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INFLUENCE OF MICROHABITAT ON THE LOCAL DISTRIBUTION
OF WHITE-FOOTED MICE (Peromyscus leucopus)
AND RED-BACKED VOLES (Clethrionomys gapperi)
IN RED MAPLE (Acer rubrum)
SWAMPS AND CONTIGUOUS UPLANDS IN RHODE ISLAND

BY

MICHAEL W. ABELL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
NATURAL RESOURCES SCIENCE

UNIVERSITY OF RHODE ISLAND

1992

MASTER OF SCIENCE THESIS

OF

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1992

ABSTRACT

Microhabitat choice by white-footed mice (Peromyscus leucopus) and red-backed voles (Clethrionomys gapperi) was studied in three Rhode Island red maple (Acer rubrum) swamps and their contiguous transition and upland zones. Significant differences were found in microhabitat use between the two species in each zone. High woody stem density (stems m^{-2}) and low herbaceous plant species richness were important factors determining white-footed mouse occurrence. Red-backed voles were found in areas of high density of shrub cover, as well as high herbaceous plant density (stems m^{-2}) and richness.

Acknowledgments

This study was funded by a grant from McIntyre-Stennis, project number MS966 through the College of Resource Development, Rhode Island Agricultural Experiment Station. I dedicate this paper to my wife Denise, whose support and understanding made this possible, and our daughter Katie (01-18-91) whose presence in my life reminds me why I've chosen this field.

Special thanks to B. Deegan and my sampling crew: D. Gendron, D. Burgess, and M. Barda.

I thank T. P. Husband and the other members of my thesis committee J. Brown, W. Eddleman, and K. Killingbeck, as well as "Swamp Thing" who has been an inspiration by example of his dedication to wetland ecology.

Preface

This thesis is a manuscript to be submitted to the Journal of Mammalogy and follows their manuscript format.

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INFLUENCE OF MICROHABITAT ON THE LOCAL DISTRIBUTION OF
WHITE-FOOTED MICE (Peromyscus leucopus) AND RED-BACKED
VOLES (Clethrionomys gapperi) IN RED MAPLE (Acer rubrum)
SWAMPS AND THEIR CONTIGUOUS TRANSITION AND UPLAND ZONES
IN RHODE ISLAND.

Red maple swamps reach their greatest abundance in southern New England and northern New Jersey where they comprise 60-70% of the total area of palustrine wetlands (Golet, et al., in press). Because of their abundance, red maple swamps are among the most frequently altered wetland types. Despite their abundance there is very little published information on the fauna of red maple swamps.

The distribution and abundance of small mammals are probably a function of habitat suitability (Vaughan, 1972:250-256), or more specifically, microhabitat suitability (Baker, 1968). Some small mammal species are limited in spatial distribution by specific habitat needs; others occupy a wide range of habitats (Kaufman and Fleharty, 1974; Kirkland and Griffin, 1974; Briese and Smith, 1974; Miller and Getz, 1977; Geier and Best, 1980). Microhabitat use by small mammals has been documented for upland deciduous and coniferous forests in the East (Dueser and Shugart, 1978, 1979; Kitchings and Levy, 1981; Adler, 1985; Parren and Capen, 1985; Seagle, 1985), but similar knowledge of small mammals in red maple swamps and

bordering upland forests in the northeastern United States is limited. Dowler et al. (1985) compared the capture effectiveness of small mammal traps in the Great Swamp National Wildlife Refuge in New Jersey. Of their five upland and wetland study sites, the site dominated by red maple, sweet gum (Liquidambar styraciflua), and American hornbeam (Carpinus caroliniana) produced the highest numbers of small mammals. No single forest type in Vermont had significantly higher mammalian diversity than any other, whereas in Connecticut, red maple swamps with 50-75% shrub cover had relatively high mammalian richness (9 species) and diversity (Shannon's $H'^2 = 2.21$) (Miller and Getz, 1977). Differences in water content of food appeared to explain differences in local distributional patterns of short-tailed shrews (Blarina brevicauda) and red-backed voles (Clethrionomys gapperi), both of which have high water requirements (Getz, 1968).

The purpose of my study was to provide baseline information on: 1) small-mammal communities in Rhode Island red maple swamps and their contiguous upland forests as well as the transitional zone (ecotone) between them, and 2) the relationships between small mammals and their habitats. The ecotone is a transition between two or more diverse communities; each commonly containing many of the organisms of each of the overlapping communities (Odum, 1971). The ecotone also has organisms that are

characteristic of and often restricted to the ecotone. The three main null hypotheses were: 1) there is no difference in species diversity (plant or small mammal) among the three habitat zones (upland, transition, and wetland); 2) there is no relationship between small mammal species richness and plant species richness; and 3) there is no difference in microhabitat preferences between white-footed mice and red-backed voles. (For detailed literature review see Appendix A.)

STUDY AREAS

Three study sites were chosen in Rhode Island: Arrow Swamp (AS, Appendix B), Exeter; Great Swamp Wildlife Management Area (GS, Appendix C), South Kingstown; and Burlingame State Park (BG, Appendix D), Charlestown. Criteria for selection study sites were: 1) size ≥ 30 ha; 2) inclusion of a red maple swamp bordered by upland forest; 3) predominance of very poorly drained soils in the swamp (Rector, 1981); 4) low to moderate ($\leq 15\%$) slopes in surrounding upland (Rector, 1981); 5) presence of homogeneous forest cover $\geq 85\%$ deciduous; 6) canopy cover $\geq 75\%$; 7) mature forest (minimum stand height of 10 m); 8) lack of recent human disturbance (≥ 40 yrs); and 9) presence of a 100-m buffer around sampled areas.

At each site three parallel transects were located 90 m apart and perpendicular to the wetland boundary. A 50-by 50-m grid was then located in the upland, transition and

wetland of each site (Appendix E). The grids were positioned such that they were bisected by the transect line, and in the transition zone they were also bisected by the very poorly drained soil edge (Appendix F). The upland overstories were dominated by red maple, scarlet oak (Quercus coccinea), and white oak (Quercus alba) at BG; red maple, white oak, and sassafras (Sassafras albidum) at GS; and mixed oak (Quercus spp.) at AS. The transition zone overstories were dominated by mixed hardwoods at BG; red maple and white oak at GS; and red maple, white oak, and scarlet oak at AS. Wetland overstories were dominated by red maple at BG; red maple, Atlantic white cedar (Chamaecyparis thyoides), and white pine (Pinus strobus) at GS; and red maple, white pine, and black gum at AS. The upland understories were dominated by red maple, sassafras, and mixed oak at BG; red maple, highbush blueberry (Vaccinium corymbosum), and white oak at GS; and mountain laurel (Kalmia latifolia), white oak, red maple, and sassafras at AS. The transition zone understory dominants consisted of witch hazel (Hamamelis virginiana), sweet pepperbush (Clethra alnifolia), red maple, yellow birch, and spice bush (Lindera benzoin) at BG; witch hazel, red maple, poison sumac (Rhus vernix), and sweet pepperbush at GS; and red maple, sweet pepperbush, poison sumac, and highbush blueberry at AS. Wetland understory dominants were sweet pepperbush, highbush blueberry, and winterberry (Ilex

verticillata) at BG; red maple, sweet pepperbush, yellow birch, and highbush blueberry at GS; and highbush blueberry, red maple, poison sumac, winterberry, and sweet pepperbush at AS.

In wooded swamps, trees and shrubs grow primarily on mounds which are raised above the swamp's seasonal high water level (Golet et al., in press). The Burlingame site was the only one in which a clear break in mound-pool topography did not correspond with the very poorly drained edge. The upland and wetland grids were positioned such that their nearest edge was >100 m from the very poorly drained edge. The wetland grid in Burlingame was shifted 5 m north of the transect line to ensure a 100-m buffer from an upland island (Appendix G).

MATERIALS AND METHODS

Mammal Trapping.--A 6- by 6-trap grid with 10 m between trap stations was established in the upland, transition, and wetland of each site. Trap stations were numbered 1-6, from south to north, and lettered A-R from upland to wetland. This helped to sort data during analysis because all upland data were A-F, transition data were G-L, and wetland data were M-R. At each station, I placed a 7.7- by 7.7- by 30.5-cm Sherman trap and a 143 ml cup as a pitfall trap. Pitfalls were included to capture small, light-weight shrews which rarely trigger a box trap. Sherman traps were covered with leaf litter and provisioned

with cotton and rolled oats. Rolled oats, which have relatively little scent, were used so to avoid attracting distant animals. Two of the three sites were sampled in rotation each trapping session. Trapping sessions were comprised of 3 consecutive nights every other week from May to August 1991 for a total of 7,531 trap nights. To reduce losses related to stress, traps were checked between 0600 and 1300 h. Captured animals were uniquely marked by toe-clipping (Melchior and Iwen, 1965) and released at the trap site after species, weight (to nearest gram), sex, age (juvenile, subadult, adult), and reproductive condition (scrotal, abdominal, pregnant, lactating, none, unknown) had been recorded.

Vegetation sampling.--Sampling followed the methods outlined by Dueser and Shugart (1978). A habitat parameter was measured if it was known or suspected to influence the distribution and local abundance of forest-floor mammals, was quickly and precisely measurable with nondestructive procedures, and helped describe the immediate environment of the trap station. The sampling scheme was designed to measure six strata: overstory [woody plants ≥ 10 cm diameter at breast height (dbh at 1.5 m)], understory (woody plants > 2.0 m in height and < 10 cm dbh), shrub stratum (woody plants > 0.4 m and ≤ 2.0 m in height), herbaceous stratum (vegetation ≤ 0.4 m in height), forest-floor characteristics (surface and cover features), and humus depth (surface to

variable depth, <11.0 cm) (Table 1). To accomplish this 3 independent sampling units were centered on each trap station: a 1-m² circle, a set of 2 perpendicular 10-m² quadrats, and a 10-m radius circular plot.

The 2 perpendicular 10-m² quadrats were used to determine stem density of the woody vegetation at shrub stratum. This was done by walking a transect across the trap station and counting the number of live woody contacts on a 1-m stick held horizontally 1 m above the ground. The quadrats were also used to determine the percentage of the ground covered by evergreen herb, exposed mineral soil or rock, sphagnum moss, as well as to establish the ratio of mounds to pools. Each radial arm was divided into five imaginary units, each one meter long. Each sampling day, a random number from 0.01 to 1.00 was selected. A distance equal to the random number was added to the 1-meter units to determine the sample points. For example, with a random number of 0.37 selected for the day, the points examined were at 0.37, 1.37, 2.37, 3.37, and 4.37 m from the trap station along each of the radii. These 20 points and the center point marked by the trap station pin flag comprised the sample points. The number of points at which a variable occurred was divided by 21 to yield a percentage.

In wooded swamps, trees and shrubs grow primarily on mounds which are raised above the seasonally high water level. I defined a mound as a raised area in which woody

plants and/or cinnamon fern (Osmunda cinnamomea) > 0.4 m in height grew. Each of the 21 sample points was recorded as occurring in a pool or mound and the number of mounds was divided by the number of pools to yield a ratio. In the case of uplands where no pools were encountered, the ratio value was recorded as 21.

Within the 10-m radius circular plot, I used the point-quarter method to determine the size and dispersion of overstory, understory, stumps, and fallen logs (Cotton and Curtis, 1956). Within the 1-m² circle the penetration resistance of the humus layer was determined by averaging four readings taken from a soil penetrometer. The depth of the humus was measured by inserting a probe until mineral soil was reached. Along the perimeter of the inner circle, four densiometer readings were averaged for each of the following: canopy coverage, evergreen canopy coverage, shrub coverage, and evergreen shrub coverage. Also within the inner circle, I measured the profile density of herbaceous and woody vegetation. This was done by inserting a pole at the trap station, and inserting a dowel into the pole perpendicular to the ground (Fig. 1). By spinning the pole and counting the number of woody and herbaceous stems contacted by the dowel, I determined the density of vegetation at each height.

A plant species was considered dominant if it fell in the top 20% of the calculated importance values. Dominance

was calculated using frequency of occurrence and basal area (Mueller-Dombois and Ellenberg, 1974). Profile densities of herbaceous and woody plants were measured on the non-trap weeks at each of the 36 trap stations beginning in mid-June to the end of July 1991. Time and staffing restraints dictated that I sample 30 of the 36 points per grid for the rest of the sampling. The number of trap stations selected for measurement were representative of the proportion of the following categories in each grid: non-capture, white-footed mouse captures only, red-backed vole captures only, and captures of both species. These two rodent species were used because of low numbers of captures of the other species.

Abiotic factors.--Factors other than vegetation are important for small mammals, including weather (Getz, 1961a; Doucet and Bider, 1974); moisture (Chenoweth, 1917; Chew, 1951; Getz, 1961b, 1961c; Miller and Getz, 1977); temperature (Brower and Cade, 1966; Getz, 1961a, 1961c); and penetration resistance of the substrate (Dueser and Shugart, 1978; Jameson, 1949). Because these variables are dynamic, they were sampled each trap day throughout the 1991 field season. Air and soil temperatures were determined by an array of three maximum/minimum thermometers (Fig. 2), with the base of one thermometer each at 7 cm below the ground surface, and 25 cm and 100 cm above the ground surface (Getz, 1961c). One thermometer

was calculated using frequency of occurrence and basal area (Mueller-Dombois and Ellenberg, 1974). Profile densities of herbaceous and woody plants were measured on the non-trap weeks at each of the 36 trap stations beginning in mid-June to the end of July 1991. Time and staffing restraints dictated that I sample 30 of the 36 points per grid for the rest of the sampling. The number of trap stations selected for measurement were representative of the proportion of the following categories in each grid: non-capture, white-footed mouse captures only, red-backed vole captures only, and captures of both species. These two rodent species were used because of low numbers of captures of the other species.

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array was placed at the center of each wetland and upland grid. An array was placed in the upland and wetland halves of the transition zone grid, each equidistant from the wetland edge and plot boundary. Aluminum foil shaded the mercury to ensure that ambient air temperature was recorded. On trap days, I measured soil moisture at each capture point with a Kelway soil probe, and for comparison, at four randomly-determined noncapture points in each grid. Penetration resistance was measured with a soil penetrometer within 0.5 m of each trap station.

Data Analysis.--Microhabitat data were placed into three categories: white-footed mouse occurrence, red-backed vole occurrence, and occurrence of both species. The data were further categorized by zone (upland, transition, and wetland) and by site (BG, AS, GS). For each variable, a Shapiro-Wilk test of normality was conducted by zone (Appendix H) and by site (Appendix I) categories. A linear ANOVA was conducted on all normally distributed variables, and a Kruskal-Wallis ANOVA of ranked data was conducted on all non-normally distributed data to test the effect of each variable on the presence of each species.

Logistic regression (SAS Institute, Inc., 1990) was performed on the subset of variables determined to be significant in explaining species distribution. The logistic procedure produced a 2 x 2 matrix of observed and

expected values for presence or absence of a species. The reported sensitivity is the percentage of points where presence of a species was predicted when it was actually recorded at that trap point. The reported specificity is the percentage of points where a species was predicted when it was not recorded at that point. Because of this feature some models were better at predicting a species absence than its presence at a zone.

The average species richness per zone was calculated by the jackknife method (Heltse and Forrester, 1983). Four different regressions using the habitat zones at each study site as sample points at each were performed with small-mammal species richness as the dependent variable and overstory, understory, shrub, and herbaceous vegetation layer richness as single independent variables ($n = 9, 7$ d.f.). All means are reported with their respective standard deviations unless otherwise indicated. Differences were considered significant at $P \leq 0.05$. SAS programs (SAS Institute, Inc., 1985, 1990) were used to sort data and conduct all analyses.

RESULTS

Mammal Captures.--Seven small mammal species were captured on the three sites (Table 2). White-footed mouse was the species most frequently captured. Captures in the upland were 5.4/100 trap nights (htn), 5.9/htn in the transition zone, and 5.7/htn in the wetland. Red-backed

voles and masked shrews (Sorex cinereus) were the only other two species caught in all three zones. The site with the highest capture rate for white-footed mouse was Burlingame (9.0/htn), which also had the lowest capture rates of red-backed vole (1.0/htn). This is likely a reflection of an absence of red-backed vole captures in the Burlingame transition zone. The average species richness per zone was 5.7 ± 1.4 in the upland, 6.7 ± 1.4 species in the transition, and 3.0 ± 1.4 in the wetland (Table 3).

All of the eastern chipmunks (Tamias striatus), 33% of the white-footed mice, 30% of the red-backed voles, and 22% of masked shrews were captured in upland zones (Table 4). White-footed mouse and red-backed vole accounted for most of the 101 captures in the upland zones (67% and 25%, respectively). Of the 42 individuals captured in the uplands, white-footed mouse and red-backed vole accounted for 54% and 36%, respectively.

The transition grids accounted for the only southern flying squirrel (Glaucomys volans), all smoky shrews (Sorex fumeus), and all short-tailed shrews (Blarina brevicauda) captured, 34% of white-footed mice, 26% of red-backed voles, and 18% of masked shrews. Of the 100 total captures in the transition grids, white-footed mouse accounted for 71% and red-backed vole 21%. Forty-eight individuals were caught in the transition grids, of which white-footed mice comprised 58% and red-backed voles 25%.

The wetland grids accounted for 56% of the masked shrew captures, 45% of red-backed vole, and 33% of white-footed mouse. A total of 112 captures occurred in the wetland with white-footed mice accounting for 63% and red-backed voles 33%. Of the 51 individuals caught in the wetlands, white-footed mice comprised 49%, red-backed voles 41%, and masked shrews, 14%. White-footed mice accounted for 67% and red-backed voles 27% of all captures, respectively. Of the 139 total individuals caught, white-footed mice comprised 54% and red-backed voles, 34%.

In the upland grids, 38% of red-backed vole capture points also had captures of white-footed mice, while 15% of the white-footed mouse capture points also had captures of red-backed voles. Fifty percent of masked shrew points had captures of white-footed mice.

In the transition grids, 40% of red-backed vole capture points overlapped with white-footed mouse capture points and 12% of the white-footed mouse capture points overlapped with red-back voles. In the wetland grids, 27% of white-footed mouse capture points overlapped with red-backed voles and 48% of red-backed vole points overlapped with white-footed mice. Forty percent of masked shrew capture points overlapped with both red-backed voles and white-footed mice.

Of all the captures, 18% of white-footed mouse capture points overlapped with red-backed voles and 43% of

red-backed vole points overlapped with white-footed mice (Table 5). Thirty-three percent of masked shrew points overlapped with white-footed mice and 22% overlapped with red-backed voles. A common resource used to measure the niche overlap of two species is space or microhabitat use (Krebs, 1989). The percentage of a generalist's capture points that also are a specialist's capture points will be smaller than the percentage for the converse. Of the 131 total capture points for the white-footed mouse, 23 points (18%) also had captures of red-backed voles. Of the 54 total capture points for the red-backed vole, 23 points (43%) also had captures of white-footed mice.

Microhabitat.--Because of the low capture rates for most species, microhabitat was analyzed only for white-footed mice and red-backed voles. Upland canopy coverage averaged about 81%, of which evergreens accounted for <5% (Table 6). Overall, upland shrub coverage was almost 44%, with evergreen shrub cover equaling 10%. The transition zone canopy coverage averaged about 77% with 1% evergreen coverage. Overall shrub coverage in transitions was 45% with 4% evergreen coverage. The mound-pool ratio in transition zones averaged 14, and sphagnum moss (Sphagnum spp) coverage was 12%. The wetland zone canopy coverage averaged 79% with 9% evergreen coverage. Overall shrub coverage in wetland zones was 58% with no evergreen shrub coverage. The wetland mound-pool ratio averaged 2,

and sphagnum moss covered 34% of the ground. Plant species richness was highest in the transition zone. Of the 19 plant species found in the overstory, 11 occurred in the upland, 16 in the transition, and 6 in the wetland (Table 7). I found 26 plant species in the understory with 18, 19, and 12 occurring in the upland, transition, and wetland, respectively (Table 8). In the shrub stratum, 12 out of 21 plant species occurred in the upland, 15 in the transition, and 6 in the wetland (Table 9). In the herbaceous stratum, the upland contained 12 of the total 22 plant species, 15 in the transition, and 6 in the wetland (Table 10).

Species richness of small mammals and plant richness in all layers showed a positive relationship, but only three with an $r^2 > 0.25$: overstory (Fig. 3), shrubs (Fig. 4), and herbaceous layer (Fig. 5). In general, areas of white-footed mouse occurrence were characterized by high woody stem density, tree stump dispersion, overstory tree size, soil surface exposure, and low evergreen coverage, sphagnum moss exposure, and evergreen herb stratum (Table 11). Significant differences between white-footed mouse capture and noncapture points were detected in 21% (5/24) of the microhabitat variables at AS and BG, and 25% (6/24) at GS. White-footed mouse occurrence in Arrow Swamp was in areas of relatively high tree stump size and evergreen closure, and low herbaceous foliage profile density,

understory tree size, and tree stump dispersion. In Burlingame, white-footed mouse microhabitat was characterized by high numbers of woody species, evergreen shrub cover, evergreenness of herbaceous stratum, and soil surface exposure, as well as by low sphagnum moss exposure. Great Swamp microhabitat for white-footed mice was characterized by high overstory tree size, and soil surface exposure, as well as by low numbers of herbaceous species, percent total canopy coverage, evergreen coverage, and evergreen herbaceous stratum.

Significant differences in white-footed mouse capture and noncapture points also were detected in 33% (8/24) of the microhabitat variables in the upland and transition zones and 21% (5/24) in the wetland. White-footed mouse occurrence in the upland zones was in areas of relatively high woody stem density, woody foliage profile density, understory tree dispersion, tree stump dispersion, and thickness of woody vegetation, and low overstory tree dispersion, numbers of herbaceous species, and smaller overstory tree size. In the transition zone, white-footed mouse microhabitat was characterized by high woody stem density, soil surface exposure, overstory tree size, and tree stump dispersion. Wetland microhabitat for white-footed mice was characterized by high herbaceous stem density, fallen log dispersion, thickness of woody vegetation, and low evergreen herbaceous stratum, and

sphagnum moss exposure. Red-backed voles were generally caught in areas of low tree stump dispersal and low canopy coverage, and low soil surface exposure (Table 12). Significant differences in red-backed vole capture and noncapture points in the sites were detected in 21% (5/24) at AS, 13% (3/24) at BG and GS, of the microhabitat variables measured. Red-backed vole occurrence in Arrow Swamp was in areas with relatively high herbaceous foliage profile density as well as small understory trees, tree stumps, low tree stump dispersion, and percent total canopy coverage. Burlingame microhabitat was characterized by low thickness of woody vegetation, tree stump dispersion, and percent total canopy coverage. In the Great Swamp, red-backed voles were found in areas of small fallen log size, low evergreen coverage, and low soil surface exposure. Significant differences in red-backed vole capture and noncapture points were detected in 17% (4/24), 21% (5/24), and 8% (2/24) of the microhabitat variables in the upland, transition, and wetland, respectively. Red-backed vole upland occurrence was in areas with relatively large understory trees and high mound-pool ratio, and low tree stump dispersion and low percent total canopy coverage. Transition microhabitat for red-backed vole was characterized by high fallen log dispersion and high evergreen coverage and low values for number of woody species, fallen log abundance, and soil surface exposure.

In the wetlands, red-backed vole was found in areas of large overstory trees and high shrub coverage.

Significant differences in red-backed vole and white-footed mouse capture points were detected in 25% (6/24), 21% (5/24), and 17% (4/24) of the microhabitat variables in Arrow, Burlingame, and Great Swamp, respectively (Table 13). In Arrow Swamp, white-footed mice were found in areas of higher numbers of woody species, tree stump size, tree stump dispersion, fallen log abundance, and evergreen coverage, while red-backed voles were found where there was higher herbaceous foliage profile density. In Burlingame, white-footed mice were in areas of high tree stump dispersal, while red-backed voles were found where there were higher values of woody stem density, thickness of woody stems, percent total canopy coverage, and sphagnum moss exposure. In Great Swamp, white-footed mice were in areas of high evergreen coverage, evergreen shrub coverage, and soil surface exposure, while red-backed voles were in areas of high evergreen herbaceous coverage.

Red-backed vole and white-footed mouse capture points differed in 21% (5/24), 38% (9/24), and 21% (5/24) of the microhabitat variables in the upland, transition, and wetland, respectively (Table 14). In the upland, white-footed mice were found in areas of higher woody stem density, woody foliage profile density, tree stump

dispersal, and evergreen coverage. Red-backed voles were found where there was a higher mound-pool ratio. In the transition zone, white-footed mice were in areas high in numbers of woody species, tree stump size, fallen log abundance, evergreen shrub cover, evergreenness of herbaceous stratum, and soil surface exposure. Red-backed voles were found where there was higher fallen log dispersion, percent total canopy coverage, and evergreen coverage. In the wetlands, white-footed mouse presence, compared to that of red-backed vole, was in areas higher in woody foliage profile density, herbaceous stem density, percent total canopy coverage, evergreen coverage, and mound-pool ratio.

In the logistic procedure, white-footed mouse presence was predicted (sensitivity 84%) in the upland by low numbers of herbaceous species, high thickness of woody vegetation, and a high woody foliage profile density (Table 15). Transition indicators of white-footed mouse presence (sensitivity 78%) were high woody stem density, high surface soil exposure, and low canopy coverage. In the wetland, white-footed mouse presence was indicated (sensitivity 79%) by high herbaceous stem density, high herbaceous foliage profile density, and low sphagnum exposure. In Arrow swamp, the only presence indicator (sensitivity 93%) was high evergreen crown coverage. Burlingame absence indicators (specificity 84%) were low

woody stem density, low sphagnum exposure, and high soil surface exposure. At Great Swamp, the sole presence indicator (sensitivity 99%) for white-footed mice was low canopy coverage. Variables which best predict that red-backed vole would not occur (specificity 100%) at a given point in upland habitats were high woody stem density, and low shrub cover (Table 16). Red-backed vole absence was indicated (specificity 100%) by high mound-pool ratio in transitional zones; and red-backed vole presence in wetlands was indicated (sensitivity 95%) by high evergreen canopy coverage, and low mound-pool ratio. In Arrow swamp, red-backed vole presence was indicated (sensitivity 91%) by low values for number of woody species, understory tree size, tree stump dispersion, canopy coverage, and mound-pool ratio. In Burlingame, the only red-backed vole presence indicator (sensitivity 100%) was high thickness (density) of woody stems. At Great swamp, the presence indicators (sensitivity 99%) were high thickness (density) of woody vegetation and low evergreen canopy.

Rainfall, temperature, and substrate moisture showed no significant differences or relationship with capture rates or species occurrence.

DISCUSSION

There was no significant difference in the numbers or capture rates of white-footed mice or red-backed voles in

each of the three zones. Small mammal and plant species richness were both significantly higher in transition than in wetland zones. There was not, however, a significant difference between upland and transition zones; in small mammal and plant richness, this may have been a reflection of the absence of mound-pool topography in the Burlingame transition zone which had surface features more characteristic of an upland zone. Richness values for small-mammals compared to vegetation strata richness show a positive relationship. Diversity of small mammals in New England forests may be related primarily to the diversity of trees and shrubs, which directly or indirectly reflects a greater diversity of available food types (Miller and Getz, 1977). In this study, higher plant species richness values likely reflect a higher diversity of food items. Greater plant species richness also may result in a more diverse phenology of food production (stem, leaf, or fruit) (Martin et al., 1951, Graves, 1952; Sutton and Sutton, 1985). A lower plant species diversity may result in food being produced at one or only a few points in the growing season.

Though masked shrews were caught in each grid, the most were captured in the Great Swamp wetland grid. Masked shrews were caught where there was a carpet of sphagnum moss.

As expected, white-footed mouse captures occurred in all grids and all sites. Densities of white-footed mice are higher in upland sites, compared to swamps, which contain seed, fruit, nut etc. producers that provide a reliable year-round food supply (Getz, 1961b).

White-footed mice usually have a generalized distribution (Hallet et al., 1983). In this study, no statistical difference was found in the numbers of white-footed mouse captures between zones. The white-footed mouse appears to be a microhabitat generalist.

Unexpectedly, red-backed vole captures occurred in all grids except the transition zone at Burlingame. Captures of red-backed voles in the upland zones are in conflict with most of the existing literature, which indicates their dependence upon moisture (Chew, 1951; Brower and Cade, 1966; Getz, 1968; Kirkland and Griffin, 1974; Miller and Getz, 1977; Degraaf and Rudis, 1983). Red-backed voles have a water requirement 2.2 times that of white-footed mice (Getz 1968). Red-backed voles must live in a situation where sufficient water is available either in free water or in succulent food items in order to accommodate their kidney functions.

In both the Great Swamp and Burlingame upland grids, cinnamon fern was associated with the capture points of red-backed voles. Cinnamon fern is classified as a facultative wetland species, occurring in wetlands from 67

to 99% of the time (Tiner 1989). Thus, presence of cinnamon fern indicates moist conditions. Cinnamon fern was present in all the capture points of red-backed vole in the Great Swamp upland, and in a band around a vernal pool in Burlingame where red-backed voles were captured. The significance of the mound-pool ratio was likely an artifact of the presence of a single vernal pool in the Burlingame upland grid. The upland grid of Arrow Swamp's upland yielded more captures of red-backed voles than Burlingame (though less than Great Swamp), yet there was no obvious indicator of moist conditions. In Arrow Swamp's upland, herbaceous species were sparse and the water table inaccessible. The only capture points of red-backed voles in Arrow Swamp were those with high evergreen herbaceous stratum formed by the low lateral branches of mountain laurel, which gave an average evergreen herbaceous coverage of 79%. I suggest that the evergreen cover would shade the humus and slow evaporation. In addition, the reduced wind flow would result in a more humid microclimate.

The transition grid captures of red-backed voles at Great and Arrow Swamp occurred only in the areas of mound/pool topography. No red-backed voles were captured in Burlingame's transition, which has little mound/pool topography. In the wetland grids, the red-backed vole was present throughout but more were captured at points with a low mound/pool ratio.

Logistic regression predicts that white-footed mice occurs in uplands and transitions where there exists a high density of shrubs and in wetlands where the density of herbaceous plants is high. More simply stated, white-footed mice prefers a high stem density. This preference for high stem density also was reported as high density of shrub-understory vegetation (Dueser and Shugart, 1978; M'Closkey and Lajoie, 1975; Seagle, 1985). My study found that the white-footed mouse preferred stone walls in the transition zone, confirming a preference for rocks noted in previous studies (Lackey et al., 1985). The red-backed vole was present in Arrow Swamp's thickets of mountain laurel (Fig. 6), which had a low density of stems with many leafy lateral branches. Similarly, red-backed voles in Connecticut were more abundant at sites with >50% shrub cover (Miller and Getz, 1977). In this study, the average shrub coverage was $53\% \pm 6.7$. In the transition zones, red-backed voles were primarily caught on the very poorly drained side of the transition grid. A high mound-pool ratio (drier) predicted the absence of red-backed voles in the transition zone in the logistic regression model. Red-backed voles are restricted to low, wet areas, often with standing water, or to moist areas where the water content of the vegetation was high as a result of high soil moisture (Getz, 1968). Mound/pool topography is an indicator of low wet areas.

Red-backed voles in New England occur in cool, moist forests with mossy rocks, logs, tree roots, or other cover; they also require water sources such as springs, brooks, or bogs, and debris cover such as fallen trees, stumps, rocks, or slash (Degraaf and Rudis, 1983).

In the wetlands, mound-pool topography and evergreen coverage were predictors of red-backed vole presence. Burlingame's wetland, which had a high mound-pool-ratio and a low value for evergreen coverage, yielded the lowest capture of red-backed voles. Water appears to be a key factor in the local distribution of the red-backed vole.

A common resource used to measure the niche overlap of two species is space or microhabitat use (Krebs, 1989). I used the degree of overlap in capture points as an index of niche overlap between the white-footed mouse and the red-backed vole. This was based upon the premise that an animal classified as a habitat generalist would have a relatively higher number of capture points than one classified as a habitat specialist. The percentage of a generalist's capture points that also are a specialist's capture points will be smaller than the percentage for the converse. Therefore, my study indicates that the white-footed mouse is a microhabitat generalist relative to the red-backed vole which is a microhabitat specialist.

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Table 1.--Designation, descriptions and sampling methods for 28 characteristics of microhabitat structure in red maple (*Acer rubrum*) swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991. Acronyms for variables indicated by parentheses after the variable name.

<u>Variable</u>	<u>Methods</u>
Overstory	
1) Overstory Tree Size (Otry Tr Sz)	Average diameter (cm) of the nearest overstory tree, in quarters around trap station (Cottam and Curtis 1956).
2) Overstory Tree Dispersion (Otry Tr Dsp)	Average distance (m) from trap station to nearest overstory tree, in quarters (Cottam and Curtis 1956).
3) Percent Canopy Coverage (% Canpy Cvrq)	Average of 4 densiometer readings centered on trap station.
4) Evergreen Coverage (Evgn Cvrq)	Average of 4 densiometer readings, for presence of evergreen canopy, centered on trap station.
Understory	
5) Understory Tree Size (Utry Tr Sz)	Average diameter (cm) of the nearest understory tree, in quarters around trap station (Cottam and Curtis 1956).
6) Understory Tree Dispersion (Utry Tr Dsp)	Average distance (m) from trap station to nearest understory tree, in quarters (Cottam and Curtis 1956).
Shrub Stratum	
7) Number of Woody Species (No Wdy Sp)	Woody species count within a 1-m ² ring centered on the trap station.
8) Woody Stem Density (Wd Stm Den)	Live woody stem count at ground level within a 1-m ² ring centered on the trap station.
9) Short Woody Stem Density (Sht Wd Stm Den)	Live woody stem count within a 1-m ² ring centered on the trap station (stems <0.40 meters in height)

Table 1--continued

Table	Methods
10) Woody Foliage Profile Density (Wd Fol Pfl Den)	Average numbers of live woody stem contacts with a 0.80-cm diameter rod rotated 360 degrees, describing a 1-m ² ring centered on the trap station and parallel to the ground, at heights of 0.05, 0.10, 0.20, 0.40, 0.60, ..., 2.00 m above ground level.
11) Thickness of Woody Vegetation (Thck Wd Veg)	Average number of waist-height contacts (tree and shrub) along center lines of two perpendicular 10 m ² transects centered on trap station (James and Shugart 1971).
12) Shrub Coverage (Shb Cvrgr)	Average of 4 densiometer readings, for shrub-level vegetation, centered on trap station.
13) Evergreen Shrub Coverage (Evg Shb Cvrgr)	Average of 4 densiometer readings, for presence of evergreen shrub-level vegetation, centered on trap station.
Herbaceous Stratum	
14) Number of Herbaceous Species (No Hrb Sp)	Herbaceous species count within a 1-m ² ring centered on the trap station.
15) Herbaceous Stem Density (Hrb Stm Den)	Live herbaceous stem count at ground level within a 1-m ² ring centered on the trap station.
16) Short Herbaceous Stem Density (Sht Hrb Stm Den)	Live herbaceous stem count within a 1-m ² ring centered on the trap station (stems ≤ 0.40 meters in height)
17) Herbaceous Foliage Profile Density (Hrb Fol Pfl Den)	Average numbers of live herbaceous stem contacts with a 0.80-cm rod rotated 360 degrees, describing a 1-m ² ring centered on the trap station and parallel to the ground, at heights of 0.05, 0.10, 0.20, 0.40, 0.60, ..., 2.00 m above ground level.

Table 1--continued

Table	Methods
Forest Floor Characteristics	
18) Evergreenness of Herb Stratum (Evgn Hrb Sttm)	Percentage of points with evergreen herbaceous-level vegetation, from 21 step-point samples along center lines of 2 perpendicular 10 m ² transects centered on trap station (Dueser and Shugart 1978).
19) Tree Stump Size (Tr Stmp Sz)	Average diameter (cm) of the nearest tree stump ≥ 10 cm in diameter and ≤ 1.00 m in height, in quarters around trap station.
20) Tree Stump Dispersion (Tr Stmp Dsp)	Average distance (m) from trap station to nearest tree stump ≥ 10 cm in diameter and ≤ 1.00 m in height, in quarters.
21) Fallen Log Abundance (Fln Lg Abn)	Average total length of fallen logs ≥ 10 cm in diameter, per quarter.
22) Fallen Log Dispersion (Fln Lg Dsp)	Average distance (m) from trap station to nearest fallen log ≥ 10 cm in diameter, in quarters.
23) Fallen Log Size (Fln Lg Sz)	Average diameter (cm) of the nearest fallen log ≥ 10 cm in diameter, in quarters around trap station.
24) Soil Surface Exposure (Sl Sfce Exp)	Percentage of points with exposed mineral soil or rock, from 21 step-point samples along center lines of 2 perpendicular 10 m ² transects centered on trap station (Dueser and Shugart 1978).
25) Sphagnum Moss Exposure (Sphgm Mss Exp)	Percentage of points with sphagnum moss, from 21 step-point samples along center lines of 2 perpendicular 10 m ² transects centered on trap station (Dueser and Shugart 1978).
26) Mound to Pool Ratio (Mnd Pl Rtio)	Ratio of the number of points with mound topography to those with pool topography.

Table 1 --continued

Table	Methods
Humus Layer	
27) Humus Depth (Hmus Dpth)	Average of four depth measurements taken within the 1-m ² ring centered on the trap station. A 1.27 cm diameter wooden dowel was inserted into the duff until contact with mineral soil.
28) Penetration Resistance of Humus (Ptn Res Hmus)	Average of four penetrometer readings of the duff layer taken within the 1-m ² ring centered on the trap station (Dueser and Shugart 1978).

Table 2.--Captures of small mammals and capture rates (per 100 trap nights) in red maple swamps (W), and contiguous transition (T) and upland (U) zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Species	Number of Individuals Captured											
	Arrow Swamp			Burlingame			Great Swamp			All Sites		
	U	T	W	U	T	W	U	T	W	U	T	W
<u>Peromyscus leucopus</u>	4 (2.0)	7 (4.0)	6 (4.9)	11 (10.1)	12 (7.8)	12 (8.9)	8 (3.4)	9 (6.5)	6 (2.4)	23 (5.4)	28 (5.9)	24 (5.7)
<u>Clethrionomys gapperi</u>	5 (1.7)	6 (2.5)	8 (3.0)	1 (0.5)	0 (0.0)	3 (2.5)	9 (3.9)	6 (3.2)	9 (3.6)	15 (2.1)	12 (1.7)	20 (3.0)
<u>Tamias striatus</u>	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	2 (0.4)	0 (0.0)	0 (0.0)
<u>Sorex fumeus</u> ^a	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	0 (0.0)	2 (0.2)	0 (0.0)
<u>Sorex cinereus</u> ^a	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.5)	1 (0.2)	0 (0.5)	0 (0.0)	1 (0.2)	5 (0.5)	2 (0.2)	2 (0.1)	5 (0.3)
<u>Blarina brevicauda</u> ^a	0 (0.0)	2 (0.2)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.1)	0 (0.0)
<u>Glaucomys volans</u>	0 (0.0)	1 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	0 (0.0)
Total Caught	10	17	14	14	14	15	18	17	20	42	48	49
Trap Nights	843	837	843	838	835	807	851	835	807	2532	2503	2495

^a Sorex spp. and Blarina were caught in pitfalls.

Table 3.--Vegetation and mammal richness calculated by the jackknife method (Heltshe and Forrester, 1983) in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Species	Zone					
	Upland		Transition		Wetland	
	X	+ SD	X	+ SD	X	+ SD
Mammal	5.7	+ 1.4	6.6	+ 1.4	3.0	+ 1.4
Overstory	13.7	+ 4.0	25.7	+ 3.0	7.3	+ 1.8
Understory	24.6	+ 3.0	25.0	+ 2.6	14.3	+ 3.0
Shrub Layer	16.4	+ 4.0	18.7	+ 1.5	6.3	+ 1.5
Herbaceous	9.3	+ 4.2	21.2	+ 1.5	10.6	+ 0.0

Table 4.--Numbers of captures, individuals and capture points in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

<u>Zone</u>	<u>Number of Captures</u>	<u>No. Ind-viduals captured</u>	<u>Capture points</u>	<u>1 species capture points</u>	<u>>1 species capture points</u>
<u>Peromyscus leucopus</u>					
Upland	68	23	40	32	8
Transition	71	28	50	43	7
Wetland	70	24	41	29	12
Total	209	75	131	104	27
<u>Clethrionomys gapperi</u>					
Upland	25	15	16	10	6
Transition	21	12	15	9	6
Wetland	37	20	23	10	13
Total	83	47	54	29	25
<u>Tamias striatus</u>					
Upland	6	2	6	4	2
Transition	0	0	0	0	0
Wetland	0	0	0	0	0
Total	6	2	6	4	2
<u>Glaucomys volans</u>					
Upland	0	0	0	0	0
Transition	1	1	1	1	0
Wetland	0	0	0	0	0
Total	1	1	1	1	0

Table 4.--continued.

<u>Zone</u>	<u>Number of Captures</u>	<u>No. Ind- viduals captured</u>	<u>Capture points</u>	<u>1 species capture points</u>	<u>>1 species capture points</u>
<u>Blarina brevicauda</u>					
Upland	0	0	0	0	0
Transition	3	3	3	2	1
Wetland	0	0	0	0	0
Total	3	3	3	2	1
<u>Sorex cinereus</u>					
Upland	2	2	2	1	1
Transition	2	2	2	2	0
Wetland	5	5	5	1	4
Total	9	9	9	4	5
<u>Sorex fumeus</u>					
Upland	0	0	0	0	0
Transition	2	2	2	1	1
Wetland	0	0	0	0	0
Total	2	2	2	1	1
<u>Grand Totals</u>					
Upland	101	42	64	47	17
Transition	100	48	73	58	15
Wetland	112	49	69	40	29
<u>Grand Total</u>	<u>313</u>	<u>139</u>	<u>206</u>	<u>145</u>	<u>61</u>

Table 5.--Points where more than one small-mammal species was captured in red maple swamps, and contiguous transition and upland zones at three Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Bristol; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

	Number of capture points where the capture of both species occurred						
	Pl	Cg	Ts	Sf	Sc	Bb	Gv
Upland							
<u>Peromyscus leucopus</u>	--	6	3	0	1	0	0
<u>Clethrionomys gapperi</u>	--	--	1	0	0	0	0
<u>Tamias striatus</u>	--	--	--	0	0	0	0
<u>Sorex fumeus</u>	--	--	--	--	0	0	0
<u>Sorex cinereus</u>	--	--	--	--	--	0	0
<u>Blarina brevicauda</u>	--	--	--	--	--	--	0
<u>Glaucomys volans</u>	--	--	--	--	--	--	--
Transition							
<u>Peromyscus leucopus</u>	--	6	0	0	0	1	0
<u>Clethrionomys gapperi</u>	--	--	0	1	0	0	0
<u>Tamias striatus</u>	--	--	--	0	0	0	0
<u>Sorex fumeus</u>	--	--	--	--	0	0	0
<u>Sorex cinereus</u>	--	--	--	--	--	0	0
<u>Blarina brevicauda</u>	--	--	--	--	--	--	0
<u>Glaucomys volans</u>	--	--	--	--	--	--	--
Wetland							
<u>Peromyscus leucopus</u>	--	11	0	0	2	0	0
<u>Clethrionomys gapperi</u>	--	--	0	0	2	0	0
<u>Tamias striatus</u>	--	--	--	0	0	0	0
<u>Sorex fumeus</u>	--	--	--	--	0	0	0
<u>Sorex cinereus</u>	--	--	--	--	--	0	0
<u>Blarina brevicauda</u>	--	--	--	--	--	--	0
<u>Glaucomys volans</u>	--	--	--	--	--	--	--
Overall							
<u>Peromyscus leucopus</u>	--	23	3	0	3	1	0
<u>Clethrionomys gapperi</u>	--	--	1	1	2	0	0
<u>Tamias striatus</u>	--	--	--	0	0	0	0
<u>Sorex fumeus</u>	--	--	--	--	0	0	0
<u>Sorex cinereus</u>	--	--	--	--	--	0	0
<u>Blarina brevicauda</u>	--	--	--	--	--	--	0
<u>Glaucomys volans</u>	--	--	--	--	--	--	--

Table 6.--Habitat variable average values (+ SD) measured in three habitat zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	Upland			Transition			Wetland		
	X	+	SD	X	+	SD	X	+	SD
No wdy spp	2.9	+	1.2	2.6	+	1.2	2.8	+	0.8
Wd stm den	20.9	+	18.6	21.4	+	20.1	50.4	+	50.4
Wd fol pfl den	5.8	+	4.6	4.7	+	4.1	8.4	+	5.0
No hrb spp	1.6	+	1.7	2.5	+	1.3	2.0	+	1.1
Hb stm den	24.1	+	35.7	34.7	+	28.5	28.4	+	27.9
Hb fol pfl den	3.4	+	4.8	4.7	+	4.8	5.3	+	6.1
Otry tr sz	19.7	+	4.6	24.9	+	7.3	28.1	+	7.8
Otry tr dsp	4.8	+	1.2	5.2	+	1.2	5.2	+	1.2
Utry tr sz	4.9	+	2.6	4.1	+	1.6	3.5	+	1.7
Utry tr dsp	5.2	+	1.9	3.6	+	2.0	3.5	+	2.1
Tr stmp sz	2.1	+	6.8	2.3	+	7.8	2.5	+	6.5
Tr stmp dsp	9.9	+	0.4	9.9	+	0.4	9.7	+	0.6
Fln lg abn	6.0	+	3.7	4.0	+	4.6	3.0	+	3.3
Fln lg dsp	7.7	+	2.0	8.5	+	1.7	8.6	+	2.1
Fln lg sz	15.7	+	9.7	10.7	+	11.2	9.2	+	10.5
Thck wd veg	26.8	+	18.4	27.1	+	15.0	44.6	+	15.3
% canpy cvrg	81.4	+	11.2	76.7	+	14.2	78.6	+	13.0
Evgn cvrg	2.1	+	11.3	0.8	+	4.9	9.2	+	17.6
Shb cvrg	43.5	+	28.7	45.1	+	26.3	57.7	+	24.1
Evgn Shb cvrg	10.0	+	20.2	3.9	+	12.1	0.0	+	0.0
Evgn hrb sttm	23.5	+	31.8	3.8	+	12.0	0.1	+	0.5
Sl sfce exp	0.4	+	1.3	2.4	+	5.1	0.0	+	0.0
Sphgm mss exp	0.0	+	0.0	11.7	+	22.4	34.4	+	24.6
Mnd/pl rtio	20.8	+	1.5	13.5	+	9.1	1.6	+	1.7

Table 7.-Overstory importance values (Based upon basal area and frequency) in maple swamps (W), and contiguous transition (T) and upland (U) zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Westerly; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

	Arrow Swamp			Burlingame			Great Swamp		
	U	T	W	U	T	W	U	T	W
<u>Acer rubrum</u>	4.6	45.3	38.1	38.0	32.0	88.0	41.7	45.7	56.3
<u>Quercus coccinea</u>	54.5	17.3		37.0					
<u>Quercus alba</u>	24.6	26.5		16.6	10.3		25.2	36.3	
<u>Quercus rubra</u>	6.0			4.0	12.6		7.1	5.1	
<u>Quercus velutina</u>	6.3			2.8					
<u>Sassafras albidum</u>	1.3				2.7		13.9		
<u>Nyssa sylvatica</u>		2.7	13.6	1.0	17.9	1.5	8.6	1.0	
<u>Pinus strobus</u>	2.8	2.7	40.2						10.9
<u>Pinus rigida</u>								2.7	
<u>Ilex opaca</u>							1.7	3.4	
<u>Betula papyrifera</u>		0.8					1.6		
<u>Betula alleghaniensis</u>			5.3	16.6	10.3				10.4
<u>Carya glabra</u>				5.4			1.0		
<u>Rhus vernix</u>		3.7	2.6					2.9	
<u>Fagus grandifolia</u>								2.7	
<u>Fraxinus americana</u>					1.6				
<u>Populus gradidentata</u>	1.2								
<u>Prunus serotina</u>					0.9				
<u>Acciparis thyoides</u>									22.2

Table 8.--Understory importance values (Based upon basal area and frequency) of maple swamps (W), and contiguous transition (T) and upland (U) zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Westtown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

	Arrow Swamp			Burlingame			Great Swamp		
	U	T	W	U	T	W	U	T	W
<i>Acer rubrum</i>	15.3	44.8	23.0	40.5	13.1	5.3	64.5	25.9	33.4
<i>Quercus coccinea</i>	5.8	2.6		16.5					
<i>Quercus alba</i>	25.6			7.1			5.9	0.9	
<i>Quercus rubra</i>							0.8		
<i>Vaccinium corymbosum</i>	2.7	10.6	26.2	19.9	1.2	24.5	2.2	3.1	14.5
<i>Sassafras albidum</i>	6.9			1.0	2.0		11.4		
<i>Myrica sylvatica</i>		0.9	1.5	2.7	6.6		4.2	2.1	
<i>Pinus strobus</i>			1.0						
<i>Ilex opaca</i>							1.5	3.6	
<i>Ilex glabra</i>				2.2					
<i>Ilex verticillata</i>	0.9		12.4		1.8	17.4	1.0	2.1	9.8
<i>Betula papyrifera</i>	2.9			1.5			1.1		
<i>Betula alleghaniensis</i>			3.9	1.2	9.9	7.1			14.6
<i>Carya tomentosa</i>	2.6						1.6		
<i>Rhus vernix</i>		13.5	16.5					11.6	
<i>Fagus grandifolia</i>	1.8						0.9	1.7	
<i>Prunus serotina</i>				1.0			0.8		
<i>Viburnum lentago</i>		2.2		3.1			4.5		
<i>Viburnum dentatum</i>					0.7	1.4	0.9		
<i>Kalmia latifolia</i>	35.5	8.7						1.0	
<i>Clethra alnifolia</i>		16.1	13.3	3.2	14.0	44.6		4.3	20.7
<i>Hammamelis virginiana</i>					40.4			42.5	
<i>Lindera benzoin</i>		1.2	1.2		7.7			1.1	
<i>Lyonia ligustrina</i>			2.7		1.7				4.9
<i>Corylus cornuta</i>					0.8				
<i>Thuja racemosa</i>									1.9

Table 9.--Species richness of the shrub layer in red maple swamps (W), and
 Aquous transition (T) and upland (U) zones at three Rhode Island sites
 Arrow Swamp, Exeter; Burlingame State Forest, Charlestown; and Great Swamp
 Wildlife Management Area, South Kingstown) from May to August 1991.

	Arrow Swamp			Burlingame			Great Swamp		
	U	T	W	U	T	W	U	T	W
<u>Clethra alnifolia</u>		X	X	X	X	X	X	X	X
<u>Vaccinium corymbosum</u>		X	X	X	X	X	X	X	X
<u>Vaccinium angustifolium</u>	X	X		X	X				
<u>Smilax rotundifolia</u>		X	X	X	X	X	X	X	X
<u>Smilax glauca</u>				X					
<u>Acer rubrum</u>	X	X	X	X	X	X	X	X	X
<u>Gaylussacia baccata</u>	X			X			X		
<u>Ilex verticillata</u>		X	X		X	X		X	X
<u>Ilex opaca</u>								X	
<u>Ilex glabra</u>				X					
<u>Hamelis virginiana</u>					X			X	
<u>Quercus alba</u>	X	X		X	X				
<u>Quercus coccinea</u>	X								
<u>Prunus serotina</u>	X								
<u>Parthenocissus quinquefolia</u>					X				
<u>Rhus radicans</u>					X				
<u>Sassafras albidum</u>	X	X							
<u>Kalmia latifolia</u>	X	X			X				
<u>Kalmia angustifolia</u>		X							
<u>Leucothoe racemosa</u>									X
<u>Juniper</u>								X	

Table 10.--Herbaceous layer species richness in red maple swamps (W), and
 aquatic transition (T) and upland (U) zones at three Rhode Island sites
 Great Swamp, Exeter; Burlingame State Forest, Charlestown; and Great Swamp
 Wildlife Management Area, South Kingstown) from May to August 1991.

	Arrow Swamp			Burlingame			Great Swamp		
	U	T	W	U	T	W	U	T	W
<u>Osmunda cinnamomea</u>		X	X		X	X	X	X	X
<u>Osmunda regalis</u>						X			X
<u>Thelypteris simulata</u>		X	X		X	X		X	X
<u>Thelypteris noveboracensis</u>							X		
<u>Symplocarpus foetidus</u>		X	X			X		X	X
<u>Iris versicolor</u>								X	
<u>Viola cucullata</u>		X	X			X		X	X
<u>Streptopus amplexifolius</u>	X	X	X	X	X	X	X	X	X
<u>Trientalis borealis</u>	X	X	X	X	X	X	X	X	X
<u>Mianthemum canadense</u>	X	X	X	X	X	X	X	X	X
<u>Panax quinquefolius</u>		X	X				X	X	X
<u>Medeola virginiana</u>					X				
<u>Dennstaedtia punctilobula</u>		X	X		X	X	X	X	X
<u>Grass and sedges</u>	X	X		X	X			X	
<u>Ariseama stewardsonii</u>		X			X			X	
<u>Aristolochia durior</u>								X	
<u>Uscuta gronovii</u>		X							
<u>Aralia nudicaulis</u>		X			X			X	
<u>Monotropa uniflora</u>		X			X			X	
<u>Lycopodium</u>	X	X		X	X		X	X	
<u>Dewberry</u>	X	X		X	X		X	X	
<u>Urtica repens</u>	X			X					

Table 11.--Parametric and nonparametric tests of significance for *Peromyscus leucopus* microhabitat difference between capture and noncapture points on variables measured in red maple swamps, and contiguous transition and wetland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

	P	Df	P	Df
	<u>Upland</u>		<u>Arrow Swamp</u>	
Wd stm den	0.012 (+)	1		
Wd fol pfl den	0.007 (+)	1		
Hb fol pfl den			0.013 (-)	74,32
No hrb spp	0.045 (-)	68,38		
Otry tr sz	0.011 (-)	1		
Otry tr dsp	0.033 (-)	1		
Utry tr sz			0.013 (-)	59,31
Utry tr dsp	0.022 (+)	38,56		
Tr stmp sz			0.000 (+)	31,59
Tr stmp dsp	0.007 (+)	56,38	0.027 (-)	59,31
Thck wd veg	0.559 (+)	1		
Evgn cvrg			0.000 (+)	30,59
	<u>Transition</u>		<u>Burlingame</u>	
No wdy spp			0.035 (+)	39,65
Wd stm den	0.000 (+)	51,55		
Hb stm den	0.023 (-)	55,51		
Otry tr sz	0.040 (+)	1		
Tr stmp dsp	0.000 (+)	48,48		
% canpy cvrg	0.000 (-)	44,48		
Evgn cvrg	0.000 (-)	48,48		
Evgn Shb cvrg			0.000 (+)	59,27
Evgn hrb sttm			0.000 (+)	60,27
Sl sfce exp	0.000 (+)	48,48	0.000 (+)	60,27
Sphgm mss exp	0.031 (-)	48,48	0.000 (-)	28,60
	<u>Wetland</u>		<u>Great Swamp</u>	
No hrb spp			0.047 (-)	74,32
Hb stm den	0.051 (+)	42,64		
Otry tr sz			0.024 (+)	1
Pln lg dsp	0.001 (+)	48,38		
Thck wd veg	0.040 (+)	1		
% canpy cvrg			0.000 (-)	32,74
Evgn cvrg			0.002 (-)	74,32
Evgn hrb sttm	0.000 (-)	49,38	0.000 (-)	68,32
Sl sfce exp			0.000 (+)	32,68
Sphgm mss exp	0.028 (-)	38,48		

(+) Average value of variable was significantly greater

(P < 0.05) at *Peromyscus leucopus* capture points than at non-capture points.

(-) Average value of variable was significantly lower

(P < 0.05) at *Peromyscus leucopus* capture points than at non-capture points.

Table 12.--Parametric and nonparametric tests of significance for *Clethrionomys gapperi* microhabitat difference between capture and noncapture points on the variables measured in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	P	Df	P	Df
	<u>Upland</u>		<u>Arrow Swamp</u>	
Hb fol pfl den			0.024 (+)	87,19
Utry tr sz	0.035 (+)	78,16	0.018 (-)	1
Tr stmp sz			0.002 (-)	18,72
Tr stmp dsp	0.006 (-)	16,78	0.006 (-)	18,72
% canpy cvrg	0.001 (-)	16,77	0.052 (-)	78,18
Mnd/pl rtio	0.050 (+)	16,89		
	<u>Transition</u>		<u>Burlingame</u>	
No wdy spp	0.011 (-)	92,14		
Tr stmp dsp			0.028 (-)	8,79
Fln lg abn	0.021 (-)	83,13		
Fln lg dsp	0.020 (+)	83,13		
Thck wd veg			0.052 (-)	93,8
% canpy cvrg			0.018 (-)	71,8
Evgn cvrg	0.000 (+)	13,83		
Sl sfce exp	0.012 (-)	13,83		
	<u>Wetland</u>		<u>Great Swamp</u>	
Otry tr sz	0.044 (+)	18,72		
Fln lg sz			0.035 (-)	69,23
Shb cvrg	0.004 (+)	13,84		
Evgn cvrg			0.000 (-)	72,28
Sl sfce exp			0.007 (-)	73,27

(+) Average value of variable was significantly greater ($P \leq 0.05$) at *Clethrionomys gapperi* capture points than at non-capture points.

(-) Average value of variable was significantly lower ($P \leq 0.05$) at *Clethrionomys gapperi* capture points than at non-capture points.

Table 13.--Results of one-way analysis of variance for Clethrionomys gapperi (Cg) and Peromyscus leucopus (Pl) species microhabitat differences on the variables measured at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	<u>Cg</u> X	<u>Pl</u> X	P	Df
<u>Arrow Swamp</u>				
No wdy spp	2.22	3.06	0.039	32,22
Hb fol pfl den	5.63	3.87	0.005	22,32
Tr stmp sz	0.68	1.77	0.000	31,21
Fln lg abn	2.30	3.82	0.050	31,21
Evgn cvrg	5.77	14.61	0.001	30,21
<u>Burlingame</u>				
Wd stm den	55.00	38.79	0.024	8,67
Tr stmp dsp	9.81	9.92	0.024	8,60
Thck wd veg	42.56	37.17	0.041	65,8
% canpy cvrg	76.33	75.66	0.016	53,8
Sphgm mss exp	8.44	2.98	0.024	8,60
<u>Great Swamp</u>				
Evgn cvrg	0.83	2.55	0.000	32,28
Evgn Shb cvrg	0.00	2.37	0.000	28,32
Evgn hrb sttm	1.57	1.06	0.000	27,32
Sl sfce exp	0.18	0.45	0.003	32,27

Table 14.--Parametric and nonparametric test statistics for Clethrionomys gapperi (Cg) and Peromyscus leucopus (Pl) microhabitat differences in three habitat zones on the variables measured at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	Cg X	Pl X	P	Df
<u>Upland</u>				
Wd stm den	13.83	28.74	0.001	1
Wd fol pfl den	4.58	7.67	0.003	1
Tr stmp dsp	7.80	9.94	0.002	17,38
Evgn cvrg	0.00	2.42	0.010	17,37
Mnd/pl rtio	21.00	20.62	0.046	17,38
<u>Transition</u>				
No wdy spp	2.00	2.69	0.013	51,14
Tr stmp sz	0.00	8.51	0.000	48,13
Fln lg abn	2.07	3.80	0.026	48,13
Fln lg dsp	9.12	8.41	0.012	48,13
% canpy cvrg	74.43	74.03	0.038	44,13
Evgn cvrg	3.07	0.67	0.000	13,48
Evgn Shb cvrg	0.00	3.16	0.002	48,13
Evgn hrb sttm	0.00	3.02	0.011	13,48
Sl sfce exp	0.00	3.89	0.013	13,48
<u>Wetland</u>				
Wd fol pfl den	7.11	8.44	0.005	1
Hb stm den	32.11	34.33	0.044	42,27
% canpy cvrg	76.71	80.83	0.000	27,34
evgn cvrg	3.86	11.84	0.000	36,27
Mnd/pl rtio	1.73	1.98	0.012	33,24

Table 15.--Logistic regression models for predicting presence (p) or absence (a) of Peromyscus leucopus based upon data collected in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	R ²	SE
<u>Upland (p)</u>		
(+) Wd fol pfl den	-0.6150	0.4233
(-) No hrb spp	0.8988	0.4154
(+) Thck wd veg	-0.8880	0.4073
Constant	3.5373	1.0623
<u>Transition (p)</u>		
(+) Wd stm den	-0.0328	0.0159
(-) % canpy cvrg	0.0287	0.0183
(+) Sl sfce exp	-0.1500	0.0635
Constant	-1.1912	1.4580
<u>Wetland (p)</u>		
(+) Hb stm den	-1.4853	0.5287
(+) Hb fol pfl den	1.1840	0.6815
(-) Sphgm mss exp	0.8597	0.2643
Constant	0.1185	0.8924
<u>Arrow Swamp (p)</u>		
(+) Evgn cvrg	-0.2471	0.1449
Constant	0.9051	0.2712
<u>Burlingame (a)</u>		
(-) Wd stm den	-0.6069	0.2675
(+) Sl sfce exp	-0.6578	0.3734
(-) Sphgm mss exp	0.6301	0.2082
Constant	0.8399	0.8118
<u>Great Swamp (p)</u>		
(-) % canpy cvrg	3.2378	1.7194
Constant	-13.3380	7.5384

(+) Relatively high values for the variable.

(-) Relatively low values for the variable.

Table 16.--Logistic regression models for predicting presence (p) or absence (a) of *Clethrionomys gapperi* based upon data collected in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites: Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	R ²	SE
<u>Upland (a)</u>		
(+) Wd stm den	-0.0435	0.0238
(-) Shb cvrg	0.0183	0.0102
Constant	-1.6757	0.6817
<u>Transition (a)</u>		
(+) Mnd/pl rtio	-0.2127	0.0652
Constant	-0.1241	0.4062
<u>Wetland (p)</u>		
(-) Evgn cvrg	0.3051	0.1880
(-) Mnd/pl rtio	-0.8279	0.5783
Constant	1.3376	0.5984
<u>Arrow Swamp (p)</u>		
(-) No wdy spp	2.3756	1.1855
(-) Utry tr sz	1.9025	0.9809
(-) Tr stmp dsp	17.8686	8.5250
(-) % canpy cvrg	2.0986	0.9367
(-) Mnd/pl rtio	0.9704	0.3243
Constant	-58.0658	22.7356
<u>Burlingame (p)</u>		
(+) Thck wd veg	-1.2207	0.7018
Constant	6.4034	2.6263
<u>Great Swamp (p)</u>		
(+) Thck wd veg	-1.1476	0.6347
(-) evgrn cvrg	0.4166	0.2892
Constant	4.9580	2.3042

(+) Relatively high values for the variable.

(-) Relatively low values for the variable

Fig. 1.--Diagram of vegetation profile measurements recorded at all trap stations in red maple swamps, and contiguous transition and upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Fig. 2.--Diagram of maximum/minimum thermometer placement.

Fig. 3.--Relationship between small mammal species richness and the species richness of the overstory.

Fig. 4.--Relationship between small mammal species richness and the species richness of the shrub layer.

Fig. 5.--Relationship between small-mammal species richness and the species richness of the herbaceous layer.

Fig. 6.--Schematic of small mammal capture points recorded at the upland grids at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Forest, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

	1	2	3	4	5	6	
A	P						Arrow Swamp
B				C P			
C	P T	P	T	P	C		
D						P	
E	T		C				
F		T				CTP	

A	P	P				P	Burlingame
B		P	P	P		P	
C	P	P	Sc P	P		Sc	
D	P	C P	P	P	P	P	
E	C		P	P			
F		P	P	P		P	

A		C			C		Great Swamp
B		C					
C	P	C P				P	
D	C P	C		T P		P	
E	C P		P	C		P	
F				C	C		

C-Clethrionomys gapperi
 P-Peromyscus leucopus
 T-Tamias striatus
 Sc-Sorex cinereus

APPENDIX A

Literature Review

In New England, wetlands and their contiguous upland buffers provide the last, isolated refuges for many wildlife species. Buffers or transition zones from wetland to upland represent unique habitats, and have many important inherent values to wildlife (Husband and Eddleman, 1990). These zones are areas of high species richness, foraging areas, corridors of dispersal, areas of escape from flooding, sites for hibernation, areas of breeding and nesting, areas of low predator and nest parasite density, and they serve as buffers of disturbances from outside of wetlands.

The distribution and abundance of small mammals are probably a function of habitat suitability (Vaughan, 1972:250-256), or more specifically, microhabitat suitability (Baker, 1968). Some small-mammal species are limited in spatial distribution by specific habitat needs; others occupy a wide range of habitats (Kaufman and Fleharty, 1974; Kirkland and Griffin, 1974; Briesse and Smith, 1974; Miller and Getz, 1977; Geier and Best, 1980). Characteristics of microhabitats of small mammals have been documented for upland deciduous and coniferous forests in the East (Adler, 1985; Dueser and Shugart, 1978, 1979; Kitchings and Levy, 1981; Parren and Capen, 1985; Seagle,

1985), but similar information for small mammals in red maple swamps and bordering upland forests in the northeastern United States is severely limited.

Of their five upland and wetland study sites at Great Swamp National Wildlife Refuge in New Jersey, the one dominated by red maple, sweet gum, and American hornbeam produced the highest numbers of small mammals (Dowler et al., 1985). No single forest type in Vermont had significantly higher mammalian diversity than any other, whereas in Connecticut, red maple swamps with 50-75% shrub cover had relatively high mammalian richness (9 species) and diversity (Shannon's $H'^2 = 2.21$) (Miller and Getz, 1977). Most species of small mammals in New England are primarily granivorous or insectivorous, while the most common sources of seeds are from trees and shrubs, especially mast from trees. The combined species richness of trees and shrubs at a site was the only variable correlated (+) with species diversity of small mammals; diversity and availability of food may affect the diversity of forest small mammals in New England (Miller and Getz, 1977).

In general, the diversity of forest species of small mammals in New England is related primarily to the diversity of the trees and shrubs, as they directly or indirectly reflect a greater diversity of available food types (Miller and Getz, 1977). Differences in water

content of food appeared to explain differences in local distributional patterns of short-tailed shrews and red-backed voles, both of which have high water requirements (Getz, 1968; Miller and Getz, 1977). Getz (1961b) described white-footed mouse habitat as areas in which the cover is in the form of shrub stratum or fallen trees as debris. He found higher densities of white-footed mice in upland sites compared to swamps; he attributed this to lower densities of mast producers (primarily oak and hickory) which produce a reliable year-round food supply. The white-footed mouse is nocturnal, and because the microclimates of swamps and uplands are similar at night, water balance is not a factor in the local distribution of this species (Getz, 1968). White-footed mice have a generalized distribution and reach their highest densities in brushy fields and in woodlots dominated by deciduous trees Hallet et al., 1983).

Microhabitat features that determine the distribution and abundance of white-footed mice are: deciduous canopy and low shrub evergreenness (Dueser and Shugart, 1978); high density of shrub-understory vegetation (Dueser and Shugart, 1978; M'Closkey and Lajoie, 1975; Seagle, 1985); and high plant species richness in herbaceous and shrub strata (Parren and Capen, 1985). Their habitat typically includes a canopy (may only be shrub), woody debris and often rocks (Lackey et al., 1985).

Captures of Peromyscus leucopus have been significantly greater than captures of Peromyscus maniculatus at higher temperatures, higher relative humidity, under overcast skies, and during light rains at night (Parren and Capen, 1985). White-footed mouse densities increase with increasing shrub species richness, and generally are positively associated with woody microhabitat or negatively associated with herbaceous habitats (Adler, 1985). White-footed mice eat mainly insects, 71.4%; fruit, 52.3%; and mast, 20.8% (Hamilton, 1977).

In Southern New England, red-backed voles are restricted to low, wet areas, with standing water or an accessible water table (Getz, 1968). Red-backed voles are found in moist areas where the water content of the vegetation is directly influenced by the soil moisture (Miller and Getz, 1977). In Vermont, red-backed voles are less abundant in sites with less tree cover, while in Connecticut they are more abundant in sites with >50% shrub cover and in sites with >25% herbaceous cover. Red-backed voles also have been found in mesic forest habitats with an abundance of stumps and exposed roots (Merritt, 1981); a high density of fallen logs (Merritt, 1981; Belk et al., 1988); and dense canopy cover and dense woody vegetation (Belk et al., 1988). Red-backed vole habitat can be generally described as cool, moist forests with mossy

rocks, logs, tree roots, or other cover (DeGraaf and Rudis, 1983). They are found less commonly near stone walls at woodland edges, or on talus slopes. Red-backed voles require both water sources such as springs, brooks, or bogs, and debris cover such as fallen trees, stumps, rocks, or slash. Green vegetation (too finely ground to identify) was the principle food of 75% of the red-backed voles sampled (Hamilton, 1941).

The eastern chipmunk occurs at sites with primarily deciduous canopy, a high density of trees, a low density of shrubs, and high shrub evergreenness (Dueser and Shugart, 1978). Eastern chipmunks also occur in bushy habitats as well as forest, especially where there was an abundance of crevices for refuge (Snyder, 1982). The eastern chipmunk is a woodland generalist, using a wide range of microhabitats within forests, and exhibits no particularly strong association with any one type (Kitchings and Levy, 1981).

The short-tailed shrew has more than double the water equilibrium of Peromyscus at a temperature of 61° C, and receives half of its water intake from the foods eaten (Chew, 1951). Even so, short-tailed shrews drink water, demonstrating that a need to drink may still exist even if a considerable amount of water is received from food. Short-tailed shrews are subjected to less loss of body moisture from evaporation because of its subterranean

habitat (Chew, 1951). Short-tailed shrews are found in moist habitats, but not in standing water (Getz, 1961c). They are scarce or absent in these habitats because the available food supply (consisting of large forms of invertebrates) are also low or absent. Short-tailed shrews are approximately twice as abundant in areas with > 50% herb cover than in areas with < 50% herb cover, and slightly more abundant in the more moist sites of Connecticut (Miller and Getz, 1977). Short-tailed shrew habitat is deciduous woodlands, but they rarely occur in areas with heavy undergrowth (Kitchings and Levy, 1981). They consistently occupy areas of high stump and log density, hard ground, few shrubs, and dense overstory.

Masked shrews are less abundant in drier habitats than were short-tailed shrews and they did not avoid standing water (Getz, 1961c). They may be able to better utilize smaller prey items (collembolans, ants, spiders) than do short-tailed shrews. Masked shrew activity increases or decreases with corresponding changes in the mean nighttime temperature from that of the previous night (Doucet and Bider, 1974). They also increase activity on cloudy nights; the highest activity was recorded with rainfall from 1800-2400h. Smoky shrews are restricted to the cool forested regions of Pennsylvania, New York, and New England in habitats with a ground cover of loose leaf mold (humus) and black friable soil (Hamilton, 1940).

Very little literature was found on southern flying squirrel habitat. In general, southern flying squirrel habitat is mature deciduous and mixed forests with cavity trees, especially beech-maple, oak-hickory and aspen (DeGraaf and Rudis, 1983).

Appendix B.

Fig. 7.--Transect placement and habitat types in Arrow Swamp, Exeter, Rhode Island. Derived from 1985 airphotos, flight line 19, no. 2005.

Appendix C.

Fig. 8.--Transect placement and habitat types in Great Swamp Wildlife Management Area, South Kingstown, Rhode Island. Derived from 1985 airphotos, flight line 17, no. 13.

Appendix D.

Fig. 9.--Transect placement and habitat types for a study in red maple swamps, and contiguous transition and upland zones at Burlingame State Forest, Charlestown, Rhode Island. Derived from 1985 airphotos, flight line 11, no. 541.

Appendix E.

Fig. 10.--Trapping grid placement in red maple swamps, and contiguous transition and upland zones at Arrow Swamp, Exeter, Rhode Island.

Appendix F.

Fig. 11.--Trapping grid placement in red maple swamps, and contiguous transition and upland zones at Great Swamp Wildlife Management Area, South Kingstown, Rhode Island.

Appendix G.

Fig. 12.--Trapping grid placement in red maple swamps, and contiguous transition and upland zones at Burlingame State Forest, Charlestown, Rhode Island.

Appendix H.

Table 17.--Results of Shapiro-Wilk test for normal distribution on the microhabitat variables measured at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	Great Swamp		Arrow Swamp		Burlingame	
	S	P	S	P	S	P
No wdy spp	0.869	0.000	0.893	0.000	0.872	0.000
Wd stm den	0.987	0.845	0.954	0.004	0.969	0.108
Wd fol pfl den	0.971	0.137	0.967	0.065	0.949	0.001
No hrb spp	0.891	0.000	0.866	0.000	0.878	0.000
Hb stm den	0.901	0.000	0.842	0.000	0.850	0.000
Hb fol pfl den	0.949	0.001	0.893	0.000	0.917	0.000
Otry tr sz	0.983	0.699	0.966	0.088	0.990	0.957
Otry tr dsp	0.988	0.895	0.976	0.363	0.968	0.127
Utry tr sz	0.880	0.000	0.960	0.028	0.981	0.595
Utry tr dsp	0.947	0.001	0.959	0.025	0.969	0.126
Tr stmp sz	0.513	0.000	0.283	0.000	0.286	0.000
Tr stmp dsp	0.485	0.000	0.244	0.000	0.254	0.000
Fln lg abn	0.802	0.000	0.711	0.000	0.768	0.000
Fln lg dsp	0.854	0.000	0.664	0.000	0.822	0.000
Fln lg sz	0.617	0.000	0.672	0.000	0.700	0.000
Thck wd veg	0.944	0.000	0.934	0.000	0.932	0.000
% canpy cvrg	0.483	0.000	0.504	0.000	0.766	0.000
Evgn cvrg	0.524	0.000	0.624	0.000		
Shb cvrg	0.668	0.000	0.769	0.000	0.726	0.000
Evgn Shb cvrg	0.232	0.000	0.555	0.000	0.430	0.000
Evgn hrb sttm	0.494	0.000	0.663	0.000	0.488	0.000
Sl sfce exp	0.268	0.000	0.332	0.000	0.487	0.000
Sphgm mss exp	0.695	0.000	0.717	0.000	0.631	0.000
Mnd/pl rtio	0.700	0.000	0.720	0.000	0.701	0.000

Appendix I.

Table 18.--Results of Shapiro-Wilk test for normal distribution on the microhabitat variables measured at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great swamp Wildlife Management Area, South Kingstown) from May to August 1991 and categorized into habitat zones.

Variable	Upland		Transition		Wetland	
	S	P	S	P	S	P
No wdy spp	0.887	0.000	0.896	0.000	0.856	0.000
Wd stm den	0.970	0.130	0.951	0.002	0.979	0.470
Wd fol pfl den	0.972	0.165	0.968	0.078	0.989	0.918
No hrb spp	0.851	0.000	0.885	0.000	0.865	0.000
Hb stm den	0.839	0.000	0.888	0.000	0.873	0.000
Hb fol pfl den	0.851	0.000	0.933	0.000	0.957	0.009
Otry tr sz	0.977	0.381	0.978	0.418	0.931	0.000
Otry tr dsp	0.983	0.677	0.986	0.851	0.948	0.004
Utry tr sz	0.938	0.000	0.881	0.000	0.951	0.006
Utry tr dsp	0.931	0.000	0.967	0.086	0.931	0.003
Tr stmp sz	0.457	0.000	0.362	0.000	0.457	0.000
Tr stmp dsp	0.330	0.000	0.315	0.000	0.432	0.000
Fln lg abn	0.716	0.000	0.810	0.000	0.755	0.000
Fln lg dsp	0.866	0.000	0.789	0.000	0.581	0.0
Fln lg sz	0.671	0.000	0.732	0.000		
Thck wd veg	0.938	0.000	0.978	0.000	0.985	0.767
% canpy cvrg	0.454	0.000	0.761	0.000	0.553	0.0
Evgn cvrg	0.253	0.000	0.185	0.000	0.737	0.0
Shb cvrg	0.744	0.000	0.736	0.000	0.740	0.0
Evgn Shb cvrg	0.605	0.000	0.401	0.000		
Evgn hrb sttm	0.789	0.000	0.396	0.000	0.107	0.0
Sl sfce exp	0.288	0.000	0.558	0.000		
Sphgm mss exp	0.673	0.000	0.797	0.000		
Mnd/pl rtio	0.097	0.000	0.706	0.000	0.911	0.000

Appendix J.

Table 19.--Microhabitat variable average values (+ SD) for Peromyscus leucopus and Clethrionomys gapperi in red maple swamps, and contiguous transition and upland zones at Arrow Swamp, Exeter, Rhode Island from May to August 1991.

Variable	<u>Clethrionomys gapperi</u>			<u>Peromyscus leucopus</u>		
	X	+	SD	X	+	SD
No wdy spp	2.2	+	0.8	3.1	+	1.2
Wd stm den	22.4	+	18.8	23.1	+	15.7
Wd fol pfl den	5.7	+	3.6	5.7	+	3.6
No hrb spp	2.1	+	1.4	2.2	+	1.7
Hb stm den	30.1	+	29.6	26.9	+	24.9
Hb fol pfl den	5.6	+	5.5	3.9	+	3.2
Otry tr sz	22.5	+	9.3	24.4	+	9.8
Otry tr dsp	5.3	+	1.7	4.8	+	1.3
Utry tr sz	3.7	+	2.0	4.1	+	1.8
Utry tr dsp	3.3	+	2.0	3.9	+	2.1
Tr stmp sz	0.7	+	3.2	1.8	+	9.1
Tr stmp dsp	9.9	+	0.4	10.0	+	0.3
Fln lg abn	2.3	+	3.6	3.8	+	5.5
Fln lg dsp	9.4	+	0.9	9.4	+	1.1
Fln lg sz	7.8	+	11.6	11.0	+	14.5
Thck wd veg	31.4	+	15.4	29.6	+	15.0
% canpy cvrg	72.9	+	19.9	79.8	+	14.2
Evgn cvrg	5.8	+	12.5	14.6	+	25.4
Shb cvrg	49.8	+	21.6	36.9	+	23.3
Evgn Shb cvrg	5.5	+	14.6	6.5	+	15.4
Evgn hrb sttm	14.9	+	32.0	14.9	+	26.4
Sl sfce exp	0.2	+	1.1	0.3	+	1.2
Sphgm mss exp	23.3	+	19.8	14.9	+	18.4
Mnd/pl rtio	5.8	+	8.4	10.1	+	9.6

Appendix K.

Table 20.--Microhabitat variable average values (+ SD) for *Peromyscus leucopus* and *Clethrionomys gapperi* in red maple swamps, and contiguous transition and upland zones at Burlingame State Park, Charlestown, Rhode Island from May to August 1991.

Variable	<u><i>Clethrionomys gapperi</i></u>			<u><i>Peromyscus leucopus</i></u>		
	X	+	SD	X	+	SD
No wdy spp	3.2	+	0.7	3.0	+	1.0
Wd stm den	55.0	+	61.8	38.8	+	37.6
Wd fol pfl den	7.4	+	2.9	8.2	+	6.2
No hrb spp	1.3	+	1.2	1.6	+	1.2
Hb stm den	26.6	+	28.0	33.0	+	37.7
Hb fol pfl den	6.0	+	7.1	5.7	+	7.2
Otry tr sz	27.8	+	6.0	26.3	+	6.4
Otry tr dsp	6.0	+	1.1	5.6	+	1.3
Utry tr sz	2.9	+	1.2	3.3	+	1.8
Utry tr dsp	4.2	+	1.9	4.1	+	2.3
Tr stmp sz	1.4	+	4.2	1.5	+	5.9
Tr stmp dsp	9.8	+	0.6	9.9	+	0.3
Fln lg abn	2.9	+	3.2	4.1	+	4.3
Fln lg dsp	9.2	+	1.0	8.6	+	1.7
Fln lg sz	11.4	+	12.9	10.4	+	10.6
Thck wd veg	42.6	+	11.5	37.2	+	23.1
% canpy cvrg	76.3	+	6.1	75.7	+	14.2
Evgn cvrg	0.0	+	0.0	0.0	+	0.0
Shb cvrg	51.2	+	23.0	46.2	+	28.2
Evgn Shb cvrg	3.1	+	9.3	4.5	+	12.5
Evgn hrb sttm	9.4	+	23.5	11.1	+	24.1
Sl sfce exp	0.0	+	0.0	2.9	+	5.9
Sphgm mss exp	8.4	+	11.6	3.0	+	7.1
Mnd/pl rtio	7.9	+	9.0	14.6	+	8.6

Appendix L.

Table 21.--Microhabitat variable average values (+ SD) for Peromyscus leucopus and Clethrionomys gapperi in red maple swamps, and contiguous transition and upland zones at Great Swamp Wildlife Management Area, South Kingstown, Rhode Island from May to August 1991.

Variable	<u>Clethrionomys gapperi</u>			<u>Peromyscus leucopus</u>		
	X	+	SD	X	+	SD
No wdy spp	2.8	+	0.9	2.4	+	0.9
Wd stm den	26.0	+	28.2	32.7	+	31.5
Wd fol pfl den	6.3	+	4.0	5.9	+	4.5
No hrb spp	2.6	+	1.1	2.4	+	1.0
Hb stm den	32.5	+	24.4	29.8	+	20.7
Hb fol pfl den	4.6	+	3.6	3.5	+	3.1
Otry tr sz	24.1	+	5.3	25.1	+	5.8
Otry tr dsp	4.7	+	1.3	5.2	+	1.2
Utry tr sz	4.5	+	2.0	4.5	+	1.8
Utry tr dsp	4.5	+	2.2	4.7	+	2.5
Tr stmp sz	2.8	+	7.2	3.7	+	8.2
Tr stmp dsp	9.7	+	0.9	9.7	+	0.8
Fln lg abn	4.9	+	2.7	4.3	+	2.7
Fln lg dsp	7.2	+	2.2	7.4	+	2.3
Fln lg sz	13.5	+	5.0	13.0	+	6.6
Thck wd veg	42.2	+	14.5	38.3	+	13.2
% canpy cvrg	81.0	+	10.2	78.4	+	12.1
Evgn cvrg	0.8	+	2.5	2.6	+	6.9
Shb cvrg	59.8	+	25.2	56.6	+	20.2
Evgn Shb cvrg	0.0	+	0.0	2.3	+	9.4
Evgn hrb sttm	1.6	+	5.8	1.1	+	2.4
Sl sfce exp	0.2	+	0.9	0.5	+	1.9
Sphgm mss exp	27.2	+	30.3	17.8	+	25.5
Mnd/pl rtio	9.9	+	9.8	12.5	+	9.9

Appendix M.

Table 22.--Microhabitat variable average values (+ SD) for Peromyscus leucopus and Clethrionomys gapperi in red maple swamp's contiguous upland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	<u>Clethrionomys gapperi</u>			<u>Peromyscus leucopus</u>		
	X	+	SD	X	+	SD
No wdy spp	2.7	+	1.0	3.0	+	1.1
Wd stm den	13.8	+	9.2	28.7	+	20.9
Wd fol pfl den	4.6	+	2.6	7.7	+	5.3
No hrb spp	2.2	+	1.7	1.2	+	1.4
Hb stm den	28.1	+	28.3	23.8	+	38.6
Hb fol pfl den	4.5	+	4.6	3.0	+	4.8
Otry tr sz	19.5	+	5.3	20.6	+	4.3
Otry tr dsp	4.6	+	1.1	5.2	+	1.3
Utry tr sz	5.3	+	1.7	4.2	+	2.2
Utry tr dsp	4.5	+	1.6	5.4	+	2.3
Tr stmp sz	2.2	+	6.7	1.5	+	6.4
Tr stmp dsp	9.8	+	0.6	9.9	+	0.3
Fln lg abn	5.5	+	3.1	6.3	+	3.7
Fln lg dsp	7.1	+	2.1	7.9	+	1.8
Fln lg sz	14.6	+	7.9	15.2	+	9.1
Thck wd veg	31.2	+	18.2	33.3	+	18.2
% canpy cvrg	80.6	+	16.5	78.6	+	11.6
Evgn cvrg	0.0	+	0.0	2.4	+	9.6
Shb cvrg	53.3	+	28.4	44.9	+	25.8
Evgn Shb cvrg	8.3	+	16.7	10.4	+	18.0
Evgn hrb sttm	25.4	+	35.1	26.6	+	30.9
Sl sfce exp	0.6	+	0.9	0.3	+	1.1
Sphgm mss exp	0.0	+	0.0	0.0	+	0.0
Mnd/pl rtio	21.0	+	0.00	20.6	+	2.4

Appendix N.

Table 23.--Microhabitat variable Average values (+ SD) for Peromyscus leucopus and Clethrionomys gapperi in red maple swamp's contiguous transition zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	<u>Clethrionomys gapperi</u>			<u>Peromyscus leucopus</u>		
	X	+	SD	X	+	SD
No wdy spp	2.0	+	0.7	2.7	+	1.2
Wd stm den	19.7	+	24.8	25.4	+	25.7
Wd fol pfl den	5.9	+	5.5	5.4	+	5.0
No hrb spp	2.2	+	1.3	2.6	+	1.2
Hb stm den	31.3	+	33.6	32.9	+	23.6
Hb fol pfl den	3.9	+	4.6	4.9	+	4.5
Otry tr sz	23.1	+	5.9	26.4	+	6.4
Otry tr dsp	5.4	+	1.8	5.2	+	1.2
Utry tr sz	3.1	+	1.9	4.1	+	1.5
Utry tr dsp	4.3	+	2.6	3.8	+	2.1
Tr stmp sz	0.0	+	0.0	2.1	+	8.5
Tr stmp dsp	10.0	+	0.0	9.9	+	0.3
Fln lg abn	2.1	+	2.6	3.8	+	4.7
Fln lg dsp	9.1	+	1.0	8.4	+	1.9
Fln lg sz	7.3	+	7.2	11.1	+	11.7
Thck wd veg	38.6	+	14.9	25.9	+	15.7
% canpy cvrg	74.4	+	10.6	74.0	+	18.1
Evgn cvrg	3.1	+	11.5	0.7	+	3.3
Shb cvrg	52.4	+	22.4	42.7	+	27.0
Evgn Shb cvrg	0.0	+	0.0	3.2	+	10.8
Evgn hrb sttm	0.0	+	0.0	3.0	+	12.0
Sl sfce exp	0.0	+	0.0	3.9	+	6.5
Sphgm mss exp	31.3	+	26.4	7.6	+	18.4
Mnd/pl rtio	2.8	+	5.4	14.3	+	8.8

Appendix O.

Table 24.--Microhabitat variable Average values (+ SD) for Peromyscus leucopus and Clethrionomys gapperi in red maple swamp's wetland zones at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great Swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	<u>Clethrionomys gapperi</u>			<u>Peromyscus leucopus</u>		
	X	+	SD	X	+	SD
No wdy spp	2.9	+	0.8	2.9	+	1.8
Wd stm den	43.5	+	41.5	47.4	+	42.8
Wd fol pfl den	7.1	+	3.2	8.4	+	5.4
No hrb spp	2.3	+	1.0	1.9	+	1.1
Hb stm den	32.1	+	21.8	34.3	+	31.6
Hb fol pfl den	6.3	+	5.2	6.1	+	7.2
Otry tr sz	27.6	+	7.3	29.3	+	8.0
Otry tr dsp	5.2	+	1.5	5.5	+	1.4
Utry tr sz	3.5	+	1.7	3.2	+	1.7
Utry tr dsp	3.5	+	2.1	3.5	+	2.0
Tr stmp sz	2.5	+	6.2	2.7	+	7.1
Tr stmp dsp	9.7	+	0.9	9.7	+	0.8
Fln lg abn	3.1	+	3.3	2.2	+	3.2
Fln lg dsp	8.7	+	1.9	9.1	+	1.6
Fln lg sz	10.1	+	11.4	7.2	+	10.4
Thck wd veg	42.4	+	11.8	48.9	+	16.8
% canpy cvrg	76.7	+	14.7	80.8	+	6.2
Evgn cvrg	3.9	+	8.4	11.1	+	23.0
Shb cvrg	57.3	+	21.6	53.9	+	23.5
Evgn Shb cvrg	0.0	+	0.0	0.0	+	0.0
Evgn hrb sttm	0.0	+	0.0	0.0	+	0.0
Sl sfce exp	0.0	+	0.0	0.0	+	0.0
Sphgm mss exp	33.8	+	23.1	23.0	+	18.8
Mnd/pl rtio	1.7	+	1.2	2.0	+	2.1

Appendix P.

Table 25.--Microhabitat variable average values (+ SD) for all habitat zones measured at three Rhode Island sites (Arrow Swamp, Exeter; Burlingame State Park, Charlestown; and Great swamp Wildlife Management Area, South Kingstown) from May to August 1991.

Variable	Arrow Swamp			Burlingame			Great Swamp		
	X	+	SD	X	+	SD	X	+	SD
No wdy spp	2.8	+	1.1	2.9	+	1.1	2.6	+	1.0
Wd stm den	21.0	+	16.2	40.2	+	48.2	31.6	+	33.4
Wd fol pfl den	5.1	+	3.7	7.6	+	5.9	6.2	+	4.3
No hrb spp	1.8	+	1.5	1.7	+	1.3	2.6	+	1.3
Hb stm den	24.0	+	26.7	34.7	+	40.1	28.5	+	23.5
Hb fol pfl den	3.9	+	4.4	5.7	+	7.0	3.8	+	3.9
Otry tr sz	22.5	+	9.0	26.2	+	6.5	23.9	+	6.4
Otry tr dsp	4.8	+	1.4	5.6	+	1.3	4.8	+	1.2
Utry tr sz	4.5	+	2.4	3.2	+	1.7	4.6	+	1.8
Utry tr dsp	4.1	+	2.1	4.0	+	2.1	4.4	+	2.6
Tr stmp sz	1.3	+	6.4	1.4	+	5.4	4.0	+	8.5
Tr stmp dsp	9.9	+	0.3	9.9	+	0.4	9.6	+	0.9
Fln lg abn	3.3	+	4.7	4.4	+	4.1	5.4	+	3.2
Fln lg dsp	9.3	+	1.2	8.5	+	1.7	7.1	+	2.3
Fln lg sz	10.1	+	13.5	12.3	+	11.0	13.6	+	6.9
Thck wd veg	25.9	+	16.0	35.1	+	21.4	37.9	+	15.1
% canpy cvrg	78.1	+	16.0	77.4	+	13.2	80.7	+	8.9
Evgn cvrg	8.9	+	18.9	0.0	+	0.0	3.1	+	10.3
Shb cvrg	39.8	+	25.6	47.3	+	29.4	57.0	+	24.4
Evgn Shb cvrg	9.4	+	20.1	3.2	+	10.6	1.7	+	8.6
Evgn hrb sttm	19.0	+	30.7	8.0	+	20.6	1.7	+	5.0
Sl sfce exp	0.5	+	1.7	2.1	+	5.2	0.3	+	1.4
Sphgm mss exp	13.8	+	19.2	6.6	+	13.7	23.0	+	30.8
Mnd/pl rtio	12.1	+	9.7	13.8	+	9.1	12.5	+	9.7

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