

The Effect of Habitat Patch Size on Small Mammal Populations

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Abstract: Habitat fragmentation is one of the greatest threats to the conservation of biodiversity and has 3 components: habitat loss, patch isolation, and patch size. We tested the effects of forest-clearing size on small mammal populations in the Upper Coastal Plain of South Carolina. These clearings act as islands for many species of small mammals, particularly old-field mice (*Peromyscus polionotus*) and cotton rats (*Sigmodon hispidus*). We live-trapped small mammals in 3 size classes of clearcuts (small <6 ha, medium 10–15 ha, and large >25 ha) on the Savannah River Site and compared relative density and diversity of small mammal species among the patch size classes. *Peromyscus polionotus* were captured on all grids and were the only species captured on small grids; *P. polionotus* relative density did not vary significantly among patch sizes. In contrast, *S. hispidus* relative density, and relative density of all species combined, tended to increase with increased patch size, although the differences in relative density among size classes were not statistically significant. Species diversity (H') increased with patch size and was significantly greater in large patches than in small patches. Thus, patch size may be an important factor affecting diversity of early successional species, but its influence varies among species.

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Destruction and fragmentation of natural landscapes has increased dramatically in recent years due to human population growth and accompanying exploitation of land resources (Saunders et al. 1991). The type, size, and arrangement of resulting habitat patches may affect distribution and abundance of floral and faunal populations

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(Burgess and Sharpe 1981). However, much of the literature on the effects of habitat patch size is theoretical (e.g., MacArthur and Wilson 1967, Levins 1968, Williamson 1983, Hanski 1991, Hanski and Gilpin 1991), and few field experiments have been conducted to test these hypotheses. As concern about habitat fragmentation increases (e.g., Wilcox and Murphy 1985, Saunders et al. 1991), more data are needed on how fragmentation affects animal populations.

In 1967, MacArthur and Wilson published the theory of island biogeography dealing with the effect of size and isolation of oceanic islands on plant and animal populations. This theory has been extended to fragmented landscapes when the habitat type surrounding a given patch is sufficiently unsuitable to isolate the population (Burgess and Sharpe 1981, Harris 1984). Island biogeography predicts that larger islands are more likely to be encountered during dispersal than small islands. Further, larger islands are more likely to have a greater diversity of habitats, allowing a wider variety of species to co-exist (MacArthur and Wilson 1967, Burgess and Sharpe 1981, Williamson 1983, Harris 1984). Levins (1968) first created simple mathematical models for describing the extinction and recolonization of habitat patches by a species in a metapopulation or group of populations in a landscape. According to models of metapopulation and island biogeography, when isolation is equal, larger islands will support larger, more stable populations. Models for metapopulation dynamics predict that smaller habitat patches tend to have higher extinction rates than larger habitat patches within that metapopulation (Ebenhard 1991, Hanski 1996). Both of these models can be used to predict the effects of patch size on population densities in a landscape.

Many early successional species of small mammals depend on disturbances to create suitable habitat (Gashwiler 1970, Kirkland 1977, Buckner and Shure 1985). Such habitats may be created naturally (e.g., fire, disease, severe weather) or anthropogenically (e.g., forest clearcutting, agriculture, other land development). Kirkland (1990) reviewed the results of 21 published studies on the effects of clearcutting on small mammal communities. In most cases, he found that the abundance of small mammals increased considerably after clearcutting. This increase was accompanied by a shift in composition from species found in forested ecosystems to those found in early successional clearings.

Because the surrounding forested habitat is presumably inhospitable to many species dependent on early successional habitat and creates an isolated habitat patch, factors such as opening size and degree of isolation may affect species composition and abundance. However, studies conducted on small mammals suggest that the effect of patch size may be species dependent. For example, harvest mice (*Reithrodontomys megalotis*), prairie voles (*Microtus ochrogaster*), and deer mice (*P. maniculatus*) densities were higher in small patches of old-field habitat in Kansas than in large patches, whereas cotton rats (*S. hispidus*) densities were higher on larger patches than on small patches (Foster and Gaines 1991). Buckner and Shure (1985) found that the size of the forest opening had an influence on both the density of small mammals and species utilization.

In the southeastern United States, early successional habitats such as old-fields and clearcuts support some of the most abundant and diverse small mammal

communities (Golley et al. 1965). The most commonly captured species of small mammals in these habitats are the old-field mouse (*P. polionotus*) and the cotton rat. *Peromyscus polionotus* have fairly specialized habitat requirements and are found predominantly in open fields with sandy soils (Schwartz 1954, Golley et al. 1965, Selander et al. 1971, Burt and Grossenheider 1980, Humphrey and Barbour 1981). Cotton rats are found predominantly in early successional fields, particularly areas dominated by grasses and vines with little or no upper canopy (Golley et al. 1965, Fleharty and Mares 1973, Cameron and Spencer 1981). For these 2 species, early successional habitats in forested landscapes may act as habitat islands.

The objectives of this study were to test the effects of habitat patch size on small mammal populations and community composition. Because recently clearcut forest stands were used as habitat patches, we were particularly concerned with the effects of patch size on the 2 species that are restricted to early successional habitats, *P. polionotus* and *S. hispidus*.

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Methods

This study was conducted on the Department of Energy's Savannah River Site (SRS) in the Upper Coastal Plain of South Carolina. The approximately 78,000-ha site is dominated by longleaf (*Pinus palustris*) and loblolly pine (*P. taeda*) stands with mixed pine-hardwood stands along streams and bottoms (Workman and McLeod 1990).

Eight recently clearcut and replanted timber stands were chosen for 3 replications of 3 size classes: small (<6 ha), medium (10–15 ha), and large (>25 ha). Replications 1 and 2 consisted of a small, medium, and large clearcut. Replication 3 consisted of only a small and large clearcut because a medium clearcut was not available. Stands within each replication were harvested in the same year and replanted with the same species of pine (loblolly or longleaf). All grids in a given replication were located relatively close together to minimize differences resulting from geographical location on the site. Due to limited availability of clearcuts, we were not able to control for either patch shape or isolation.

Sherman live traps (23 × 8 × 9 cm) were placed in grids at a spacing of 20 × 20 m. Grids were placed as close to the center of each clearcut as possible to minimize edge effect. Grid size varied according to clearcut size class. Twenty-four traps (4 × 6 grid) were placed in each small clearcut, 50 traps (5 × 10 grid) in each medium clearcut, and 100 traps (10 × 10 grid) in each large clearcut.

Traps were baited with rolled oats and checked twice daily at sunrise and in the afternoon. Individuals captured were identified to species, uniquely toe-clipped (Clemson Univ. Animal Use Protocol No. 597), weighed, and sexed before being

released at the site of capture. Capture location and age class were also noted. Age class was determined by pelage color for *Peromyscus* species (Schwartz 1954, Davenport 1964) and by weight for *S. hispidus* (Chipman 1965).

Five trapping sessions were conducted on each site between November 1991 and May 1992. We trapped as close as possible to the quarter moon to minimize the possible effect of moonlight on capture probabilities. There were 4 short trapping sessions (3 or 4 trap nights each) and a final long trapping period (8 or 9 trap nights).

Because sample sizes were low, an index of population size was used instead of a statistical population estimator. The number of individuals captured per 100 trap nights (N individuals/ N trap nights * 100) was calculated for each species and for all species combined. Because the number of traps per grid was proportional to clearcut size, this index was considered to be an index of relative population density. The null hypothesis that clearcut size did not affect *P. polionotus*, *S. hispidus*, or total species relative densities was tested using Friedman's random block test (Iman and Davenport 1980, Potvin and Roff 1993). A nonparametric multiple comparisons test was used to detect differences between each patch size (Conover 1980). Because Friedman's random block test requires a balanced design, a density index value of a medium size plot in Replication 3 was estimated for all species, *P. polionotus* and *S. hispidus* using a least squares estimation procedure (Snedecor and Cochran 1980). These values were based on the values found in the other 2 replications.

The Shannon index of diversity (H' ; Magurran 1988) was used to estimate species diversity for each size class. A t -test (Hutcheson 1970) was used to test the null hypothesis that H' did not differ among size classes. A Bonferroni adjustment was used to control for experimentwise error ($\alpha = 0.015$).

Results

We had 542 captures representing 307 individuals of 6 different species. *Peromyscus polionotus* was the most common species captured (44%) and *S. hispidus* was the second most common species captured (36%). *Pereomyscus polionotus* was captured on all of the grids in the study and was the only small mammal captured on small clearcuts (Table 1). *Sigmodon hispidus* was only captured on 3 grids, 2 large clearcuts, and 1 medium clearcut; *S. hispidus* was not caught on the sites found on the northeast quadrant of SRS (Replication 1).

The highest relative density index for all species combined occurred on Grid M-2 (5.43 individuals/100 trap nights); the lowest total density index was Grid S-1 (0.19 individuals/100 trap nights). Only 1 mouse was caught on S-1 during the entire study. *Peromyscus polionotus* density indices were highest on S-3 (2.78 individuals/100 trap nights) and *S. hispidus* density indices were highest on Grid L-3 (2.33 individuals/100 trap nights; Table 1).

The mean ranks of the relative density index for all species combined tended to vary among size classes ($F = 5.04$, $df = 2, 4$, $P = 0.08$). The highest mean density

Table 1. Number of small mammals captured in small (<6 ha), medium (10–15 ha), and large (>25 ha) clearcuts on the Savannah River Site, South Carolina.

Grid ^a	Trap nights	Total <i>N</i> individuals	<i>Peromyscus polionotus</i>	<i>Peromyscus gossypinus</i>	<i>Sigmodon hispidus</i>	<i>Reithrodontomys humilus</i>	<i>Neotoma floridana</i>	<i>Mus musculus</i>
S-1	528	1	1	0	0	0	0	0
S-2	504	7	7	0	0	0	0	0
S-3	504	14	14	0	0	0	0	0
M-1	1,100	18	12	6	0	0	0	0
M-2	1,050	57	16	22	19	0	0	0
L-1	2,200	18	18	0	0	0	0	0
L-2	2,100	108	32	21	44	6	4	1
L-3	2,100	84	35	0	49	0	0	0
Total	10,086	307	135	49	112	6	4	1

a. Trapping grids on research plots: letters designate clear cut size (S = small, M = medium and L = large) and numerals refers to the replicate in the clear-cut plot.

index occurred in the medium clearcuts followed by the large clearcuts (Table 2). The mean relative density index in the small clearcuts was less than half of those in the medium and large clearcuts.

The relative density index rank values of *P. polionotus* did not differ significantly among size classes of clearcuts ($F = 0.54$, $df = 2, 4$, $P = 0.62$). Mean relative densities of *S. hispidus* increased from small to large patches (Table 2), although the rank values did not differ significantly among patch sizes ($F = 4.02$, $df = 2, 4$, $P = 0.11$).

Both species richness and species diversity increased with patch size (Table 3). H' did not differ significantly between small and medium size classes ($t = -2.36$, $df = 75$, $P > 0.015$) or between medium and large size classes ($t = 0.56$, $df = 230$, $P > 0.015$). However, species diversity was significantly greater in the large clearcuts than in the small clearcuts ($t = -3.02$, $df = 210$, $P < 0.015$).

Discussion

MacArthur and Wilson's (1967) theory of island biogeography and models dealing with metapopulations within a landscape predict that species richness and population densities will increase as patch area increases. We found that total small mammal relative density and *S. hispidus* relative density tended to increase with patch size while the relative density of *P. polionotus* remained fairly constant among

Table 2. Number of individuals captured/100 trap nights on small (<6 ha), medium (10–15 ha), and large (>25 ha) clearcuts on the Savannah River Site, South Carolina.

Patch size	<i>Peromyscus polionotus</i>	<i>Peromyscus gossypinus</i>	<i>Sigmodon hispidus</i>	<i>Reithrodontomys humilus</i>	<i>Neotoma floridana</i>	<i>Mus musculus</i>	All species
Small	1.43	0.00	0.00	0.00	0.00	0.00	1.43
Medium	1.30	1.30	0.88	0.00	0.00	0.00	3.49
Large	1.33	0.33	1.45	0.09	0.06	0.02	3.28

Table 3. Species richness and Shannon's diversity index of small mammal assemblages on small (< 6 ha), medium (10–15 ha), and large (> 25 ha) clearcuts on the Savannah River Site, South Carolina.

Patch size	Species richness	Shannon's diversity index (H')	Variance of H'
Small	1	0.00	0.00
Medium	3	1.08	0.21
Large	6	1.45	0.23

patch sizes. The greatest difference in total relative density occurred between small and medium clearcut sizes; the medium size class had the greatest relative density, and the small size class the lowest. While the increase in total small mammal relative density with clearcut size may have been related to increases in densities of some species such as *S. hispidus*, the increase in number of species inhabiting larger clearcuts also contributed to the increased total densities.

Peromyscus polionotus was the only species found on all the study sites, and clearcut size did not seem to affect its relative density. Several factors may account for this lack of response to clearcut size. The low relative density of *P. polionotus* on several sites (e.g., S-1, L-1) may have resulted from low trappability because even at high densities, *P. polionotus* can have very low trappability (Kaufman et al. 1974). Perhaps the scale of clearcut sizes in this study may have been too large to affect clearcut preference by *P. polionotus* because this species may not distinguish among clearcuts > 6 ha. A comparison among clearcuts of smaller size scale may be needed to reveal a response to clearcut size.

However, other studies have revealed no response or a negative response to increasing patch size. Densities of *R. megalotis*, *P. maniculatus*, and *M. ochrogaster* are inversely related to patch size in grassland communities (Foster and Gaines 1991), as are *P. leucopus* densities in woodlots (Nupp and Swihart 1996). Further, Dooley and Bowers (1996) found no relationship between patch size and the densities of *P. leucopus* and *M. pennsylvanicus* in old-fields. These responses may be related to 3 different factors: a lack of territory establishment in small habitat patches, competitive release due to lower densities of other species, or microhabitat variables exhibiting a greater influence on habitat selection than patch size or shape variables (Foster and Gaines 1991, Dooley and Bowers 1996, Nupp and Swihart 1996).

Peromyscus polionotus do not generally exhibit territorial behavior, although territoriality may be exhibited by females during the rearing of young (Davenport 1964). Therefore, a lack of territory establishment in small patches was probably not responsible for equitable densities among patch sizes. Further, the sex ratio of *P. polionotus* remained at parity regardless of clearcut size (Yates 1994). Because *P. polionotus* are predominantly monogamous, a 1:1 sex ratio suggests that resident breeding populations existed on all patch sizes and no patch size represented either a sink or source habitat. *Peromyscus polionotus* was the only species captured on small clearcuts. Thus, the lack of competition may have allowed greater densities on small

patches, whereas the presence of other species may have reduced the potential densities on larger patches.

Although the relative density of *S. hispidus* did not vary significantly among size classes, a trend of increasing density with larger clearcut sizes did exist. *Sigmodon hispidus* was only captured on medium and large clearcuts. Similarly, *S. hispidus* was absent from small grassland patches in Kansas (Foster and Gaines 1991). However, the small habitat patches in the Foster and Gaines (1991) study were much smaller than the size classes used in our study.

The absence of *S. hispidus* on smaller clearcuts may have been related to their relatively large body size (Price 1983). The size of the small clearcuts may not have been large enough for cotton rats to establish resident populations. The average home range of cotton rats is 0.39 ha for males and 0.22 ha for females (Cameron and Spencer 1981). Cotton rats exhibit strong territorial behavior (Glass and Slade 1980, Spencer and Cameron 1983), which may inhibit the formation of resident populations on smaller clearcuts. No *S. hispidus* were present on any of the sites in Replication 1, regardless of patch size. This was most likely due to the lower percent cover values present on these sites (Yates 1994). Adequate cover, especially of *Andropogon* species have been cited as a prominent factor in cotton rat habitat selection (Cameron and Spencer 1981).

Both species richness and species diversity increased with clearcut size as predicted by MacArthur and Wilson (1967). As patch size increases, the diversity of microhabitats on the clearcut is also likely to increase. Greater microhabitat diversity would allow more species to utilize the area (Dueser and Brown 1980, Williamson 1983). Plant density and composition at the microhabitat level can greatly affect the species of small mammals that inhabit an area (Pearson 1959, Golley et al. 1965, Langley and Shure 1980, Dooley and Bowers 1996). Although neither plant density nor composition varied significantly among size classes in this study (Yates 1994), larger clearcuts may have provided larger total areas of microhabitats than small clearcuts, even though the percent area in each microhabitat type may have been equal among size classes. The increased area of favorable microhabitats in larger clearcuts may have allowed for larger, more territorial species, such as *S. hispidus*, to establish and maintain higher population levels thus reducing the possibility of local population extinction.

Management Implications

Trends displayed by small mammals in this study suggest that patch size is an important factor determining the abundance and diversity of small mammal communities. Therefore, very small clearcuts will not maintain a high diversity of early successional small mammals. Also, the populations on these smaller patches are more susceptible to local extinction than patches with larger population densities. Later successional species may also respond to patch area, particularly larger species such as flying squirrels (*Glaucomys volans*) and woodrats (*Neotoma floridana*). Because large clearcuts may fragment late successional forests to unacceptable levels,

a balance must be maintained between the number and size of early and late successional patches so that a full complement of species is maintained within an area. Connectivity between patches of similar habitat must also be preserved to ensure that animals can colonize these habitats when they become available, supplement existing populations, and re-colonize areas after local population extinctions (Merriam 1995). Due to the temporal nature of early successional patches as desirable habitat, care must be taken to provide a variety of successional stages over time in order to provide early successional patches to which dispersers can emigrate and maintain the metapopulation. Thus, conservation of biodiversity in managed forested ecosystems necessitates consideration of many aspects of landscape spatial structure including patch size, patch quality, connectivity, and temporal changes in the landscape (Fahrig and Merriam 1994).

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