

Microhabitat preferences of *Peromyscus maniculatus* (Rodentia, Cricetidae) in young pine plantations in the Canadian boreal forest

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Abstract. *The fluorescent pigment tracking technique was used to identify features of microhabitats preferred by Peromyscus maniculatus (Deer mouse) and to examine the ecological significance of such preferences in the Canadian boreal forest. Data were also analyzed by sex. Mice spent most of their travel time in areas lacking plant cover, or in areas associated with low shrubs, herbaceous dicots, leaf litter, and woody debris. They preferred deciduous trees as canopy cover, logs 5-10 cm in diameter as understory cover, and leaf litter as a substrate. Grass and bare soil were avoided as understory cover and substrate, respectively. Males showed no preference for low shrubs and avoided herbaceous dicots, whereas females showed no preference for herbaceous dicots and avoided low shrubs. Males showed no preference for sand and avoided rocks, whereas females preferred sand and showed no preference for rocks.*

Resumen. *Se utilizó polvo fluorescente para identificar las preferencias de Peromyscus maniculatus (Rodentia, Cricetidae) por distintos rasgos del microhabitat y para examinar el significado ecológico de tales preferencias. Se realizó análisis de datos por sexo. Los resultados muestran que P. maniculatus utilizará áreas sin cobertura vegetal del estrato más alto, o áreas con cobertura de arbustos bajos o plantas herbáceas en el estrato bajo, y hojarazca y broza leñosa como sustrato. Los ratones prefirieron la cobertura de árboles descuidados en el estrato de vegetación más alto, tronco caídos de 5 a 10 cm de diámetro como cobertura del estrato bajo, y hojarazca como sustrato. La cobertura de pastos y el suelo desnudo fueron evitados. Los machos fueron indiferentes a la cobertura de arbustos bajos y evitaron la cobertura de dicotiledóneas herbáceas, mientras que las hembras prefirieron arena como sustrato y fueron indiferentes en el uso de rocas.*

Introduction

Studies of associations between species and habitats are essential to understand the use of space by animals. Furthermore, conservation biology sets new challenges for the understanding of animal-habitat relationships that provides basic information to develop habitat management strategies. The mechanisms that determine patterns of habitat use and selection by small mammals may differ according to the scale and nature of movements, e.g., mechanisms that determine species distribution at the large scale, habitat selection by colonizers through dispersal at intermediate scales, or selection of microhabitat features through movements within home ranges at smaller scales.

The pattern of colonization by *Peromyscus maniculatus* (Deer mouse) is consistent with the general model proposed by Svårdson (1949) on habitat use by birds, and generalized later by Grant (1975) for small mammals. Following removal from both shrubby and grassland areas, mice first settle in the shrubby area and, as population numbers increase, some colonists start to occupy the less favoured grasslands (Merkt 1981). Thus, intraspecific competition seems to be the mechanism that prevents settlement of some individuals in the preferred habitat. At smaller scales, predation, food availability (Kaufman et al. 1983), and intra- and interspecific competition (Van Horne 1982, Wolff

and Hurlbutt 1982) influence microhabitat selection, although predation risk seems to be one of the most important factors determining selection of microhabitat features in *Peromyscus* (Kotler 1984). *Peromyscus maniculatus* is a common species in the Canadian boreal forest. In northern Ontario, where this study was conducted, *P. maniculatus* occurs mainly in clearcuts, young plantations, and mixed deciduous-coniferous forests (Naylor and Bendell 1983, D'Eon and Watt 1994). In 4-10 year old plantations of *Pinus banksiana* (Jack pine), *P. maniculatus* is the most abundant small mammal species (Bellocq and Smith 1994). Microhabitat use by *P. maniculatus* has been described in deciduous forests in southern Ontario (e.g., Morris 1979); however, we are not aware of any study on microhabitat preferences in jack pine (*Pinus banksiana*) plantations in the boreal forest. In this study, we identify those features of microhabitat used and preferred by *P. maniculatus* using the fluorescent pigment tracking technique, and examine the ecological significance of such preferences.

Materials and Methods

Study area

The study area was located in an extensive sand-flat region of the southern boreal forest, approximately 30 km south of Gogama, Ontario, Canada (47°31'N, 81°44'W), where *P. banksiana* predominates. Artificial regeneration after clearcutting or wildfire has created extensive areas of monospecific forest ranging in age from 1 to over 60 years, although mixed forests are also present in the area. Deciduous trees such as *Populus tremuloides* (Trembling aspen) and *Betula papyrifera* (White birch) occur with *P. banksiana* in most non-herbicide young plantations. This work was conducted in *P. banksiana* stands planted in 1988.

Small mammal sampling

Mice were trapped on two grids (Grid 1 and 2) using 44 Sherman and Longworth traps per grid, arranged in a 4 x 11 pattern with 12.9 m between stations, and covering an area of approximately 0.5 ha. Grids were approximately 500 m apart. Traps were operated for 2 consecutive days every 2 to 3 weeks (total effort of 88 trap nights per sampling period) during June-September of 1993 and 1994. Traps were checked daily between 7:00 and 9:00 and baited with peanut butter. Captured mice were identified and their sex, reproductive condition, and mass were recorded. Mice were ear-tagged and released at the site of capture.

Vegetation sampling

To estimate availability of plant cover (both woody and herbaceous) and substrate, 22 quadrats (1 x 1 m) were sampled on each grid in a regular pattern (1-m apart from every other trap station) in August of 1993 and 1994. Percentage cover was visually estimated for the following microhabitat variables: 1) canopy cover including Jack pine, deciduous trees, and no canopy cover; 2) understory cover including low shrubs (*Vaccinium* spp. -blueberries- and *Kalmia angustifolia* -Sheep laurel-), herbaceous dicots, grass, small-size logs (diameter 2-5 cm), medium-size logs (diameter 5-10 cm), large-size logs (diameter > 10 cm and stems), and no understory cover; and 3) substrate including leaf litter, bare soil, woody debris (<2 cm diameter), moss, sand, rock, and pine needles. Data were summarized as mean percentage cover for each variable.

Microhabitat preferences

Animals use a number of different features of the microhabitat. When a given feature is used in a higher proportion than its availability, then that feature is *preferred*. In contrast, if a given feature is used by animals in a lower proportion than its availability, then the feature is *avoided*. When animals use a feature of the microhabitat in a similar proportion to the feature availability, then there is *no preference*.

Microhabitat use and preferences of *P. maniculatus* have usually been quantified employing mark-

Table 1. Mean percentage canopy cover (SE), understory cover, and substrate in two grids set in a young *Pinus banksiana* plantation in northern Ontario during 1993 and 1994. *P < 0.05, **P < 0.005, ***P < 0.001.

Microhabitat variables	Grid 1	Grid 2	t-test
Sample size (N)	44	44	
Canopy cover			
Jack pine	15.0 (3.5)	22.0 (4.1)	1.199
Deciduous trees	20.4 (3.7)	4.6 (1.4)	4.713***
No cover	64.5 (4.5)	73.3 (4.6)	1.730
Understory cover			
Low shrubs	16.0 (2.5)	12.6 (2.1)	1.734
Herbaceous dicots	30.2 (2.5)	23.0 (2.7)	5.404***
Grass	15.2 (3.0)	23.1 (2.1)	3.188**
Small logs	2.0 (0.6)	2.4 (0.5)	1.308
Medium logs	3.0 (0.6)	2.3 (0.6)	1.126
Large logs	6.0 (1.4)	6.9 (1.8)	0
No cover	27.4 (3.3)	29.5 (3.0)	0.558
Substrate			
Leaf litter	23.2 (2.8)	12.0 (2.0)	3.673***
Bare soil	10.8 (1.6)	14.0 (2.0)	1.075
Woody debris	32.5 (2.4)	26.9 (2.4)	1.829
Moss	24.2 (2.9)	23.2 (2.4)	0.163
Sand	3.6 (1.2)	12.3 (2.4)	3.935***
Rock	1.5 (0.7)	3.4 (2.0)	2.325*
Pine needle	4.0 (0.9)	8.1 (2.3)	1.928

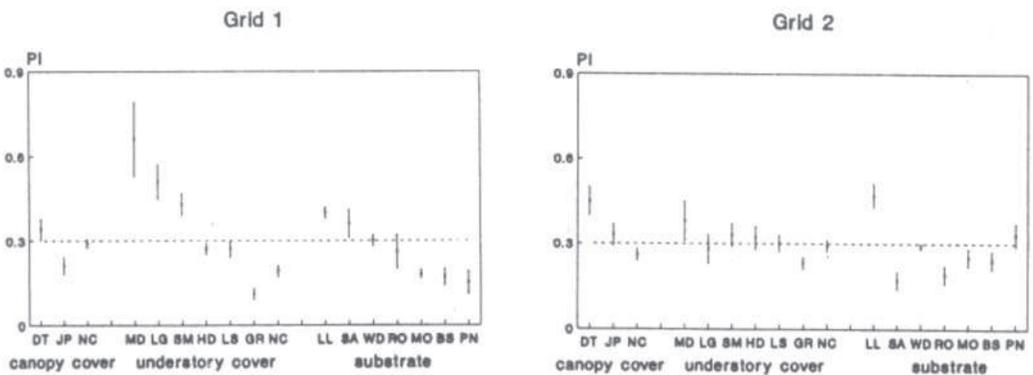


Figure 1. Standardized preference indices (PI), and standard errors of the jackknife estimates, of *Peromyscus numiculatus* for microhabitat variables of the canopy cover, understory cover, and substrate in two grids in *Pinus banksiana* plantations in the Canadian boreal forest. The hatched line indicates no preference (0.3); greater values indicate an increasing degree of preference, and values < 0.3 indicate that the variable is avoided. If the standard error bar touches the hatched line, the PI is not significantly different from the value of no preference. DT: deciduous trees; JP: jack pine; NC: no cover; SM: logs 2-5 cm diameter; MD: logs 5-10 cm diameter; LG: logs > 10 cm diameter and steams; HD: herbaceous dicots; LS: low shrubs; GR: grass; LL: leaf litter; PN: pine needles; RO: rocks; WD: woody debris <2 cm diameter; SA: sand; BS: bare soil; MO: moss.

recapture techniques (e.g., M'Closkey 1976) and radiotelemetry (e.g., Wolff and Hurlbutt 1982) followed by multivariate analysis. The fluorescent pigment tracking technique applied to the study of microhabitat use is a relatively recent technique (Lemen and Freeman 1985) and was employed in several studies of *Peromyscus* in general (e.g., Etheredge et al. 1989, Planz and Kirkland 1992), and *P. maniculatus* in particular (e.g., Graves et al. 1988, Kaufman 1989).

We placed captured mice in a plastic bag containing either orange or red fluorescent pigment (Radiant Color Co., Richmond, California) (Lemen and Freeman 1985). After the fur was saturated with powder, animals were released at the trap site. A maximum of three animals was released with powder per day and each individual was powdered only once. Approximately 36 hours after release, trails left by the animals were followed with an ultra-violet lamp (UVP, Inc., ML49, 12V) after sunset, and colour markers were placed at each turn of the trail to allow the identification of the path during daylight. Using the same microhabitat variables as described above, distance travelled under different kinds of canopy and understory cover and on different substrate was measured with a measuring tape and recorded for each path. Data were summarized for each path as percentage distance travelled under each kind of plant coverage and on each kind of substrate.

Standardized preference indices (PI) were estimated as $PI = \log(1 + U/A)$, where U is the percentage of each microhabitat variable used by the animal and A is the mean percentage of that variable available in the field (Duncan 1983, Tew et al. 1992). PI varies from 0 (microhabitat avoided), through 0.3 (no preference), to greater values indicating an increasing degree of preference. Mean preference index for each microhabitat variable was calculated for both grids and sexes. Because age may influence selective behaviour in *P. maniculatus* (Van Horne 1982), only adults were used to analyze microhabitat preferences by sexes.

Data analysis

Two-way ANOVA and two-tailed t-tests were conducted on either square root or arcsine (when data were expressed in percentages) transformed data to test for differences in percentage cover, length of trails, and microhabitat used by mice. The null hypotheses were rejected at $P < 0.05$. The jackknife technique was used to compute standard errors of the estimated mean of PI. Most statistic tests were performed using SAS/STATS software.

Results

Pinus banksiana, *P. tremuloides* and *Alnus rugosa* (Specked alder) dominated the canopy; *Vaccinium* spp. and *K. angustifolia* dominated the understory, and mosses dominated the low stratum in both grids. Overall ANOVA showed no differences in percentage cover by plants and substrates between Grids ($F=0.037$, $P > 0.5$). Further analysis, however, showed that percentage cover by deciduous trees and herbaceous dicots was higher and percentage cover by grasses was lower in Grid 1 than in Grid 2 (Table 1). Leaf litter covered a larger area of the substrate in Grid 1 than in Grid 2, while sand and rocks covered a larger area in Grid 2 than in Grid 1.

Twenty-five *P. maniculatus* were caught 55 times in Grid 1 and 5 specimens were captured 12 times in Grid 2 in 1993. In 1994, 13 and 9 individuals were caught 47 and 31 times in Grid 1 and 2, respectively. More mice were captured in Grid 1 than in Grid 2 in 1993 ($X^2=13.367$, $P < 0.001$) but not in 1994 ($X^2=0.773$, $P > 0.5$). A total of 34 individuals was powdered, 20 in Grid 1 and 14 in Grid 2. Of the mice powdered in Grid 1, 8 were adult males; 8 adult females; 2 juvenile males; and 2 juvenile females. Mice powdered in Grid 2 were not considered for the analysis by sex because only four of them were adults (3 were adult males; 1 adult female; 6 juvenile males; and 4 juvenile females).

Mice primarily used areas with no canopy cover and areas associated with low shrubs, herbaceous dicots, leaf litter, and woody debris (Table 2). Overall use of microhabitat features was similar between plots ($F=0.119$, $P > 0.5$). Mean distance of travel paths was 26.5 ± 4.6 m in Grid 1 and 30.0 ± 5.9 m in Grid 2, and there was no significant difference in the mean distance between plots ($t=0.019$, $P > 0.5$).

Table 2. Mean percentage distance (SE) travelled by *Peromyscus maniculatus* associated with 17 microhabitat variables of canopy cover, understory cover, and substrate in two grids in young *Pinus banksiana* plantations in northern Ontario during 1993 and 1994.

Microhabitat variables	Grid 1	Grid 2
Sample size (N)	20	14
Canopy cover		
Jack pine	10.6 (1.7)	29.0 (4.9)
Deciduous trees	26.5 (3.8)	9.5 (1.4)
No cover	62.9 (4.4)	61.6 (5.0)
Understory cover		
Low shrubs	15.0 (2.1)	23.9 (3.1)
Herbaceous dicots	27.5 (2.4)	15.2 (2.5)
Grass	5.0 (1.3)	16.9 (1.9)
Small logs	3.8 (0.5)	3.0 (0.5)
Medium logs	16.0 (3.8)	4.2 (1.1)
Large logs	16.4 (2.5)	7.6 (1.9)
No cover	16.2 (2.1)	29.3 (3.1)
Substrate		
Leaf litter	37.4 (3.3)	24.8 (3.0)
Bare soil	5.8 (1.1)	10.9 (1.7)
Woody debris	34.2 (3.3)	25.9 (1.3)
Moss	12.7 (1.3)	19.4 (2.9)
Sand	5.9 (1.3)	10.4 (3.0)
Rock	1.7 (0.5)	2.0 (0.4)
Pine needle	2.2 (0.8)	10.4 (1.9)

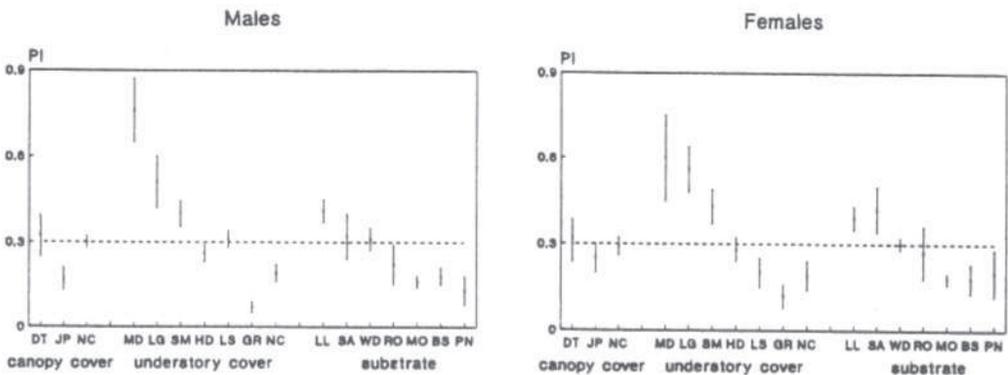


Figure 2. Standardized preference indices (PI), and standard errors of the jackknife estimates, of male and female *Peromyscus maniculatus* for microhabitat variables of the canopy cover, understory cover, and substrate in Grid 1 in a *Pinus banksiana* (Jack pine) plantation in the boreal forest of Ontario, Canada. Hatched line and abbreviations as in Fig. 1.

The preference indices showed that *P. maniculatus* was more selective in the use of canopy cover and understory cover in Grid 1 than in Grid 2 (Fig. 1). In Grid 1, mice showed no preference for three of the 17 microhabitat variables considered in this study, while in Grid 2 the standard error of eight means included the no preference value (0.3). Consistent results of microhabitat preferences in both grids showed that *P. maniculatus* preferred deciduous trees as canopy cover, logs 5-10 cm in diameter, and leaf litter as a substrate. Grass and bare soil were consistently avoided as understory cover and substrate, respectively.

Males and females showed a similar degree of preference for 13 microhabitat variables in Grid 1 (Fig. 2). Males showed no preference for low shrubs and avoided herbaceous dicots, whereas females showed no preference for herbaceous dicots and avoided low shrubs. Males showed no preference for travelling on sand and avoided rocks, whereas females preferred sand and showed no preference for rocks.

Discussion

Mice preferred to travel under deciduous trees rather than under Jack pine. Previous studies on microhabitat selection showed that *P. maniculatus* is more abundant in deciduous than in coniferous forests. *Peromyscus maniculatus* was found to avoid coniferous areas in a study of microhabitat use in a deciduous and coniferous forest ecotone in New York (Kirkland and Griffin 1974). This species was associated with a high diversity in foliage heights in deciduous forests of the Appalachian Mountains (Buckner and Shure 1985), and it occurred in higher numbers in mixed deciduous-coniferous forests than in pure coniferous stands in northern Ontario (Naylor and Bendell 1983).

Our study showed that *P. maniculatus* preferred logs. Some rodent species are more abundant when slash is left at a site following clearcutting (Larson et al. 1986). In the same plantation, we recorded a higher abundance of *P. maniculatus* close to a slash pile than 100-m away from the same slash (Bellocq and Smith 1995). Using fluorescent pigments and trapping in an experiment of woody litter removal (greater than 1 cm diameter) in a mid-age deciduous forest, Planz and Kirkland (1992) recorded a significant decrease in the frequency of capture of *P. leucopus* in plots where litter was removed. We recorded a preference for logs 5-10 cm in diameter. In contrast, Hayes and Cross (1987) reported no significant correlation between the number of *P. maniculatus* caught in traps and the diameter of logs. It has been suggested that *P. maniculatus* use logs as travel routes to avoid detection by auditory predators (Smith and Speller 1970).

Most studies of microhabitat preferences by small mammals have not considered analysis by sex, and those that did have reported contrasting results. We found that male and female *P. maniculatus* differed only in their preferences for four of the 17 microhabitat variables considered here. Previous studies have shown habitat partitioning between male and female *P. maniculatus*, where females inhabit moist microhabitats but males occupy xeric sites in some communities (Bower and Smith 1979). *Peromyscus leucopus* of different sex used microhabitat differently, with females distributed in sites providing greater herbaceous cover (Seagle 1985). Another study, however, showed no difference in the pattern of capture success associated with woody vegetation between male and female *P. leucopus* (Kaufman et al. 1985). We did not consider juveniles in this analysis because age may influence habitat selection. Intraspecific competition appeared to be responsible for niche displacement of juvenile *P. maniculatus* along the habitat dimension, where adult high-density microhabitats have more cover (and are more favourable) than juvenile high-density microhabitats (Van Horne 1982).

Our results showed that *P. maniculatus* tended to avoid sites lacking canopy and understory cover, which would reduce the risk of aerial predation. High vegetation coverage seems to reduce predation by owls in *Peromyscus* (Kaufman 1974) which is consistent with the preference of *P. maniculatus* to forage in covered areas (Kotler 1984). Kaufman et al.'s (1983) work on the effects of microhabitat features and habitat use by *P. leucopus* showed results consistent with the use of microhabitat features to avoid predators. More recent studies have also shown consistency between the selection of microhabitat features and the reduction in predation risk; for instance, *P. leucopus* may avoid auditory predators by travelling silently across substrata (e.g., Fitzgerald and Wolff 1988,

Barnum et al. 1992, Planz and Kirkland 1992). We found *P. maniculatus* using logs both as cover (travelling beside or underneath logs) and a substrate to travel, and preferred leaf litter while bare soil was avoided. These results may reflect a low risk of predation by auditory predators like owls. We did not see or hear any owls in the study plots, and diurnal predators like hawks are likely avoided by differences in activity time. However, we frequently found tracks of weasels and other carnivores in the plots. Besides, food availability (seeds and insects) is higher in leaf litter than in bare soil, and the selection of microhabitat features should result from a trade-off between food availability and predation risk, as suggested by Rosenzweig (1974).

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