8		67.0	15.8	0.0	0.0	0.2	0.1
Tree sparkleberry	4	7.2	0.1	7.5	0.4	56.6	16.4	53.4	12.3	0.8	0.6	0.0	0.0
Browse - Vine													
Catbrier	3	10.9	0.0	10.5	0.5	65.4	10.5	68.9	9.4	0.1	0.1	0.2	0.1
Japanese honeysuckle	3	9.9	1.0	8.4	0.7	77.7	6.0	81.0	5.1	1.8	0.7	1.7	0.4
Muscadine[ghi]	4	11.2	0.4	9.2	0.2	68.1	3.6	63.2	3.8	9.0	3.0	2.4	0.6
Blackberry[c]	4	12.0	1.3			61.4	19.6			8.9	2.8	0.1	0.1
Alabama supple-jack	4	9.9		7.8	0.2	88.8		76.3	10.5	0.5	0.2	0.6	0.2
Total - moderate use	3									1.9	0.6	1.9	0.4
Total - high use[j]	4									32.2	4.8	5.1	1.1

[a] Annual preference rating of 1, seldom eaten; 3, moderate use; 4, high use (Warren and Hurst 1981).

[b] Composite samples collected across study areas where species occured.

[c] Treatment effect on digestible protein ($P < 0.05$).

[d] Treatment by year interaction on digestibility ($P = 0.025$); $\bar{x}$ (SE), treated 2000 = 45.6 (2.0) A, untreated 2000 = 57.1 (1.5) B, treated 2001 = 79.6 (1.0) C, untreated 2001 = 81.7 (0.8) C; means with common letters do not differ ($P > 0.05$).

[e] Year effect on digestibility ($P \leq 0.001$); $\bar{x}$ (SE), 2000 = 50.0 (1.5), 2001 = 65.9 (1.7).

[f] Treatment by year interaction on digestible protein ($P = 0.049$); $\bar{x}$ (SE), treated 2000 = 3.4 (1.7) A, untreated 2000 = 0.4 (0.3) A, treated 2001 = 10.1 (2.2) B, untreated 2001 = 0.3 (0.3) A; means with common letters do not differ ($P > 0.05$).

[g] Treatment effect on protein ($P < 0.01$).

[h] Year effect on protein ($P < 0.01$); $\bar{x}$ (SE), 2000 = 9.7 (0.3), 2001 = 10.9 (0.5).

[i] Year effect on digestibility ($P \leq 0.001$); $\bar{x}$ (SE), 2000 = 57.0 (2.4), 2001 = 74.4 (1.3).

[j] Treatment effect on digestible protein ($P \leq 0.001$).

Muscadine CP was higher in treated plots ($F_{1,6}$= 62.18, $P \leq 0.001$) and during 2001 ($F_{1,6}$=22.27, P= 0.003). There was a sweetgum treatment × year interaction ($F_{1,6}$=8.90, P=0.025), resulting from a treatment-related decrease in digestibility; however, digestibility increased from 2000 to 2001. American beautyberry ($F_{1,6}$=53.98, $P \leq 0.001$) and muscadine ($F_{1,6}$=49.73, $P \leq 0.001$) IVDMD increased in treated plots during 2001. Beggar's lice ($F_{1,6}$=6.75, P= 0.041) and blackberry ($F_{1,6}$=11.94, P=0.014) available digestible protein was greater in treated compared to untreated plots. There was a treatment × year interaction ($F_{1,6}$=6.05, P=0.049) for American beautyberry digestible protein. The treatment increased digestible protein available from high-use forages ($F_{1,6}$=40.56, $P \leq 0.001$).

Cowpea food plot total biomass ($F_{1,6}$=18.54, P= 0.005), leaf biomass ($F_{1,6}$=25.02, P=0.002), and available digestible protein ($F_{1,6}$=10.53, P=0.018) were greater during 2000 than during 2001 (Table 4). Conversely, IVDMD was greater during 2001 than 2000 ($F_{1,6}$=114.51, $P \leq 0.001$).

Total biomass of forages averaging 12% CP was greater in treated plots compared to untreated plots (Table 5). As a result, white-tailed deer carrying capacity was greater in treated plots ($F_{1,6}$= 53.76, $P \leq 0.001$).

Treatment costs included application of ARSENAL via skidder ($173/ha), prescribed fire ($25/ha), and fertilizing ($62/ha), for a treatment cost of $260/ha. The average annual cost of establishing and maintaining cowpea food plots was

Table 4. Total biomass (kg/ha), leaf biomass (kg/ha), crude protein (%), in vitro digestibility (%), and available digestible protein (kg/ha) of cowpeas grown in food plots (n = 4) during the 2000 and 2001 growing seasons in Noxubee County, Mississippi.

	2000		2001	
	$\bar{x}$	SE	$\bar{x}$	SE
Total biomass[a]	2,886	191	1,533	249
Leaf biomass[a]	732	70	358	27
Crude protein	26.2	0.8	25.9	4.6
Digestibility[b]	69.3	2.3	93.5	0.9
Digestible protein[c]	133	13	87	6

[a] Year effect ($P < 0.01$).
[b] Year effect ($P \leq 0.001$).
[c] Year effect ($P < 0.05$).

$263/ha and included seed, fertilizer, lime, and equipment (e.g., tractor, fuel, herbicides, implements to disk plot, spread seed, and cover seed) based on Nagel et al. (2000). Labor costs were not included, because most landowners provide their own labor in establishing and maintaining food plots.

The cost of producing 1 kg of digestible protein averaged across years 2 and 3 post-treatment was $8 for treated plots and $5 for cowpea food plots. When extrapolated over a 10-year economic planning horizon, assuming equivalent productivity levels and a 10% interest rate, the present value of producing 1 kg of digestible protein was $8 for treated plots and $15 for cowpea food plots.

Discussion

The experimental treatment promoted growth of preferred deer forage species. ARSENAL removed the hardwood midstory component (W. Burger and J. Jones, Mississippi State University, unpublished report), which allowed sunlight to reach the forest floor. A prescribed fire during the spring following herbicide treatment removed residual hardwood standing debris and litter layer, releasing desirable herbaceous vegetation. Desirable plant growth probably was additionally promoted by a summer fertilizer application. Increases in beggar's lice, American beautyberry, and blackberry were evident in total biomass, leaf biomass, and digestible protein in the treated plots. These species are not labeled as target vegetation species and therefore were not controlled by the herbicide.

Table 5. Total biomass (kg/ha) of selected deer forages combined to average 12% crude protein and associated carrying capacity estimates (deer-days/ha, assuming 1.36 kg/day consumption) in the understory of loblolly pine stands treated (n = 4) during 1998–1999 or untreated (n = 4) in Noxubee County, Mississippi, 2000–2001.

	Total biomass				Carrying capacity			
	Treated		Untreated		Treated		Untreated	
Year	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
2000	297	101	8	5	218	75	6	4
2001	433	92	12	8	318	68	9	6

The herbicide treatment eliminated undesirable species (e.g., sweetgum) from the treated midstory. However, sweetgum seedlings germinated post-treatment as part of the understory community. Future development of undesirable woody species can be limited by prescribed-burning at least every 5 years (S. Demarais, Mississippi State University, unpublished data).

When comparing the cost of producing 1 kg of digestible protein during years 2 and 3 post-treatment, cowpea food plots appeared to yield the greatest investment return. However, for long-term production of high-quality, natural deer forages, treated plots yielded the greatest investment return because the treatment was a one-time cost with results lasting >10 years if maintained with periodic prescribed burning, versus the annual cost of establishing and maintaining a cowpea food plot. Untreated plots obviously had the least investment ($0.00), but also produced the least amount of quality deer forages.

We assumed that the nutritional constraints model (Hobbs and Swift 1985) accurately indexed carrying capacity in our treatment plots. While our choice of values for CP diet level and dry-matter-intake rate are debatable, the relative comparison of carrying-capacity levels between treated and untreated plots is unequivocal. That is, deer carrying-capacity estimates in treated plots greatly exceeded those from untreated plots.

Cowpea food plots produced large amounts of digestible protein, but limitations were associated with these food plots. The primary limiting factor was the high annual cost of establishment and maintenance. It also is important to note that we measured cowpea food plot production within exclosures, with no deer utilization. Deer typically forage heavily in cowpea food plots; thus, annual production may be significantly less than we reported. Also, drought conditions or overutiliza-

Quality Vegetation Management effectively removed the hardwood midstory in mature pine forests and released high-quality, shade-intolerant deer forages. Increased production of highly preferred forages greatly increased the habitat's deer nutritional carrying capacity.

White-tailed deer nutritional carrying capacity in pine-dominated southeastern forests is often limited by a dense midstory of undesirable hardwood species and understory litter layers.

tion in high-deer-density areas may prevent cowpea food plots from ever becoming established. Additionally, there were season-of-availability differences between cowpeas (3-4 months) and native vegetation (5-6 months), which limited deer utilization.

Removal of undesirable midstory hardwoods can have positive effects on pine growth rate. During 2 years following an ARSENAL and prescribed-fire treatment, Harty (1996) reported a 6% radial growth rate increase in treated 35-42-year-old loblolly pines. Based on this trend, it is plausible that the pine growth rate continued to increase in subsequent years. If so, and assuming the final product was sawtimber crop trees, the volume increase and associated economic return at harvest may allow the landowner to recover a portion of the treatment cost.

Conclusions and management implications

This combination of vegetation management techniques was effective for removing the hardwood midstory and litter layers in mature pine forests to release high-quality, shade-intolerant, natural deer forages. Increased production of highly preferred forages in treated plots greatly increased the habitat's deer nutritional carrying capacity. Cowpea food plots produced large amounts of digestible protein, but were more expensive to establish and maintain over time.

Recently, agencies have incorporated this combination of vegetation management techniques, collectively referred to as quality vegetation management (QVM), into their cost-share programs for non-industrial private forest landowners. The Natural Resources Conservation Service in Mississippi provides cost-share for QVM in thinned pine stands and for restoration of early successional vegetation for wildlife habitat in abandoned fields. The Mississippi Forestry Commission also provides cost-share assistance to private landowners for wildlife habitat improvement in pine forests under the Forest Land Enhancement Program. Furthermore, the Farm Services Agency in Mississippi and other southeastern states have identified selective herbicide and fire as cost-shared, mid-contract management practices approved for use in mid-rotation Conservation Reserve Program pine stands.

Active forest management can ensure significant financial returns to non-industrial forest landowners and simultaneously fulfill their wildlife-based management goals. Applying QVM within pine stands can provide wildlife managers a cost-effective method to increase the natural forage base for white-tailed deer.

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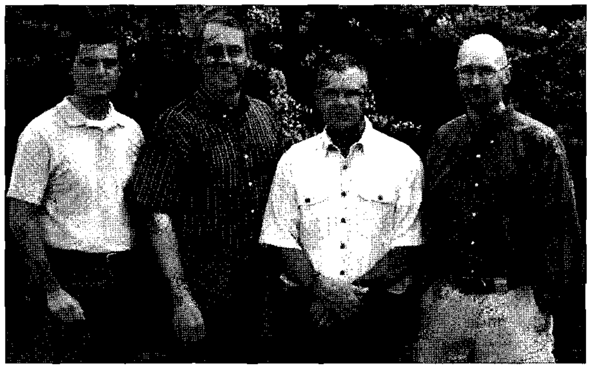

Scott L. Edwards (left) is a graduate research assistant in the Department of Wildlife and Fisheries at Mississippi State University (MSU). He received a B.S. in forestry and wildlife management from MSU in 2001. He divides his time between church activities, the pistol range, and researching the effects of intensive forestry practices on wildlife habitat quality, specifically white-tailed deer forage production. ***Steve Demarais*** (second from left) is a professor in the Department of Wildlife and Fisheries at MSU. He received a B.S. from the University of Massachusetts in 1977 and M.S. and Ph.D. degrees from MSU in 1979 and 1984, respectively. Steve enjoys integrating basic ecology and applied management of large mammals, especially white-tailed deer. ***Bobby Watkins*** (third from left) is a technical specialist in the BASF Special Products Department. He received a B.S. in animal science in 1973 and an M.S. in agronomy in 1974 from MSU. He is regularly invited by timber companies and conservation organizations throughout the Southeast to present his knowledge and expertise on wildlife habitat. He currently conducts research on the use of herbicides to improve wildlife habitat and silvicultural practices. ***Bronson K. Strickland*** (right) is a research associate and Ph.D. candidate in the Department of Wildlife and Fisheries at MSU. He received a B.S. in forest resources from the University of Georgia in 1995 and completed an M.S. at Texas A&M University-Kingsville in 1998, where his research involved estimating white-tailed deer carrying capacity in southern Texas. His research interests include large-mammal ecology and management.

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