Reprinted from Wildlife Society Bulletin
Volume 27, Number 4 Winter 1999

Effects of different silvicultural systems on initial soft mast production

Roger W. Perry, Ronald E. Thill, David G. Peitz, and Philip A. Tappe

Abstract Recent policy changes by federal land management agencies such as the United States Forest Service have led to increased use of silvicultural systems other than clearcutting. Because soft mast is an integral part of wildlife habitat and the effects of these alternative silviculture systems on soft mast production are unknown, we evaluated effects of different stand-level silvicultural systems on soft mast production in the Ouachita Mountains of Arkansas and Oklahoma. We evaluated differences in soft mast production and coverage among 4 replications of 5 treatments (clearcut, shelterwood, group selection, single-tree selection, and late-rotation, unharvested forest stands) during the first (1994), third (1996), and fifth (1998) years after initial timber harvest. Coverage of all mast-producing plants combined did not differ among treatments over all years. Soft mast production did not differ among treatments the first year after timber harvest, but was greater in harvested stands than in unharvested stands in the third post-harvest year. Production in shelterwood cuts and clearcuts was greater than in single-tree selection, group selections, and unharvested stands the fifth post-harvest year. Unharvested stands, greenbelts (unharvested buffers surrounding stream drainages), and the thinned matrix of group-selection stands produced little mast in all years. A significant linear relationship between soft mast production and residual overstory basal area was present in years 3 and 5. We present equations to predict soft mast production 3 and 5 years after harvest when residual overstory basal areas are known. Without additional stand treatments (e.g., thinning or burning), we expect production in even-aged stands (clearcuts and shelterwood cuts) to decline as canopy closure progresses; likewise, production in single-tree selection stands will likely decline due to midstory development.

Key words Arkansas, clearcut, even-aged management, forest management, fruit, group selection, Oklahoma, Ouachita Mountains, shelterwood, silviculture, single-tree selection, soft mast, uneven-aged management

Soft mast (fleshy fruits of trees, shrubs, vines, and herbaceous plants) is an important food source for many wildlife species. For example, soft mast comprised up to 96% of the summer diet of black bears (*Ursus americanus*) in Arkansas (Clapp 1990), and the movements, survival, and reproductive output of black bears may coincide with soft mast availability (Rogers 1976). Furthermore, white-tailed deer (*Odocoileus virginianus*), many songbirds, numerous small and medium-sized mammals, and some reptiles forage extensively on soft mast (Martin et al. 1951).

Even-aged forest management involving clearcutting, site preparation, and planting of seedlings has been the dominant method to regenerate pine (*Pinus* spp.) on southern national forests for over 30 years. However, recent political and environmental concerns have prompted the United States Forest Service to rely less on clearcutting and planting and to increase the use of alternative even-aged

Address for Roger W. Perry: Southern Research Station, United States Forest Service, Hot Springs, AR 71902, USA. Address for Ronald E. Thill: Southern Research Station, United States Forest Service, Nacogdoches, TX 75962, USA. Address for David G. Peitz and Philip A. Tappe: School of Forest Resources, Arkansas Forest Resources Center, University of Arkansas, Monticello, AR 71656, USA.

(e.g., seed tree and shelterwood) and uneven-aged (single-tree selection and group selection) silvicultural systems (Baker 1994). Because partial timber harvesting methods and natural regeneration appear to be the primary United States Forest Service management approach of the future, managers need to know how these systems and their varying amounts of residual basal area (BA) affect soft mast production.

Because reductions in amount of forest canopy typically increase soft mast production (Lay 1966, Halls and Alcaniz 1968), young clearcuts (<5-7 years after harvest) provide abundant soft mast. Many studies have evaluated soft mast production in young clearcuts (e.g., Johnson and Landers 1978, Campo and Hurst 1980, Stransky and Halls 1980, Stransky and Roese 1984), and other studies have compared production among forest stands differing in age, site, or overstory species composition (e.g., Clapp 1990, Noyce and Coy 1990). However, few studies have compared soft mast production among stands differing in BA or silvicultural system. Furthermore, we are unaware of any published data comparing soft mast production under even- and uneven-aged silvicultural systems.

We compared shrub-level (<2 m in height) soft mast production and coverage in late-rotation, unharvested forest stands and in stands under 4 silvicultural systems (single-tree selection, group selection, shelterwood, and clear-cut) during the first, third, and fifth growing seasons after harvest. We also measured soft mast production in unharvested greenbelts (unharvested buffers routinely retained along ephemeral and intermittent stream drainages) and developed models of expected soft mast production as a function of residual pine and hardwood overstory basal area.

Methods

Study areas

We conducted the study in the Ouachita Mountains of west-central Arkansas and east-central Oklahoma, throughout the Ouachita National Forest, and in the southernmost district of the Ozark-St. Francis National Forest. The Ouachita Mountains are a series of east-west ridges and valleys where elevations range from 152 to 853 m, mean annual precipitation ranges from 111.8 to 137.2 cm, and mean annual temperatures range from 13.9 to 16.1°C (Skiles 1981).

We selected 5 late-rotation, mixed pine-hardwood stands in 4 physiographic zones (henceforth, the north, south, east, and west blocks) of the Ouachita Mountains, for a total of 20 stands (Baker 1994). Prior to harvest, each stand was >70 years old, >14 ha, located on southerly aspects, had slopes predominantly <20%, pine BAs from 13.8 to 27.5 m^2/ha, and hardwood BAs of 4.2-l 1.5 m^2/ha. Collectively, the most abundant tree species within study stands were shortleaf pine (I? *echinata*), post oak (*Quercus stellata*), white oak (*Q. alba*), sweetgum (*Liquidambar styraciflua*), and hickories (*Carya* spp., Guldin et al. 1994). Prior to implementing treatments, no differences existed in pine or hardwood BA by dbh class, grass or forb cover, horizontal vegetative cover, or horizontal vegetative patchiness among stands when analyzed by future treatment (Thill et al. 1994).

Treatments

Within each of the 4 blocks, forest stands that met our selection criteria (Baker 1994) were randomly assigned 1 of 5 treatments; thus, each treatment was replicated 4 times in a randomized complete block design. Treatments were 3 partial-harvest prescriptions (single-tree selection, group selection, and shelterwood cut), clearcut, and late-rotation, unharvested. Harvesting was conducted late May-mid September 1993; site preparation occurred the following winter.

All stands contained ephemeral or intermittent streams that typically flow only during high-runoff events. Unharvested buffer strips or greenbelts (typically 15 m on both sides of ephemeral and intermittent streams) were established to protect water quality. Total percentage of each stand retained as greenbelt ranged from 4 to 20% and averaged 10.9% across all 16 harvested stands. We considered greenbelts a subtreatment of harvested stands; we averaged greenbelt data from all 16 harvested stands for comparison with other treatments but did not included it in the treatment effect estimates.

The 4 silvicultural prescriptions were:

1) Pine-hardwood single-tree selection: Some pines and hardwoods were removed throughout the stand (except greenbelts;Table 1). Site preparation consisted of removing all hardwoods <15-cm dbh by chainsaw felling.

2) Pine-hardwood group selection: All pines and most hardwoods were removed in group openings ranging from 0.04 to 1.9 ha in size, representing 6- 14% of the stand area (Table 1). Pines outside

Table 1. Range and mean (±SE) BA (m^2/ha) for pines, hardwoods, and total, by harvest type, for 20 stands in the Ouachita Mountains of Oklahoma and Arkansas immediately following harvest treatments.

	Pine BA		Hardwood BA		Total BA	
	Range	Mean	Range	Mean	Ranee	Mean
Unharvested	19.4-27.5	22.7f1.7	4.2-9.8	6.6fl.3	24.4-31.7	29.4f1.7
Single-tree selection	10.1-14.4	12.4±0.9	1.7-5.3	3.1k0.8	14.5-16.2	15.5±0.4
Group selection						
Openings	o-o.7	0.3f0.2	2.4-4.9	3.9f0.5	2.4-5.6	4.1f0.7
Matrix	9.6-17.4	14.2±1.6	3.9-10.8	6.2±1.6	18.3-22.2	20.3±0.8
Shelterwood	6.4-9.3	8.3±0.7	2.6-4.4	3.1±0.4	9.0-I 2.9	11.4±0.9
Clearcut	O-I .0	0.3f0.2	0.7-1.6	1.2f0.2	0.7-2.6	1.4±0.4
Greenbelt	3.8-19.9	11.6±1.3	5.0-18.2	10.4±1.0	16.3-26.0	22.0rt0.7

group openings (surrounding matrix) were thinned, and no hardwoods were harvested outside the group openings. Within group openings, all hardwoods <15-cm dbh were felled with chainsaws; no site preparation was applied in the surrounding matrix. Soft mast production data from group openings and the surrounding matrix were combined to estimate total production within these stands.

3) Pine-hardwood shelterwood: From 49 to 99 of the largest pines and hardwoods/hectare were retained (Table 1). All other pines and hardwoods were harvested or felled.

4) Clearcut: All merchantable pines and hardwoods (except a few scattered trees retained for wildlife den, mast, and perch trees) were harvested (Table 1). Site preparation consisted of injecting all non-merchantable trees (except retained wildlife trees) with Garlon® (Baker 1994). Two of the 4 clearcut stands were mechanically ripped on 3-m centers to a depth of 15-20 cm the following summer (1994), and 2 of the clearcuts were not ripped. Ripped clearcuts were hand-planted at 2.4-m intervals within the rips, and non-ripped clearcuts were hand-planted in a 2.4x3-m grid.

Soft mast sampling

Prior to timber harvest, we established 100 permanent sampling stations at 15-m intervals along 4-9 (depending on stand size and shape) parallel transects in each stand (Figure 1, Thill et al. 1994). Transects were 30-95 m apart, ran perpendicular to stand slope, and were >50 m from the stand edge. We randomly selected a subsample of these 100 stations where soft mast was sampled for the entire study period (1994, 1996, and 1998), although plot and sample size was increased after 1994 (see below).

We measured soft mast production and estimated percent coverage of soft mast producing plants, by species, during summers of 1994, 1996, and 1998 (Table 2). Prior to the study, we anticipated greater levels of production and coverage in stands with the greatest reductions in BA. Therefore, we initially sampled these stands with a smaller sample area. In 1994, we sampled 3 1-m^2 plots, located at 30 of the 100 sampling stations (90 m^2 sample area), in each unharvested and group-selection stand and 1 1-m^2 plot at 40 of the stations in each clearcut, shelterwood, and single-tree-selection stand (40-m^2 sample area). However, because we observed heterogeneous distribution of soft mast within all stands in 1994, we increased sampling effort in all stands to 1 3x3-m plot, located at each of 60 stations (540-

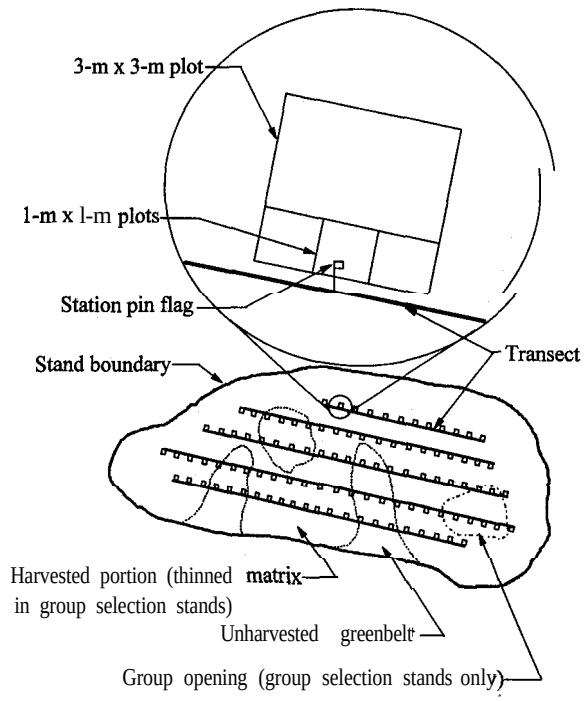

Figure 1. Stand, transect, and plot layout used to estimate soft mast production and cover in 20 pine-hardwood stands under various silviculture systems in the Ouachita Mountains of Arkansas and Oklahoma during summer 1994, 1996, and 1998.

Table 2. Soft-mast-producing taxa surveyed for production and coverage in 20 forest stands under various treatments in the Ouachita Mountains of Arkansas and Oklahoma during mid-June, mid-July, and mid-August 1994, 1996, and 1998.

Rattan (*Berchemia scandens*)	Carolina buckthorn (*Rhamnus caroliniana*)
American beautyberry (*Callicarpa americana*)	Fragrant sumac (*Rhus aromatica*)
Hackberries (*Celtis* spp.)	Winged sumac (*Rhus copallina*)
Fringe tree (*Chionanthus virginicus*)	Smooth sumac (*Rhus glabra*)
Redberry moonseed (*Cocculus carolinus*)	Wild roses (*Rosa* spp.)
Flowering dogwood (*Cornus florida*)	Blackberries (*Rubus* spp.)
Narrow-leafed dogwood (*Cornus obliqua*)	Sassafras (*Sassafras albidum*)
Hawthorns (*Crataegus* spp.)	Greenbriers (*Smilax* spp.)
Persimmon (*Diospyros virginiana*)	Coralberry (*Symphoricarpos orbiculatus*)
Deciduous holly (*Ilex decidua*)	Poison ivy (*Toxicodendron radicans*)
American holly (*Ilex opaca*)	Sparkleberry (*Vaccinium arboreum*)
Partridgeberry (*Mitchella repens*)	Blueberries (*Vaccinium* spp.)
Mulberry (*Morus rubra*)	Rusty blackhaw (*Viburnum rufidulum*)
Poke (*Phytolacca americana*)[a]	Muscadine grape (*Vitis rotundifolia*)
Black cherry (*Prunus serotina*)	Other grapes (*Vitis* spp.)
Wild plums (*Prunus* spp.)	

[a] Herbaceous species.

m^2 total sample area) in 1996 and 1998 (Table 3). We excluded data from greenbelts and greenbelt edges from analysis because soft mast production in greenbelts may have been affected by the surrounding harvest treatments.

We conducted soft mast surveys in mid-June, mid-July, and mid-August. During each of these sampling periods, we measured a different set of species to coincide with ripening phenology of the major fruit-producing species. During each sampling period, we counted all soft mast, including green fruits, located within plots to a height of 2 m. To reduce potential bias resulting from herbivory, we tallied evidence of removed fruits when possible. We developed wet to dry mass conversion factors by collecting, counting, and weighing samples of each fruit type, then drying samples of fruit to constant mass and weighing. We visually estimated percent coverage of each fruit-producing species at each plot in mid-July. A single observer estimated coverage in west- and south-block stands, and another observer estimated coverage in east- and north-block stands.

For species with large seed heads containing numerous individual fruits (e.g., *Rhus copallina*), we developed regression equations to convert volume estimates to mass. First, we collected a sample of 20-50 fruit heads per species. We measured these fruit heads in 3 dimensions to determine volume, then measured mass to derive our mass-per-volume estimates. During fruit surveys, we measured volume of each seed head on each plot to estimate mass produced.

Data analysis

We derived means of soft mast production (kg/ha dry mass) and percent coverage for each stand. We calculated treatment means from the 4 stands/treatment, except for clearcuts in 1994. In 1994, one clearcut was being ripped during the July surveys; therefore, we included only 3 clearcuts in the 1994 analysis. We sampled the same stands each year except for 1 unharvested stand. In 1997, the east-block unharvested stand was inadvertently harvested and subsequently replaced in 1998 with a similar stand. We compared means among treatments using analysis of variance (ANOVA) and Duncan's Multiple Range Test at the 0.10 level (SAS Institute, Inc. 1988). We log-transformed ($\ln[x+1]$) all means to reduce possible correlation between the mean and variance (Sokal and Rohlf 1969).

We determined total soft mast production in the greenbelts of each stand (n=15 stands in 1994 and n=16 stands in 1996 and 1998). We then determined mean greenbelt production by averaging the production among stands. Because surrounding

Table 3. Mean (±SE) amount of area (m^2) sampled for soft mast production and cover, by harvest type in 1994, 1996, and 1998 in the Ouachita Mountains of Oklahoma and Arkansas.

	1994		1996 and 1998	
Treatment	n[a]	Mean	n	Mean
Unharvested	4	90.0 ± 0.0	4	540.0 ± 0.0
Single-tree selection	4	32.5 ± 3.1	4	427.5 ± 35.0
Group selection				
Thinned matrix	4	56.3 ± 8.4	4	326.3 ± 33.3
Openings	4	14.2 ± 4.3	4	101.3 ± 17.4
Shelter-wood cut	4	32.3 ± 1.4	4	402.8 ± 31.0
Clearcut	3	31.3 ± 1.2	4	429.8 ± 5.7
Greenbelt	15	7.5 ± 1.3	16	78.8 ± 9.91

[a] Number of stands sampled.

harvest treatments may have affected soft mast production of greenbelts located within those treatments and because greenbelts and unharvested stands were similar unharvested treatments, we did not statistically analyze greenbelt data.

We regressed mean pine and hardwood basal area for each treatment with total soft mast production within that treatment to derive predictive equations. We combined all greenbelt data and included it in the model as a separate, single treatment. We considered group openings and the thinned matrix of group selection stands separate treatments because of the differences in BA between these 2 subtreatments. We log-transformed (ln[x+1]) total production data.

Results and discussion

In harvested stands, total coverage of soft mast producing species was relatively low the first year after harvest, but increased rapidly thereafter (Figure 2). No difference in coverage existed among the treatments the first post-harvest year ($F_{4,14}$=1.48, P=0.260), the third year ($F_{4,15}$=1.27, P=0.324), or the fifth year ($F_{4,15}$=1.45, P=0.266).

Percent coverage of fruit-producing plants in clearcuts was less than expected, given the level of canopy removal in these stands. However, vegetation growth in 2 of the 4 clearcut stands was dominated by grasses, which limited soft mast producing plant growth 5 years after harvest. Percent coverage of mast producing plants in these grass-dominated clearcuts averaged (±SE) 26.86f2.03 compared to 85.88±12.42 in the other 2 clearcuts (Student's t-test, t_2=7.00, P=0.020). Soft mast coverage within the 2 stands that were not grass-dominated was similar to other intensely logged areas (shelterwood cuts and group openings). The reason for this difference among clearcuts was unclear. Although 2 of the 4 clearcut stands were ripped and 2 were not, one grass-dominated stand was ripped and the other was not, eliminating ripping as a possible source of the difference. Because all stands were second-growth forest (logged previously in the early 1900s), existing seed bank and previous land uses may have been factors. Stransky and Halls (1980) found lower percent coverage and production of fruit-producing plants in second-growth forests previously used for agriculture. We suspect the 2 grass-dominated clearcuts may previously have been pine-bluestem communities (open pine woodland ecosystems with understories dominated by grasses and forbs and sustained by frequent burning) that were abundant in the western Ouachitas prior to the turn of the century (Foti and Glenn 1991).

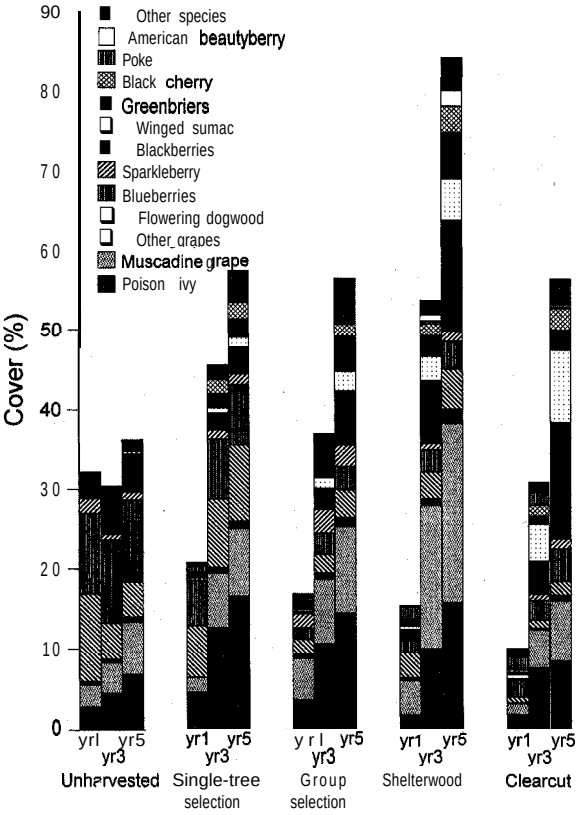

Figure 2. Mean percent coverage of dominant (based on coverage) soft mast producing taxa in unharvested, single-tree-selection, group-selection, shelterwood, and clearcut silvicultural treatments during July of the first (yr 1), third (yr 3), and fifth (yr 5) years after timber harvest in the Ouachita Mountains of Arkansas and Oklahoma, 1994-1998. Harvesting occurred during summer 1993. Significant differences (P<0.10) in coverage did not exist among treatments within years.

Percent coverage estimates were not a reliable index for potential soft mast production in our study because some abundant fruit-producing plants produced few fruits. For example, poison ivy (*Toxicodendron radicans*) was a dominant (by percent coverage) soft mast species in all study areas but produced few fruits, even in the intensely logged areas. Thus, although total coverage of fruiting species in clearcuts and shelterwoods did not differ from other treatments the third and fifth years, fruit production there was greater than in unharvested and single-tree-selection stands.

Fruit production in the.. intensely logged areas was dominated by poke (*Phytolacca americana*)

during the first year after harvest, whereas fruit from the unharvested stands consisted mainly of flowering dogwood (*Cornus florida*), grapes (*Vitis* spp.), and blueberries (*Vaccinium* spp., Figure 3). Although total fruit production did not differ among treatments the first year after harvest ($F_{4,14}$=1.62, P=0.225), poke production was greater in shelterwood cuts and clearcuts than in unharvested stands and single-tree selection treatments ($F_{4,14}$=2.56, P=0.085). Poke, a colonizing herbaceous species, was virtually gone by the fifth year, when most intensively logged stands were dominated by shrub-level woody vegetation. In the third post-harvest year, total production was significantly greater in harvested stands than in unharvested stands ($F_{4,15}$=4.91, P=0.01). By the fifth year, total fruit production was similar in clearcuts and shelterwood cuts (Figure 3), but clearcuts and shelterwood cuts produced significantly more soft mast than unharvested stands, single-tree-selection cuts.

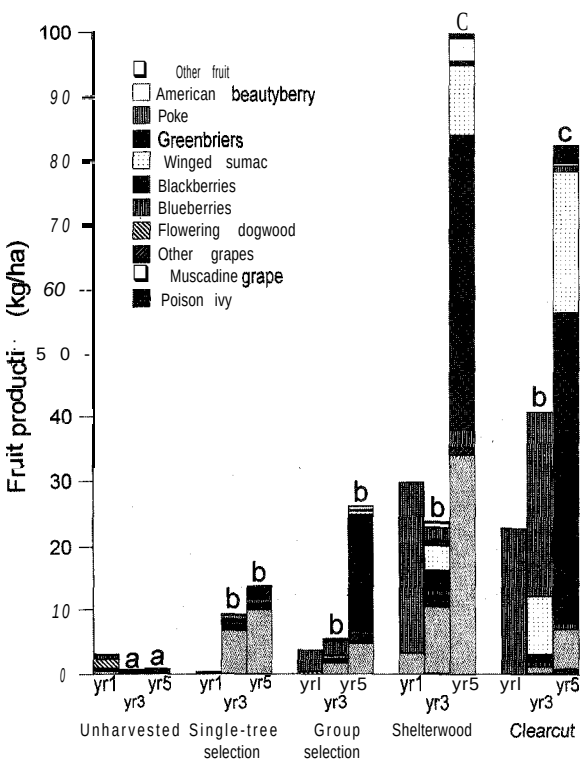

Figure 3. Mean fruit production (kg/ha dry mass) in unharvested, single-tree-selection, group-selection, shelterwood, and clearcut silvicultural treatments during summer the first (yr 1), third (yr 3), and fifth (yr 5) after timber harvest in the Ouachita Mountains of Arkansas and Oklahoma, 1994-1998. Harvesting occurred during summer 1993. Within the third and fifth years, bars with the same letter do not differ significantly (P<0.10); differences were not significant (P>0.10) the first year.

Poke (*Phytolacca americana*) is an abundant early successional soft mast species in disturbed forest habitats.

or group-selection cuts ($F_{4,15}$=21.82, P<0.001). The dominant soft mast producer in intensively logged areas the fifth year was blackberry (*Rubus* spp.), which was almost nonexistent in the unharvested stands, single-tree-selection cuts, and group-selection thinned matrix areas.

Our regression model for total soft mast production, with pine and hardwood BA as regressors, was not significant the first year after harvest ($F_{2,21}$=0.19, P=0.832, R^2=2.0). Our regression model for total soft mast production the third year was significant ($F_{2,22}$=7.08, P=0.004, R^2=39.0). Fruit production was inversely, but weakly, related to residual pine BA (P=0.01); hardwood BA did not contribute significantly to the model (P=0.366). A much stronger relationship existed 5 years post-harvest, with pine (P<0.001) and hardwood (P=0.032) BA affecting soft mast production ($F_{2,22}$=37.94, P<0.001, R^2=78.0). Our predictive equation for soft mast production 3 years after a reduction in BA was $y=3.17 - 0.09x_1$, where x_1=the residual pine BA (m^2/ha) and y=the log (ln[x+1]) of total soft mast production (kg/ha dry mass). Our predictive equation 5 years after harvest was $y=5.02-0.15x_1-0.16x_2$, where x_1=overstory pine BA (m^2/ha) and x_2=overstory hardwood BA (m^2/ha). This second model also can be used to predict soft mast production in unharvested, late rotation, pine-hardwood stands.

Similar amounts of soft mast were produced in group-selection stands (26.4±4.9 kg/ha) and single-tree-selection stands (13.3±4.5 kg/ha) the fifth post-harvest year. However, within group selection stands, group openings and the thinned matrix differed greatly in BA. In the thinned matrix areas, mean total soft mast production was 4.13 kg/ha

A S-year-old clearcut with retained wildlife trees.

(similar to production in unharvested stands), whereas production in openings was 101.65 kg/ha (similar to production in clearcuts and shelter-wood cuts). Therefore, group-selection management may offer mast-consuming wildlife better habitat than single-tree selection because group openings provide concentrated sources of abundant soft mast, which may reduce animal search and travel times, thus reducing energy expenditures.

Mean (±SE) soft mast production in greenbelts was 5.88±4.65 kg/ha the first year after harvest, 1.58f0.95 kg/ha the third year, and 3.76±2.18 the fifth year. These low production levels were similar to production in unharvested stands. Thus, retention of greenbelts reduced total soft mast production in forest stands under intensive management, such as clearcuts and shelterwood cuts. However, greenbelts provide hard mast and other important habitat features (e.g., travel corridors, snags, cavities) in addition to protection of water quality.

A shelterwood cut immediately after harvest.

Shelterwood cuts and group-selection openings provided about the same level of early successional soft mast production as clearcuts. However, with only about 10% of the stand in openings, the group-selection treatment produced less mast than either clearcuts or shelterwood cuts on a per-stand basis. Therefore, shelterwood cuts more closely approximated the abundant soft mast production of clearcuts. Clark et al. (1994) suggested female black bears in the Ouachitas avoided clearcuts, possibly due to the lack of mature trees that cubs may use for escape and hiding. Thus, shelterwood cuts may provide better foraging habitat for species such as black bear that select areas providing abundant forage and arboreal structure for hiding, escape, and other purposes.

Soft mast abundance within treated areas will continue to change as these stands mature or receive additional treatments. Although the even-aged treatments (clearcut and shelterwood) provided abundant soft mast the first few years after harvest, canopies eventually will close as these stands mature, reducing soft mast production. Other studies (e.g., Campo and Hurst 1980, Stransky and Roese 1984) suggested fruit production in clearcut stands begins to decline 3-6 years after harvest. Disturbance and reduced BA associated with removal of all or most of the seed trees (typically at about 10 years after harvest) in shelter-woods may increase soft mast production. Likewise, clearcuts, shelter-wood cuts, and group openings may be thinned or burned to promote pine regeneration and growth, which may increase soft mast production. Because single-tree-selection stands in this study were undergoing initial conversion to an uneven-aged structure, we expect shading caused

A single-tree-selection stand following initial harvest.

by midstory development to reduce soft mast production in these stands, although the effect of future overstory thinnings (roughly every 10 years) on production is equivocal. We expect group-selection stands, which have new openings created on a periodic basis, will continue to provide moderate amounts of fruit annually However, additional research on the long-term effects of silviculture systems on the dynamics of soft mast production is needed.

In conclusion, no difference in soft mast production or cover existed among silvicultural systems the first year after harvest. Clearcuts, shelterwood cuts, and group openings provided the greatest amounts of soft mast in the third and fifth years. Because of the small percentage of group-selection stands in openings, only shelterwood cuts produced initial total soft mast levels comparable to traditional clearcuts. However, without additional management such as burning or thinning, we expect mast production to decline significantly in the clearcuts and shelterwood cuts as their canopies eventually close. Unharvested stands and greenbelts produced little soft mast when compared with areas that had been harvested. Single-tree selection provided low to moderate amounts of soft mast, but we expect these levels to decrease as these stands progress toward a more uneven-aged structure with well-developed midstories. The long-term effects of additional overstory thinnings in uneven-aged stands are unknown. Group-selection management provided moderate amounts of soft mast, and we expect these stands to produce moderate, yet sustained, soft mast yields as new openings are created (roughly every 10 years).

Acknowledgments. We thank R. Lay, K. Corbin, C. Watt, and M. Lorenz for help with field measures. We also thank B. Parresol for biometrics review and T. B. Wigley and R. E. Masters for reviewing an earlier draft.

Literature cited

BAKER, J. B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. Pages 18-28 in Ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings. United States Forest Service General Technical Report SO-1 12.

CAMPO, J. J., AND G.A. HURST. 1980. Soft mast production in young loblolly plantations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 34:470–475.

CLAPP, D. L. 1990. Availability and consumption of foods and importance of habitats used by black bear in Arkansas. Thesis, University of Arkansas, Fayetteville.

CLARK, J. D., D. L. CLAPP, K. G. SMITH, AND B. EDERINGTON. 1994. Black bear habitat use in relation to food availability in the Interior Highlands of Arkansas. International Conference of Bear Research and Management 9:309–318.

FOTI, T. L., AND S. M. GLENN. 1991. The Ouachita Mountain landscape at the time of settlement. Pages 49-65 *in* Henderson, D. and L. D. Hedrick, editors. Proceedings of the conference on restoration of old growth forests in the Interior Highlands of Arkansas and Oklahoma. Winrock International, 19-20 September, Morrilton, Arkansas.

GULDIN, J. M., J. B. BAKER, AND M. G. SHELTON. 1994. Midstory and overstory plants in mature pine-hardwood stands of the Ouachita/Ozark National Forests. Pages 29-49 *in* Ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings. United States Forest Service General Technical Report SO-1 12.

HALLS, L. K., AND R. ALCANIZ. 1968. Browse plants yield best in forest openings. Journal of Wildlife Management 32:185–186.

JOHNSON, A. S., AND J. L. LANDERS. 1978. Fruit production in slash pine plantations in Georgia. Journal of Wildlife Management 42:606–613.

LAY, D.W. 1966. Forest clearings for browse and fruit plantings. Journal of Forestry 64:680–683.

MARTIN, A. C., H. S. ZIM, AND A. L. NELSON. 195 1. American wildlife and plants. McGraw-Hill, New York, New York.

NOYCE, K. V., AND I? L. COY. 1990. Abundance and productivity of bear food species in different forest types of northcentral Minnesota. International Conference of Bear Research and Management 8:169–181.

ROGERS, L. L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Transactions of the North American Wildlife and Natural Resources Conference 41:431–438.

SAS INSTITUTE, INC. 1988. SAS/STAT user's guide, Version 6.03 edition. SAS Institute, Cary, North Carolina.

SKILES, A. 1981. Arkansas climate atlas. Arkansas Energy Office, Arkansas Industrial Development Commission, Little Rock.

SOKAL, R. R., AND E J. ROHLF. 1969. Biometry W. H. Freeman, San Francisco, California.

STRANSKY, J. J., AND L. K. HALLS. 1980. Fruiting of woody plants affected by site preparation and prior land use. Journal of Wildlife Management 44:258-263.

STRANSKY, J. J., AND J. H. ROESE. 1984. Promoting soft mast for wildlife in intensively managed forests. Wildlife Society Bulletin 12:234-240.

THILL, R. E., P.A. TAPPE, AND N. E. KOERTH. 1994. Wildlife habitat conditions in mature pine-hardwood stands in the Ouachita/Ozark National Forests. Pages 126-143 *in* Ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings. United States Forest Service General Technical Report SO-1 12.

Roger W. Perry (photo) is a wildlife biologist with the United States Forest Service, Southern Research Station, Wildlife Habitat and Silviculture Lab, stationed in Hot Springs, Arkansas. He received his B.S. in fisheries and wildlife from the University of Missouri and his M.S. in zoology (emphasis in wildlife ecology) from the University of Arkansas, Fayetteville. His research interests include the effects of forest management on wildlife habitat and nongame populations and applied wildlife research. ***Ronald E. (Ron) Thill*** is a research wildlife biologist with the United States Forest Service, Southern Research Station, and is project leader of the Wildlife Habitat and Silviculture Lab in Nacogdoches, Texas. He received his B.S. and his M.S. in wildlife management from Humbolt State University and South Dakota State University, respectively, and his Ph.D. in range management from the University of Arizona. His current research focuses on the effects of even- and uneven-aged management on wildlife communities. ***David G. (Dave) Peitz*** is a research associate with the Agriculture Experiment Station, School of Forest Resources, University of Arkansas, Monticello. He received his M.S. in wildlife and fisheries ecology from Oklahoma State University and his B.S. in fisheries and wildlife biology from Iowa State University. He has been a member of The Wildlife Society since 1991 and is a certified wildlife biologist. His research interests include wildlife nutrition and habitat-population relationships for both game and nongame birds and mammals. ***Philip A. Tappe*** is associate professor of wildlife ecology with the School of Forest Resources and the Arkansas Forest Resources Center, University of Arkansas, Monticello. He received his B.S. and M.S. from Stephen F. Austin State University and his Ph.D. from Clemson University. His research and teaching interests center on relationships between forests and wildlife. His research has focused on wildlife community and population responses to forest management activities for both game and nongame species.

Associate editor: *Miller*