INITIAL SMALL MAMMAL RESPONSES TO ALTERNATIVE PINE REGENERATION METHODS IN ARKANSAS AND OKLAHOMA: PRELIMINARY FINDINGS

Ronald E. Thill, Roger W. Perry, Nancy E. Koerth, Philip A. Tappe, and David G. Peitz[1]

Abstract—We studied winter small mammal communities in the Ouachita Mountains of west-central Arkansas and eastern Oklahoma using Sherman live traps in four replications of four regeneration treatments (clearcut/plant, shelterwood, single-tree selection, and group selection), plus four mature, untreated "controls." Data on relative small mammal abundance, species richness, and diversity after one, three, and five growing seasons after harvest are presented. Capture success (all species included) generally peaked in all harvested treatments after the first growing season, declined markedly thereafter, but remained 2.6 (single tree) to 4.1 (clearcut) times greater than in controls five growing seasons after harvest. Total small mammal abundance in clearcut and shelterwood stands was significantly higher ($P \leq 0.05$) than in controls all years. With data for all species included, species richness and diversity did not differ among harvested stands in any year, but shelterwood stands had higher richness and diversity than controls in the third growing season.

INTRODUCTION

Small mammals play key roles in ecosystem processes. They occupy important trophic levels of the food web, often serving both as predators and as prey for many vertebrates. Fungus-consuming species are largely responsible for dispersal of hypogeous fungal spores that form mycorrhizae, which are required by most higher plants for optimum growth and health (Maser and others 1978). Many species of small mammals consume detrimental insects (for example, see Elkinton and others 1996) and aid in seed dispersal. Their digging and burrowing improve soil aeration and friability, and can significantly influence forest hydrology (Ursic and Esher 1988).

Consumption of pine seeds by small mammals can adversely affect pine regeneration (Pank 1974, Smith and Aldous 1947, Stephenson and others 1963), but impacts likely vary from trivial during years of bumper seed crops to devastating in years of below average seed production (Wittwer and Shelton 1992). For shortleaf pine (*Pinus echinata* Mill.) in the Ouachita and southern Ozark Mountains, seed production typically follows a feast or famine pattern with roughly one-third of the seed crops "good" or "better" (≥80,000 sound seeds per acre) (Shelton and Wittwer 1996). Seed production varies widely from year to year, and long periods of low seed production may occur, especially in the drier western portions of the Ouachita Mountains. Given this variability in shortleaf pine seed production, small mammal population responses to silvicultural practices that rely on natural regeneration are of paramount importance.

In response to growing public concern over clearcutting and hardwood control practices on national forests in Arkansas and Oklahoma, a long-term, multidisciplinary, stand-level, research and demonstration project was begun in the Ouachita Mountains in 1991 (Baker 1994). A primary objective of this research is to compare effectiveness of different partial cutting methods for natural regeneration of shortleaf pine relative to clearcutting and planting. As part of this multidisciplinary project, we are evaluating temporal changes in small mammal and bird communities and habitat conditions under these cutting treatments, which were implemented during the summer of 1993. We studied small mammal populations during two winters prior to harvesting (Tappe and others 1994). Here we summarize preliminary findings on small mammal responses to alternative pine regeneration methods at the ends of the first, third, and fifth growing seasons after harvest.

METHODS

Study Areas

Four replications of five treatments, blocked by physiographic zones (Baker 1994), were randomly assigned to 20 stands located on 9 districts of the Ouachita National Forest and the southernmost district of the Ozark-St. Francis National Forest (Thill and others 1994). All stands were late-rotation (≥60 years old), ≥35 acres in size (and blocky in shape to minimize confounding edge influences), and occupied predominantly south, southeastern, or southwestern aspects.

All stands contained ephemeral, or occasionally intermittent, stream drainages that typically flow only for short periods after heavy storms. Unharvested buffer strips ("greenbelts" henceforth) were retained along these drainages for watershed protection. Ephemeral and intermittent greenbelts were typically 65 and 130 feet wide, respectively. Greenbelts comprised 4 to 20 percent of stand acreage and averaged 10.9 percent across all 16 harvested stands.

[1] Supervisory Research Wildlife Biologist, USDA Forest Service, Southern Research Station, Nacogdoches, TX; Wildlife Biologist, USDA Forest Service, Southern Research Station, Hot Springs, AR; Statistician, USDA Forest Service, Southern Research Station, Nacogdoches, TX; Associate Professor and Research Associate, School of Forest Resources and Arkansas Forest Resources Center, University of Arkansas at Monticello, Monticello, AR, respectively.

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Pretreatment conifer basal area for all 20 stands averaged 76.7 square feet per acre and consisted almost entirely of shortleaf pine and a few eastern redcedars (*Juniperus virginiana* L.); hardwood basal area averaged 36.6 square feet per acre (Thill and others 1994). Stand conditions immediately after treatment are described by Thill and others (2000).

For additional information on study areas, climate, geology, stand selection, and experimental design, see Baker (1994) and Thill and others (2000). For information on pretreatment stand conditions and wildlife habitat characteristics, see Guldin and others (1994) and Thill and others (1994), respectively.

Treatments

Although the larger study involves 13 treatments, we chose a subset of treatments where an overstory hardwood component was retained to improve wildlife habitat and aesthetics. We also included clearcutting, which had been the principal Forest Service pine regeneration method in the Ouachitas for decades. Four treatments (clearcut, shelterwood, single-tree selection, and group selection) plus untreated controls were compared. Harvesting was completed between June 1 and September 30, 1993; site preparation, where needed, was conducted during the winter of 1993-94.

Clearcut—All merchantable pines and hardwoods were harvested except for 2 to 5 square feet per acre of hardwood basal area retained for mast production and/or cavity and den sites. All trees not harvested or retained were injected with herbicide (Baker 1994). After harvesting, all clearcuts were to be mechanically ripped to facilitate pine planting, but contractors could not be located to rip two stands. With this exception, all clearcuts were treated identically (Thill and others 2000). Genetically improved shortleaf pines were planted on an 8- by 10-foot spacing between December 1994 and March 1995. One stand was replanted in February 1996 due to inadequate stocking.

Shelterwood—From 20 to 40 of the largest pines and hardwoods per acre were retained. The basal area of trees that were left was 30 to 40 square feet per acre, of which 5 to 15 square feet per acre were overstory hardwoods. All other pines and hardwoods were harvested or felled and left on the ground.

Single-tree selection—Partial harvest of pines and hardwoods resulted in residual basal areas of 45 to 65 square feet per acre. From 5 to 20 square feet per acre of the residual basal area was in hardwoods. Site preparation consisted of removing all hardwoods <5.9 inches diameter at breast height (d.b.h.).

Group selection—Approximately 10 percent of each stand was clearcut in openings generally ranging from 0.5 to 2.0 acres in size. Most pines were cut within these openings, but 5 to 10 square feet per acre of overstory hardwood basal area was retained. Within the matrix surrounding these openings, pines were thinned to 70 to 80 square feet per acre basal area, but no hardwoods were removed. Site preparation in group openings consisted of chain-saw felling all hardwoods <5.9 inches d.b.h.; no site preparation occurred in the surrounding matrix.

Untreated controls—These areas supported second-growth, late rotation (62 to 76 years old), largely even-aged, pine-hardwood stands. Management consisted of protection from wildfire and insects.

Transects/Trap Stations

Eighty permanent trap stations were established along transects oriented parallel to topographic contours of each stand. No two transects were closer than 98 feet, trap stations were at least 49 feet apart, and no station was closer than 164 feet from stand boundaries (Thill and others 1994).

Trapping

Small mammals were trapped for seven consecutive nights between January 5-14 in 1995, 1997, and 1999. Consequently, our data characterize small mammal communities present one, three, and five full growing seasons after harvesting. Two Sherman live traps (3.0 by 3.5 by 9.0 inches) were placed at each of the 80 trap stations in each stand to ensure opportunities for multiple captures per trap station. These traps are sufficient to capture mammals as small as southern short-tailed shrews (*Blarina carolinensis*) and as large as eastern woodrats (*Neotoma floridana*); however, we were unable to adjust trigger sensitivity enough to consistently capture least shrews (*Cryptotis parva*). Traps were placed on bare ground within 16.4 feet of each station center, and (where possible) adjacent to down logs, burrows, stumps, and rocks to increase trap success. At least eight (10 percent) of the trap stations were placed within greenbelts if transects crossed sufficient greenbelt area.

Traps were baited with rolled oats, and cotton was placed in each trap to minimize trap mortality. Captured mammals were marked and released at the site of capture after recording species, sex (when possible), and trap location.

Small mammal nomenclature follows Sealander and Heidt (1990). Because accurate separation of our sympatric *Peromyscus* species is not possible in the field (Laerm and Boone 1994, Rich and others 1996), all white-footed mice (*Peromyscus leucopus*), cotton mice (*P. gossypinus*), Texas mice (*P. attwateri*), and deer mice (*P. maniculatus*) were grouped as *Peromyscus* spp.

Analyses

We computed captures per 100 trap nights as an index of relative abundance. Total available trap nights were computed by adjusting for empty sprung traps; traps that contained recaptured animals were also considered unavailable. An index of species richness was calculated as the number of species encountered on each area over the 7-day trapping period. Species diversity (Shannon-Weiner diversity index) was based on these composited data (Magurran 1988). Differences among treatments for all variables were evaluated using one-way ANOVAs (n = 20 stands). We used REGWQ multiple range tests (alpha = 0.05) to separate means (SAS Institute Inc. 1988). Analyses were run with and without *Peromyscus* data to ensure that the relatively high abundance of this group was not masking treatment effects. Variances of new captures per 100 trap nights were heterogeneous in 1995 with *Peromyscus* data included and in 1997 and 1999 with *Peromyscus* excluded; in each of these cases, values were rank transformed prior to analyses of variance. Except where noted, presented results include *Peromyscus* data.

Posttreatment surveys sampled a mixture of habitat conditions within the 16 treated stands included treated openings and thinned areas, temporary logging roads, and greenbelts. These differences within treated areas are ignored and small mammal responses to operational, stand-level conditions are reported here.

RESULTS AND DISCUSSION

Trap Success

Small mammal captures (excluding recaptures) across all treatments totaled 1,501; 1,151; and 1,091 during 1995, 1997, and 1999. Total trap nights, adjusted for recaptures and empty sprung traps, were 20,560; 20,774; and 19,131; respectively, for 1995, 1997, and 1999. Trap success across all 20 stands declined from an average of 7.3 captures per 100 trap nights in 1995 to 5.5 in 1997 and 5.7 in 1999.

Relative Abundance

Approximately 1.5 years after harvest (January 1995), small mammal trap success was about 3.0 to 5.5 times higher in harvested stands than in controls (fig. 1). Clearcut and shelterwood stands had higher capture rates than controls

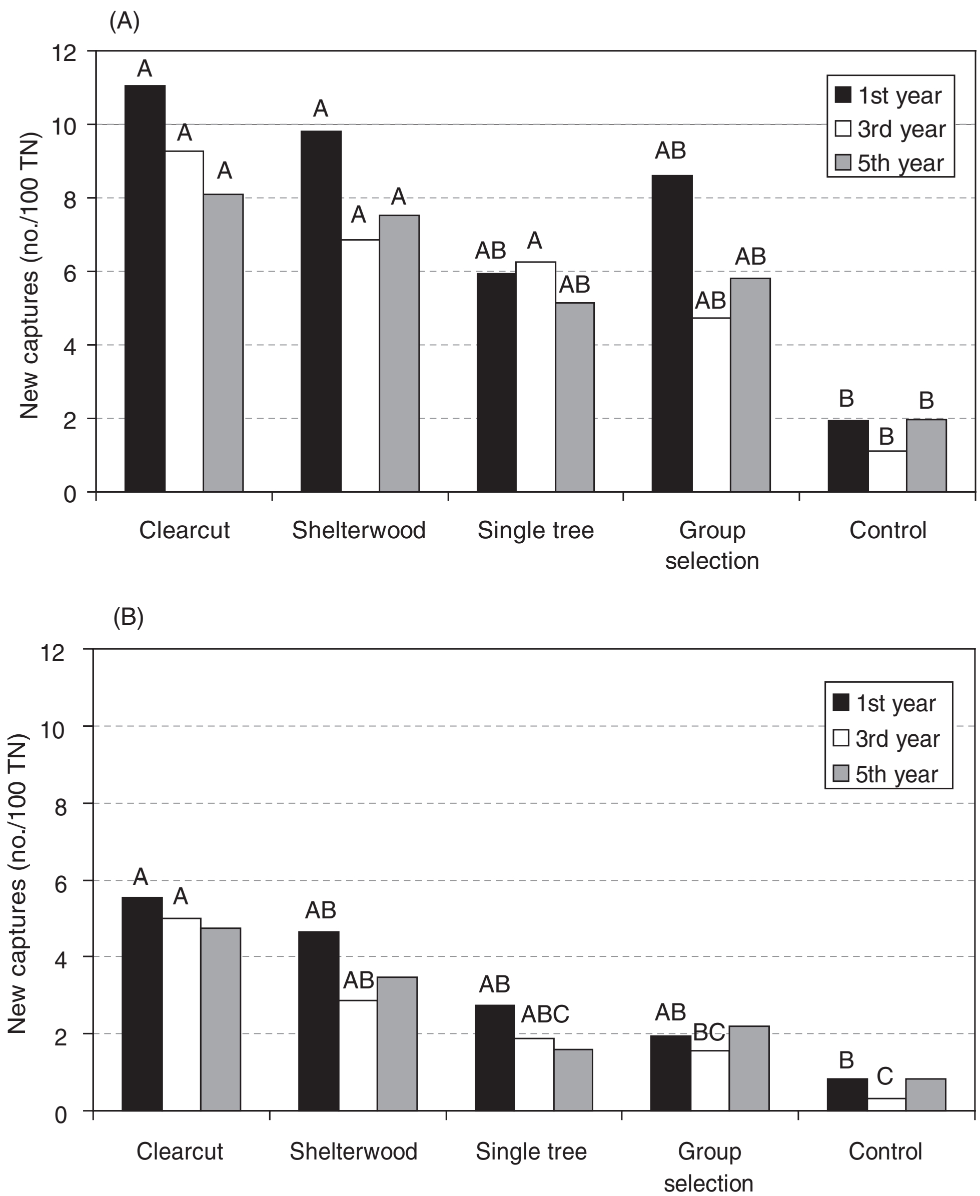

Figure 1—Relative abundance of small mammals (mean number of new captures per 100 trap nights, all species combined) by treatment following the first, third, and fifth growing seasons after harvesting pine-hardwood forests in the Ouachita Mountains of Arkansas and Oklahoma. Within years, bars with different letters are significantly different ($P \leq 0.05$). Top graph (A) includes *Peromyscus* spp.; bottom graph excludes *Peromyscus* spp.

all three sampling years; however, except for single-tree selection in 1997, differences between single-tree and group selection stands and controls were not significant ($P>0.05$) (fig. 1). Among the four harvested treatments, small mammal abundance was highest the first year after harvest, except in single-tree selection stands. When data for the four harvested treatments were averaged within years, small mammal abundance was 4.6, 6.2, and 3.5 times greater than in controls during 1995, 1997, and 1999, respectively.

With *Peromyscus* data excluded, clearcuts had significantly greater relative abundance of small mammals than the controls during 1995. In 1997, clearcut and shelterwood stands had significantly greater small mammal abundance than controls; clearcuts also had greater ($P<0.05$) abundance than group selection stands (fig. 1). By 1999, none of the treatment differences were significant.

Species Richness

Ten taxa were captured, but five (*Peromyscus* spp., *Reithrodontomys fulvescens, Blarina carolinensis, Ochrotomys nuttalli,* and *Neotoma floridana*) consistently comprised over 95 percent of captures during all three sampling years after treatment (table 1). Except for two least shrews captured in one clearcut during 1997, all species trapped after harvest were also encountered prior to treatment (Tappe and others 1994).

Small mammal species richness did not differ ($P>0.05$) among treatments in 1995 or 1999 (fig. 2). The only significant difference occurred in 1997, when richness was 2.4 times greater in shelterwood stands than in controls. *Peromyscus* spp. were present on all areas; excluding Peromyscus did not change the relationships among the treatments.

Diversity

As with species richness, there were generally no differences in small mammal diversity among treatments (fig. 3). The only significant difference occurred in 1997 when diversity was 2.2 times greater in shelterwood than in control stands. With *Peromyscus* data excluded, single-tree stands were more diverse than control stands in 1997.

CONCLUSIONS

Prior to treatment, study areas were characterized by high canopy coverage, an abundance of relatively small diameter midstory and overstory hardwoods, and limited understory browse and herbage (Thill and others 1994). These untreated, late-rotation stands also were characterized by low small mammal abundance, species richness, and diversity (Tappe and other 1994). We suspect this condition is related, at least partially, to limited soft and hard mast availability [Perry and others, in press (a); in press (b)]. Following harvest, these forage items increased rapidly.

Table 1—Nomenclature, trapping effort, total winter captures, and percent composition of small mammals by species/species group following the first (1995), third (1997), and fifth (1999) growing seasons after harvesting of pine-hardwood stands in the Ouachita Mountains of Arkansas and Oklahoma[a]

		1995		1997		1999	
Nomenclature	Common name	Captures	Percent	Captures	Percent	Captures	Percent
Order Insectivora							
Family Soricidae							
Blarina carolinensis	Southern short-tailed shrew	114	7.6	95	8.2	115	10.5
Cryptotis parva	Least shrew	0	0.0	2	0.2	0	0.0
Order Rodentia							
Family Muridae							
Microtus pinetorum	Woodland vole	5	0.3	31	2.7	33	3.0
Mus musculus	House mouse	0	0.0	0	0.0	0	0.0
Neotoma floridana	Eastern woodrat	82	5.5	71	6.2	101	9.3
Ochrotomys nuttalli	Golden mouse	132	8.8	53	4.6	70	6.4
Oryzomys palustris	Marsh rice rat	5	0.3	0	0.0	0	0.0
Peromyscus spp.[b]	Mice	866	57.7	676	58.7	609	55.8
Reithrodontomys fulvescens	Fulvous harvest mouse	277	18.4	213	18.5	143	13.1
Sigmodon hispidus	Hispid cotton rat	19	1.3	9	0.8	5	0.5
Family Sciuridae							
Glaucomys volans	Southern flying squirrel	1	0.1	0	0.0	15	1.4
Tamias striatus	Eastern chipmunk	0	0.0	1	0.1	0	0.0
Total captures:		1,501		1,151		1,091	
Total trap nights (TN)[c]:		20,560		20,774		19,131	
Total captures/100TN:		7.3		5.5		5.7	

TN = trap nights.

[a] Logging within the 16 harvested stands occurred during summer 1993. Data from all 20 stands are combined.

[b] Includes *P. leucopus*, *P. gossypinus*, *P. maniculatus*, and *P. attwateri*.

[c] Trap nights were adjusted for recaptures and sprung/empty traps; total unadjusted trap nights was 22,400 per year or 1,120 stand per year.

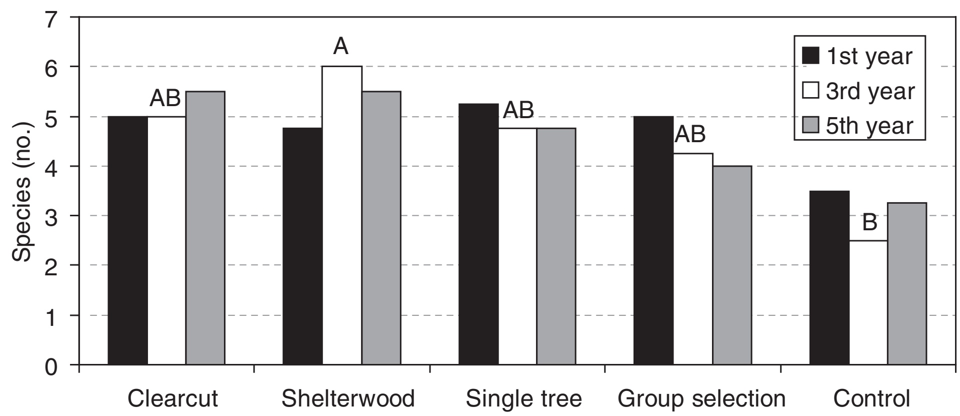

Figure 2—Small mammal species richness by treatment following the first, third, and fifth growing seasons after harvesting pine-hardwood forests in the Ouachita Mountains of Arkansas and Oklahoma. Within years, bars with different letters are significantly different ($P \leq 0.05$). Statistical results are similar with and without *Peromyscus* spp.

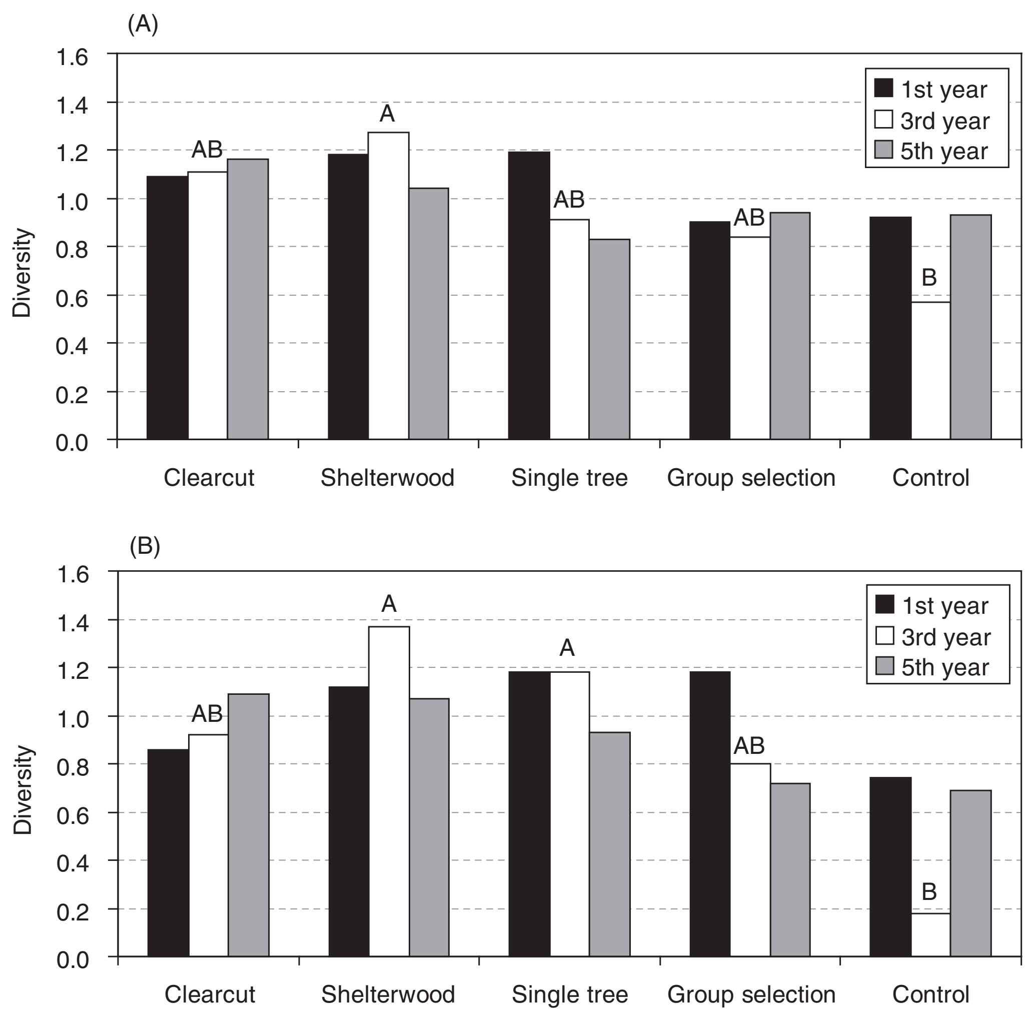

Figure 3—Small mammal species diversity by treatment following the first, third, and fifth growing seasons after harvesting pine-hardwood forests in the Ouachita Mountains of Arkansas and Oklahoma. Within years, bars with different letters are significantly different ($P \leq 0.05$). Top graph (A) includes *Peromyscus* spp.; bottom graph excludes *Peromyscus* spp.

Single-tree and group-selection stands, largely even-aged at study initiation, are in transition to an uneven-aged stand structure. Before these stands attain this structure, they must be harvested additional times and obtain satisfactory pine regeneration and survival. Consequently, it is too soon to draw definitive conclusions about small mammal responses to even- and uneven-aged regeneration methods. However, during the early stages of this transition, our data suggest that both uneven-aged treatments should yield similar small mammal species richness and diversity to those yielded by the two even-aged treatments on sites similar to those studied here. Likewise, although small mammal abundance was somewhat lower in single-tree and group- selection stands than in clearcut or shelterwood stands in all 3 years, these differences were not statistically significant. Additionally, single-tree and group-selection stands both had substantially (though not always statistically) higher small mammal abundance than unharvested stands.

From a pine regeneration standpoint, small mammal numbers increased rapidly and were at their highest level soon after harvesting. Because of logging and site preparation disturbances, seedbed conditions are also typically optimal for natural pine regeneration soon after harvesting. Given these conditions, the seed production characteristics of shortleaf pine, and the rapid response of small mammals to harvesting, foresters have legitimate concerns about seed consumption by small mammals (and other wildlife). Thus, additional research investigating actual impacts under these silvicultural systems may be advisable. Increases in bird abundance following these treatments were not as rapid as for small mammals (Thill and others 2000).

Small mammal abundance, richness, and diversity did not differ ($P>0.05$) between clearcut and shelterwood stands during any sampling year with or without inclusion of *Peromyscus* data. Thus, shelterwood regeneration methods can achieve similar small mammal responses as clearcutting within aesthetically more-pleasing settings (Personal communication. Victor A. Rudis. 2000. Research Forester, USDA Forest Service, Southern Research Station, Forestry Sciences Laboratory, 201 Lincoln Green, Starkville, MS 39759) during at least the first 5 years after harvest. Healthy small mammal populations should benefit a host of vertebrate predators.

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