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Effects of Timber Harvesting on the Abundance and Diversity of Small Mammals on Non-Industrial Private Forestlands in South-central Virginia

Hannah S. Shively, Jason D. Fiore, and Todd S. Fredericksen[1]

Life Sciences Division
Ferrum College
Ferrum, Virginia 24088

ABSTRACT

Most of the forestlands in Virginia are classified as non-industrial private forestlands (NIPFs). Conservation of wildlife is also an important ownership objective for many NIPF owners when they harvest timber. We studied how timber harvesting affected the abundance and species richness of small mammals on NIPFs in south-central Virginia. We sampled small mammal populations in 18 different stands each year during 2004 and 2005 in Franklin, Henry, and Patrick counties. All study sites were natural stands dominated by hardwood tree species. Stands ranged in size from ca. 8-40 hectares. Stands included nine recently (1-2 years ago) logged stands and nine mature forest stands that had not been logged within the past 40-50 years. Small mammals were captured using Sherman live traps and, in the first year only, pitfall traps. We captured a total of 170 individuals of nine species on all sites. By far, the most commonly captured species (154 captures) was the White-footed Mouse (*Peromyscus leucopus*). Logged stands yielded 122 captures of nine species, whereas unlogged stands yielded 48 captures of two species. During the first year of the study, small mammal abundance was negatively correlated with overstory cover and positively correlated with herbaceous layer cover and amount of coarse woody debris. No significant relationships were observed between mammal captures and habitat variables in the second year of the study.

Key words: biodiversity, logging, small mammals, timber harvesting, hardwood forest, Virginia.

INTRODUCTION

Timber harvesting is increasing in southwest Virginia, leading to increasing concern about habitat alterations that affect biological biodiversity (Johnson, 2004). Over 75% of Virginia's commercial forestland is classified as non-industrial private forestland (NIPF) (Thompson & Johnson, 1996). NIPFs include forestlands that are part of residential holdings, farms, and other lands of owners who do not own wood-processing facilities. The majority of NIPF owners in the eastern United States consistently cite observing or protecting wildlife as an important management objective for their property (Birch et al., 1998). Timber management is another goal for many NIPF owners and there is often concern about how logging may affect wildlife on their property. Increasing publicity about possible negative effects of timber management on wildlife diversity, and forest ecosystems, in general, has altered the perceptions of private landowners about logging.

Some silvicultural treatments, especially clearcutting, dramatically change environmental conditions, species composition, and vegetative structure within a forest (Chen et al., 1999; Zheng et al., 2000), but not all species are negatively affected by these changes. Wildlife species react differently to the variety of habitat modifications caused by timber harvesting, including decreased overstory cover, increased ground vegetation cover, increased large woody debris, and changes in the abundance of food resources (DeCalesta, 1989; Healy, 1989; Hunter, 1990; Hanson et al., 1991; DeGraaf, 1992).

[1] Corresponding author: TFredericksen@FERRUM.EDU

Linkages between small mammal communities and habitat changes caused by logging on NIPFs are not well studied. It is known that slash piles, snags, fallen trees, canopy gaps, decaying wood, and litter are important structural elements that function in maintaining soil productivity, plant community diversity, and fungal and invertebrate communities. These structural habitat features are especially critical to small mammal communities that inhabit the forest floor (Carey & Johnson, 1995; Bowman et al., 2000; Carey & Harrington, 2001). Mammals use woody debris for a variety of functions and this resource is critically important to the survival and reproduction of many species (Maser et al., 1979). Small mammal communities may be used as indicators of forest floor habitat quality. They help to disseminate seeds and spores, fungi and lichens, physically mix soil, decompose organic matter and litter, and help to regulate invertebrate populations (Maser et al., 1978; Elkinton et al., 1996). They also represent an important link in the food web as prey for many terrestrial and avian predators including snakes, birds of prey, coyotes, foxes, skunks, and other predators (Terman, 1965).

Both loggers and landowners often lack information on how timber harvesting affects wildlife and how best management forestry practices can mitigate potentially negative impacts of logging. We initiated a study in 2004 to help determine the impacts of logging on small mammal abundance and species richness on NIPF lands in the southern portion of the Blue Ridge physiographic province in Virginia (Franklin, Henry, and Patrick counties). This paper reports on the results of the first two years of this study.

METHODS

Mammal communities were sampled on 18 NIPF stands from mid-May through late July of 2004 and 2005. Sites were located in Franklin, Henry, and Patrick counties. Nine sites were logged and 9 stands were mature forest stands that had not been logged for at least 40-50 years. Logging intensities ranged from intensive harvesting (clearcuts) to selective harvests with many trees remaining after harvest. Harvested sites were logged within the past two years. The mean and ranges of remaining overstory cover are presented in Table 1. Care was taken to select sites that had similar a similar composition of tree species, which included mixed hardwood species with some scattered White Pine (*Pinus strobus*) and Virginia Pine (*Pinus virginiana*). Selected sites were also similar in size (8-40 hectares) and imbedded within a similar landscape matrix (percentage of farms, fields, urban development, and forest). Two harvested sites used in 2004 were not available for use in 2005 and were replaced with two other sites harvested in the previous year.

We trapped two sites each week, including one logged stand and one unlogged stand in order to reduce confounding variables due to weather patterns and moon phases. We used systematic random sampling to locate 15 sampling points within each study site. At each sampling point, we placed two Sherman live traps and, in 2004 only, 1 pitfall trap, consisting of a 2-l metal can buried flush with the soil surface. Pitfall traps were located along fallen logs or at the base of rock outcrops, areas that are typically used as runways for small mammals. Traps were set out for three consecutive nights and checked early the next morning. Total Sherman trap-nights for each year of the study was 1620 (15 traps x 18 sites x 3 nights). We baited traps every day with peanut butter and oats. At initial capture, each animal was marked with a numbered ear tag for individual recognition and to avoid recounting recaptured animals. Shrews and voles were not ear-tagged, but were marked on the top of the head with a non-toxic ink marker. Sex, age, weight, and the site of capture for each individual captured were also noted.

We collected vegetation cover data at ca.10 locations in each stand. Percentage overstory tree cover (>10 m tall) and midstory vegetation cover (2-10 m) cover were estimated using a transparent grid densiometer. Percentage shrub cover (0.5-2 m) and ground cover (<0.5 m) were estimated visually to the

Table 1. Percent vegetation cover at different forest layers and woody debris index (mean of the sum of diameters of woody debris on five 50-m transects) in nine recently logged and nine unlogged stands in Franklin, Patrick and Henry counties, Virginia. Overstory cover included vegetation cover >10 m; shrub layer cover included vegetation cover >0.5 m and <2 m; herbaceous layer cover included vegetation cover <0.5 m. Means are presented with ± 1 standard deviation. Minimum and maximum values are included in parentheses.

Variable	**Logged**	**Unlogged**
Overstory cover (%)	27 ± 21.7 (0-55)	74 ± 15.0 (54-96)
Shrub layer cover (%)	28 ± 14.8 (7-53)	25 ± 16.4 (5-57)
Herbaceous layer cover (%)	51 ± 26.1 (13-78)	18 ± 11.5 (5-46)
Woody debris volume Index	199 ± 51.1 (136-282)	68 ± 27.6 (18-107)

nearest 5% using a 1-m^2 sampling frame. Woody debris cover >5 cm in diameter was estimated using five or more 50 cm line-intercept transects within which the diameter of each woody debris item was measured where it crossed the transect. Diameters were summed over each transect for use as an index of the amount of coarse woody debris cover on each site.

Data were analyzed using the SYSTAT (version 10.2) statistical program. Because of failure to meet assumptions for a parametric test, Wilcoxon's rank sum test (paired by trapping period) was used to test for significant differences in abundance and species richness of small mammals between logged and unlogged sites. Pearson's correlation test was used to test for relationships between overstory, midstory, herbaceous cover, and woody debris with the abundance and species richness of small mammals. Only new captures (not recaptures) were included in the data analysis. Statistical tests were considered statistically significant at $p \leq 0.05$.

RESULTS

Logged stands had, on average, nearly three times the percentage herbaceous layer cover and amount of large woody debris compared to unlogged stands (Table 1). Unlogged stands had three times more percentage overstory cover and twice the percentage midstory cover compared to logged stands. Percentage shrub cover was similar between logged and unlogged stands.

In all, a total of 170 small mammals of nine species were captured during the study (Table 2). White-footed Mice (*Peromyscus leucopus*) represented 90% of all captures. Captures on logged stands were 2.5 times higher than unlogged stands (122 and 48 captures, respectively). All nine species captured were present in at least one logged stand during 2004 or 2005, while only two species, *P. leucopus* and *Tamias striatus*, were captured on unlogged stands. During 2004, the abundance of small mammals was significantly higher on logged stands than unlogged stands ($p = 0.05$), but the difference was not significant in 2005 ($p = 0.11$). Only one capture (*Sorex cinereus*) was made in a pitfall trap in 2004 and, therefore, the method was discontinued in 2005.

In 2004, the number of small mammals was positively correlated ($p = 0.003$) with the amount of large woody debris volume (Table 3). Small mammal abundance was also significantly and negatively correlated ($p = 0.005$) with percent overstory cover ($p = 0.0005$) and positively correlated with herbaceous cover ($p< 0.001$) (Table 3). Small mammal abundance was not significantly related to any habitat variables in 2005 (Table 3).

DISCUSSION

The abundance of mammals was more than twice as high in recently logged stands compared to unlogged mature forest stands and nine species were observed in logged stands while only two species were observed in unlogged stands. Mammal capture rates were driven largely by the abundance of White-footed Mice (Table 2), with all other species being represented by a total of four or fewer individuals. Kirkland (1977) observed a similar increase in small mammal abundance and diversity in clearcut hardwood stands in West Virginia.

Small mammal species may be responding positively to increases in certain habitat resources on the forest floor created by logging, including increased vegetation cover, food, travel routes, and woody debris (Yahner, 1990; Loeb, 1993). Slash piles and other concentrations of course woody debris are particularly important habitat components for many mammals.

Table 2. Number of new captures of small mammal species on logged and unlogged stands in Franklin, Patrick, and Henry counties, Virginia during 2004 and 2005 (n= 9 for both logged and unlogged stands each year).

	2004		2005	
Species	**Logged**	**Unlogged**	**Logged**	**Unlogged**
Eastern Chipmunk (*Tamias striatus*)	2	1	0	0
White-footed Mouse (*Peromyscus leucopus*)	50	18	57	29
Golden Mouse (*Ochrotomys nuttalli*)	1	0	3	0
Eastern Harvest Mouse (*Reithrodontomys humulis*)	0	0	4	0
Southern Redbacked Vole (*Clethrionomys gapperi*)	0	0	1	0
Meadow Vole (*Microtus pennsylvanicus*)	0	0	1	0
Norway Rat (*Rattus norvegicus*)	0	0	1	0
Short-tailed Shrew (*Blarina brevicauda*)	0	0	1	0
Masked Shrew (*Sorex cinereus*)	1	0	0	0
TOTAL	**54**	**19**	**68**	**29**

Table 3. Correlation matrix, including Pearson's correlation coefficient and probability values in parentheses, for relationships between small mammal abundance and habitat variables (overstory cover, shrub cover, herbaceous cover, and woody debris) for 18 NIPF stands in south-central Virginia with different timber harvest intensities during 2004 and 2005.

Small mammal abundance	% overstory cover	% shrub cover	% herb cover	Woody debris index
2004	-0.64 (0.08)	0.34 (0.005)	0.77 (0.001)	0.67 (0.003)
2005	-0.02 (0.94)	0.02 (0.95)	0.02 (0.93)	0.38 (0.23)

Over half (55) of the 81 of mammal species found in the southeastern United States use slash piles (Loeb, 1993). Many studies show that downed logs represent an important habitat feature for small mammals (Barry & Francq, 1980; Corn et al., 1988, Gore, 1988; Graves et al., 1988; Kennedy et al., 1991; Planz & Kirkland, 1992). Soil disturbance and canopy gaps created by logging provide foraging and burrowing sites for many species of mice, shrews, and ground squirrels (Beatty & Stone, 1986; Graves et al., 1988; Planz & Kirkland, 1992).

The abundance of White-footed Mice on both logged and unlogged sites reflects the wide ecological tolerance of this generalist species (Webster et al., 1985; Brannon, 2005), but the abundance of this species was 2-3 times higher in logged stands compared to unlogged stands. In the southern Appalachians of western North Carolina, Buckner & Shure (1985) found that the White-footed Mouse readily used forest openings of various sizes created by logging. Another study, however, conducted in the southern Appalachians recently found that there was no difference in the capture success among the study sites before or after logging, but the abundance of the White-footed Mouse varied among years (Greenberg, 2002).

Except for the White-footed Mouse, relatively few individuals of all other species were captured, with many species represented by only one individual or a few individuals captured on a single study site. Still, nearly all these captures occurred in logged stands. The Eastern Harvest Mouse (*Reithrodontomys humulis*), which prefers old field habitats (Webster et al., 1985), was captured on logging decks in one harvested stand. A species of grassy fields, the Meadow Vole (*Microtus pennsylvanicus*), was captured only once on a logging deck recently replanted with grass species. The Southern Red-backed Vole (*Clethrionomys gapperi*) and Golden Mouse (*Ochrotomys nuttalli*) were found on logged sites with understories having a high percentage of herbaceous and shrub cover.

Despite the higher absolute mammal abundance observed in logged stands during both studies, the difference was only significant during the first year of the study. There was, however, a strong trend for more captures in logged stands during the second year. Variability in capture rates was high among stands. Captures at a site were not consistent from year to year, probably reflecting interannual population cycles within individual sites and microhabitat differences within stands of each treatment. In addition, the abundance of small mammals was significantly and positively related to percent herbaceous cover and the amount of woody debris within stands. Mammal abundance was negatively related to percent overstory cover during the first year of the study, but no such trends were observed in the second year of the study. Other studies also have found mixed responses in mammal abundance and species richness to timber harvesting, or correlations with habitat variables, with some authors citing population fluctuations as a possible explanation (Healy & Brooks, 1988; Fredericksen et al., 2000). Variability between years seemed to be highest in the logged stands of our study. For example, the logged stand with the most captures of new individuals (17) in 2004 had no captures during 2005. Another logged stand where there were no captures in 2004 had nine captures in 2005.

Pitfall traps were not very effective when used during the first year of this study, perhaps because of their small size and because we did not use drift fences. As part of another study, one of the unlogged control sites of our study had drift fence arrays installed using 17-liter pitfall buckets and large numbers of shrews were captured in these traps (T.S. Fredericksen, unpubl. data). Based on these data, we believe that the abundance of shrews was not adequately assessed in our study. It was not logistically possible for us, however, to erect pitfall-drift fence arrays on the large number of sites in this study.

CONCLUSIONS

This study revealed that small mammals were more abundant and species richness was higher in logged compared to unlogged stands, although mammal abundance was dominated by one species, the White-footed Mouse, in both habitat types. It should be noted, however, that shrews were not well sampled by our methods. Increased abundance and captures of small mammals on logged sites were correlated, at least during one year of our study, with increased amounts of herbaceous cover and coarse woody debris. Continued sampling in these stands is planned in upcoming years to determine how small mammal species respond to vegetation succession following logging. The results of this paper can be incorporated into literature that helps NIPF owners understand how small mammals are likely respond to timber harvesting on their stands.

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