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Small Mammal Assemblages on Fort A. P. Hill, Virginia: Habitat Associations and Patterns of Capture Success

A. Scott Bellows

Department of Biology
Virginia Commonwealth University
Richmond, Virginia 23284

Joseph C. Mitchell

Department of Biology
University of Richmond
Richmond, Virginia 23229

John F. Pagels

Department of Biology
Virginia Commonwealth University
Richmond, Virginia 23284

INTRODUCTION

Ecological studies of small mammals in Virginia's Coastal Plain have been sporadic and geographically limited. Most focused on a limited number of species or were general surveys over a larger geographical area than the Coastal Plain (Pagels & Aldeman, 1971; Pagels, 1977; Rose, 1986; Pagels, 1987; Cawthorn & Rose, 1989; Erdle & Pagels, 1995); relatively few surveyed complete small mammal assemblages (Rose et al., 1990; Mitchell et al., 1993). Other studies targeted small mammal assemblages but used protocols that are not effective in capturing the entire fauna (Jackson et al., 1976; Pagels & French, 1987). The Coastal Plain of Virginia harbors a rich diversity of small mammals (Webster et al., 1985; Linzey, 1998). An understanding of small mammals and their habitats in this region of Virginia would provide important information for elucidation of biogeographic patterns of community structure.

The United States Department of Defense is the fifth largest landowner of the federal landholding agencies and currently manages over 25 million acres of land (10.1 million ha) (Boice, 1997). Most of these holdings are military installations that are largely protected from development and other activities that adversely effect native flora and fauna. For this and other reasons, these installations are becoming islands of biodiversity (Mitchell & Roble, 1998).

The rich diversity of terrestrial habitats found on Fort A. P. Hill, Caroline County, Virginia, should contain robust assemblages of small mammals characteristic of the Coastal Plain Physiographic region. The initial objective of this survey was to describe the small mammal assemblages of eleven Society of American Foresters (SAF) habitat types found on Fort A. P. Hill. Secondary objectives were to evaluate the effectiveness of multiple trapping techniques and the effectiveness of the duration of our sampling periods.

MATERIALS AND METHODS

Study Location and Site Selection

This study was conducted at Fort A.P. Hill, Caroline County, a 30,329 ha field-training military installation in which the majority of the area is comprised of managed forestlands. Descriptions of the area are found in Mitchell & Roble (1998) and Bellows (1999).

We selected sites that represented seral stages ranging from grasslands to mature hardwood forests. Habitat types sampled were: unmaintained grasslands (UNGR), 5 to 10 yr old clearcuts not replanted with pines

(CCNR), 5 to 10 yr old pine plantations (PIPL), 30 to 50 yr old mixed loblolly and Virginia pines (MPN1), 60 to 90 yr old mixed loblolly and Virginia pines (MPN2), 30 to 50 yr old mixed hardwoods and pines (MHP1), 50 to 70 yr old mixed hardwoods and pines (MHP2), 60 to 80 yr old mixed hardwoods (MHW1), 90 to 139 yr old mixed hardwoods (MHW2), 60 to 80 yr old white oak (OAK1), and 90 to 125 yr old white oak (OAK2).

Potential sites were initially chosen using Geological Information System (GIS) maps provided by Fort A. P. Hill. Potential site locations were associated with established Land Condition Trend Analysis (LCTA) plots when feasible. All sites were ground-truthed to confirm the accuracy of SAF descriptions. There were conspicuous discrepancies between the descriptive sources provided and the actual vegetation present in some sites we examined. Final site selection was based on consistency with the aforementioned habitat types. Other consid-erations for site selection were avoidance of restricted impact areas and the 1997 National Boy Scout Jamboree activities.

Sampling and Collection Methods

We selected three replicates of each of the eleven habitat types for a total of 33 study sites. A sampling area approximately 30 m in diameter was established at each site. Sampling areas were a minimum of 45 m from a different habitat type and a minimum of 675 m from other sampling areas. Pitfall/drift fences and snap traps were used to collect animals. These two methods are com-plementary when assessing small mammal assemblages (Kalko & Handley, 1993; Bury & Corn, 1987). Pitfall traps work well for capturing long-tailed shrews (Kalko & Handley, 1993; Mengak et al. 1987; Mitchell et al., 1993) and jumping mice (Kalko & Handley, 1993) and often capture semi-fossorial species that are rarely captured by live-trapping or snap-trapping methods (Williams & Braun, 1983). Snap traps work well for capturing mice and voles and are generally as effective as pitfall traps for capturing short-tailed shrews (Kalko & Handley, 1993).

Three pitfall arrays were constructed approximately 120^o apart and 15 m ($\pm$ 2 m) from the center of each study site (Figure 1). Nine Museum Special snap traps, three per 120^o sector, were set in each site at the beginning of each trapping session as shown in Figure 1. Pitfall arrays were constructed following the design in Handley & Varn (1994). Drift fences were constructed of silt fencing 61 cm high and one m in length. A plastic 3.8-l bucket (18 cm in diameter x 19 cm in height) was used for the center pitfall. Plastic 2-l soda bottles with the tops cut off (11 cm in diameter x 20 cm in length) were used for the peripheral pitfalls; one 2-l bottle was placed on each side of the distal end of all three drift fences. There were a total of seven pitfalls per array.

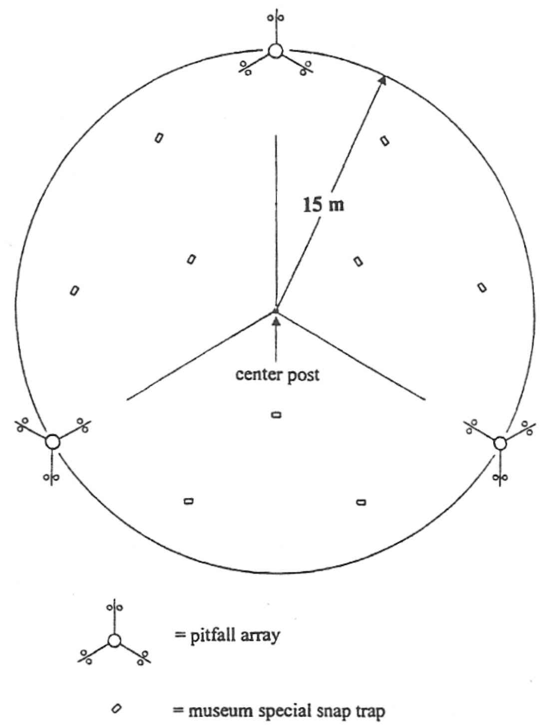

Figure 1. Sampling scheme in a study site showing orientation of pitfall arrays and generic snap trap locations with respect to pitfall arrays (not to scale).

Trapping sessions were conducted every 12-16 days from 1 March 1997 through 20 October 1997, with an additional winter trapping session 24-26 January 1998. There were a total of 16 trapping sessions, each four days (three nights) in duration, yielding 18,936 trap nights associated with pitfall arrays and 9,680 trap nights associated with snap traps, for a total of 28,616 trap nights. Pitfall traps, when uncovered and not flooded, were considered functional. A snap trap found sprung and empty was considered nonfunctional and one trap night was subtracted from the total effort, modified after Nelson & Clark (1973) who subtracted one half of a trapnight from total effort for each sprung trap.

At the beginning of each trapping session, pitfall traps were uncovered and filled with water to a depth of

6 to 9 cm and snap traps were baited with peanut butter and oatmeal. Animals were collected on days 2-4. At the end of each trapping session, pitfalls were rendered nonfunctional by covering them or adding sticks and snap traps were removed from the site. All mammals collected will be deposited in the Virginia Commonwealth University Mammal Collection.

Monthly rainfall from March 1997 through January 1998 averaged 91.6 ±7.7 mm and was 8.4% above average for the period. Considering only months when trapping was conducted, monthly rainfall ranged from 44.5 mm in May 1997 to 186.2 mm in January 1998; average rainfall, 92.7 ±8.1 mm, was 4.4% above normal. However, 15 of the 16 trapping sessions were conducted from March through October and rainfall for this period (94.1 ±7.4 mm) was 9.0% below normal (Figure 2) (National Oceanic & Atmospheric Administration, Climatological Data for Virginia, 1997 and 1998).

Habitat Analysis

We identified to species all trees ≥ 4.5 m in height within each study site. Trees were placed into size classes based on diameter at breast height (dbh): saplings (< 2.5 cm), understory trees (2.5-9.9 cm), and overstory trees (≥ 10 cm).

We assessed habitat variables of study sites by a line intercept method (after Canfield, 1941) using eight equally-spaced 25-m transects that radiated from a central point of the study site. Variables were recorded at one-meter intervals (total = 200) and included presence or absence of downed woody debris (DWD), stumps, snags, herbs, and shrubs. We also recorded litter type (e.g., evergreen, deciduous, both) and the species of all herbs and shrubs.

Habitat Descriptions

UNGR (unmaintained grasslands): Grasslands in mid- to late old-field succession. Dominant vegetation was perennial grasses, especially broomsedge (*Andropogon virginicus*) and redtop (*Agrostis alba*). Forbs were mostly perennials (e.g., yarrow, *Achillea millefolium*; slender bush clover, *Lespedeza virginica*; goldenrods, *Solidago* spp.) and biennials (e.g., spotted knapweed, *Centauea maculosa*; common evening primrose, *Oenothera biennis*). Blackberry (*Rubus* spp.) was a common shrub, as was Russian olive (*Elaeagnus augustifolia*: introduced). Trees were sparse and were mostly sapling and small hardwood species (winged sumac, *Rhus copallina*; sassafras, *Sassafras albidum*; black cherry, *Prunus serotina*; oaks, *Quercus* spp.). No trees with a dbh ≥ 10 cm were present in any of the three grassland sites. DWD, stumps, and snags were scarce.

CCNR (5 to 10 yr old clearcuts not replanted with pines): Early successional densely forested habitat dominated by

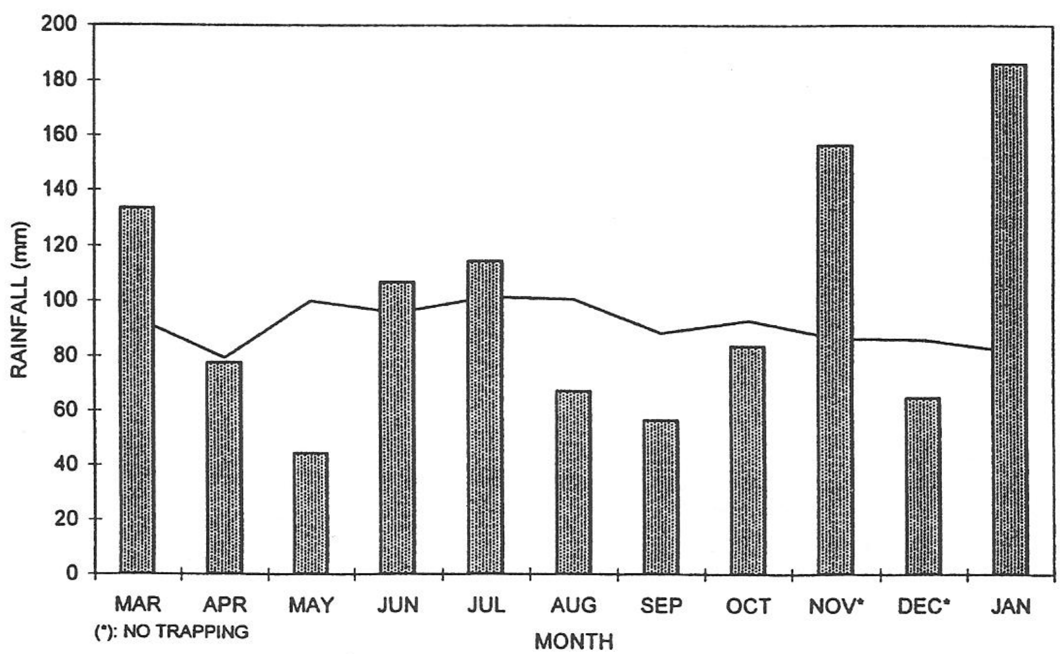

Fig. 2. Monthly rainfall (mm) from March 1997 through January 1998. Bars represent rainfall totals during the study and the line indicates average monthly rainfall.

loblolly pine (*Pinus taeda*) and Virginia pine (*P. virginiana*). Other tree species included *Quercus* spp., bigtooth aspen (*Populus grandidentata*), sweetgum (*Liquidambar styraciflua*), American holly (*Ilex opaca*), flowering dogwood (*Cornus florida*), and *S. albidum*. Most trees were 2.5 to 9.9 cm dbh. Seedlings, both evergreen and deciduous, were uncommon. Density of understory vegetation varied among study sites, but was generally low and dominated by blueberry (*Vaccinium* spp.). Herbaceous plants were uncommon in all study sites. Woody structure, especially DWD, were common forest floor components. Leaf litter was primarily a mix of evergreen and deciduous material.

PIPL (5 to 10 yr old pine plantations): This tree community was similar to CCNR and was densely forested and dominated by pines, *P. taeda* and especially *P. virginiana*. Other common tree species were *Quercus* spp., mockernut hickory (*Carya tomentosa*), tulip-tree (*Liriodendron tulipifera*), *I. opaca*, and *L. styraciflua*. Most trees were 2.5 to 9.9 cm dbh. Both evergreen and deciduous seedlings were relatively uncommon. As in CCNR, density of understory vegetation varied, but was relatively abundant overall, and predominated by *Vaccinium* spp. Coast pepperbush (*Clethra alnifolia*) occurred in substantial numbers in one study site. Herbaceous plants were less common than in more mature habitats. DWD and other woody structure were less frequent than in CCNR but not uncommon. Leaf litter was mostly a mix of evergreen and deciduous plant material.

MPN1 (30 to 50 yr old mixed pines): Earliest successional habitat sampled to have distinct overstory and understory tree communities. Pines, mostly *P. virginiana*, dominated the overstory. Southern red oak (*Quercus falcata*) was the only abundant overstory hardwood tree species. Understory tree species were a mix of small overstory trees such as *P. virginiana*, *Quercus* spp., red maple (*Acer rubrum*), American beech (*Fagus grandifolia*), and understory species such as *I.*

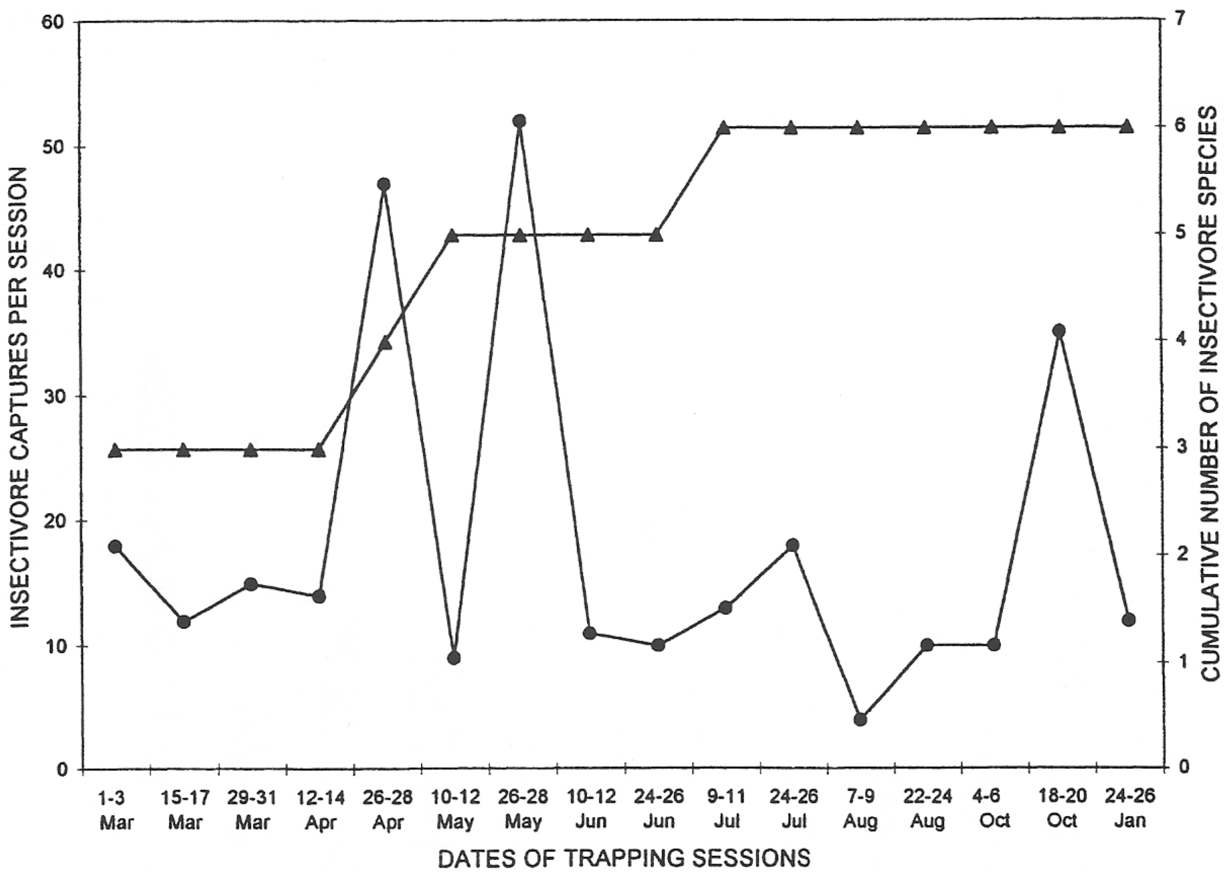

Fig. 3. Comparison of total captures per trapping session and cumulative number of insectivore species for eleven terrestrial habitat types on Fort A. P. Hill, March 1997 to January 1998. Circles represent insectivore captures for all habitat types in specific trapping sessions and triangles represent cumulative insectivore species captured in the study.

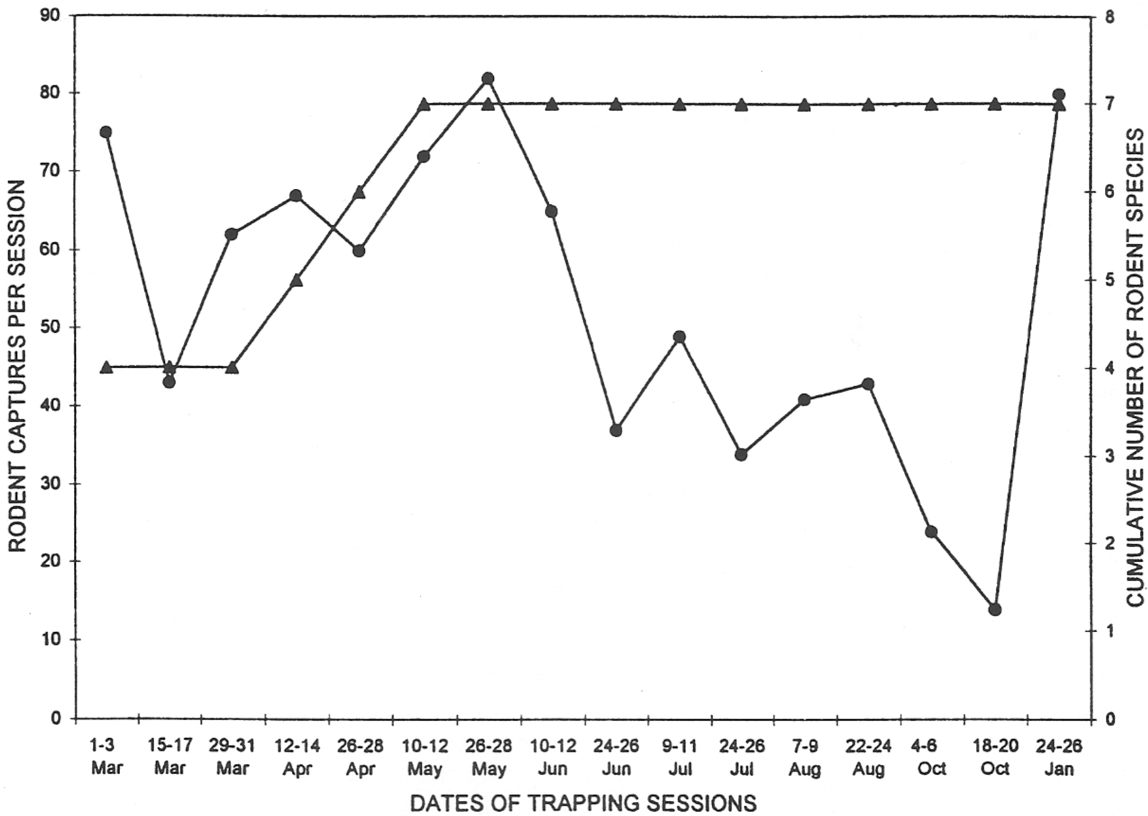

Fig. 4. Comparison of total captures per trapping session and cumulative number of rodent species for eleven terrestrial habitat types on Fort A. P. Hill, March 1997 to January 1998. Circles represent rodent captures for all habitat types in specific trapping sessions and triangles represent cumulative rodent species captured in the study.

opaca, *S. albidum*, and *C. florida*. Deciduous seedlings were more common than evergreen, but neither was particularly abundant. The most frequent shrubs were *Vaccinium* spp. Herbaceous plants were sparse in all three study sites. DWD was relatively abundant in all study sites. Leaf litter was mostly a mix of evergreen and deciduous plant material.

MPN2 (60 to 90 yr old mixed pines): Pines, both *P. taeda* and *P. virginiana*, were the dominant overstory tree species. No other overstory species was abundant in all study sites. However, *Q. falcata* was common in one study site. The most common tree in the understory was *I. opaca*. Also abundant were *L. styraciflua*, *Q. falcata*, *S. albidum*, and *C. florida*. Both evergreen and deciduous seedlings were more abundant in this habitat than in MPN1. Shrub density varied substantially among sites; *Vaccinium* spp. were the most commonly observed species. Herbaceous plants occurred in low numbers in all study sites. DWD was relatively abundant in all study sites. Forest floor leaf litter was both evergreen and deciduous.

MHP1 (30 to 50 yr old mixed hardwoods and pines): The dominant overstory tree species was *P. virginiana*. Other abundant overstory tree species were *Q. falcata*, sourwood (*Oxydendron arboreum*), *P. taeda*, white oak (*Quercus alba*), *L. styraciflua*, *L. tulipifera*, and *F. grandifolia*. No one species dominated the understory, however, the most abundant species were *A. rubrum*, *I. opaca*, and *O. arboreum*. Other common species that varied substantially in numbers among the study sites were *Q. alba*, *F. grandifolia*, black gum (*Nyssa sylvatica*), *C. florida*, and *Q. falcata*. Deciduous seedlings were more common than evergreen, but neither was particularly abundant. *Vaccinium* spp. were the only shrubs observed, and density varied from sparse to dense among study sites. Herbaceous plants were scarce. Frequency of DWD was relatively high among in all study sites; stumps were frequent in one study site. Leaf litter was primarily a mix of deciduous and evergreen plant material.

Table 1. Summary of effort, capture statistics (total, insectivores, and rodents per 100TN), and H’. J’. (Shannon Index $\log_{10}$) in eleven terrestrial habitat types from March 1997 through January 1998 on Fort A.P. Hill. Between session and incidental captures are not included. See Materials and Methods for habitat descriptions. Variance (± SD) is provided for mean values.

Species	UNGR	CCNR	PIPL	MPN1	MPN2	MHP1	MHP2	MHW1	MHW2	OAK1	OAK2
Insectivores											
S. longirostris	0.2 (0.1, 0.4)	0.1 (<0.1, 0.6)	0.2 (0.1, 0.3)	0.1 (<0.1, 0.2)	0.3 (0.3, 0.5)	0.1 (0.1, 0.2)	0.3 (0.2, 0.4)	0.3 (0.1, 0.6)	0.1 (<0.1, 0.3)	0.1 (0.1, 0.2)	0.1 (<0.1, 0.1)
S. hoyi	0.0 (0.0, 0.1)	0.0 (0.0, 0.2)	0.2 (0.2, 0.5)	0.0 (0.0, 0.1)	0.0 (0.0, 0.3)	0.1 (0.1, 0.4)	0.2 (0.1, 0.3)	0.1 (<0.1, 0.3)	0.1 (<0.1, 0.2)	0.3 (0.2, 0.4)	0.1 (<0.1, 0.2)
B. brevicauda	0.3 (0.2, 0.4)	0.3 (0.2, 0.5)	0.8 (0.5, 1.4)	0.4 (0.2, 0.4)	0.7 (0.4, 0.8)	0.5 (0.2, 0.8)	0.2 (0.2, 0.6)	0.2 (0.2, 0.4)	0.4 (0.4, 0.8)	0.6 (0.6, 0.8)	0.8 (0.8, 1.1)
C. parva [1]	0.3 (0.2, 0.7)	0.0 (0.0, 0.1)	0.1 (<0.1, 0.1)	x	0.0 (0.0, 0.1)	x	x	x	x	x	0.0 (0.0, 0.1)
Rodents											
R. humulis [1]	0.4 (0.2, 0.6)	0.0 (0.0, 0.1)	x	x	x	x	x	0.0 (0.0, 0.1)	x	x	x
P. leucopus	2.1 (0.6, 3.3)	0.3 (0.3, 1.3)	0.9 (0.9, 2.1)	1.1 (1.1, 1.9)	3.8 (1.9, 5.4)	2.9 (1.6, 4.0)	2.4 (2.2, 2.8)	2.8 (2.3, 7.8)	1.9 (1.4, 5.4)	3.1 (2.8, 4.4)	2.1 (1.1, 4.3)
M. pennsylvanicus [1]	0.7 (0.6, 1.1)	x	x	x	0.0 (0.0, 0.1)	x	x	0.1 (<0.1, 0.1)	x	0.0 (0.0, 0.1)	x
M. pinetorum	0.1 (<0.1, 0.1)	0.0 (0.0, 0.1)	0.1 (<0.1, 0.1)	0.0 (0.0, 0.1)	0.1 (<0.1, 0.1)	x	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.1 (<0.1, 0.1)
Z. hudsonius [1]	0.3 (0.2, 1.1)	x	x	x	x	x	x	x	x	0.0 (0.0, 0.2)	x

(1) higher ($P<0.05$) numbers in UNGR than all other habitats.

x = no captures

Table 2. Summary of median captures/100TN (25%, 75% quartiles) for four insectivores and five rodents among eleven terrestrial habitat types on Fort A.P. Hill. See Material and Methods for habitat descriptions.

Habitat	Total Captures	Total trap nights	Tot cap /100TN	Insect cap /100TN	Rodent cap /100TN	Species (mean *n*)	H'	J'
UNGR	133	2793	4.8 ±1.9	1.6 ±0.5	10.0 ±4.2	7.7 ±1.2 [2]	0.661 ±0.046 [2]	0.752 ±0.061
CCNR	43	2707	1.6 ±1.2	1.2 ±0.8	2.2 ±1.9	4.0 ±1.0 [3]	0.522 ±0.112	0.880 ±0.071
PIPL	75	2525	3.1 ±1.6	2.3 ±0.7	4.3 ±2.6	5.3 ±1.2	0.557 ±0.072	0.781 ±0.118
MPN1	49	2473	1.9 ±0.8	0.7 ±0.5	4.8 ±1.3	3.3 ±1.2 [3]	0.316 ±0.159 [3]	0.609 ±0.147
MPN2	132	2677	5.1 ±2.8	1.8 ±0.9	10.6 ±6.8	4.7 ±1.5	0.375 ±0.015	0.598 ±0.143
MHP1	93	2454	3.7 ±1.8	1.3 ±0.9	9.2 ±4.1	4.0 ±0.0 [3]	0.345 ±0.105 [3]	0.574 ±0.174
MHP2	88	2580	3.6 ±0.5	1.3 ±0.4	7.6 ±0.5	4.0 ±1.0 [3]	0.370 ±0.097	0.623 ±0.096
MHW1	153	2643	5.8 ±3.9	1.2 ±0.6	14.1 ±10.7	4.7 ±0.6	0.323 ±0.169 [3]	0.473 ±0.224
MHW2	106	2511	4.1 ±3.4	1.2 ±0.9	10.0 ±7.5	3.7 ±0.6 [3]	0.317 ±0.033 [3]	0.576 ±0.130
OAK1	126	2630	4.8 ±1.0	1.7 ±0.5	10.8 ±4.2	5.0 ±1.0	0.387 ±0.063	0.566 ±0.123
OAK2	102	2623	3.8 ±2.0	1.7 ±0.1	7.7 ±5.5	4.3 ±1.5 [3]	0.382 ±0.128	0.610 ±0.130
Total	1100	28616	-	-	-	-	-	-
Mean	100 ±35	2601 ±105	3.9 ±2.2 [1]	1.5 ±0.7 [1]	8.3 ±5.5 [1]	4.6 ±1.4	0.414 ±0.140	0.640 ±0.160 [1]

(1) No significant differences among the 11 habitats

(2) Significantly higher than (3)

MPH2 (50 to 70 yr old mixed hardwoods and pines): Dominant overstory tree species were *P. virginiana* and *P. taeda*. *Quercus alba* was the most abundant overstory tree in one study site. Other species common in the overstory but varied in numbers among study sites were princess tree (*Ailanthus altissima*), *L. tulipifera*, *Q. falcata*, black oak (*Q. velutina*), *L. styraciflua*, and *A. rubrum*. No one tree species was dominant in the understory; however, *I. opaca*, *A. altissima*, *C. florida*, *A. rubrum* were all abundant. Deciduous seedlings were common; evergreen seedlings were observed but uncommon. Shrub density among study sites ranged from sparse to dense, with *Vaccinium* spp. and mountain laurel (*Kalmia latifolia*) abundant in one study site, and *Vaccinium* spp. only were present in the other two sites. One herb, partridgeberry (*Mitchella repens*) was common to all study sites. Two other herbs, spotted wintergreen (*Chimaphila maculata*) and hog-peanut (*Amphicarpa bracteata*) were observed but were not common. DWD was relatively abundant in all study sites. Forest floor leaf litter was primarily a mix of both evergreen and deciduous plant material.

MHW1 (60 to 80 yr old mixed hardwoods): Hardwoods (*Quercus alba* and *L. tulipifera*) dominated the overstory tree community. Other common overstory species were *L. styraciflua*, *O. arboreum*, and *F. grandifolia*, *C. tomentosa*, and pignut hickory (*Carya glabra*). The most abundant understory tree species were *C. florida* and *F. grandifolia*. Also common, but in varying degrees among study sites, were American hornbeam (*Carpinus caroliniana*), *I. opaca*, *A. rubrum*. Seedlings were predominately deciduous and ranged from abundant to uncommon among study sites. *Vaccinium* spp. was abundant in one study site, spicebush (*Lindera benzoin*) and viburnums (*Viburnum* spp.) were observed in moderately low numbers in the other two sites. Two herbs, *M. repens* and *A. bracteata*, were relatively common in two areas. DWD was relatively abundant in all study sites. Forest floor leaf litter was primarily deciduous material.

MHW2 (90 to 139 yr old mixed hardwoods): Dominant overstory tree species were *L. tulipifera* and *Q. alba*. Other abundant overstory tree species were *C. tomentosa*, northern red oak (*Quercus rubra), F. grandifolia*, and *O. arboreum*. *Ilex opaca* and *C. florida* were the most abundant tree species in the understory. Other common species were *N. sylvatica*, *F. grandifolia*, *C. tomentosa*, *A. rubrum*, and *O. arboreum*. Deciduous seedlings were common; evergreen seedlings were present in low numbers in all study sites. *Vaccinium* spp. was abundant in one study site, *Viburnum* spp. were observed in low numbers in two areas. Two herbs, *M. repens* and *A. bracteata*, were moderately common in all study sites. Frequency of DWD was relatively high in all study sites. Leaf litter was primarily deciduous in two study sites and a mix of deciduous and evergreen in the third.

OAK1 (60 to 80 yr old white oaks): The dominant overstory tree species was *Q. alba*. Other species that were abundant in the overstory but that varied in numbers among study sites were *L. tulipifera*, *C. glabra*, and *F. grandifolia*. The dominant understory tree species was *I. opaca*. *Cornus florida*, *F. grandifolia*, *N. sylvatica*, and *C. caroliniana* were well represented in the understory. Deciduous seedlings predominated; evergreen seedlings were present in very low numbers. Shrub density ranged from sparse to moderately dense and included, from most to least abundant, *L. benzoin*, *Vaccinium* spp., *Viburnum* spp., and *Rubus* spp. Herb density was relatively high and commonly observed species included *A. bracteata*, *M. repens*, and to a lesser extent, *C. maculata*. DWD was common, but not particularly abundant in any study site. Forest floor leaf litter was primarily a mix of both evergreen and deciduous plant material.

OAK2 (90 to 125 yr old white oaks): As in OAK1, the dominant overstory tree species was *Q. alba*. Other abundant overstory species were *F. grandifolia*, *Q. rubra*, and *L. tulipifera*. The dominant understory tree species was *F. grandifolia. Cornus florida*, *I. opaca* and *L. styraciflua* were also well represented in the understory. Deciduous seedlings predominated, comparable to OAK1, and evergreen seedlings were present in low numbers. Shrub density was relatively sparse compared to other hardwood habitats, with *Vaccinium* spp. most abundant. Herb density was relatively low with *M. repens* most commonly observed; *C. maculata* and *A. bracteata* were present in very low numbers. DWD was common, even abundant in one study site. Forest floor leaf litter was primarily deciduous plant material

Statistical Analyses

Most analyses were based on captures per unit effort because effort varied among study sites, and because some snap traps were found sprung and empty. Species diversity (H') and evenness (J') for small mammal assemblages in all habitat types and associated habitat replicates were calculated using the Shannon index ($\log_{10}$ H'). One-way ANOVA followed by Tukey's post hoc analysis were used to compare mean total captures/100 trap nights (TN), mean captures of insectivores/100TN, mean captures of rodents/100TN, mean small mammal H', mean J', and mean species richness among habitat types (Zar, 1996). Kruskal-Wallis nonparametric ANOVA on ranks followed by Student-Newman-Keuls multiple comparison tests were used to compare captures/100TN among all small mammal species and captures/100TN of individual species among the eleven habitats. Nonparametric techniques were used because of questionable degrees of normality and/or equality of variance in some capture data sets (Zar, 1996). Due to non-normality within associated data sets, Mann-Whitney rank-sum test was used to compare captures/study session between insectivores and rodents (Ott, 1992).

RESULTS

A total of 1,164 small mammals representing 15 species was captured in the study. Six of the 15 species (eastern mole, *Scalopus. aquaticus*; star-nosed mole, *Condylura cristata*; eastern cottontail, *Sylvilagus floridanus*; eastern chipmunk, *Tamias striatus*; southern flying squirrel, *Glaucomys volans*, and least weasel, *Mustela nivalis*), representing 1.82 % of all captures, were collected incidentally and not included in most analyses. Additionally, animals collected in pitfall traps between trapping session when pitfalls were assumed to be nonfunctional are excluded from many analyses. With these reductions in total captures considered, most analyses were based on 1,100 individuals represented by nine species. Insectivores (southeastern shrew, *Sorex longirostris*; pygmy shrew, *Sorex hoyi*; northern short-tailed shrew, *Blarina brevicauda*; and least shrew, *Cryptotis parva*) collected totalled 274, whereas rodents (eastern harvest mouse, *Reithrodontomys humulis*; white-footed mouse, *Peromyscus leucopus*; meadow vole, *Microtus pennsylvanicus*; woodland vole, *Microtus pinetorum*; meadow jumping mouse, *Zapus hudsonius*) totalled 826. *Peromyscus leucopus* accounted for 68.5% of the 1,100 captures.

Mean captures/100TN for all habitats ranged from 1.6 ±1.2 in CCNR to 5.8 ±3.9 in MHW1 (Table 1). There were no significant differences (P=0.41) in mean captures/100TN among the eleven habitat types. Considering all habitats, median captures/100TN for *P. leucopus* were significantly higher (P<0.05) than the other eight species, and captures/100TN for *B. brevicauda* were significantly higher (P<0.05) than *C. parva*, *R. humulis*, *M. pennsylvanicus*, *M. pinetorum*, and *Z. hudsonius*. Median captures/100TN for one insectivore, *C. parva* (P=0.04), and three rodents, *R. humulis* (P=0.01), *M. pennsylvanicus* (P=0.01), and *Z. hudsonius* (P<0.01), were higher in UNGR than in all other habitat types (Table 2). There were no significant differences in median captures/100TN of *S. longirostris* (P=0.58), *S. hoyi* (P=0.34), *B. brevicauda* (P=0.12), *P. leucopus* (P=0.19), and *M. pinetorum* (P=0.95) among the 11 habitat types.

Mean H' for all habitats ranged from 0.316 ±0.159 in MPN1 to 0.661 ±0.046 in UNGR (Table 1). Mean H' was significantly higher (P<0.05) in UNGR than MPN1, MHP1, MHW1, and MHW2. Mean J' ranged from 0.473 ±0.224 in MHW1 to 0.880 ±0.071 in CCNR (Table 1). There were no significant differences (P=0.06) in mean J' among habitat types. Mean species richness ranged from 3.3 ±1.2 in MPN1 to 7.7 ±1.2 in UNGR (Table 1). Mean species richness was significantly higher (P<0.05) in UNGR than in CCNR, MPN1, MHP1, MHP2, MHW2, and OAK2.

Mean captures/100TN for insectivores for all habitats ranged from 0.7 ±0.5 individuals in MPN1 to 2.3 ±0.7 individuals in PIPL (Table 1). There were no significant differences (P=0.30) among the eleven habitat types. Mean captures/100TN for rodents for all habitats ranged from 2.2 ±1.9 individuals in CCNR to 14.1 ±10.7 individuals in MHW1 (Table 1). There were no significant differences (P=0.32) among the eleven habitat types.

Captures of insectivores per trapping session averaged 18.1 ±14.0 and ranged from four individuals during trapping session 12 (7-9 August 1997) to 52 individuals during trapping session 7 (26-28 May 1997). All six insectivore species represented in this study were encountered in ten trapping sessions over five months (Figure 3). Captures of rodents per trapping session averaged 53.0 ±20.4 and ranged from 14 individuals during trapping session 15 (18-20 October 1997) to 82 individuals during trapping session 7 (26-28 May 1997). The seven rodent species were encountered in six trapping sessions over about 2.5 months (Figure 4). Median captures per trapping session for rodents (54.5) was significantly higher (P<0.01) than median captures per trapping session for insectivores (12.5).

DISCUSSION

Most of the mammal species encountered in this study are known from the mid-Atlantic region (Hall, 1981; Webster et al., 1985; Hamilton & Whitaker, 1998; Linzey 1998). Only *Mustela nivalis* was unexpected; its discovery was the first for the Coastal Plain in Virginia (Bellows et al., 1999). No introduced species, such as the black rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*), and house mouse (*Mus musculus*), were encountered in the habitats studied.

We attribute much of our trapping success to the use of multiple capture techniques, especially pitfall traps. For example, as recently as 1980 *S. hoyi* was known from only seven Virginia locations totaling eight specimens (Handley et al., 1980), yet 53 specimens were collected in this study. Our trapping protocol was designed to account for biases associated with snap or live trap and pitfall techniques (Brown, 1967; Pucek, 1969; Bury & Corn, 1987; Cawthorn & Rose, 1989; Walters, 1989). Rodents usually dominate captures in snap and live traps, whereas long-tailed shrews often dominate captures in pitfall traps, with or without drift fences (Briese & Smith, 1974; Williams & Braun, 1983; Dowler et al., 1985; Mitchell et al., 1993). The combination of the snap trap grid with the small-scale drift fence arrays and pitfall traps ensured that the range of non-volant small mammal species richness expected for the Fort A. P. Hill area would be encountered. Even so, the disproportionate numbers of captures between rodents and insectivores in this study is consistent with other studies that have used both snap trap and pitfalls (Snyder & Best, 1988; Kalko & Handley, 1993).

Species accumulation curves for insectivores (Figure 3) and rodents (Figure 4) and associated trapping success over time in 1997 and early 1998 allowed us to make two conclusions. First, with the techniques used in this study, obtaining knowledge of full species richness and the composition of small mammal assemblages (relative abundance, diversity, evenness) can be accomplished during the months of March through July. We suggest that the minimum length of time for any small mammal study within the region should be about five months. However, because rodent capture success was high in January 1998, we also suggest that small mammal trapping surveys should include mid-winter trapping sessions to provide an accurate assessment of all species present. Second, because rainfall patterns affect small mammal activity, and therefore capture success (Gentry & Odum, 1957; Sidorowicz, 1960; Mystkowska & Sidorowicz, 1961; Vickory & Bider, 1978; Kalko & Handley, 1993), we attribute the reduction in captures in late summer 1997, in part, to below normal rainfall. We attribute fluctuations in capture success to episodic rainfall events. For example, the most productive trapping session for insectivores and rodents was conducted during May 1997, the month with the lowest rainfall and the greatest departure from normal rainfall during the study. Importantly, rainfall during the three day period of trapping session 7 accounted for 70.1% (31.2 of 44.5 mm) of all rainfall for May 1997. This suggests that both insectivores and rodents respond to episodic rainfall by increasing activity patterns, and is consistent with other studies (Gentry & Odum, 1957; Pearson, 1960a, 1960b; Getz, 1968; Doucet & Bider, 1974). Captures of insectivores appeared to be more effected by fluctuations in rainfall patterns—they tracked rainfall patterns more closely than rodents—and is likely due to high moisture requirements of shrews (Getz, 1961).

The primary determinant for differences in H' and species richness among habitat types was the distribution of grassland specialists that utilized forested habitats sparingly and habitat generalists that are able to find food and shelter in a variety of habitats. With the exception of grassland habitats, composition of small mammal assemblages of most other habitat types studied were similar, with *P. leucopus* and *B. brevicauda* dominating the number of small mammals captured. Only four species, *S. longirostris*, *S. hoyi*, *B. brevicauda*, and *P. leucopus*, were captured in all eleven habitats. All of these species are well documented habitat generalists (Jameson, 1949; Getz, 1961; M'closkey, 1975; Miller & Getz, 1977; Dueser & Shugart, 1979; Wrigley et al., 1979; Kirkland, 1981; Adler, 1985; Adler & Wilson, 1987; Pagels, 1987; Jones et al., 1991; Pagels et al., 1992), and their numbers are directly responsible for the lack of significant differences in mean captures per 100TN among the habitats sampled. Grasslands were clearly preferred by some species of small mammals over more forested habitat types. *Cryptotis parva*, *R. humulis*, *M. pennsylvanicus*, and *Z. hudsonius* are grassland specialists (Hamilton, 1935; Dunaway, 1968; Kirkland, 1981; Adler et al., 1984; Adler, 1985; Cawthorn & Rose, 1989; Pagels et al., 1992), and in this study they were rarely encountered in forested habitats. *Microtus pinetorum* was rare in all of the ten habitats in which it was encountered. Low capture success for this species may have been due to its semi-fossorial habits (Jameson, 1949; Miller & Getz, 1977; Webster et al., 1985). *Microtus pinetorum* should, however, have been equally trappable in all habitats even if captures do not reflect actual abundance.

Similarities among many of the ten forested habitat types we sampled may have confounded our efforts to elucidate habitat preferences for any of the five aforementioned habitat generalists. It is difficult to determine from our results whether our habitat designations (LCTA/SAF) needed to be less specific with regard to stand age and/or major vegetation characteristics. In another analysis of this data set, Bellows (1999) classified only five habitat types based on forest types described by the United States Forest Service (Thompson, 1991) combined with tree dbh data (after Ware, 1998). The following habitat types were used by Bellows (1999): old-fields (independent of tree data), pine (mean dbh 10.0-14.9 cm), pine (15-19.9 cm), oak-pine (20.0-24.9 cm), and oak-hickory (mean dbh $\geq$ 25.0 cm). Even at this lowered habitat type resolution, Bellows failed to isolate habitat preferences for the five generalist species. The lack of an apparent habitat preference for these small mammals at both resolutions of macrohabitat scale is a testament to their generalist nature. Many studies have addressed microhabitat affinities of habitat generalists (Dueser & Shugart, 1978, 1979; Morris, 1979; Kitchings & Levy, 1981; Yahner, 1982; Adler, 1985;

Snyder & Best, 1988), the results of which explain the coexistence of these small mammals with similar physiological requirements within the same habitat (Rosenzweig & Winakur 1969; Schoener, 1974; Rosenzweig, 1981; Doyle, 1987). These studies often show that generalists are very specific about microhabitat requirements and that they are often associated with microhabitat components common to a wide variety of habitat types. It is therefore critical to understand both macro- and microhabitat scales of habitat use of small mammals in order to understand patterns of their distributions (Morris, 1984).

Military installations like Fort A. P. Hill provide excellent opportunities to evaluate the ecologies of small mammal species and their distributions within and among relatively undisturbed habitats. These opportunities are becoming increasingly more important as the dynamic land-use practice on surrounding properties become more complex and adverse in their affects on regional flora and fauna.

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