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Effects of clearcutting with corridor retention on abundance, richness, and diversity of small mammals in the Coastal Plain of South Carolina, USA

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Abstract

We studied six pine plantations in coastal South Carolina to determine the influence of clearcutting with corridor retention on small mammal abundance, richness, and diversity. Small mammals were live-trapped in recently clearcut stands that retained pine corridors 100 m in width and in adjacent pine plantations, 20–23-years-old. We compared small mammal communities between harvested stands with corridors and non-harvested pine stands. We captured 1158 small mammals, representing 844 unique individuals and seven different species in 94,080 trap nights. Rodent abundance, richness, and diversity indices were greater in harvested stands with corridors than in non-harvested pine stands. The early successional habitat created by clearcutting was used by many small mammal species, including cotton rats (*Sigmodon hispidus*) and marsh rice rats (*Oryzomys palustris*). Species composition of small mammals within the corridor habitats was similar to that in the non-harvested pine stands. The inclusion of corridors in pine plantation management enhances habitat diversity and ecosystem maintenance and contributes to local diversity of the small mammal community.

Keywords: Clearcutting; Corridors; Pine plantations; Pinus; Small mammals

1. Introduction

In the southeastern United States, pine (*Pinus* spp.) plantations occupy approximately 12 million hectares (Ince, 2001). Wildlife habitat conditions in pine plantations are dependent upon the availability of

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associated plant resources (Huntly and Inouye, 1987). Although young pine stands are used by a variety of small mammal species (e.g., herbivores and granivores), other species associated with later successional habitat (e.g., insectivores) may occur in low abundances.

Studies from various regions have examined the influence of clearcutting on small mammal communities (Gashwiler, 1970; Kirkland, 1977, 1990; Pagels et al., 1992; Steventon et al., 1998; Sullivan et al., 1999). However, little attention has been given to small mammal communities within pine plantations of the southeastern United States, particularly in the Lower Coastal Plain physiographic region. Most studies conducted in the southeastern United States have focused on the effects of various silvicultural practices (e.g., thinning, herbicide application, and site preparation) on small mammal communities (Brooks, 1992; O'Connell and Miller, 1994; Rodrigue, 1994; Moore, 1996; Sparling, 1996; Johannsen, 1998). Clearcutting causes substantial changes in small mammal community structure (Kirkland, 1990). Although the influence of clearcutting on small mammal diversity and richness is unclear (studies reviewed by Kirkland, 1990), the abundance of small mammals tends to increase after timber harvest (Trousdell, 1954; Umber and Harris, 1974; Kirkland, 1977).

Forest product companies often use short-rotation, even-aged silvicultural systems to manage pine plantations in the southeastern United States. However, because of environmental and societal concerns, companies typically have multiple resource management goals (e.g., timber, wildlife, water quality). The use of streamside management zones (SMZs) are one strategy commonly used in sustainable forestry programs to meet multiple resource goals. Although SMZs were designed to protect water systems from potential impacts of silvicultural operations, they also increase wildlife habitat diversity (Thurmond and Miller, 1994). Based on this concept, the MeadWestvaco Corporation developed a strategy known as Ecosystem-based Forestry to augment habitat heterogeneity for wildlife species. Employed at the landscape level, this program involves the overlap of a mosaic of later successional habitats. These habitats primarily include SMZs and special habitat zones. However, where these features do not exist, 100-m wide corridors of pines are retained in harvested stands to maintain connectivity among late successional stands. These retained corridors may serve as residual habitat for small mammal species associated with closed-canopy forests (e.g., insectivores), while the adjacent harvested stands may provide habitat for other species associated with early successional stages (e.g., herbivores and granivores). Furthermore, retaining corridors creates edge and ecotones between harvested areas and forested corridors and may affect small mammal species richness and diversity.

Although retained corridors may benefit wildlife species, few studies have examined the ecological value of corridor networks in pine forest ecosystems. Our study provides basic information on the impact of clearcutting and the importance of retained corridors for the maintenance of small mammal communities within managed pine forest ecosystems. We compared small mammal communities (i.e., abundance, richness, and diversity) in three harvested stands with 100-m wide retained corridors of pine and three non-harvested pine stands.

2. Methods

Our study was conducted in six intensively-managed loblolly pine (*P. taeda*) plantations (16–20 ha, 20–23-years-old) within MeadWestvaco's South Region in the Lower Coastal Plain of South Carolina. These plantations are productive with site indices averaging 24.4 m for loblolly pine, base age 25 years. The average number of trees/ha for all sites was 672.5, the average basal area was 32.1 m^2/ha, and the average diameter at breast height was 27.9 cm. Elevations range from 20 to 30 m above sea level. All plantations were sheared, root raked, and bedded upon establishment, but no additional management practices were applied to the plantations thereafter. Vegetation was dominated by loblolly pine with scattered hardwoods, primarily sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*), in the midstory. The understory vegetation was dominated by wild grape (*Vitis* spp.), greenbrier (*Smilax* spp.), poison ivy (*Toxicodendron radicans*), and Virginia creeper (*Parthenocissus quinquefolia*).

We established rectangular small mammal trapping grids that overlapped the proposed corridor and

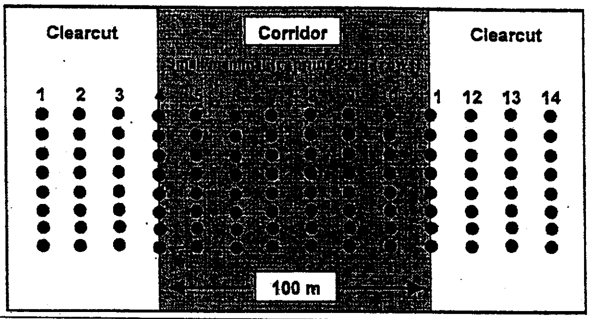

Fig. 1. Design of the small mammal trapping grids within 16–20 ha harvested pine stands with mature pine corridors (n =3) in the Lower Coastal Plain of South Carolina. The numbers correspond to live-trap stations along transects (n = 8), with trap locations indicated with black circle. Each of the 14 trap stations is 14.3 m apart. Similar trapping grids were established within non-harvested pine stands (n = 3).

adjacent proposed clearcut areas (Fig. 1). We paired each harvested stand with an adjacent non-harvested stand of intact pine forest and established similar trapping grids. Within each grid we placed 14 trapping stations at 14.3 m intervals along eight transects (n = 112 traps/grid). We placed one Sherman live-trap at each trapping station. We baited traps with commercial pellets (Flint River Mills, Bainbridge, Georgia, USA) and set them for five consecutive nights during each month. We trapped each grid pair simultaneously.

We surveyed small mammal populations within the harvested and non-harvested stands during one pre-harvest (April 1998) and 27 post-harvest (June 1998–August 2000) monthly sampling periods. We did not sample in May 1998 because of ongoing timber harvests. Upon capture, we identified each individual to species, weighed it to the nearest gram, determined sex and age class (adult, subadult, or juvenile), uniquely marked it with a numbered monel ear tag, and released it at the capture location. Additionally, we recorded morphological measurements and recapture status of each individual. All small mammal capture and handling protocols were approved by the University of Georgia's Institutional Animal Care and Use Committee (Permit No. A3437-01).

We grouped capture data from the 27 post-harvest samples into nine, 3-month periods based on season and duration since timber harvest. These periods were June–August 1998 (1–3 months post-harvest), September–November 1998 (4–6 months post-harvest), December 1998–February 1999 (7–9 months post-harvest), March–May 1999 (10–12 months post-harvest), June–August 1999 (13–15 months post-harvest), September–November 1999 (16–18 months post-harvest), December 1999–February 2000 (19–21 months post-harvest), March–May 2000 (22–24 months post-harvest), and June–August 2000 (25–27 months post-harvest). We averaged relative abundance, species richness, and species diversity of small mammals for each 3-month period post-harvest and during the 1 month pre-harvest. We based abundance, richness, and diversity calculations on the captures of unique individuals. We calculated capture rates (i.e., measure of relative abundance) as the number of small mammals captured/100 trap nights, where a trap night was one trap set over one night. We calculated species richness for each trapping grid (i.e., 1.9 ha) based on the number of species detected. We estimated species diversity with the Shannon Index (Pielou, 1966) because it gives preference to rare species (Krebs, 1966), and it is important to look at rare species in studies concerned with changes in habitat (Sekgororoane and Dilworth, 1995).

For our analyses, we used a randomized complete block design with three replications of two treatments (i.e., harvested stands with corridors and non-harvested stands). Harvested and non-harvested stands were paired based on proximity and pre-harvest characteristics (e.g., stand age, soil type). We used stand pairings as our blocking factor. We did not combine pre-harvest and post-harvest data because combining data can mask a potential treatment effect (Cody and Smith, 1991). We used 2-sample t tests to compare capture rates, species richness, and species diversity between the two treatments during the pre-harvest sampling period (i.e., April 1998). We used repeated-measures ANOVA (split-plot in time) to examine post-harvest data for treatment- (i.e., harvested stand with corridor or non-harvested stand, the whole unit) and period- (i.e., months post-harvest, the subunit) related differences in capture rates, species richness, and species diversity (SAS Institute Inc., 1990). Capture rate data for rodents (i.e., herbivores and granivores) and shrews (i.e., insectivores) were analyzed separately. We used Tukey's Honestly Significant Difference (HSD) test to identify post-harvest differences in small mammal communities between treatments and among periods. If the repeated-measures ANOVA revealed a significant treatment × period interaction, then we reassigned unique designations for each level of treatment and period, reanalyzed the data, and conducted multiple comparisons with Tukey's HSD test. The relevant comparisons were treatment differences within a given period and period differences within a given treatment. For all tests, we accepted significance at $\alpha \leq 0.10$, but considered $P \leq 0.15$ to be biologically meaningful (Tacha et al., 1982).

3. Results

During 94,080 trap nights, we recorded 1158 captures of 844 small mammals consisting of 503 rodents (60%) and 341 shrews (40%). Cotton mice (*Peromyscus gossypinus*) and cotton rats were the most commonly captured rodent species, representing 31 and 24% of all captures, respectively. Southern short-tailed shrews (*Blarina carolinensis*) were the most commonly captured shrew species, representing 32% of all captures. Eastern harvest mice (*Reithrodontomys humulis*) represented 12% of all captures. Marsh rice rats, golden mice (*Ochrotomys nuttalli*), and southeastern shrews (*Sorex longirostrus*), collectively represented 1% of all captures.

Capture rates of rodents ($t = 0.46$, d.f. = 4, $P = 0.67$) and shrews ($t = 0.58$, d.f. = 4, $P = 0.60$), species richness ($t = 0.90$, d.f. = 4, $P = 0.42$), and species diversity ($t = 0.59$, d.f. = 4, $P = 0.59$) did not differ between the two treatments during pre-harvest sampling. Preliminary analyses of post-harvest capture rates revealed a treatment × period interaction for rodents ($F = 3.01$, d.f. = 8,16, $P = 0.05$). Therefore, we tested for differences between treatments within each period post-harvest ($n = 9$) and for differences among period post-harvest within each treatment. Rodent capture rates were greater ($P \leq 0.10$) in harvested stands with corridors than in non-harvested stands during several periods post-harvest (Table 1). In non-harvested stands, the capture rates of rodents did not differ among periods post-harvest. However, in harvested stands with corridors rodent capture rates varied among periods following harvest (Table 1).

Because the model for post-harvest shrew capture rates lacked significant interaction, treatment- and period-related differences were examined. Shrew capture rates did not differ ($F = 0.45$, d.f. = 1,2, $P = 0.57$) between harvested stands with corridors and non-harvested stands. However, shrew capture rates declined ($F = 35.61$, d.f. = 8,16, $P < 0.0001$) with period post-harvest (Table 1).

Table 1
Mean (±S.E.) relative abundance (captures/100 trap nights) of rodents and shrews in three harvested pine stands with corridors and three non-harvested pine stands in the Lower Coastal Plain of South Carolina, 1998–2000

Months post-harvest	Rodent relative abundance[a,b]			Shrew relative abundance[c,d]		
	Harvested[e]	Non-harvested	Treatment difference	Harvested[e]	Non-harvested	Treatment difference
Pre-harvest	1.19 (0.61)	0.94 (0.49) A	–	0.20 (0.28)	0.45 (0.53)	–
1–3 (period 1)	1.51 (0.27) BCDE	0.12 (0.06) A		1.12 (0.66)	1.55 (0.41)	A
4–6 (period 2)	0.72 (0.94) CDE	0.08 (0.03) A		0.83 (0.70)	0.76 (0.4)	AB
7–9 (period 3)	1.81 (0.51) ABCD	0.18 (0.26) A	*	0.63 (0.65)	0.48 (0.52)	B
10–12 (period 4)	3.23 (0.34) A	0.28 (0.25) A	*	0.20 (0.05)	0.02 (0.03)	B
13–15 (period 5)	2.82 (0.38) AB	0.66 (0.06) A	*	0.03 (0.03)	0.07 (0.08)	B
16–18 (period 6)	0.97 (0.46) CDE	0.11 (0.11) A		0.06 (0.01)	0.02 (0.03)	B
19–21 (period 7)	0.70 (0.16) CDE	0.07 (0.13) A		0.11 (0.04)	0.00 (0.00)	B
22–24 (period 8)	1.12 (0.38) CDE	0.05 (0.09) A		0.05 (0.08)	0.02 (0.04)	B
25–27 (period 9)	2.21 (0.23) CDE	0.09 (0.12) A	*	0.17 (0.11)	0.02 (0.04)	B

[a] Significant treatment × period interaction ($P \leq 0.05$); means (±S.E.) within a given treatment column followed by the same letter are not different ($P \leq 0.10$); asterisks indicate which means for a given period differ significantly between treatments ($P \leq 0.10$).
[b] Rodents included golden mice, marsh rice rats, cotton mice, eastern harvest mice, and cotton rats.
[c] Period effect ($P < 0.0001$); treatment × period means (±S.E.) are shown; periods followed by the same letter are not different ($P \leq 0.10$).
[d] Shrews included southern short-tailed shrews and southeastern shrews.
[e] With corridors.

Table 2
Mean (±S.E.) species richness (number of species captured/1.9 ha sample area) and species diversity (Shannon Index) of small mammals (rodents and shrews combined) in three harvested pine stands with corridors and three non-harvested pine stands in the Lower Coastal Plain of South Carolina, 1998–2000

Months post-harvest	Species richness[a,b]			Species diversity	
	Harvested[c]	Non-harvested	Period difference	Harvested[c]	Non-harvested
Pre-harvest	1.67 (1.15)	2.67 (1.53)	–	0.31 (0.54)	0.57 (0.44)
1–3 (period 1)	2.78 (0.51)	1.22 (0.69)	AB	0.68 (0.23)	0.09 (0.16)
4–6 (period 2)	2.67 (0.34)	1.33 (0.67)	AB	0.72 (0.28)	0.19 (0.26)
7–9 (period 3)	3.22 (1.07)	0.78 (0.19)	AB	0.83 (0.30)	0.05 (0.09)
10–12 (period 4)	3.44 (0.20)	0.89 (0.51)	A	0.90 (0.08)	0.17 (0.15)
13–15 (period 5)	2.67 (0.88)	1.55 (0.69)	A	0.61 (0.14)	0.32 (0.16)
16–18 (period 6)	1.56 (1.02)	0.67 (0.67)	BC	0.33 (0.38)	0.12 (0.21)
19–21 (period 7)	1.78 (0.84)	0.33 (0.00)	C	0.50 (0.27)	0.00 (0.00)
22–24 (period 8)	1.89 (0.19)	0.22 (0.19)	C	0.59 (0.04)	0.22 (0.19)
25–27 (period 9)	2.45 (0.69)	0.67 (0.34)	ABC	0.72 (0.13)	0.07 (0.12)

[a] Treatment effect ($P \leq 0.02$); harvested > non-harvested.
[b] Period effect ($P \leq 0.003$); treatment × period means (±S.E.) are shown; periods followed by the same letter are not different ($P \leq 0.10$).
[c] With corridors.

No significant treatment × period interaction occurred with small mammal richness or diversity. Species richness (i.e., number of species per grid) was greater ($F = 55.69$, d.f. = 1,2, $P = 0.02$) in harvested stands with corridors than in non-harvested stands and differed ($F = 5.16$, d.f. = 8,16, $P = 0.003$) among periods post-harvest (Table 2). Small mammal diversity was greater ($F = 51.01$, d.f. = 1,2, $P = 0.02$) in harvested stands with corridors than in non-harvested stands, but did not differ ($F = 1.82$, d.f. = 8,16, $P = 0.17$) among periods post-harvest (Table 2).

Although eastern harvest mice were often captured in harvested stands with corridors, cotton mice and cotton rats were the most commonly captured rodents in this habitat type. Clearcut habitats within the harvested stands with corridors were the only habitat type where marsh rice rats were found (Table 3). Overall, cotton rats and cotton mice were most common in clearcut habitats (Table 3). Eastern harvest mice were more common in clearcut habitats than in corridor habitats, although several eastern harvest mice were captured at the interface between the clearcut and corridor habitats. Southern short-tailed shrews were the most commonly captured small mammal in non-harvested stands and in the pine corridors of harvested stands. Golden mice were captured in non-harvested stands and within the pine corridors of harvested stands, but not in adjacent clearcut habitats (Table 3).

There were several significant ($P < 0.10$ or close approximates $P = 0.13$) within-species differences in capture rates between harvested and non-harvested

Table 3
Mean (±S.E.) relative abundance (captures/100 trap nights) of small mammals by species in three harvested pine stands with corridors (i.e., overall, clearcut areas, and corridors) and three non-harvested pine stands (i.e., forest) in the Lower Coastal Plain of South Carolina, 1998–2000

Habitat type	Species[a]							
	BLCA	OCNU	ORPA	PEGO	REHU	SIHI	SOLO	ALL
Harvested stand[b]	0.13 (0.14)	0.003 (0.01)	0.003 (0.007)	0.13 (0.05)	0.08 (0.12)	0.15 (0.09)		0.68 (0.26)
Clearcut	0.09 (0.08)		0.007 (0.02)	0.17 (0.12)	0.16 (0.26)	0.31 (0.19)		1.15 (0.55)
Corridor	0.20 (0.26)	0.002 (0.006)		0.04 (0.03)	0.02 (0.03)	0.002 (0.02)		0.31 (0.28)
Non-harvested stand	0.13 (0.22)	0.004 (0.008)		0.02 (0.01)	0.004 (0.009)	0.003 (0.007)	0.001 (0.003)	0.19 (0.20)
P value[c]	0.98	0.62		0.0001	0.13	0.006		0.001

[a] BLCA: southern short-tailed shrews; OCNU: golden mice; ORPA: marsh rice rats; PEGO: cotton mice; REHU: eastern harvest mice; SIHI: cotton rats; SOLO: southeastern shrews; ALL: all species combined.
[b] Entire treatment area (i.e., both clearcut and corridor habitats combined) including edge captures.
[c] *P* value of difference between harvested and non-harvested stands.

stands (Table 3). Capture rates of all small mammals combined ($t = 1.75$, d.f. = 15, $P = 0.001$), cotton mice ($t = 5.22$, d.f. = 15, $P = 0.0001$), eastern harvest mice ($t = 1.70$, d.f. = 8, $P = 0.13$), and cotton rats ($t = 3.72$, d.f. = 8, $P = 0.006$) were greater in harvested stands with corridors than in non-harvested stands. Southern short-tailed shrew and golden mice capture rates in the harvested stands with corridors were similar ($t = 0.02$, d.f. = 14, $P = 0.98$; $t = 0.51$, d.f. = 10, $P = 0.62$, respectively) to those of the non-harvested stands (Table 3).

4. Discussion

Mosaic landscapes such as those created by clearcutting with corridor retention may contribute to habitat heterogeneity and ecosystem maintenance, two critical components in sustainable resource management (Franklin and Forman, 1987). Retaining corridors of pine at harvest will increase habitat diversity and perhaps maintain some small mammal species that are characteristic of later successional habitats while creating habitat for others that are characteristic of early successional habitats.

Although insectivorous species, such as southern short-tailed shrew, tend to exhibit a more temperate response to timber harvest than granivorous and herbivorous species (Kirkland, 1990), we found no differences in shrew numbers between treatments, suggesting that their numbers remained high following harvest because of the retention of the pine corridor. Additionally, we found no differences in golden mice numbers between treatments. We only captured golden mice, a semi-arboreal species that generally inhabits forested areas (Linzey and Packard, 1977), in non-harvested stands and in pine corridors. Thus, pine corridors may have served as refugia for some forest dwelling, small mammal species.

Whereas corridors provided habitat for some forest dwelling small mammals, recently clearcut areas adjacent to these stands provided habitat for other small mammal species. Consistent with the findings of others (Perkins et al., 1988; Pagels et al., 1992), we found greater rodent abundance, species richness, and species diversity in harvested stands with corridors than in non-harvested stands. The clearcut areas within the harvested stands were invaded by small mammals typical of early successional habitats. Cotton rats, an edge/old-field species (Pagels et al., 1992), tend to favor habitats with dense herbaceous understory plants (Atkeson and Johnson, 1979; Cameron and Spencer, 1981; Langley and Shure, 1980; Thurmond and Miller, 1994) and this species occurred in greatest numbers in our recently clearcut areas. Cotton mice, a species that uses clearcut habitats more than corridor habitats (Bayne and Hobson, 1998), were captured more often in recently clearcut areas than in adjacent forest patches. Marsh rice rats may have colonized recently clearcut areas because of the standing water, which resulted from a rise in the water table following clearcutting (Xu et al., 1999).

The retention of corridors can increase the number of niches available to wildlife by increasing the amount of edge. Eastern harvest mouse captures were highest in harvested stands with corridors and harvest mice, an edge-specialist (Lidicker and Koening, 1996), prefers areas with dense grass (Thurmond and Miller, 1994). Retention of corridors created an ecotone that was favorable to harvest mice, which is consistent with other findings (Mengak and Tipton, 1978).

Variation in rodent captures among periods following harvest in harvested stands with corridors may be a result of natural fluctuations. Periodic, cyclic fluctuations in abundance of some small mammal populations are common (Krebs, 1966). Furthermore, cotton rats, one of the most commonly captured small mammals in harvested stands with corridors, reach peak abundance during the summer in the southeastern United States (Odum, 1955), whereas cotton mice abundance peaks during the winter (Wolfe and Linzey, 1977).

The decline in shrew numbers at 7–9 months post-harvest (i.e., December 1998–February 1999) coincides with the start of drought conditions at our study sites (Southeast Regional Climate Center, 2000). Rainfall for the period of December 1998 to February 1999 was 52.5 mm below normal (National Oceanic and Atmospheric Administration, 1998; Southeast Regional Climate Center, 2000). Furthermore, abundance of southern short-tailed shrews in wooded habitats is limited by the availability of food (George et al., 1986) and insects, the primary food resource of shrews, may have declined during dry periods.

Small mammal communities in pine plantations are positively affected by clearcutting with corridor retention. Relatively narrow corridors (e.g., 100 m) of mature pine forest may maintain small mammals that are characteristic of later successional habitats (e.g., shrews and golden mice), while clearcutting creates early successional habitat that is favored by other small mammals (e.g., cotton rats). Inclusion of corridors in pine plantation management enhances habitat diversity and ecosystem maintenance and thereby contributes to local diversity of the small mammal community.

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