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**Distribution and Microhabitat of the Woodland Jumping Mouse,
Napaeozapus insignis, and the White-footed Mouse,
Peromyscus leucopus, in the Southern Appalachians**

M. PATRICK BRANNON*

Abstract - The distributions of woodland jumping mice (*Napaeozapus insignis* Miller) and white-footed mice (*Peromyscus leucopus* Rafinesque) and their associated microhabitats were examined in four habitat types in the Pisgah National Forest of western North Carolina. A total of 115 jumping mice and 192 white-footed mice were collected using arrays of drift fences with pitfalls in 3 north-facing and 3 south-facing upland plots, and in 3 north- and 3 south-facing streamside plots, during the autumn of 1996 and the spring and summer of 1997. *Napaeozapus* were strongly associated with cooler, moister habitats with high volume of heavily decomposed logs, but *P. leucopus* were ubiquitous. Results indicate that *P. leucopus* is a habitat generalist whereas *N. insignis* is a habitat specialist. Indirect effects such as the availability of subterranean fungi as food may explain the distribution of *Napaeozapus* at smaller scales.

Introduction

Distributions of small mammals across landscapes are greatly affected by habitat availability (Orrock et al. 2000). The Southern Appalachians are comprised of a complex mosaic of habitats (Whittaker 1956). Steep slopes along higher-order streams create abrupt shifts from mesic to xeric habitats, along with associated changes in vegetation (McShea et al. 2003). North-facing slopes are typically cooler and wetter than south-facing slopes because duration and intensity of sunlight exposure are reduced (Wales 1972). Because habitat type can vary greatly even between neighboring patches, it is important to examine species at an appropriate scale (Bowman et al. 2001).

For small mammals, especially those associated with mesic environments, species presence and abundance may be most predictable at a habitat scale with a high degree of resolution (McShea et al. 2003, Orrock et al. 2000). The woodland jumping mouse (*Napaeozapus insignis* Miller) is a relatively common rodent of higher-elevation forests of the southern Appalachian mountains. Close associations with hemlock-hardwood forests, especially those along streams, suggest a specialization for cool, wet environmental conditions (Whittaker and Wrigley 1972, Wrigley 1972). Ground cover may also be important to the distribution of these mice (Brower and Cade 1966, Whittaker 1963).

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In contrast, the white-footed mouse (*Peromyscus leucopus* Rafinesque) is one of the most widespread and abundant small mammals in the Southern Appalachians. Although it is most commonly associated with hardwood forests, areas with large volumes of stumps and logs (Greenberg 2002, Menzel et al. 1999), or dense ground cover (M'Closkey 1975, Myton 1974), this species occurs in a variety of habitats (Kaufman et al. 1983, Lackey et al. 1985, McShea et al. 2003) and is considered to be a habitat generalist (Alder and Wilson 1987, Dueser and Shugart 1978). This study compared populations of *Napaeozapus insignis* and *Peromyscus leucopus* to determine whether they maintain disproportionate distributions in select habitats of the Southern Appalachians, and how these distributions are affected by heterogeneity of the microhabitat at smaller scales.

Methods

In conjunction with another study (Brannon 2002), twelve 50- by 50-m plots were established in an approximately 1.5-km² area of the Gingercake Creek drainage of the Pisgah National Forest, Burke County, NC (35°55'30"N, 81°52'0"W). This area consisted of steep (20–38°) north- and south-facing slopes separated by a relatively narrow riparian corridor. Three plots were located on upland north-facing slopes and three were located on north-facing riparian habitats. Three more were located on south-facing upland areas and another three in south-facing riparian habitats.

Stands were approximately 55 years of age and elevations averaged 787 m. Woody vegetation on north-facing slopes consisted primarily of white pine (*Pinus strobus* L.), chestnut oak (*Quercus montana* Willd.), and red maple (*Acer rubrum* L.) with an understory of rhododendron (*Rhododendron maximum* L.) and mountain laurel (*Kalmia latifolia* L.) at upland plots. Eastern hemlock (*Tsuga canadensis* Carr.) and black birch (*Betula lenta* L.), along with a dense understory of rhododendron, dominated at north-facing streamside plots. South-facing slopes consisted mainly of white pine, chestnut oak, and red oak (*Q. rubra* L.) with a sparse understory of mountain laurel at upland plots. Tulip poplar (*Liriodendron tulipifera* L.), eastern hemlock, and rhododendron were the primary species at south-facing streamside plots.

Rodents were captured at each plot using a single Y-shaped drift fence array with associated pitfalls as described in Brannon (2002). Pitfalls were open for 5 to 7 consecutive nights each month from August to November 1996 and from March to August 1997, for a total of 2544 trap nights (TN). Rodents were removed daily during each trapping period and deposited in the Appalachian State University mammal collection.

Environmental conditions at each plot were measured for each trapping period. Measurements of average daily high temperatures, volume and

decay classes of coarse woody debris (CWD), and percentage leaf litter moisture content were obtained using the methods described in Brannon (2002). In addition, a 50-m transect was established down the middle of each plot, and a 1-m² quadrat was located at each 5-m interval for a total of 10 quadrats per plot. Average leaf litter depths per plot for each trapping period were measured by pressing a metric ruler through the litter to the A-horizon of the soil in the center of each of the ten quadrats. Also during each trapping period, percentage cover of herbaceous plants < 0.5 m high was estimated visually for each quadrat and averaged to obtain percentage cover per plot.

Differences in total captures of *Napaeozapus* and *Peromyscus* between plots in each of the four habitats were examined using χ^2 goodness of fit tests. Student's *t*-tests were used to examine differences in average maximum temperatures, percentage herbaceous cover, average leaf litter depths and percentage moisture, and total volume of moderately (CWD 2 and 3) and heavily decomposed (CWD 4 and 5) logs between sites. Logs of decay class 1 were not examined as they are uncommon in mature forests and provide minimal cover because they are suspended above ground (Maser et al. 1979). All percent values were arcsine-transformed prior to analyses (Sokal and Rohlf 1987). To assess their influence on the relative abundance of each mouse species, mean values of each habitat variable and capture data for each plot were subjected to Spearman's rank correlation analyses. For CWD, total volume of logs per plot were used for correlation analyses rather than mean values.

Results

South-facing slopes were significantly warmer ($t = 1.67$, $df = 59$, $p < 0.001$) and drier ($t = 1.67$, $df = 59$, $p < 0.001$) than north-facing slopes, and upland sites were warmer ($t = 1.67$, $df = 59$, $p < 0.05$) and drier ($t = 1.67$, $df = 59$, $p < 0.05$) than streamside sites. Mean (± 1 SE) maximum temperatures were higher on both south-facing upland (27.1 ± 0.8 °C) and streamside sites (25.7 ± 0.8 °C) than on north-facing upland (21.5 ± 0.8 °C) and streamside sites (20.9 ± 0.8 °C). Likewise, mean percentage litter moisture was lower on south-facing upland ($46.21 \pm 2.04\%$) and streamside ($51.57 \pm 1.76\%$) sites than on north-facing upland ($56.55 \pm 1.81\%$) and streamside ($62.66 \pm 1.38\%$) sites. Leaf litter depths did not differ significantly between north- and south-facing sites ($t = 1.67$, $df = 59$, $p = 0.13$) or between upland and streamside sites ($t = 1.67$, $df = 59$, $p = 0.07$).

Percentage herbaceous cover was significantly different between north- and south-facing sites ($t = 1.67$, $df = 59$, $p = 0.01$), and between upland and streamside habitats ($t = 1.67$, $df = 59$, $p = 0.04$). South-facing upland sites had the greatest percentage of cover ($18.91 \pm 1.93\%$), whereas north-facing upland sites had the lowest ($11.11 \pm 1.32\%$). Mean percentage herbaceous

cover was similar at streamside sites on south- ($17.24 \pm 1.98\%$) and north-facing ($17.50 \pm 2.68\%$) slopes.

Volume of heavily decomposed logs differed significantly between north- and south-facing sites ($t = 2.02$, $df = 5$, $p < 0.01$), and between upland and streamside sites ($t = 2.02$, $df = 5$, $p = 0.03$). Mean volume of CWD 4 and 5 was highest at north-facing streamside sites ($16.60 \pm 1.59 \text{ m}^3$), intermediate at north-facing upland ($6.91 \pm 1.04 \text{ m}^3$) and south-facing streamside ($5.53 \pm 1.78 \text{ m}^3$) sites, and lowest at south-facing upland sites ($1.64 \pm 1.64 \text{ m}^3$). Two of the three upland south-facing slopes had no logs that were classified as CWD 4 or 5. No significant differences existed in the volume of moderately decomposed logs (CWD 2 and 3) between north- and south-facing sites ($t = 2.02$, $df = 5$, $p = 0.17$) or between upland and streamside habitats ($t = 2.02$, $df = 5$, $p = 0.69$).

Five species of rodents were collected (Table 1). Captures of *Napaeozapus* differed significantly among sites ($\chi^2 = 87.26$, $d.f. = 3$, $p < 0.001$). More jumping mice were captured at mesic sites (Table 1). North-facing sites yielded significantly more captures of *Napaeozapus* than did south-facing slopes ($\chi^2 = 46.34$, $d.f. = 1$, $p < 0.001$), and captures were also significantly greater at stream sites than at upland sites ($\chi^2 = 39.73$, $d.f. = 1$, $p < 0.001$). Captures of *Napaeozapus* ($n = 115$) were strongly positively correlated with percentage litter moisture and volume of CWD 4 and 5, and

Table 1. Summary of rodent captures in each habitat type in the study area in autumn 1996 and spring and summer 1997.

Species	N-facing upland	S-facing upland	N-facing streamside	S-facing streamside	Total
<i>Clethrionomys gapperi</i>	1	2	12	1	16
<i>Napaeozapus insignis</i>	23	7	71	14	115
<i>Ochrotomys nuttalli</i>	4	1	5	1	11
<i>Peromyscus leucopus</i>	49	56	48	39	192
<i>Tamias striatus</i>	1	0	0	1	2

Table 2. Correlation coefficients (r_s) between measured habitat variables and two species of rodents in the study area in autumn 1996 and spring and summer 1997.

Habitat variable	<i>Napaeozapus insignis</i> ($n = 115$)	<i>Peromyscus leucopus</i> ($n = 192$)
CWD 2 and 3 (m^3)	-0.346	-0.382
CWD 4 and 5 (m^3)	0.783**	0.136
% herbaceous cover	0.119	0.274
Leaf litter depth (cm)	-0.162	0.059
% litter moisture	0.887***	-0.271
Maximum temperature	-0.704**	0.376

** $p \leq 0.01$
*** $p \leq 0.001$

significantly negatively correlated with mean maximum temperature (Table 2).

In contrast, captures of *Peromyscus* did not differ significantly between sites ($\chi^2 = 3.04$, d.f. = 3, $p > 0.05$). No significant differences in captures of white-footed mice existed between north- and south-facing slopes ($\chi^2 = 0.02$, d.f. = 1, $p > 0.50$) or between upland and stream sites ($\chi^2 = 1.78$, d.f. = 1, $p > 0.10$). Captures of *Peromyscus* ($n = 192$) were not significantly correlated with any habitat variable (Table 2).

Discussion

Diversity of small mammals is often greater in riparian than in upland areas (Doyle 1990), and on north-facing than on south-facing slopes (Brannon 2002, McComb and Rumsey 1982). Results of this study were consistent with those of others (e.g., Dueser and Shugart 1978, McShea et al. 2003, Wrigley 1972): within deciduous forests, *Napaeozapus insignis* and *Peromyscus leucopus* may be considered to be a habitat specialist and a habitat generalist, respectively. Whereas woodland jumping mice were strongly associated with mesic habitats, white-footed mice were ubiquitous. Because they can tolerate a wider range of temperatures and moisture conditions (Getz 1961), white-footed mice can inhabit drier upland wooded areas (Getz 1968) and occur at high densities in all sizes of forest openings in the Southern Appalachians (Buckner and Shure 1985).

Woodland jumping mice are found almost exclusively in mesic habitats, such as hemlock-hardwood habitats (Whitaker and Wrigley 1972). However, Brower and Cade (1966) and Whitaker (1963) found that, unlike some small mammal species such as shrews that may be restricted to mesic environments because of their ecophysiology (Brannon 2002), there is no direct relationship between *Napaeozapus* and environmental moisture. Although ground cover in the form of herbaceous cover and leaf litter contribute to the distribution of woodland jumping mice (Vickery 1981, Whitaker 1963, Wrigley 1972), xeric environments, even with abundant cover, are usually avoided (McShea et al. 2003, Wrigley 1972).

In this study, ground cover was generally not found to influence the distribution of woodland jumping mice, with the exception of heavily decomposed logs. The importance of moisture and temperature on the distribution of *Napaeozapus* may lie in their effects on the availability of food. Although most logs can function as foraging cover, nesting sites, and runways for small mammals (Barnum et al. 1992, Loeb 1993), those in the advanced stages of decay also contain high volumes of water and mycorrhizal fungi (Maser et al. 1979).

Subterranean fungi are important components of the diets of *Napaeozapus* in hemlock and mixed mesophytic habitats (Orrock et al.

2003). *Glomus* spp., *Endogone* spp., *Elaphomyces* spp., *Melanogaster* spp., and *Hymenogaster* spp. are consumed in large quantities (Orrock et al. 2003; Whitaker 1962, 1963). In studies of woodland jumping mice from several localities, *Endogone* was found to be the single most important food, comprising roughly a third of the diet by volume (Linzey and Linzey 1973; Whitaker 1962, 1963). In contrast, fungus is seldom consumed by *P. leucopus* (Whitaker 1962). Although further studies may elucidate the importance of other factors over a wider geographic area and within a variety of forest communities, the indirect effects of mesic environments and their associated microhabitats on the availability of hypogeal fungi may explain the distributions of mycophagic small mammals such as *Napaeozapus* at smaller scales.

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