Small Mammal and Herpetile Response to Mid-rotation Pine Management in Mississippi

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Abstract: Prescribed burning and/or herbicide applications are performed in managed pine (*Pinus* spp.) forests to control non-pine vegetation. Little research has examined small mammal or herpetile community response to these treatments in mid-rotation pine stands. Therefore, our objective was to determine prescribed burning and herbicide treatments effects on small mammal and herpetile communities within mid-rotation pine plantations in Mississippi. We established 4 treatments (herbicide only, herbicide/burn, burn only, control) with 6 replicates within thinned, mid-rotation (18–22 years old) loblolly pine *(P. taeda)* stands. We applied 697–872 ml/ha of Arsenal herbicide during September 1999 and conducted prescribed burning during January 2000. We captured small mammals and herpetiles to examine abundance, richness, and diversity as related to habitat conditions before and 2 years after treatment. We captured 15 species of small mammals and 21 species of herpetiles. Use of a skidder for herbicide application may have reduced small mammal richness and diversity during the first winter after treatment. Overall species diversity and richness did not differ between the pretreatment growing season and the first year post-treatment growing season. However, small mammals, particularly peromyscids, generally responded favorably to burning and burning with herbicide treatments the first and second growing seasons after treatment. Treatments in mid-rotation pine plantations that maintain early successional vegetation and open canopy structure should be beneficial to small mammal and herpetile communities, although more years of post-treatment response are needed to make definitive management recommendations.

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Private industry owns more forestland in the southeastern United States than any other single entity (Mobley and Balmer 1981). Of the 86.2 million ha of timberlands in the 13 southeastern states, forest industry owns 14.4 million ha (16.7%; U.S.

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Forest Ser. 2002). This includes ownership of 1.3 million ha of 7.6 million ha of timberlands in Mississippi (17%; U.S. Forest Ser. 2002). Most of this land is dominated by loblolly pine *(Pinus taeda)* plantations on a 27- to 35-year harvest rotation which will undergo commercial thinnings and treatments, such as prescribed burning and/or herbicide applications, to reduce hardwood and herbaceous competition (Schultz 1997). With such a large amount of land under 1 type of management, it is important to understand how this land use may affect wildlife communities.

Several studies have examined effects of herbicide applications on wildlife communities in the Southeast (e.g., Hurst 1987, Hurst and Watkins 1988, Watkins et al. 1989, Howell et al. 1996). Counter to public opinion that herbicides have direct toxicity to wildlife, their impact is through changes in vegetation composition and structure (Borrecco et al. 1979, Sullivan and Sullivan 1982, Morrison and Meslow 1983, McComb and Hurst 1987, Sullivan et al. 1998*a, b*). Several authors have investigated small mammal response to herbicide-induced changes (e.g. Sullivan and Sullivan 1982, Anthony and Morrison 1985, Lautenshlager 1993), but data on such effects generally are lacking for mid-rotation pine stands in the southern United States (Howell et al. 1996). Additionally, although effects of fire on vegetation and soil are well documented, information on effects of fire to small mammal and herpetile communities is lacking (Means and Campbell 1981, Taylor 1981, Landers 1987, Ford et al. 1999, Russell et al. 1999), especially in mid-rotation pine stands of the southeastern United States.

Although a few studies have investigated effects of burning and herbicide treatments together on wildlife communities (Chen et al. 1977, Sullivan and Boateng 1996, Cole et al. 1998, Brockway and Outcalt 2000), only Chen et al. (1977) examined these effects in mid-rotation pine plantation communities. Brennan et al. (1998) suggested that managers may derive greater habitat benefits by using selective herbicide and burning in combination, rather than each alone. However, further research is needed to substantiate this. Given the lack of information on effects of burning and herbicide treatments on wildlife communities and the increasing constraints on conducting prescribed burning (Haines et al. 2001), there is a need to experimentally determine effects of burning and herbicide treatments in mid-rotation pine plantation communities. Additionally, in spite of recognized worldwide population declines of herpetiles (Ryan et al. 2002) and the importance of these species to forested ecosystems, herpetiles are often ignored in forest management planning (Russell et al. 2002). Recently, however, Russell et al. (2002), working in South Carolina, investigated effects of clearcutting and site preparation in upland forests adjacent to isolated wetlands on herpetiles inhabiting these wetlands. Our objective was to experimentally examine effects of prescribed burning and herbicide application on small mammal and herpetile communities in post-thinned, mid-rotation pine plantations in east-central Mississippi.

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Methods

Study Area

We conducted our study on Weyerhaeuser Company timberlands in the Interior Flatwoods Resource Area, within the upper coastal plain of Kemper County, Mississippi (Pettry 1977). The 9,700-ha area containing the study plots was dominated by short-rotation (27–32 years), intensively-managed loblolly pine plantations. The area also included mature pine-hardwood forests (17%), mature hardwood forests (10%, primarily in riparian zones), and non-forested areas (3%). Prior to treatment, these stands were characterized by an abundant midstory layer of hardwood trees, particularly hickory (*Carya* spp.), red maple *(Acer rubra)*, sweetgum *(Liquidambar styraciflua)*, and oak (*Quercus* spp.). Common understory species were blackberry (*Rubus* spp.), poison ivy *(Toxicodendron radicans)*, Japanese honeysuckle *(Lonicera japonicus)*, and grasses (Poaceae).

Stand Establishment and Treatment Applications

We selected 6 stands based on similarity of stand condition and a minimum size (>58 ha). At the start of the study (1999), stands were between 18 and 22 years old, were thinned 2 to 5 years prior, and were fertilized immediately after thinning. Within each of the 6 replicate stands, we established 4 286-x 350m treatment plots which were separated from each other by at least 50 m. Buffer width was arbitrarily selected to provide enough estimated distance to prevent adjacent treatments from affecting one another while allowing enough room within stands to place all 4 treatments. We randomly assigned 1 of 4 treatments to each plot: control (no treatment), prescribed burning, herbicide application, or herbicide application followed by a prescribed burn. Therefore, our experimental design consisted of 4 treatments with 6 replicates of each treatment.

We applied herbicide during September 1999 and conducted prescribed burning during January 2000. For herbicide treatments, a skidder sprayer applied 150-187 liters/ha containing 697–872 ml/ha of imazapyr (Arsenal; BASF Corporation, Mount Olive, N. J.) diluted with water and 0.5% of total solution of a surfactant (Timbersurf 90, Timberland Enterprises, Inc., Monticello, Ark.), added. We initiated prescribed fires with drip torches and began with lighting a backing fire, followed by igniting several strip headfires. We burned all 6 stands between 6 and 21 January 2000. For all burns, mean ambient temperature was 34 C (range=26–38 C), windspeed varied from 1.7–4.8 km/hr, relative humidity was 29%–30% for 5 burns and 39% for 1 burn, cloud cover ranged from 0%–5%, and mean fuel moisture was 17.8% (range= 14.8%–21.7%; Hood 2001).

Animal Community Sampling

We collected 1 year pre-treatment (1999) data for small mammals and herpetiles, 1 year post-treatment data for herpetiles (2000), and 2 years post-treatment data for small mammals during winters 2000 and 2001. We trapped small mammals during winters (Jan–Mar) of 1999–2001 using 7.6- × 7.6- × 27.9-cm Sherman live traps baited with a peanut butter and oatmeal mixture wrapped in wax paper. We randomly established a 5 × 5 trap grid in 1999 and 2001, and a 7 × 7 trap grid in 2000, within each treatment plot but not within 50 m of the plot edge. Traps were 20 m apart so that the entire grid covered 80 × 80 m in 1999 and 2001 and 120 × 120 m in 2000. Because the additional effort of an increased grid during 2000 did not increase number of captures, we decreased grid size to the original 5 × 5 spacing during 2001 (Hood 2001). We waited at least 30 days before trapping during winter 2000 in plots that were burned. We trapped 2 stands simultaneously (8 grids) until all 6 stands were sampled. We opened and checked traps daily for 10 days, or until we obtained a >50% recapture rate with many individuals captured multiple times. For 1 trapping session, we kept traps open for 15 days because of very low capture success. We identified all small mammals captured to species and gender (when possible), and weighed and toe-clipped each individual (Melchior and Iwen 1965).

We also sampled small mammals and herpetiles using 3 drift fence arrays in each plot. Arrays consisted of 3 5-m long fences at 120° angles from each other with pitfall traps at the end of each fence and in the center of the fences (N=4 pitfall traps/array; Enge 1997). We used 0.35-m aluminum flashing for the fences and plastic 18.5-liter buckets for the pitfall traps. To increase snake captures, we constructed double-opening funnel traps from aluminum screening according to Enge (1997), and, in 2000, we placed 3 at each array (1 against each fence approximately in the middle of the fence). We installed arrays diagonally across each plot, with the end arrays being 50 m in from plot boundaries and the center array being in the plot center. We opened pitfall traps for 10 days in June 1999, and pitfall and funnel traps for 10 days in May, June, and October, 2000. We intended to also sampling during late February/early March, but logistic difficulties prevented this. Therefore, we likely missed documentation of some species, particularly amphibians, which are more active during this time of year. We simultaneously sampled 3 stands (36 arrays), checking all traps daily and identifying all individuals captured to species before release. In addition, we sexed, weighed, and toe-clipped all small mammals captured. We covered pitfall traps and removed funnel traps when not in use. We followed Mississippi State University's Institutional Animal Care and Use (IACUC) protocol #98-046 for all capture and handling of animals.

Statistical Analyses

We calculated catch per unit effort (CPUE; number captured per trap night) for all species within each trapping grid used only for small mammal captures during winter and within each pitfall array. Although we captured white-footed *(Peromyscus leucopus)* and cotton mice *(P. gossypinus),* field identification of these species was difficult. Therefore, we combined these 2 species for all analyses except that of species richness and refer to them as peromyscids. Similarly, toads *(Bufo* spp.) we captured likely included American *(B. americanus)* and Fowler's *(B. fowleri)* toads, and possible hybrids. For all analyses, including that of species richness, *Bufo* species were combined and counted as only 1 species. We calculated species richness (number of species captured) and Shannon-Weaver species diversity (Shannon and Weaver 1963) within each winter trapping grid and each pitfall array. For analyses, each pitfall array was treated as subsamples within plots (N=24 plots; 4 treatments with 6 replicates).

We tested the null hypotheses that there were no differences in CPUE, species richness, or species diversity among treatments. We used a mixed-models analysis of variance (ANOVA) with location (each of 6 stands) as a random effect and treatment as a fixed effect in a 2×2 factorial arrangement of treatments [burn without herbicide, herbicide without burn, both herbicide and burn, or neither herbicide nor burn (control)]. For all analyses, we included all captures in analyses of overall capture rates and species richness and diversity, but only species captured greater than 5 times were analyzed independently. We analyzed 1999 data as if treatments had been applied to determine if there were pre-existing differences among treatments. We considered significance as α=0.05.

Results

Vegetation Changes Due to Treatments

The following summary of vegetation changes due to the applied treatments is from Thompson (2002). During 2000, the first growing season post-treatment, the herbicide/burn treatment resulted in the greatest reduction of midstory basal area, foliage height density, and woody plants. Conversely, midstory basal area, foliage height density, plant species richness and diversity, and percentage cover of grasses, grass-likes, and woody plants were all greatest in the control plots. Plant community response to the prescribed burn treatments was most similar to the control plots. Percentage cover of forbs was an exception to this trend with the greatest coverage in the prescribed burn and herbicide/burn plots.

During the second growing season post-treatment (2001), plant communities became more similar among treatments. Midstory basal area was still lowest in the herbicide/burn treatment. However, there was no difference in midstory basal area between the prescribed burn, herbicide, and control treatments. Foliage height from 0.6–1.8 m above ground was lowest in the herbicide/burn and herbicide treatments. Plant species richness, diversity, and percentage cover of woody stems were greatest in the prescribed burn and control plots. Percentage cover of forbs was greatest in the herbicide/burn treatment, whereas percentage cover of grasses and grass-likes were lowest in the herbicide treatments.

Winter Small Mammal Trapping

Common and scientific epithets of the small mammals and herpetiles captured in mid-rotation pine plantations are found in Table 1. During 1999, we made 330 captures of 154 separate individuals comprising 8 species (Table 2).

Neither overall nor any individual species' capture rates differed significantly (P>0.05) among treatments during the pre-treatment year, indicating pre-treatment differences among treatments did not exist. During 2000, we made 652 captures of 276 individuals comprising 8 species (Table 2).

Burning and herbicide did not interact($F_{1,5}$≤5.3, P>0.05) to affect overall or any

Table 1. List of small mammal and herpetile species captured during winter 1999–2001 (small mammals only in Sherman live traps) and summer 1999–2000 (pitfall arrays) in thinned, mid-rotation loblolly pine plantations in east-central Mississippi.

Small mammals		Herpetiles	
Common name	Scientific name	Common name	Scientific name
Cotton mouse	*Peromyscus gossypinus*	American toad	*Bufo americana*
Eastern harvest mouse	*Reithrodontomys humulis*	Central newt	*Notophthalmus viridescens louisianensis*
Eastern mole	*Scalopus aquaticus*	Eastern narrowmouth toad	*Gastrophyrne carolinensis*
Golden mouse	*Ochrotomys nuttalli*	Five-lined skink	*Eumeces fasciatus*
Hispid cotton rat	*Sigmodon hispidus*	Fowler's toad	*Bufo woodhousii fowleri*
House mouse	*Mus musculus*	Green anole	*Anolis carolinensis*
Least shrew	*Cryptotis parva*	Ground skink	*Scinella lateralis*
Pine vole	*Pitymys pinetorum*	Midland brown snake	*Storeria dekayi wrightorum*
Rice rat	*Oryzomys palustris*	Mississippi ringnake snake	*Diadophus punctatus stictogenys*
Southern short-tailed shrew	*Blarina carolinenesis*	Mississippi slimy salamander	*Plethodon mississippi*
White-footed mouse	*Peromyscus leucopus*	Northern fence lizard	*Sceloporus undulates*
		Smallmouth salamander	*Ambystoma texanum*
		Southern black racer	*Coluber constrictor priapus*
		Southern copperhead	*Akgistrodon contortrix contortrix*
		Southern leopard frog	*Rana utricularia*
		Speckled kingsnake	*Lampropeltis getula holbrooki*
		Spring peeper	*Pseudacris crucifer*
		Timber rattlesnake	*Crotalus horridus*
		Upland chorus frog	*Pseudacris feriarum*
		Western pygmy rattlesnake	*Sistrurus miliarus streckeri*

Table 2. Mean ($\bar{x}$) ± standard error (SE) for catch per unit effort (number of captures/trapnight) for (1) all small mammals captured and (2) species for which at least 5 individuals were captured using Sherman traps within thinned loblolly pine plantations during winter in Kemper County, Mississippi, 1999–2001. Data from 1999 were pre-treatment.

		Catch per unit effort					
		1999		2000		2001	
Species	Treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
All species combined[b]	B	0.051	0.021	0.096	0.026	0.064	0.016
	BH	0.036	0.022	0.065	0.013	0.165	0.039
	C	0.121	0.046	0.073	0.027	0.104	0.031
	H	0.082	0.025	0.022	0.007	0.075	0.016
South. short-tailed shrew	B	0.004	0.004	0.006	0.001	0.001	0.001
	BH	0.001	0.001	0.005	0.003	0.001	<0.001
	C	0.002	0.002	0.003	0.002	0.008	0.004
	H	0.002	0.001	<0.001	<0.001	<0.001	<0.001
Peromyscids[c]	B	0.043	0.02	0.055	0.026	0.046	0.013
	BH	0.027	0.022	0.05	0.009	0.161	0.041
	C	0.108	0.044	0.046	0.025	0.05	0.031
	H	0.052	0.014	0.016	0.007	0.062	0.017
Golden mouse	B	0.002	0.001	0.023	0.01	0.016	0.014
	BH	0.003	0.003	0.004	0.003	0	
	C	0.006	0.005	0.014	0.004	0.025	0.005
	H	0.014	0.008	0.004	0.003	0.002	0.002
Eastern harvest mouse	B	IC[d]		0.007	0.003	0	
Eastern harvest mouse	BH	IC		0.002	0.002	0.003	0.002
	C	IC		0.007	0.004	0.003	0.002
	H	IC		0		0.003	0.002
Cotton rat	B	0.001	<0.001	0.004	0.002	0.001	<0.001
	BH	0.002	0.002	<0.001	<0.001	0	
	C	0		0.003	0.002	0.019	0.011
	H	0.012	0.005	0.001	<0.001	0.007	0.004

a. B=burned winter 2000; BH=herbicide-treated September 1999 and burned winter 2000; C=control (no treatment); H=herbicide-treated September 1999.

b. Includes species with ≤ 5 individual captures.

c. Includes white-footed mice and cotton mice.

d. IC=Insufficient captures (≤ 5 individuals) during that year.

individual species' capture rate. However, herbicide application lessened capture rates of golden mice (*Ochrotomys nuttalli;* $F_{1,5}$=7.70, *P*=0.039). During 2001, we recorded 580 captures of 184 individuals of 6 species (Table 2). Burning and herbicide interacted ($F_{1,5}$=15.7, *P*=0.011) to increase overall capture rate. This interaction ($F_{1,5}$=8.51, *P*=0.033) was also observed for peromyscids, but no other treatment interactions nor main effects were detected ($F_{1,5}$≤5.72, *P*≥0.06).

During 1999, plots to be burned had fewer species, on average, than other treatment plots ($F_{1,5}$=6.62, *P*=0.05/ Table 3). During 2000, burning and herbicide did not interact to affect mean species richness ($F_{1,5}$=0.05, *P*=0.833), but herbicide did lessen mean number of species captured ($F_{1,5}$=12.79, *P*=0.016). During 2001, no treatment interaction was observed ($F_{1,5}$=1.24, *P*=0.317), but burning lessened observed mean species richness ($F_{1,5}$=8.37, *P*=0.0341).

Table 3. Mean ($\bar{x}$) ± standard error (SE) for species richness and Shannon-Weaver diversity for small mammals captured with Sherman traps within thinned loblolly pine plantations during winter in Kemper County, Mississippi, 1999-2001. Data from 1999 were pre-treatment.

		Species richness		Species diversity	
Year	Treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE
1999	B	1.500	0.224	0.231	0.124
	B/H	1.000	0.365	0.146	0.059
	C	2.000	0.447	0.277	0.059
	H	2.833	0.792	0.685	0.217
2000	B	4.000	0.365	1.013	0.151
	B/H	2.500	0.562	0.547	0.149
	C	3.333	0.422	0.805	0.112
	H	2.000	0.258	0.492	0.145
2001	B	1.667	0.333	0.277	0.074
	B/H	1.667	0.422	0.141	0.092
	C	3.167	0.477	0.772	0.091
	H	2.333	0.333	0.533	0.183

B=burned winter 2000; BH=herbicide-treated September 1999 and burned winter 2000; C=control (no treatment); H=herbicide-treated September 1999.

To test if reduced mean species richness in burned plots in 2001 differed from the pre-existing difference between treatment plots observed in 1999, we examined all 3 years of species richness data for a given treatment plot (burn, burn/herbicide, herbicide, and control) with year as a fixed effect. Among burn only plots, there was a year effect ($F_{2,15}$=19.91, P≤0.001) with mean species richness being greater in 2000 than in 1999 (t_{15}=5.64, P≤0.001) but not different in 2001 from 1999 (t_{15}=0.38, P=0.712). Mean species richness decreased in these plots between 2000 and 2001 (t_{15}=5.27, P≤0.001). Among burn/herbicide plots ($F_{2,15}$=2.70, P=0.1), herbicide only plots ($F_{2,15}$=0.66, P=0.534), and control plots ($F_{2,15}$=2.61, P=0.106), there was no year effect.

For species diversity (Table 3) during 1999, no interaction ($F_{1,5}$=3.97, P=0.103) nor main effects (burn: $F_{1,5}$=3.57, P=0.117; herbicide: $F_{1,5}$=1.27, P=0.311) were observed among treatments, indicating pre-treatment differences did not exist. During 2000, no treatment interaction was observed ($F_{1,5}$=0.49, P=0.516), but herbicide application reduced species diversity ($F_{1,5}$=7.52, P=0.041). During 2001, there was again no treatment interaction ($F_{1,5}$=0.35, P=0.582), but, in this second post-treatment year, burning reduced species diversity ($F_{1,5}$=19.90, P=0.007).

Summer Small Mammal and Herpetile Trapping

During 1999, we recorded 566 captures of 23 species (Table 4) which included 264 captures of 11 mammalian species and 302 captures of 12 herpetile species. Although no individual species (N=13) exhibited pre-existing differences ($F_{1,5}$≤6.49, P>0.05) in capture rates among treatment plots, total capture rate was less ($F_{1,5}$=6.74, P=0.048) in plots to be burned. When overall captures were separated as herpetile or small mammal, we observed lesser capture rates for herpetiles in plots to be burned

($F_{1,5}$=10.02, *P*=0.025) and the burn and herbicide interaction ($F_{1,5}$=10.07, *P*=0.025).

During summer 2000, we recorded 813 captures of 25 species, including 288 captures of 10 mammalian species and 525 captures of 15 herpetile species (Table 4). No treatment interactions ($F_{1,5}$≤4.91, *P*≥0.06) nor main effects were observed on overall capture rates for all individuals captured or when separated into mammal and herpetile captures. To determine if pre-existing differences affected observed treatment effects, we re-analyzed these 2000 capture rates as differences from the 1999 rates. This upheld the prior results of no treatment interactions (*P*<0.05) or main effects on the overall capture rates or total herpetile capture rates. During 2000, extremely low capture rates prevented analyses of fall (Oct) pitfall surveys.

Although treatment type did not affect overall capture rates, several individual species' capture rates were affected. Capture rates of fence lizards *(Sceloporus undulatus)* were positively affected by the burning and the herbicide applications (burn: $F_{1,5}$=9.90, *P*=0.026; herbicide: $F_{1,5}$=10.25, *P*=0.024), and captures of least shrews (*Cryptotis parva;* $F_{1,5}$=9.42, *P*=0.028) and golden mice ($F_{1,5}$=6.90, *P*=0.047) were affected negatively by herbicide application.

For species richness (Table 5), no pre-existing differences (*P*<0.05) among treatment plots were observed in 1999. During 2000, neither burning nor herbicide affected mean species richness for combined herpetile and small mammal captures (burn*herbicide: $F_{1,5}$=0.26, *P*=0.629; burn: $F_{1,5}$=0.59, *P*=0.476; herbicide: $F_{1,5}$= 2.38, *P*=0.184), herpetile richness (burn*herbicide: $F_{1,5}$=0.16, *P*=0.709; burn: $F_{1,5}$=1.41, *P*=0.289; herbicide: $F_{1,5}$=1.41, *P*=0.289), nor small mammal richness

Table 4. Mean ($\bar{x}$) ± standard error (SE) for catch per unit effort (number of captures/trapnight) for all species captured, all herpetile species captured and, all small mammal species captured, via pitfall arrays, within thinned loblolly pine plantations during summer in Kemper County, Mississippi, 1999 and 2000. See Hood (2001) for individual capture rates. Data from 1999 were pre-treatment.

		Catch per unit effort			
		1999		2000	
Species group	Treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE
All captures	B	0.711	0.114	0.556	0.073
	B/H	0.678	0.035	0.639	0.159
	C	0.961	0.139	0.542	0.058
	H	0.822	0.112	0.525	0.094
Herpetile captures	B	0.311	0.082	0.350	0.049
	B/H	0.322	0.053	0.458	0.118
	C	0.633	0.146	0.286	0.063
	H	0.411	0.053	0.367	0.079
Small mammal captures	B	0.383	0.053	0.206	0.030
	B/H	0.350	0.034	0.181	0.047
	C	0.317	0.011	0.256	0.053
	H	0.411	0.086	0.158	0.031

a. B=burned winter 2000; BH=herbicide-treated September 1999 and burned winter 2000; c=control (no treatment); H=herbicide-treated September 1999.

Table 5. Mean $\bar{x}$ ± standard error (SE) for species richness (richness) and Shannon-Weaver species diversity (diversity) for (1) all species captured, (2) all hepetile species captured, and (3) all small mammals species captured via pitfall arrays within thinned loblolly pine plantations during summer in Kemper County, Mississippi, 1999 and 2000. See Hood (2001) for individual capture rates. Data from 1999 were pre-treatment.

		Richness				Diversity			
		1999		2000		1999		2000	
Species group	Treatment[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
All captures	B	8.167	0.601	9.167	0.833	1.838	0.052	1.768	0.072
	BH	7.500	0.719	8.500	0.764	1.755	0.118	1.597	0.151
	C	9.167	0.477	10.00	0.258	1.717	0.118	1.796	0.079
	H	8.667	0.494	8.667	0.615	1.839	0.075	1.692	0.086
Herpetile captures	B	2.500	0.428	4.333	0.333	0.644	0.088	0.964	0.049
	BH	2.667	0.760	3.667	0.667	0.660	0.147	0.874	0.156
	C	3.667	0.760	4.667	0.211	0.750	0.112	0.842	0.072
	H	3.167	0.167	4.333	0.333	0.726	0.071	1.005	0.111
Small mammal captures	B	5.665	0.494	4.833	0.601	1.194	0.08	0.803	0.066
	BH	4.833	0.654	4.833	0.477	1.095	0.125	0.723	0.078
	C	5.500	0.619	5.333	0.211	0.967	0.154	0.925	0.099
	H	5.500	0.428	4.333	0.494	1.113	0.098	0.687	0.086

a. B=burned winter 2000; BH=herbicide-treated September 1999 and burned winter 2000; C=control (no treatment); H=herbicide-treated September 1999.

(burn*herbicide: $F_{1,5}$=1.43, P=0.286; burn: $F_{1,5}$≤0.001, P=1.00; herbicide: $F_{1,5}$=1.25, P=0.314).

For species diversity (Table 5), there were no pre-existing differences (P<0.05) among plots to be treated. During 2000, no differences in species diversity for combined herpetile and small mammal captures (burn*herbicide: $F_{1,5}$=0.25, P=0.64; burn: $F_{1,5}$=0.24, P=0.643; herbicide: $F_{1,5}$=1.64, P=0.256), herpetiles alone (burn*herbicide: $F_{1,5}$=1.96, P=0.221; burn: $F_{1,5}$=0.00, P=0.966; herbicide: $F_{1,5}$=0.10, P=0.759), nor small mammals alone (burn*herbicide: $F_{1,5}$=1.29, P=0.307; burn: $F_{1,5}$=0.38, P=0.563; herbicide: $F_{1,5}$=2.78, P=0.156) were observed among treatments.

Discussion

Our results need to be viewed within the limitations of this study. We only examined 1 year post-treatment for summer sampling and although we conducted 2 years of winter sampling for small mammals, the first post-treatment sampling session occurred only 30 days after burning was applied. In addition, drought conditions during 1999 and 2000 likely negatively affected capture rates for herpetiles. A single burning treatment does not allow development of a plant community that would result from a complete burning rotation (Waldrop et al. 1992, Haywood et al. 2001). In addition, because burning and herbicide treatments affect successional trajectories, it may take several years to fully assess changes in wildlife communities due to these treatments (Engstrom et al. 1984, Miller and Witt 1990, O'Connell and Miller 1994, Cole et al. 1998, Brockway and Outcalt 2000). Therefore, our results should be interpreted as a preliminary assessment of effects of burning and herbicide treatments immediately following implementation, and not an indication of the end result of these treatments.

During winter 2000 (first sampling after treatment), herbicide treatments reduced small mammal richness and diversity, and CPUE of golden mice. The reduction in species diversity was likely a direct result of the observed reduction in species richness. However, no differences in species richness nor diversity was observed during summer 2000, although CPUE for golden mice and southern short-tailed shrews *(Blarina carolinensis)* were reduced due to herbicide treatments during summer 2000 (see below). Given that winter 2000 was prior to the first growing season after herbicide treatment (i.e., reduced growth and mortality due to herbicide application not yet manifested) and small mammal species diversity and richness were unaffected during the first growing season (summer 2000), it is unlikely that the herbicide itself caused the reduction in species richness and diversity.

The machinery used to apply herbicide may have caused the observed differences. Golden mice are semi-arboreal, using brushy midstory trees and woody vines for nesting and feeding platforms (Goodpaster and Hoffmeister 1954, Dueser and Shugart 1978, Wagner et al. 2000). Herbicide was skidder-applied between every other row of pine trees and may have greatly reducing the structure of midstory vegetation and vines. Many of the smaller midstory trees were bent over, and blackberry (*Rubus* spp.) tangles and vines were broken up and flattened. It is possible that this modification of the vegetation negatively impacted feeding and nesting sites for golden mice and may also have negatively influenced other species sufficiently to reduce overall richness values. Further, perhaps some of the initial mortality of midstory hardwoods due to the herbicide acted synergistically to reduce golden mice CPUE and overall species richness.

In our study, small mammals, particularly peromyscids (white footed and cotton mice), appeared to generally respond positively to prescribed fire and prescribed fire with herbicide. Species richness increased on burned plots during 2000, and overall CPUE and peromyscid CPUE increased due to burning and herbicide treatment in 2001. Prescribed fire benefits small mammals via exposure of seeds in the soil (Ahlgren 1966, Landers 1987), increase in abundance of some invertebrates (Hurst 1971), and by creating a diverse herbaceous understory (e.g., Hodgkins 1958, Lewis and Harshbarger 1976, Landers 1987, Haywood et al. 2001). Bock and Bock (1983) suggested white-footed mice are attracted to newly burned areas due to a temporary increase in food quality or quantity and Arsenal has been shown to increase frequency of forbs and grasses in pine plantations (Hurst 1987). Herbicide treatments in general tend to shift vegetation communities from woody vegetation dominated to forb dominated (Miller and Witt 1990). Preliminary habitat data indicate the plots in our study that were treated with herbicide and subsequently burned developed a very diverse herbaceous understory with little midstory.

During summer 2001, 65% of all small mammal captures were of peromyscids. Linzey (1989) determined white-footed mice may be a dominant species following disturbance and Wolfe and Lohoefener (1987) noted that cotton mice were captured frequently in areas that had been burned the previous winter. Fala (1975) found deer mice *(Peromyscus maniculatus)* became established in burned areas within 1 month of burning. Given these past studies, it appears that the preponderance of peromyscids in our samples and creation of understory conditions desirable by most small mammals via burning and herbicide treatments likely caused differences we observed.

Although small mammals appeared to respond favorably to these treatments, there were exceptions. During winter 2001, small mammal diversity was less on burned plots. However, this was likely due to dominance of peromyscids (white-footed and cotton mice) in burned plots and in burned and herbicide-treated plots. Furthermore, during summer 2000, burning and herbicide both decreased CPUE of golden mice and shrews. Golden mice were likely negatively affected due to loss of midstory structure (Goodpaster and Hoffmeister 1954, Dueser and Shugart 1978, Wagner et al. 2000). Several studies have reported northern short-tailed shrews *(Blarina brevicauda)* to be associated with dense understory cover (Pearson 1959, Getz 1989, McComb and Rumsey 1982) and an abundance of decaying litter and shrubby vegetation (Hooven and Black 1976). Whitaker and Hamilton (1998) considered northern and southern short-tailed shrews to most likely be very similar in habitat associations. Consequently, abundance of southern short-tailed shrews would be expected to be less in recently burned and herbicide-treated stands due to temporary loss of leaf litter, shrubby cover, and a dense herbaceous understory.

Few treatment effects on herpetiles were observed. However, we did detect an increased CPUE for fence lizards due to the interaction of burning and herbicide application. Wilson (1995) and Parker (1994) determined fence lizards selected open canopy stands with ample basking sites. Reduction of midstory hardwood canopy due to the herbicide application and the decrease in dense understory vegetation due to burning may explain the positive response of fence lizards to these treatments. However, increase in food abundance, quality, and/or availability may have also been an influence.

To varying degrees, both small mammal and herpetile communities appeared to be affected by burning and herbicide treatments in the current study. However, it also is important to note that richness and diversity of small mammal and herpetile communities did not change between summer 1999 and summer 2000. This indicates that although some species were affected differently, overall diversity and richness did not differ between the pre-treatment growing season compared to the first growing season after treatment. Others have reported no changes in small mammal communities or capture rates due to burning and herbicide treatments (Brooks et al. 1995, Sullivan and Boeteng 1996). In Oklahoma, 3 different herbicide-burning combinations did not affect relative total abundance nor species richness of herpetiles (Jones et al. 2000). There are few data available on effects of fire within pine plantations on herpetiles in the Southeast (Russell et al. 1999). However, given that herpetiles within pine systems of the Southeast evolved with fire, treatments that maintain early successional vegetation and open canopies should be beneficial (Means and Campbell 1981, Harlow and VanLear 1987, Russell et al. 1999).

Management Implications

Management recommendations are not warranted based on these limited data, but some general conclusions and future research direction can be presented. Overall, we found few differences in small mammal and herpetile communities due to prescribed burning and herbicide treatments in mid-rotation, thinned loblolly pine plantations. However, effects of these treatments were somewhat species-specific, which has been reported in other studies (Beck and Vogl 1972, Borrecco et al. 1972, Bendell 1974, Lautenschlager 1993, Lyon et al. 1978). Many studies report herbaceous vegetation recovers to pre-treatment condition within 2 years post-treatment (McComb and Hurst 1987, Hurst 1989, Bock and Bock 1992, Kirkland et al. 1996, Sullivan et al. 1998*b*, Brockway and Outcalt 2000). In the current study, recovery of stands to pre-treatment condition did not occur (B. D. Leopold, unpubl.data). Thus more data are needed to fully document effect of these treatments on small mammal and herpetile communities within mid-rotation loblolly pine plantations.

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