URBAN HABITAT: A DETERMINANT OF WHITE-FOOTED MOUSE (*PEROMYSCUS LEUCOPUS*) ABUNDANCE IN SOUTHERN ILLINOIS

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ABSTRACT - The objective of this study was to assess whether differences in abundance of white-footed mice (*Peromyscus leucopus*) were related to habitat features within and surrounding 60 sampled bottomland forest patches. Habitat features included patch size, patch shape, and landuse within a 300-m buffer surrounding each patch. During 18,000 trap nights, we captured 1,308 white-footed mice within approximately 3,110 ha of bottomland forest. Type of habitat surrounding a patch was a significant determinant of white-footed mouse abundance. Sample sites where less than 10 individuals were captured were surrounded by a large percentage of upland deciduous forest and a low percentage of urban/other habitats. Sample sites where 30 or more individuals were captured were surrounded by a large percentage of urban/other habitats and a small percentage of upland deciduous forest. Sites where 10–29 individuals were captured were surrounded by intermediate amounts of upland deciduous forest and urban/other habitat. Although deciduous forest is necessary, it may not be the primary determinant of white-footed mouse abundance. Unsuitable habitat may surround and create islands of high density from which successful dispersion is difficult.

INTRODUCTION

Natural forest habitats have been altered, fragmented, and transformed by humans into heterogeneous forest patches interspersed with cities, pastures, roads, and cropland (Oxley et al. 1974, Schmid-Holmes and Drickamer 2001). Some mammal species may be well adapted to highly fragmented habitats regardless of composition. Other species may not be well adapted because of specialized life history requirements or restricted dispersal.

Ecologists have suggested that small mammals are useful for investigating landscape-level studies because detailed information is available concerning their life history, dispersal ability, biology, and ecology (Schmid 1998, Barrett and Peles 1999). Landscape-level studies attempt to relate spatial heterogeneity, or "patchiness," to differences in occur-

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rence and abundance of biological organisms (Levin 1992, Wiens et al. 1993). Effects of patchiness depend on the type and amount of habitats within the landscape and species-specific responses to habitats (Bowers and Matter 1997, Krohne and Hoch 1999).

Few studies have investigated differences in abundance patterns of woodland small mammals at spatial scales larger than a single forest stand (Bowman et al. 2001). Furthermore, many ideas common to landscape ecology are theoretical and not based on empirical data (Bowers and Matter 1997). Our objective was to assess whether differences in abundance of white-footed mice (*Peromyscus leucopus*) were related to habitat features within and surrounding patches of bottomland forest.

MATERIALS AND METHODS

We investigated a bottomland forest landscape comprising the 6 southwestern-most counties of Illinois (i.e., Alexander, Johnson, Massac, Pope, Pulaski, and Union; Fig. 1). Patches of bottomland forest were located within our study area using the Geographic Information System (GIS) ArcView (Environmental Systems Research Institute, Redlands, California) and digital Illinois Natural History Landuse Data (INHS 1995). Patches were defined as lowland deciduous forest. These were inundated temporarily with water on an annual basis. We identified these patches by overlaying the INHS Landuse Database with 7.5-minute USGS quadrangle boundaries that functioned as a survey grid. The total amount of bottomland forest (ha) was determined for each 7.5-minute USGS quadrangle, and 1.5% of each quadrangle was sampled. Sites were chosen for sampling based on public land/landowner permission and water levels that did not preclude live trapping. Our goal was to spread sampling effort evenly across the study area, and sites were > 500 m apart. A Magellan Trailblazer XL Global Positioning System (GPS) was used to identify the location of each study site (Barko 2000). Nondeciduous or upland patches were not surveyed.

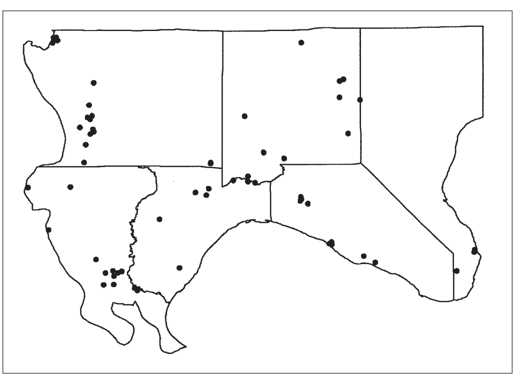

Figure 1. Patches of deciduous bottomland forest sampled from May 1998 to January 1999 and April 1999 to July 1999 in the six southwestern-most counties of Illinois.

Animals were captured from May 1998 to January 1999 and April 1999 to August 1999 using Sherman live traps (8.0 x 9.0 x 23.5 cm, H.B. Sherman Co., Tallahassee, FL) set in a single linear transect at each of the 60 study sites. Each transect was 490 m in length and placement was nonrandom because of geomorphic features (e.g., water bodies) that precluded live trapping at most sites. At each site, 50 trap stations, placed 10 m apart, were established. Two traps were placed at each station for a total of 100 traps/site. Traps were operated for 3 consecutive days (300 trap nights per site) with daily checks between 0600 and 1100 hrs. All traps were baited with cracked corn and sunflower seeds. Sites were only trapped once; hence, different sites were trapped in 1998 and 1999. Thirty-six sites were sampled in 1998 and 24 sites were sampled in 1999. *Peromyscus* spp. were toe-clipped to identify individuals and correct for "re-captures." All animals were released at the point of capture. Abundance estimates for each site are reported as the number of individuals captured/300 trap nights.

Several landscape indices were calculated using the ArcView Patch Analyst extension including patch size, patch shape, and land usage around a patch. Patch size was estimated by calculating the area (ha) within each bottomland patch. Landuse around a patch was calculated by creating a 300-m buffer around each bottomland forest study site. This buffer distance was chosen because small mammals do not generally disperse large distances. Bowman et al. (2001) reported weak relationships between small mammal species and landscape features at spatial scales greater than 250 m. The landscape surrounding a patch was reclassified, from INHS (1995) landuse data (Critical Trends Assessment Landcover Database of Illinois), into 5 general habitat classes (urban/other, cropland, grassland, coniferous forest, and upland deciduous forest). Urban/other habitat included all habitat types that were not represented in the other 4 classes, including nonforested wetlands, towns, bodies of water, and roadways. Percent occurrence of each class was estimated within the buffer area, and a suitability score was calculated by multiplying each percentage by a fixed number based on the suitability of the habitat for woodland mammals (Schmid-Holmes and Drickamer 2001). Upland deciduous forests should be the most beneficial to woodland mammals and were given the highest score of 5. Coniferous forest was given a score of 4, grassland a score of 3, cropland a score of 2, and urban/other a score of 1 (Schmid-Holmes and Drickamer 2001). These scores ranged from 100 (completely surrounded by urban/other habitat) to 500 (completely surrounded by upland deciduous forest). This index enabled us to better visualize the habitat matrices surrounding a bottomland forest patch.

The shape of each patch was determined within the GIS environment using a modified "Patton index" (Faeth and Kane 1978, Schmid-Holmes and Drickamer 2001). This index calculated the deviation from circularity of each patch as:

$$P/ [2(\pi A)^{1/2}],$$

where *P* represents the perimeter and *A* represents the area of a patch. Circles have a value of 1 and represent the least amount of edge. Values higher than 1 indicate an increased perimeter-to-area ratio, that is, more edge (Game 1980, Rex and Malanson 1990).

We used Principal Components Analysis (PCA) to reduce the dimensionality of our habitat data set and remove any effects of collinearity. Landuse percentages were normalized using the arcsine transformation (SAS v.6 1990). Data were then separated into three groups based on abundance of white-footed mice. Group 1 ("low abundance") contained sites with < 10 individuals captured/300 trap nights (n = 23), group 2 ("moderate abundance") contained sites with 10–29 individuals captured/300 trap nights (n = 18), and group 3 ("high abundance") contained sites with ≥ 30 individuals captured/300 trap nights (n = 19). We performed a stepwise discriminant function analysis (PROC STEPDISC, SAS v.6 1990) with the PCA scores to identify habitat features that contributed to the differences in abundance of white-footed mice exhibited among our three groups. The criterion for statistical significance was $P \leq 0.05$ (Steel and Torrie 1980).

RESULTS

During 18,000 trap nights, we captured 1,308 white-footed mice (93% of all small mammal captures). Number of white-footed mice on the 60 sites ranged from 0–78 with a mean of 23 ± 21 (SD). Mean (± SD) size (ha) of bottomland forest patches was 59.97 (81.00), with a range of 0.65–397.34 ha. Mean (± SD) habitat matrices (% occurrence) surrounding a patch of bottomland forest within the 300-m buffer was 72.31 (22.83) for urban/other, 11.38 (14.08) for cropland, 5.38 (8.32) for grassland, and 10.60 (18.88) for upland deciduous forest. Average suitability score (± SD) was 164.66 (74.53). No coniferous forest was located within any 300-m buffer. Index of patch shape ranged from 1.14 (most circular) to 7.04 (greatest perimeter-to-area ratio) with a mean (± SD) of 2.66 (1.14).

The first five PCA axes had eigenvalues greater than 1.0 (3.04, 2.13, 1.63, 1.44, and 1.03, respectively). However, only the first axis explained a significant amount of the variation in our three groups (e.g., "low," "moderate," and "high," $R^2 = 0.1106$, $F = 3.545$, $P = 0.0354$). The eigenvectors that defined this axis were suitability score (0.50), percent of deciduous forest surrounding a sample patch (0.44), and percent of urban/other habitat surrounding a sample patch (-0.52). Sites with < 10 captured individuals had a high suitability score, a low percentage of urban/other habitat surrounding a sample patch, and a high percentage of upland deciduous forest surrounding a sample patch (mean PC1 score = 0.47 ± 1.94 SD). Sites with 10–29 individuals captured had an intermediate suitability score and an intermediate percentage of both urban/other and upland deciduous forest habitat surrounding the sample patch (PC1 mean = 0.28 ± 1.32 SD), when compared to "low" and "high" sites (Fig. 2). Sites with ≥ 30 individuals captured had a low suitability score, a high percentage of urban/other habitat surrounding a sample patch, and a low percentage of upland deciduous forest surrounding a sample patch (PC1 mean = -0.84 ± 1.62). A noteworthy finding, although not significant, was Axis 4. The two eigenvectors defining this axis were patch shape (0.65) and patch size (0.47). This suggests that smaller patches were more circular in shape (i.e., smaller Patton's Index), whereas larger patches had a greater perimeter-to-area ratio. Mouse abundance decreased as patch size increased and deviated from circularity. When these results are compared to those from the stepwise discriminant function analysis, it becomes apparent that large bottomland forest patches in southern Illinois have low white-footed mouse abun-

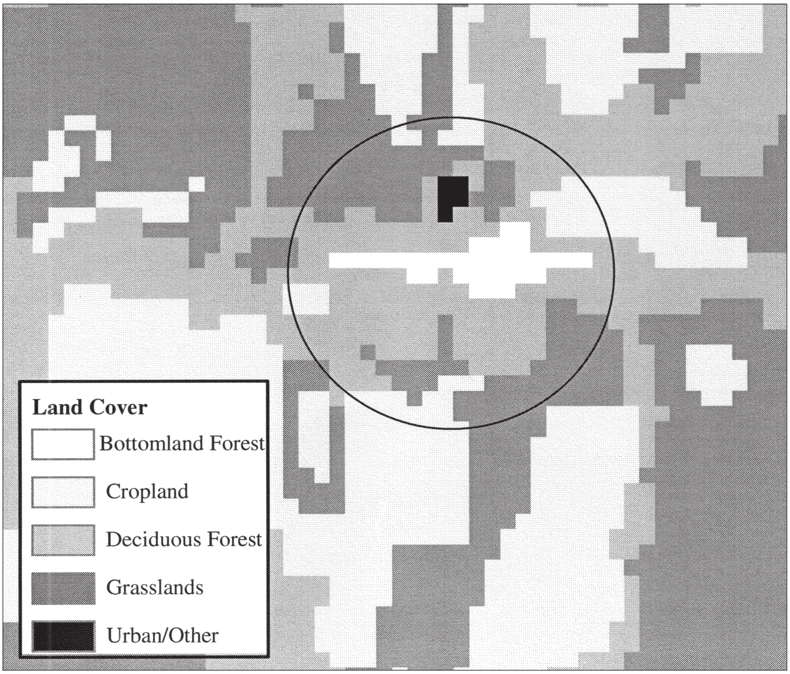

Figure 2. Representative site with 10–29 captured individuals. These sites had an intermediate suitability score based on landuse within the 300-m buffer surrounding the sampled patch.

dance (Table 1). Most of the mice in our study were captured in small patches located adjacent to urban development.

DISCUSSION

Although white-footed mice "prefer" woodland habitats, this species is one of the most ubiquitous in North America (Hoffmeister 1989). Based on a review of 17 independent studies, Nupp (1997) concluded that white-footed mice are habitat generalists and do not select patches based on forest composition or area. Henein et al. (1998) concluded that white-footed mice may be successful in fragmented landscapes largely because they can use different habitat types for dispersal between forest patches. We found high abundances of white-footed mice in forest patches surrounded by high percentages of urban area and other poor habitat and low abundances in patches surrounded by upland deciduous forest. We suggest that urban/other habitat is a significant barrier to dispersal for the white-footed mouse. Individuals inhabiting these patches surrounded by unsuitable habitat are "trapped" and have minimal opportunity for emigration, hence the high abundance.

Urban/other habitat is becoming more abundant in forested landscapes and may be the habitat type that limits or prevents dispersal of many small mammals, not only white-footed mice. Lack of dispersal could have detrimental consequences. Isolated populations could have reduced genetic heterozygosity (Merriam et al. 1989), suffer from crowding effects (Leck 1979), and face higher probabilities of extirpation (Fahrig and Merriam 1985). Because small mammals have limited dispersal ability, they are vulnerable to dispersal barriers and fragmentation (Laurance 1990).

Abundance of white-footed mice decreased within the landscape as bottomland forest patches deviated more from circularity (greater perimeter-to-area ratio) and were larger. Nupp and Swihart (1996) and Krohne and Hoch (1999) reported an inverse relationship between density of white-footed mice and patch size. In our study, the inverse

Table 1. Characteristics of patches with "high" (≥ 30), "moderate" (11 – 29) and "low" (< 10) mouse abundance in a bottomland forest landscape. Data were obtained using a Principal Components Analysis (PCA).

	Mouse abundance (Mean PCA scores)		
Patch characteristics	High (-0.84)	Moderate (0.28)	Low (0.47)
Suitability score (eigenvector = 0.50)	Low	Intermediate	High
Percent of urban/other habitat surrounding patch (eigenvector = -0.52)	High	Intermediate	Low
Percent upland deciduous forest surrounding patch (eigenvector = 0.47)	Low	Intermediate	High
Patch size (ha) (eigenvector = 0.47)	Small	Intermediate	Large
Patch shape (eigenvector = 0.65)	Small	Intermediate	Large

relationship likely was because the large forest patches had usable habitat (i.e., low percentages of urban/other habitat) surrounding them. The large forest patches were surrounded primarily by cropland, grassland, and upland deciduous forest habitats suitable for dispersal of white-footed mice (Cummings and Vessey 1994, Henein et al. 1998). In addition, these patches had a large perimeter-to-area ratio, which may have been perceived as "edge" by some species because of increases in predator abundances and subtle changes in plant composition. Different species respond to edge habitat differently, and understanding these responses is vital for forest management. Patches with large perimeter-to-area ratio had low numbers of mice. This may be an artifact of predation but is likely the result of their ability to use habitat types other than urban/other for dispersal to neighboring forest patches. Although nonwooded habitat may be suitable for dispersal of white-footed mice, woodland specialists may be affected adversely. Forest habitat is necessary for woodland small mammal species, but it may not be the primary determinant of abundance of *P. leucopus*. Instead, habitat surrounding a forest patch appears to be a critical factor.

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