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Small Mammal Habitat Associations in a Fragmented Agricultural Landscape

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SMALL MAMMAL HABITAT ASSOCIATIONS IN A FRAGMENTED AGRICULTURAL LANDSCAPE

by

WILLIAM WALL HAMRICK

(Under the Direction of C. Ray Chandler)

ABSTRACT

The purpose of this research was to examine how small mammals select habitats in a fragmented agricultural landscape in southeast Georgia. I captured small mammals at 71 trap sites within 33 locations in Bulloch and Candler Counties, Georgia. Prior to trapping, each site was classified based on predominant habitat type. Within each trap site, habitat variables were quantified for capture and non-capture trap stations. Using GPS and ArcMap GIS, I quantified surrounding land cover associated with each trap site. A total of 398 individuals of 10 different species of small mammals were captured. *Peromyscus gossypinus* and *Sigmodon hispidus* were captured most often, while shrew species and (*Reithrodontomys humulis*) were captured rarely. Relative species abundance per trapping effort was highest for old field and longleaf pine-wiregrass habitats. Pine plantation and upland hardwood habitats yielded the lowest relative abundance per trapping effort. Species showed significant differences in patterns of habitat selection. A principal components analysis (PCA) revealed two largely non-overlapping species groups defined by PC 1: those associated with more open-canopy habitats and those associated with closed-canopy, mature forest habitats. *Neotoma floridana*, *Ochrotomys nuttalli*, and *Sorex longirostris* exhibited the most specialized (least variable) habitat selection. Land cover associated with capture stations for each species was similar to land cover available in the region. Overall, my results suggest that three species of forest-dwelling mammals (*N. floridana, O. nuttalli,* and *S. longirostris*) are most susceptible to the habitat changes associated with an agricultural landscape.

INDEX WORDS: Habitat fragmentation, Small mammals, Southeast Georgia

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AGRICULTURAL LANDSCAPE

by

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS 6

LIST OF TABLES 10

LIST OF FIGURES 13

CHAPTER

1 INTRODUCTION 14

Overview 14

Background 14

2 METHODS 20

Study Area 20

Site Selection and Trapping 23

Habitat Sampling 32

Land Cover Associations 33

Statistical Analysis 34

3 RESULTS 36

Habitat Comparisons 36

Species Habitat Associations 36

Capture versus Non-capture Trap Stations 47

Land Cover Associations 52

4 DISCUSSION 58

Species Habitat Associations 58

Habitat Comparisons 62

TABLE OF CONTENTS (Continued) Page

Capture versus Non-capture Trap Stations 63

Land Cover Associations...65

Species Numbers and Relative Abundances 65

Management Implications 67

REFERENCES 68

APPENDICES 75

A HABITAT VARIABLES, GROUND COVER, AND OBSERVED FREQUENCIES OF GROUND COVER ASSOCIATED WITH TEN HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA..76

B HABITAT VARIABLES, GROUND COVER, AND OBSERVED FREQUENCIES OF GROUND COVER ASSOCIATED WITH TEN SPECIES OF SMALL MAMMALS INVENTORIED IN THIS STUDY IN BULLOCH AND CANDLER COUNTIES, GEORGIA 83

C HABITAT VARIABLES AND GROUND COVER ASSOCIATED WITH CAPTURE AND NON-CAPTURE TRAP STATIONS WITHIN TEN HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA..90

D LAND COVER CLASSES AND PERCENTAGES FOR 500-METER RADIUS HABITAT BUFFERS SURROUNDING SMALL MAMMAL TRAP SITES IN BULLOCH AND CANDLER COUNTIES, GEORGIA……………………………………………………………...95

E PLANT SPECIES COMPOSITION FOR TEN DIFFERENT HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA……………………………………….97

LIST OF TABLES

Page

Table 2.1: Land cover characteristics for Bulloch and Candler Counties, Georgia (Boatright and Bachtel 2000) 22

Table 2.2: Habitat classifications for small mammal trap sites in Bulloch and Candler Counties, Georgia (Wharton 1978, Martin et al. 1993a and b, Messina and Conner 1998) 26

Table 3.1: Numbers of individuals captured and relative abundances (captures/100 trap nights) of small mammal species among ten different habitat types in Bulloch and Candler Counties, Georgia 37

Table 3.2: Differences in quantified habitat variables among wooded habitat types of Bulloch and Candler Counties, Georgia 39

Table 3.3: Differences in quantified habitat variables among open habitat types of Bulloch and Candler Counties, Georgia 40

Table 3.4: Species differences in habitat associations among small mammal capture sites in Bulloch and Candler Counties, Georgia 41

Table 3.5: Results of the principal components analysis of habitat variables associated with small mammal capture sites in Bulloch and Candler Counties, Georgia 42

Table 3.6: Variations in small mammal habitat use in relation to habitat variables of the first two principal components 46

LIST OF TABLES (Continued) Page

Table 3.7: Habitat variables associated with small mammal capture and non-capture trap stations among different habitat types in Bulloch and Candler Counties, Georgia…………………………………………………………………..48

Table 3.8: Differences in land cover classes associated with small mammal trap sites in Bulloch and Candler Counties, Georgia...54

Table 3.9: Comparisons of available percentages of land cover types for the Bulloch/Candler landscape and percent land cover for 500-m radius buffers surrounding small mammal trap sites…………………………………………55

Table A.1: Habitat variables associated with small mammal trap sites in Bulloch and Candler Counties, Georgia…………………………………………………..77

Table A.2: Ground cover forms and litter depth associated with small mammal trap sites in Bulloch and Candler Counties, Georgia………………………………………79

Table A.3: Observed frequencies for ground cover forms associated with small mammal trap sites in Bulloch and Candler Counties, Georgia…………………………..81

Table B.1: Habitat variables associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia………………………………………84

Table B.2: Ground cover forms and litter depth associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia…………………...86

Table B.3: Observed frequencies for ground cover forms associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia……….88

Table C.1: Habitat variables associated with non-capture trap stations in Bulloch and Candler Counties, Georgia…………………………………………………..91

Table C.2: Ground cover forms and litter depth associated with non-capture trap stations in Bulloch and Candler Counties, Georgia...93

LIST OF FIGURES

Page

Figure 2.1: Location of Bulloch and Candler Counties, Georgia 21

Figure 2.2: Location of sixty-nine small mammal trap sites used during this study in Bulloch County, Georgia..24

Figure 2.3: Location of two small mammal trap sites used during this study in Candler County, Georgia 25

Figure 2.4: Small mammal trap site layout with two parallel transects 20-m apart, and trap stations established at 20-m intervals on each transect..............................31

Figure 2.5: Example of a small mammal trap site with 500-m radius buffer of surrounding land cover...35

Figure 3.1: Small mammal habitat associations plotted on the first two principal components and circled with 50% confidence ellipses to show overlap and variability among species 45

Figure 3.2: Combined land cover classes and available land cover for Bulloch and Candler Counties, Georgia 53

CHAPTER 1

INTRODUCTION

Overview. – Human population growth and the resulting needs for housing, energy, and food causes natural habitats to become altered in both structure and composition by changes in land use, fragmentation, establishment of invasive species, and/or fire suppression (Noss 1988, Soule′ 1991, Martin et al. 1993a, Cox 1999). Because much of this habitat change is permanent, plant and animal species are faced with the difficult challenge of adjusting to these changes. As a result, it has become increasingly important to understand habitat fragmentation and its potential impacts on future biodiversity. In the last twenty years, numerous studies that address the effects of habitat fragmentation on birds, large carnivores, and game species have been conducted. However, information regarding how less charismatic species, such as small mammals, respond to the effects of habitat fragmentation is lacking. Therefore, the overall objective of this study is to quantify small mammal habitat use and determine potential susceptibility of small mammal species to habitat fragmentation.

Background. – A good example of the effects of human population growth on biodiversity is the current situation in the southeastern United States. Unprecedented population growth in the last 30 years has resulted in entire landscapes composed of human-impacted habitats. The Southeast as defined by Martin et al. (1993 a,b) has a total land area of approximately 136.9 million ha and encompasses the region bordered on the west by Arkansas, Louisiana, and the 95th longitudinal meridian in Texas, and by Kentucky, West Virginia, and Virginia (south of the James River) to the north.

Historically, the Southeast was a largely forested and ecologically diverse region comprised of twenty-four different potential vegetation types (Küchler 1964, Mac et al. 1998). Presently, the Southeast's 81.3 million ha of forest lands constitutes only 60% of what existed at the time of European settlement (Wear and Greis 2002). Although forest area has remained somewhat steady during the last 40 years, much of this remaining forest land is highly fragmented and relatively young. Other forest lands have been converted to plantation forestry. Pine monocultures in the Southeast currently exceed 12.9 million ha and are predicted to increase to 21.8 million ha in the next 35 years. Agricultural lands (croplands, pasture, orchards) comprise 29.5 million ha (22%) of the landscape while the remaining 26.1 million ha (18%) is designated as urban/developed land cover (National Agricultural Statistics Service 2002, Loveland and Acevedo 2006). Presently in the Southeast, the rate of conversion from forest lands and agricultural lands to urban development is 323,000 ha per year (Roe and McKay 2007). In recent years, greatest amounts of urban growth have been heavily concentrated in the Piedmont area between Atlanta, Georgia and Raleigh, North Carolina (Exum et al. 2005). This area, along with areas in the Atlantic and Gulf Coastal Plains, and southern Appalachians are expected to be most affected by future urban growth (Wear and Greis 2002).

The landscape changes described above are largely the result of human population growth. Between 1970 and 2000, the Southeast's population increased by 36%. For comparison, the population of the coterminous United States increased only 27% during this same time period. Whereas in 1970 the Southeast represented just 4.6% of the coterminous U. S. population, as of 2000 it represented 24.6% of the U.S. population. A

2006 population estimate for the Southeast reveals an increase of 7% within the last six years (United States Census Bureau 2007).

As habitat loss and fragmentation have intensified across the Southeast, ecologists have become increasingly concerned about the potential negative impacts of such large scale land use changes on wildlife populations. During this time, numerous studies have documented the negative impacts of habitat fragmentation on certain wildlife species, in particular songbirds and large mammals.

For example, forest interior bird species, many of which are Neotropical migrants, are particularly vulnerable to habitat fragmentation. As forest breeding habitats become fragmented and edge habitats become more prevalent, levels of brood parasitism and predation increase in the remaining available habitats (Wilcove 1985, Robbins et al. 1989, Finch 1991, Keyser et al. 1998, Marzluff and Ewing 2001, Moorman et al. 2002), resulting in decreased reproductive success. In addition, loss and fragmentation of stopover habitats for migratory species reduces the availability of resources needed to complete their migrations (Moore et al. 1990) and may increase competition in small fragments (Somershoe and Chandler 2004). Habitats that survive fragmentation are at risk of becoming biological "sinks" (Donovan et al. 1995, Simons et al. 2000).

Also particularly vulnerable to habitat fragmentation are mammals with large home ranges, such as black bears (*Ursus americanus*) and Florida panthers (*Felis concolor coryi*). Once widely distributed throughout the region, the black bear's range has been reduced by 93% in the southeast (Wooding et al. 1994). Florida panthers have been reduced to a small population of about 100 individuals in southern Florida, roughly 5% of their original range (Meegan and Maehr 2002). Land conversions in the form of roads and urban sprawl continue to force these larger mammals into smaller fragments of available habitat. Because of increased isolation and greater dispersal distances these events have resulted in small populations with low genetic variability, especially in the case of the Florida panther (Frankham et al. 2004). Black bear populations in the Gulf Coastal plain are increasingly susceptible to the same fate (Triant et al. 2004, Dobey et al. 2005). Also, less available habitat and greater dispersal distances increase risks of wildlife/human conflicts (automobile collisions, encroachment on suburbia) that will further reduce these species' populations (Foster and Humphrey 1995, Woodroffe 2000, Peine 2001).

Over the years, these studies involving songbirds, large carnivores, and game species have provided conservationists with a wealth of information regarding impacts of habitat loss and fragmentation on biodiversity. However, studies focusing on less charismatic species, such as small mammals, also are needed in order to understand fully how these events affect ecological communities as a whole. Small mammal communities play an important role in many ecosystems by influencing the distribution of plant species, decomposition rates of plant materials, and soil structure and composition. They also act as secondary consumers and serve as prey items for many predators (Sieg 1987). Additionally, because of behavioral characteristics (territoriality, sex-biased dispersal, and sociality) they share with other mammal species, small mammals can provide insight as to how larger and sometimes rare species will respond to habitat changes at the landscape level (Wolff 1999).

Small mammal habitat use and their distributions within habitats are often influenced by microhabitat characteristics, such as vegetative structure, ground cover, and downed woody debris (Dueser and Shugart 1978, Kitchings and Levy 1981, Seagle, 1985). These elements provide travel and escape routes, as well as feeding and reproductive cover for many small mammal species. Furthermore, they trap moisture that creates favorable conditions for invertebrates, fungi, and herbaceous plants, thus providing small mammals with food. Recent studies have demonstrated that downed woody debris is especially important in homogenous habitats, such as managed pine forests and newly created clearcuts (Loeb 1999, McCay 2000).

Small mammal habitat use also is correlated with a species' life-history traits. Body size is often related to dispersal distance and home range size, which in turn reflect the abilities of a species to exploit complex landscapes. Whereas larger, mobile species (e.g., *Sigmodon hispidus*) are able to exploit a variety of habitats across a landscape, smaller, less-mobile species (e.g., *Sorex longirostris*) may be restricted to certain habitat patches. Because of high metabolic rates and high moisture requirements in order to achieve homeostasis, shrews have specific habitat requirements such as higher amounts of leaf litter and higher stem densities. Although these species are often sympatric with other small mammal species, they are more restricted in their movements and abilities to exploit a variety of habitats. Therefore, life-history traits may help determine a species' level of susceptibility to modified habitats.

Although microhabitat characteristics and life-history traits clearly play a major role in small mammal habitat selection at the patch level, the extent to which these factors continue to play a role among modified habitats at the landscape scale is somewhat unknown. While much information exists on small mammals and habitat selection, little information exists concerning small mammal responses to broad-scale landscape disturbances in the Southeast. Past studies, such as those by Dueser and Shugart (1978) have often focused on a particular species or small mammal communities within the same habitat type. Others have largely focused on small mammal response to forestry practices, such as clearcutting and pine monocultures (Atkeson and Johnson 1979, Mengak et al. 1989, Constantine et al. 2004, Miller et al. 2004). In order to make better management decisions, conservationists need to know which species are most susceptible to habitat modification and which habitats should be preserved to ensure their prolonged survival.

Therefore, the overall objective of this study is to understand how small mammals use habitats within a highly fragmented agricultural landscape in the coastal plain of the southeastern United States. Specifically, the objectives of this research were to (1) determine patterns of habitat use by small mammals in an agricultural landscape of southeast Georgia, (2) determine which species are most selective in their habitat use and thus potentially most susceptible to negative effects of habitat fragmentation, and (3) determine whether or not small mammals are associated with particular landscape level habitat features. Information gained from this study will enable conservationists and land managers to make appropriate management decisions pertaining to the conservation of future biodiversity in the southeastern United States.

CHAPTER 2

METHODS

Study Area. – This study was conducted in Bulloch (32.42° N; 81.75° W) and Candler (32.41° N; 82.06° W) Counties, Georgia, which combine to form a 240,788-ha agricultural landscape on the coastal plain of the southeastern United States (Fig. 2.1). Bulloch County is located on the boundary of the upper and lower coastal plain while Candler County, which borders Bulloch to the west, is located in the upper coastal plain.

Historically, the landscape of the study area was predominantly a longleaf pine (*Pinus palustris*) pyroclimax community with an average fire frequency of about 1 - 5 years (Greene 1931, Chapman 1932, Heyward 1939, Komarek 1974, Christensen 1981, Frost 1995). This community was characterized by rolling park-like woodlands of longleaf pine-wiregrass, sandhills, and flatwoods with variants in other habitats such as Carolina bays and riparian hardwood forests (Bartram 1791, Hawkins 1848, Christensen 1988, Martin et al. 1993 a and b). Forests in this region have now been extensively fragmented. Presently, only 56% of the Bulloch/Candler landscape is forested, and approximately 11% of this remaining forest land cover is comprised of longleaf pine, much of which does not resemble descriptions of the presettlement longleaf pine habitat in this region of the coastal plain. Agricultural lands now make up 34% of Bulloch/Candler's total land area, while urban land cover (9%) and open water (1%) make up the remaining 10% of this landscape (Table 2.1).

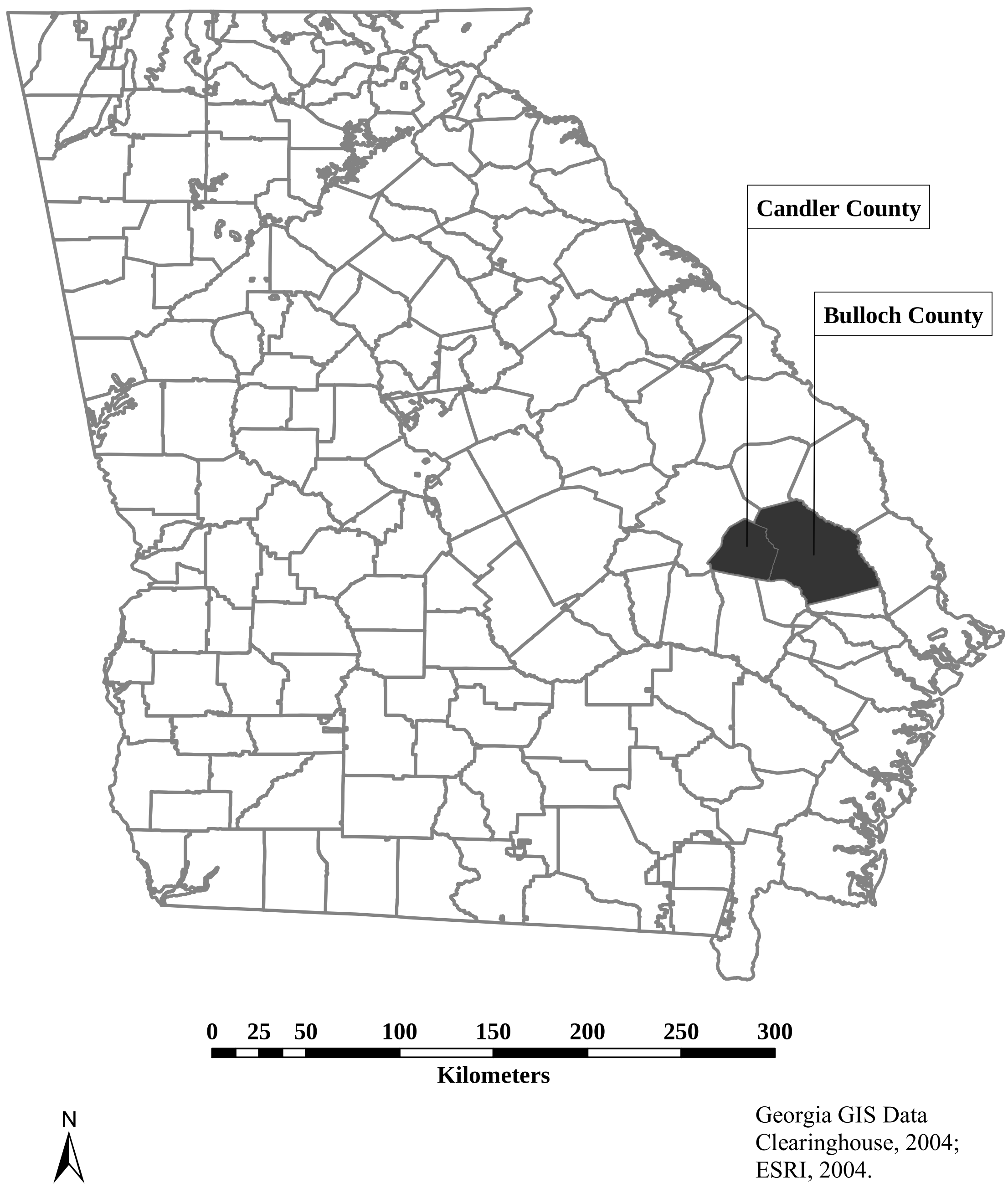

Figure 2.1. Location of Bulloch and Candler Counties, Georgia.

Table 2.1. Land cover characteristics for Bulloch and Candler Counties, Georgia (Boatright and Bachtel 2000).

	Bulloch/Candler Landscape	
Land Cover	240,788 ha	
	Area (ha)	**% of Total Area**
Forest Land	135,692	56
Longleaf/Slash	15,459	6
Loblolly/Shortleaf	36,098	15
Oak/Pine	24,969	10
Oak/Hickory	15,581	6
Oak/Gum/Cypress	40,469	17
Agricultural Land	74,064	31
CRP/WRP Land [a]	7,410	3
Urban Land	19,136	8
Open Water	3,134	1

[a] CRP = Conservation Reserve Program; WRP = Wetlands Reserve Program

Site Selection and Trapping. – I trapped small mammals (< 400 g) at 71 sites in ten qualitatively different habitat types from November 2001-December 2002 (Fig. 2.2, 2.3). Sites were selected subjectively to maximize the range of habitats sampled and included agricultural field, bottomland hardwood, clear-cut, longleaf pine-wiregrass, old field, orchard, pine flatwoods, pine plantation, sandhills, and upland hardwood. Site habitat types were characterized based on criteria described in Table 2.2.

I trapped small mammals with Sherman live traps, Victor snap traps, and pitfall traps, all of which are recognized as accepted trapping techniques by the American Society of Mammalogists (1998). Live traps were baited with black oil sunflower seeds; snap traps were baited with dry roasted peanuts and peanut butter. I constructed pitfall traps from #10 tin cans buried at ground level and filled partially with water.

At each site, I set up two parallel transects spaced 20 m apart. Transect lengths varied with size and accessibility of property, but did not exceed 200 m. Trap stations were established at 20-m intervals on each transect and consisted of two live traps on the ground, one on each side of the transect. If woody vegetation was present, every other trap station included one snap trap placed in a tree/shrub. Snap traps were fastened to woody vegetation with light gauge steel wire at heights ranging from 1.5 – 2.5 m. All live traps and snap traps were positioned within a 2-m radius of the trap station center (Fig. 2.4). Traps at each station were placed at locations selected for maximum trap success (alongside fallen logs or in the paths of small mammal runs). Pitfall trap stations positioned alongside fallen logs consisted of four pitfalls (two/side; one on each end of the fallen log), while stations that used small mammal runs consisted of no more than two pitfalls. Each trap site was active for an average of six nights, and traps were checked in

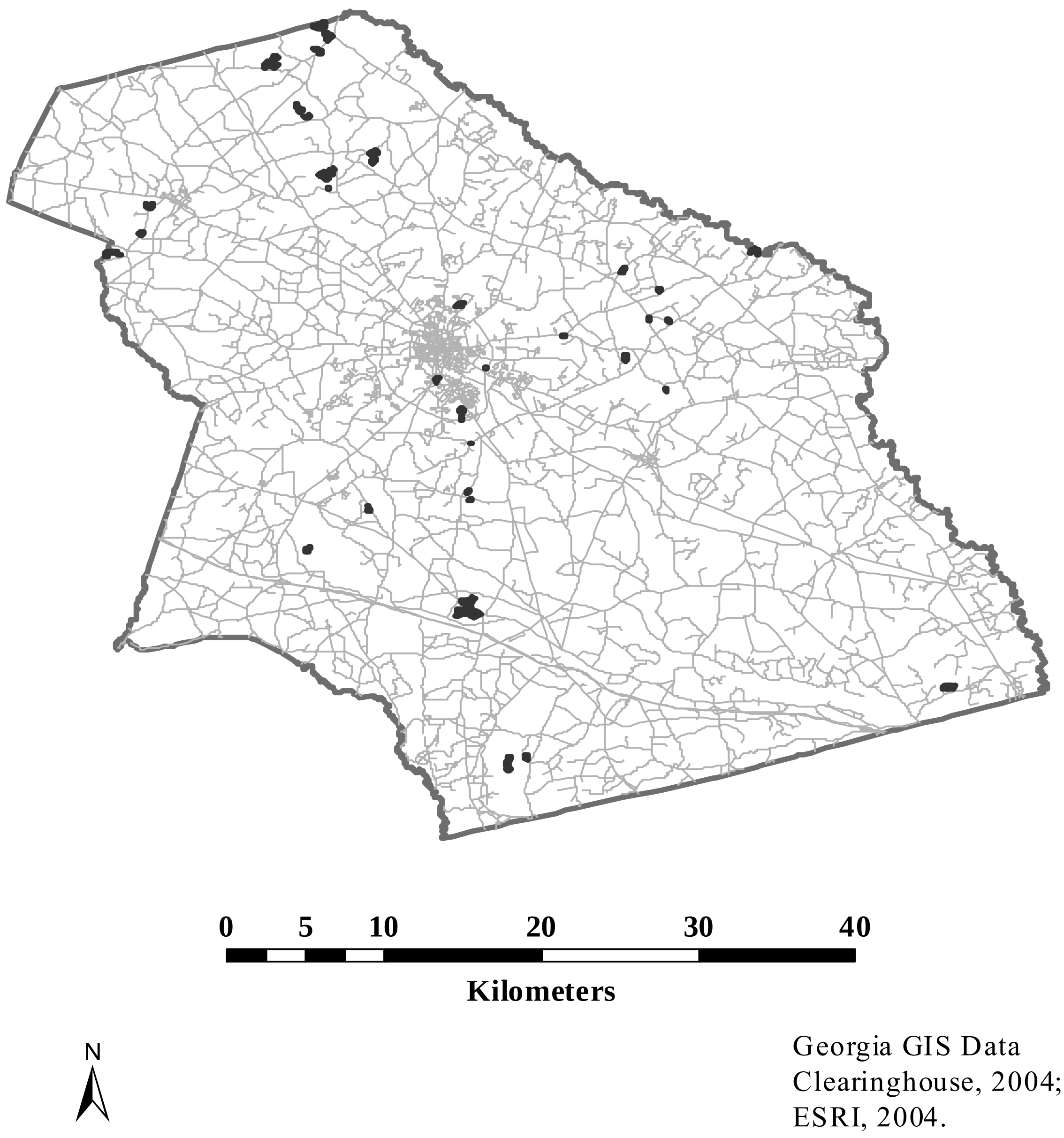

Figure 2.2. Location of sixty-nine small mammal trap sites used during this study in Bulloch County, Georgia.

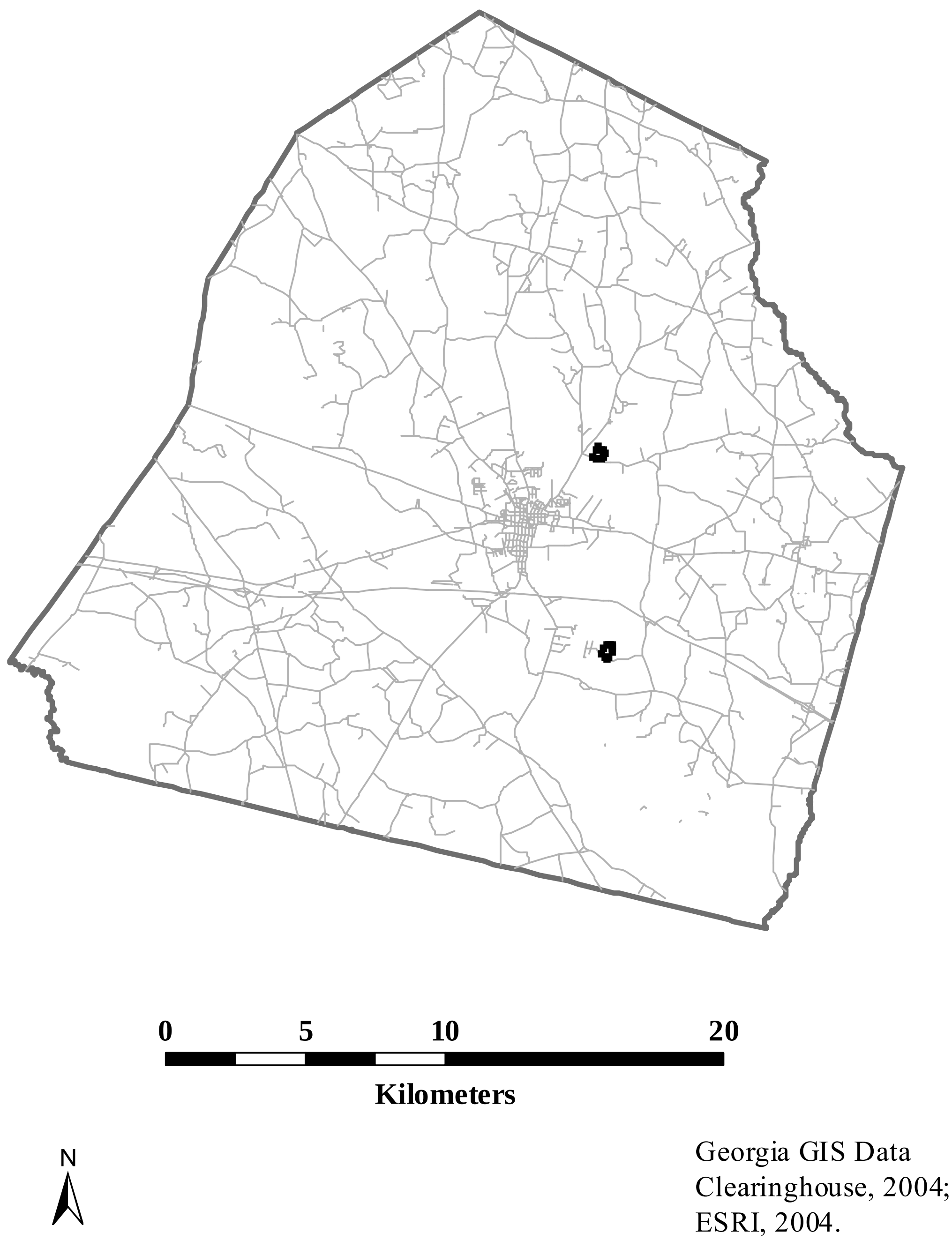

Figure 2.3. Location of two small mammal trap sites used during this study in Candler County, Georgia.

Table 2.2. Habitat classifications for small mammal trap sites in Bulloch and Candler Counties, Georgia (Wharton 1978, Martin et al. 1993a and b, Messina and Conner 1998).

Community	Description
Agricultural Field	An area of open land on which some form of cash crop is being grown. Usually a large monoculture and may be uniform or broadcast. Soil types vary and may be tilled or no-till. **Herb Layer:** *Amaranthus spinosus*, *Ambrosia* sp., *Cenchrus longispinus*, *Croton* sp., *Digitaria* sp., *Polygonum* sp., *Rumex* sp., *Sida spinosa*, *Sorghum halepense*.
Bottomland Hardwood	A low-lying, closed-canopy forest community of broadleaf deciduous trees with either a dense understory of shrubs and little ground cover, or an open understory and ground cover of ferns, herbs and grasses. Soils are generally a mixture of clay and organic materials and are inundated or saturated by surface or groundwater periodically during the growing season. Bottomland hardwoods include floodplain forests associated with alluvial rivers, hardwood flatlands bordering non-alluvial streams and scattered low spots in basins and depressions that are rarely inundated. **Trees:** *Acer rubrum*, *Aralia spinosa*, *Betula nigra*, *Carpinus caroliniana*, *Carya aquatica*, *C. ovata*, *Fraxinus caroliniana*, *Ilex opaca*, *Liquidambar styraciflua*, *Liriodendron tulipifera*, *Magnolia grandiflora*, *M. virginiana*, *Nyssa aquatica*, *N. sylvatica*, *Pinus elliottii*, *P. glabra*, *Quercus falcata* var. *pagodifolia*, *Q. laurifolia*, *Q. lyrata*, *Q. michauxii*, *Q. nigra*, *Taxodium ascendens*, *T. distichum*. **Shrubs/Woody Vines:** *Alnus serrulata*, *Ampelopsis arborea*, *Arundinaria gigantea*, *Campsis radicans*, *Cephalanthus occidentalis*, *Clethra alnifolia*, *Cliftonia monophylla*, *Cyrilla racemiflora*, *Ilex coriaceae*, *I. decidua*, *Myrica cerifera*, *Parthenocissus quinquefolia*, *Rhododendron canescens*, *Sabal minor*, *Sambucus canadensis*, *Smilax laurifolia*, *S. walteri*, *Toxicodendron radicans*, *Viburnum* sp., *Vitis* sp. **Herb Layer:** *Athyrium asplenioides*, *Boehmeria cylindrica*, *Carex* sp., *Mitchella repens*, *Saururus cernuus*, *Woodwardia areolata*.

Table 2.2. (Continued)

Community	Description
Clearcut	A previously forested community in which all or most trees have been removed and all the growing space becomes available for new plants, leading to the establishment of an even aged stand. Vegetation is largely components of the natural communities, but also will vary with stages of succession.
Longleaf Pine-Wiregrass	An upland pine forest community occurring on rolling topography and typified by an open overstory of longleaf pine and a ground cover of perennial grasses (primarily wiregrass) and forbs interspersed with deciduous oaks. Without fire, hardwoods are more predominant. Soils are well-drained fine sandy loams that are often low in organic content, light colored, and acidic with heavy clay subsoil below a sandy surface. **Trees:** *Pinus palustris*, *Quercus falcata*, *Q. incana*, *Q. laevis*, *Q. stellata*. **Shrubs/Woody Vines:** *Cornus florida*, *Crataegus flava*, *C. uniflora*, *Chrysobalanus oblongifolius*, *Diospyros virginiana*, *Gaylusaccia dumosa*, *Osmanthus americanus*, *Prunus serotina*, *Smilax* sp., *Toxicodendron radicans*, *Vitis rotundifolia*. **Herb Layer:** *Aristida stricta*, *Andropogon sp*., *Asclepias tomentosa*, *A. tuberosa*, *Baptisia* sp., *Clematis reticulata*, *Clitoria* sp., *Cnidoscolus stimulosus*, *Desmodium* sp., *Dyschoriste oblongifolius*, *Mimosa quadrivalvis*, *Pteridium aqualinum*, *Rhynchosia reniformis*, *Scutellaria multiglandulosa*, *Stillingia sylvatica*, *Tephrosia virginiana*, *Zornia bracteata*.
Old Field	Abandoned cropland and/or improved pastures in various stages of early succession. Plant species most likely to colonize such places are "weedy" species (exotics and other species that are successful in areas modified by human activity). However, many species are also components of the natural communities. **Trees:** *Liquidambar styraciflua*, *Diospyros virginiana*, *Juniperus virginiana*, *Pinus taeda*, *Sassafras albidum*.

Table 2.2. (Continued)

Community	Description
Old Field (cont.)	**Shrubs/Woody Vines:** *Baccharis halimifolia*, *Lonicera japonica*, *Prunus angustifolia*, *Rhus* sp., *Rubus* sp. **Herb Layer:** *Amaranthus* sp., *Ambrosia* sp., *Andropogon* sp., *Cassia* sp., *Croton* sp., *Cynodon dactylon*, *Digitaria* sp., *Eupatorium* sp., *Helianthus* sp., *Ipomoea* sp., *Panicum* sp., *Paspalum* sp., *Rumex* sp., *Sida spinosa*, *Solidago* sp., *Verbena* sp.
Orchard	An area consisting of planted fruit or nut trees and characterized by a uniform appearance. **Trees:** *Carya illinoensis* **Herb Layer:** *Allium* vineale, *Ambrosia* sp., *Andropogon* sp., *Cenchrus longispinus*, *Cynodon dactylon*, *Cyperus esculentus*, *Digitaria* sp., *Eupatorium* sp., *Setaria* sp., *Solanum* sp. (The herb layer will consist of many of the same "weedy species" associated with agricultural fields and old fields).
Pine Flatwoods	Mesic pine forest communities that range from relatively open forests of scattered pines with little understory to dense pine stands with a rather dense undergrowth of saw palmetto and ericaceous (heath) plants. Pine flatwoods are characterized by low, flat topography and relatively poorly drained, acidic, sandy soils sometimes underlain by an organic horizon and a clay hardpan. **Trees:** *Pinus elliottii*, *P. palustris*, *P. serotina* Infrequent species: *Acer rubrum*, *Liquidambar styraciflua*, *Persea borbonia*, *Quercus nigra*, *Q. virginiana*. **Shrubs/Woody Vines:** *Clethra alnifolia*, *Gaylusaccia dumosa*, *G. frondosa, Hypericum sp.*, *Ilex glabra*, *I. coreacea*, *Lyonia ferruginea*, *L. lucida*, *L. mariana*, *Myrica cerifera*, *Vaccinium myrsinites*, *Serenoa repens*, *Smilax* sp. **Herb Layer:** *Aristida stricta*, *Andropogon sp*., *Ctenium aromaticum*, *Elephatopus tomentosus*, *Eryngium yuccifolium*, *Polygala sp*., *Rhexia sp*., *Sabatia sp*., *Sarracenia sp*., *Syngonanthus flavidulus*, *Xyris caroliniana*.

Table 2.2. (Continued)

Community	Description
Pine Plantation	An almost exclusively pine forest artificially generated by planting seedling stock or seeds. Stands are characterized by high numbers of trees per hectare and are often uniform in appearance. Secondary vegetation often varies with stages of growth, becoming less frequent with stand age. **Trees**: *Pinus elliottii*, *P. taeda* Infrequent species: *Acer rubrum*, *Liquidambar styraciflua*, *Pinus palustris*, *Quercus* sp. **Shrubs/Woody Vines and Herb Layer:** These are most often components of the natural community, but may also consist of various invasive species (e.g. *Cynodon dactylon*, *Ligustrum sinense*, *Lonicera japonica*, *Pueraria* spp.
Sandhill	An extremely dry, open-canopy forest community of deciduous scrub oaks, with or without longleaf pine overstory. Shrubs and herbaceous vegetation may be sparse and areas of bare/exposed earth frequent. Sandhill communities occur on top of sand ridges often parallel to and east of major streams in the Coastal Plain, especially on the Tifton Plateau. Soils are deep, nutrient poor, well-drained sands that range from completely sandy to a sandy and coarse sandy loam. **Trees:** *Pinus palustris*, *Quercus incana*, *Q. laevis*, *Q. stellata*, *Q. stellata* var. *margaretta*. **Shrubs:** *Asimina parviflora*, *Chrysobalanus oblongifolius*, *Crataegus flava*, *Crataegus uniflora*, *Diospyros virginiana*, *Rhus copallina*, *Vaccinium arboreum*, *Vaccinium stamineum*, *Vaccinim tenellum*. **Herb Layer:** *Amsonia ciliate, Andropogon* sp., *Aristida stricta*, *Asclepias hemistrata.*, *Baptisia* sp., *Bonamia* sp., *Chrysopsis gossypina*, *Cladonia* sp., *Eriogonum tomentosum*, *Liatris* sp., *Lupinus* sp., *Nolina brittoniana*, *Opuntia humifusa*, *Panicum* sp., *Pityospsis graminifolia*, *Pteridium aqualinum*, *Yucca filamentosa*.

Table 2.2. (Continued)

Community	Description
Upland Hardwood	A closed-canopy forest community largely consisting of broadleaf deciduous trees and occurring on level or rolling topography. Soils are generally sandy clays with substantial organic components. The closed-canopy and presence of a substantial leaf litter help conserve soil moisture and create somewhat mesic conditions. However, nutrient poor, xeric variations occur as well. **Trees:** *Carya tomentosa*, *C. glabra*, *Cornus floridana*, *Fagus grandifolia*, *Liquidambar styraciflua*, *Nyssa sylvatica*, *Osmanthus americanus*, *Pinus echinata*, *P. palustris*, *P. taeda*, *Prunus serotina*, *Quercus alba*, *Q. falcata*, *Q. nigra*, *Q. stellata*. **Shrubs/Woody Vines:** *Ascyrum hypericoides*, *Bignonia capreolata*, *Callicarpa americana*, *Castanea floridana*, *Gelsemium sempervirens*, *Rhamnus caroliniana*, *Smilax glauca*, *S. rotundifolia*, *Symplocos tinctoria*, *Vaccinium* sp. **Herb Layer:** *Elephantopus sp.*, *Scutellaria integrifolia*, *Trillium* sp., *Viola* sp.

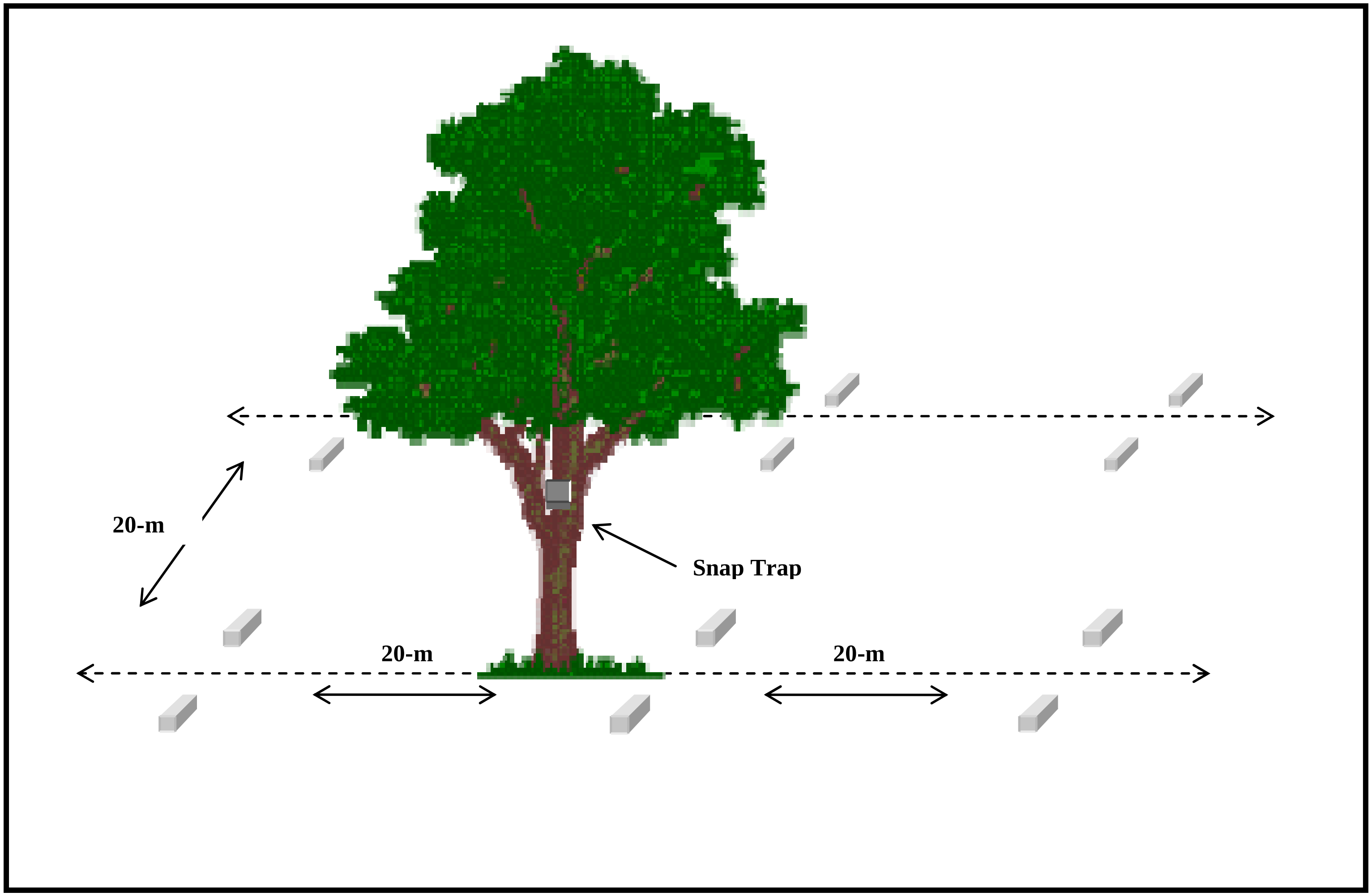

Figure 2.4. Small mammal trap site layout with two parallel transects 20-m apart, and trap stations established at 20-m intervals on each transect.

the mornings over six consecutive days following the set date. I sampled each site only once. Captured animals were identified to species, sexed, and weighed with a Pesola hanging scale to the nearest 0.5 g). Live mammals were released, while individuals captured in snap traps and/or pitfalls were retained for preparation as museum specimens. All trapping was conducted under Georgia Southern University Institutional Animal Care and Use Committee Research Protocol and Georgia Department of Natural Resources Scientific Collecting Permit No. 29-WMB-02-0.

Habitat Sampling. – Quantitative habitat analysis for capture and non-capture sites was conducted within 2 weeks of the time that each trap site was active. I measured habitat variables within a 10-m radius circular plot centered on the trap station. I quantified basal area (m^2/ha), percent canopy, percent vertical cover, stem density, species composition ($\geq$ 10-cm DBH; < 10-cm DBH and $\geq$ 1.5 m in height), and downed woody debris (DWD).

Percent canopy for each plot was quantified using a spherical densiometer. At plot center, canopy was quantified in each of the four cardinal directions resulting in average percent canopy cover for each plot. Percent vertical cover was quantified using a vegetation profile board (1.83-m high x 13.97-cm wide with six 30.48-cm alternating orange and white height intervals labeled 1-6 from bottom to top). The board was placed 10 m from plot center in each of the four cardinal directions and visual obstruction at each height interval estimated to the nearest 10%, resulting in a plot average of vertical cover for each of the six height intervals. Basal area was quantified from plot center using a 10-factor prism; stem density and species composition were quantified within 100 m^2 of plot center, as recommended by Brower et al. (1990). DWD within the plot was counted and classified according to diameter (>10 cm) and length (> 1 m). Percent ground cover was quantified using a 0.71-m x 1.41-m Daubenmire frame to establish 1-m^2 subplots within the plot (Brower et al. 1990). The frame was placed on the ground at plot center (north/south or east/west) and four random locations on a 10-m transect in each of the four cardinal directions. Within each subplot, I estimated percent cover of grasses, sedges, forbs, woody stems ($\leq$ 0.5 m in height), woody vines, herbaceous vines, ferns, other (mosses, lichens, fungi), bare ground and litter, and obtained an average for each ground cover class per sample plot. Average litter depth (cm) for each sample plot was quantified by using a metric ruler to measure loose litter depth at the center of each 1-m^2 subplot.

Land Cover Associations. – Land cover analysis for each site was conducted using ArcGIS 8.X (ESRI 2004). From the Georgia Gap Analysis Program (GAP) on the Georgia GIS Data Clearinghouse website, I downloaded a Classified Thematic Mapper image with 30-m spatial resolution. This image consisted of eleven land cover classes: clearcut/sparse, cultivated/exposed earth, emergent wetland, evergreen forest, forested wetland, hardwood forest, high density urban, low density urban, mixed forest, open water and pasture. The spatial analyst extension and a mask of Bulloch and Candler Counties were used to extract land cover classes for only these two counties.

Using 1-m resolution digital orthophotographs from the Georgia GIS Data Clearinghouse, I created a 500-m radius buffer from the center of each trap site. I used the newly created buffers to clip the land cover classes for each site and then removed the site itself using the erase command. This resulted in leaving only the surrounding land cover for each trap site (Fig. 2.5). I generated the statistics by exporting data for each trap site as a data base file. I opened each site data base file in Microsoft Excel, summarized the number of pixels (1 pixel = 900 m^2) for each land cover class and converted pixels to percent land cover.

Statistical Analysis. – Non-parametric tests were used because, in most cases, assumptions of normality could not be met. A Kruskal-Wallis test was used to test for differences in habitat variables and associated land cover classes between small mammal species, and a Mann-Whitney test was used to test for differences between capture and non-capture sites. I used a t-test to test for differences between land cover classes associated with each species and the amount of available land cover types at the landscape scale. Finally, I used principal components analysis (PCA) to describe overall habitat variation between small mammal species. All statistical analyses were performed using JMP Statistical Discovery Software (SAS Institute Inc. 2001).

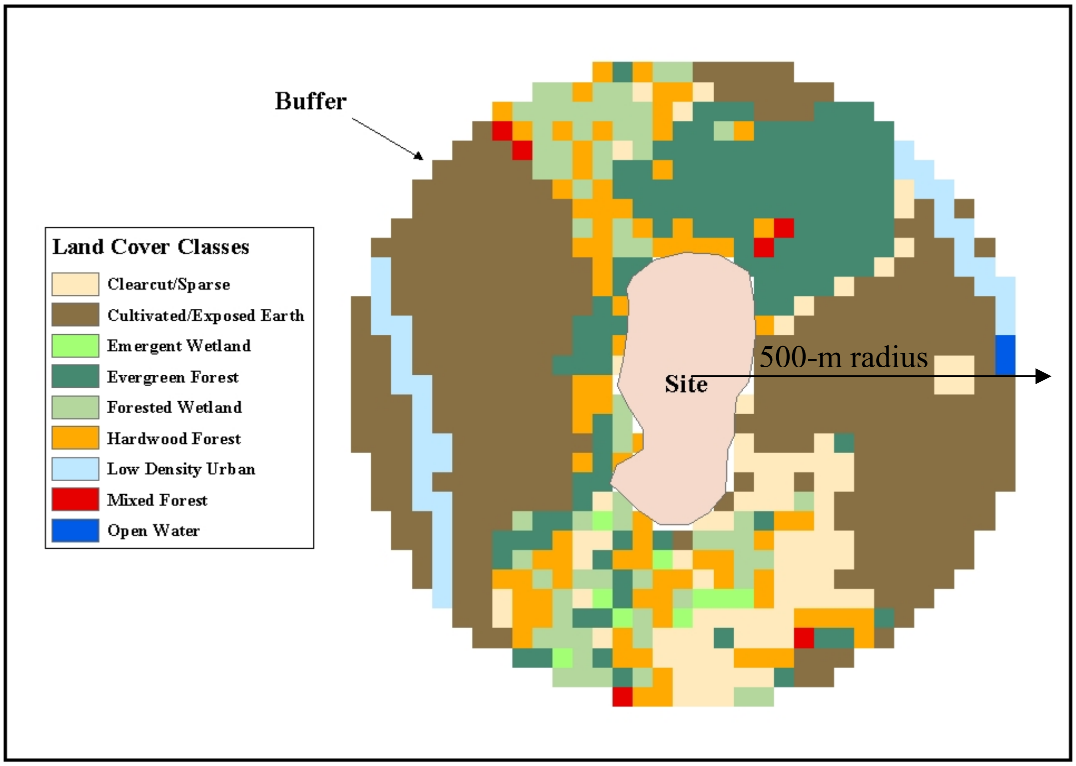

Figure 2.5. Example of a small mammal trap site with 500-m radius buffer of surrounding land cover.

CHAPTER 3

RESULTS

I set 1,312 traps for an average of 5.9 nights per trap site, resulting in 7,465 trap nights. I captured a total of 398 individuals of 10 different species of small mammals (Table 3.1). *Peromyscus gossypinus* (32% of individuals) and *Sigmodon hispidus* (22%) were captured most often, while each species of shrew (2%) and *Reithrodontomys humulis* (< 1%) were captured rarely. Relative species abundance per trapping effort was highest for old field and longleaf pine-wiregrass habitats. Pine plantation and upland hardwood habitats yielded the lowest relative abundance per trapping effort (Table 3.1).

Habitat Comparisons. – Overall, capture site habitats showed significant differences in structural components. Among habitat types, wooded habitats demonstrated differences in all categories of habitat structure (Table 3.2), while open habitats demonstrated fewer structural differences in habitat. Open habitats differed in percent canopy cover, basal area, density of small diameter stems, vertical cover (VC), ground cover forms, and bare ground (Table 3.3). In comparing open habitats, agricultural fields were associated with higher mean canopy cover and basal area, while old fields were associated with higher mean density of small diameter stems. Also, agricultural fields had higher mean VC2, sedge and forb ground cover, and bare ground. Old fields had higher mean grass and woody vine ground cover (Appendix A).

Species Habitat Associations. – Overall, statistical tests show differences among species associations with habitat variables (Tables 3.4 and 3.5). *Neotoma floridana*,

Table 3.1. Number of individuals captured and relative abundance (captures/100 trap nights) of small mammals among ten different habitat types in Bulloch and Candler Counties, Georgia.

Species	**Old Field**		**Clearcut**		**Agricultural Field**		**Orchard**		**Sandhill**		**Pine Plantation**	
Blarina carolinensis	1	0.14	0	0	0	0	0	0	1	0.23	1	0.08
Cryptotis parva	6	0.82	0	0	1	0.06	1	0.21	0	0	1	0.08
Mus musculus	26	3.56	0	0	31	1.87	11	2.32	0	0	3	0.25
Neotoma floridana	0	0	0	0	0	0	0	0	0	0	0	0
Ochrotomys nuttalli	0	0	0	0	0	0	0	0	2	0.46	4	0.33
Peromyscus gossypinus	0	0	4	5.71	3	0.18	0	0	4	0.93	20	1.66
Peromyscus polionotus	1	0.14	0	0	31	1.87	0	0	10	2.31	4	0.33
Reithrodontomys humulis	1	0.14	0	0	0	0	1	0.21	0	0	0	0
Sigmodon hispidus	46	6.3	1	1.43	15	0.91	12	2.53	0	0	8	0.66
Sorex longirostris	0	0	0	0	0	0	0	0	0	0	0	0
All Species	81	11.10	5	7.14	81	4.90	25	5.26	17	3.94	41	3.40
Trap Nights	629		70		1652		475		432		1309	

[a] Left column under each heading represents number of individuals captured.

[b] Right column under each heading represents species relative abundances (captures/100 trap nights).

Table 3.1. (Continued)

Species	**Pine Flatwoods**		**Longleaf Wiregrass**		**Upland Hardwood**		**Bottomland Hardwood**		**Total**
Blarina carolinensis	0	0	3	0.35	1	0.11	1	0.13	8
Cryptotis parva	0	0	0	0	0	0	0	0	9
Mus musculus	0	0	0	0	0	0	0	0	71
Neotoma floridana	0	0	0	0	2	0.21	10	1.3	12
Ochrotomys nuttalli	0	0	4	0.47	4	0.43	2	0.26	16
Peromyscus gossypinus	20	5.7	45	5.31	16	1.7	16	2.08	128
Peromyscus polionotus	0	0	11	1.3	0	0	0	0	57
Reithrodontomys humulis	0	0	0	0	0	0	0	0	2
Sigmodon hispidus	0	0	4	0.47	1	0.11	0	0	87
Sorex longirostris	0	0	6	0.71	1	0.11	1	0.13	8
All Species	20	5.75	73	8.61	25	2.66	30	3.91	398
Trap Nights	348		848		941		761		7,465

Table 3.2. Differences in quantified habitat variables among wooded habitat types of Bulloch and Candler Counties, Georgia.

	Kruskal-Wallis test (df = 6)	
Habitat Variable	***X^2***	***P***
Basal Area (m^2/ha)	72.78	<.0001
% Canopy	43.48	<.0001
Average DBH (cm)	59.84	<.0001
Stem Density (≥ 10-cm DBH)	35.76	<.0001
Stem Density (< 10-cm DBH)	41.27	<.0001
% Vertical Cover 1	21.46	.0015
% Vertical Cover 2	21.24	.0017
% Vertical Cover 3	35.05	<.0001
% Vertical Cover 4	38.84	<.0001
% Vertical Cover 5	29.04	<.0001
% Vertical Cover 6	36.67	<.0001
% Grass	70.58	<.0001
% Sedge	37.70	<.0001
% Forbs	58.85	<.0001
% Woody Stems	58.85	<.0001
% Woody Vines	26.93	.0001
% Herbaceous Vines	32.40	<.0001
% Fern	29.87	<.0001
% Other	29.21	.0001
% Bare Ground	20.93	.0019
% Litter	45.26	<.0001
Litter Depth (cm)	30.38	<.0001

Table 3.3. Differences in quantified habitat variables among open habitat types of Bulloch and Candler Counties, Georgia.

	Kruskal-Wallis test (df = 2)	
Habitat Variable	***X^2***	***P***
Basal Area (m^2/ha)	5.65	.0175
% Canopy	7.75	.0054
Average DBH (cm) [a]	-----	-----
Stem Density (≥ 10-cm DBH)	2.42	.1202
Stem Density (< 10-cm DBH)	5.32	.0211
% Vertical Cover 1	2.29	.1298
% Vertical Cover 2	4.97	.0258
% Vertical Cover 3	0.83	.3617
% Vertical Cover 4	0.03	.8677
% Vertical Cover 5	0.53	.4648
% Vertical Cover 6	0.02	.8786
% Grass	31.08	<.0001
% Sedge	12.43	.0004
% Forbs	9.52	.0020
% Woody Stems	1.40	.2361
% Woody Vines	4.23	.0398
% Herbaceous Vines	2.01	.1561
% Fern	3.70	.0543
% Other	2.65	.1036
% Bare Ground	25.17	<.0001
% Litter	3.76	.0525
Litter Depth (cm)	2.48	.1154

[a] Stems < 10-cm DBH were not quantified.

Table 3.4. Species differences in habitat associations among small mammal capture sites in Bulloch and Candler Counties, Georgia. See Appendix B for descriptive statistics.

	Kruskal-Wallis test (df = 8)	
Habitat Variable	X^2	P
Basal Area (m^2/ha)	101.24	<.0001
% Canopy Cover	95.38	<.0001
Average DBH (cm)	76.24	<.0001
Stem Density (≥ 10-cm DBH)	66.25	<.0001
Stem Density (< 10-cm DBH)	85.57	<.0001
% Vertical Cover 1	52.66	<.0001
% Vertical Cover 2	23.23	.0031
% Vertical Cover 3	11.28	.1862
% Vertical Cover 4	30.55	.0002
% Vertical Cover 5	57.22	<.0001
% Vertical Cover 6	65.68	<.0001
% Grass	89.01	<.0001
% Sedge	34.83	<.0001
% Forbs	103.26	<.0001
% Woody Stems	54.38	<.0001
% Woody Vines	48.41	<.0001
% Herbaceous Vines	28.06	.0005
% Fern	17.48	.0255
% Fungi/Lichen	17.50	.0253
% Bare Ground	72.83	<.0001
% Litter	109.79	<.0001
Litter Depth (cm)	91.43	<.0001

Table 3.5. Results of the principal components analysis of habitat variables associated with small mammal capture sites in Bulloch and Candler Counties, Georgia.

	Factor Loadings	
Habitat Variable	**PC 1**	**PC 2**
% Canopy	0.82	0.27
Basal Area (m^2/ha)	0.82	0.17
Stem Density (≥ 10-cm DBH)	0.74	0.24
Stem Density (< 10-cm DBH)	0.53	0.54
Average DBH (cm)	0.76	-0.01
Vertical Cover 1	-0.69	0.16
Vertical Cover 2	-0.61	0.63
Vertical Cover 3	-0.34	0.82
Vertical Cover 4	0.06	0.92
Vertical Cover 5	0.30	0.83
Vertical Cover 6	0.37	0.79
% Grass	-0.53	-0.39
% Sedge	-0.47	-0.04
% Forbs	-0.74	-0.08
% Woody Stems	0.37	0.27
% Woody Vines	0.10	0.25
% Herbaceous Vines	-0.16	-0.30
% Fern	0.19	0.10
% Fungi/Lichen	0.12	0.02
% Bare Ground	-0.56	-0.32
% Litter	0.87	0.34
Litter Depth (cm)	0.69	0.33
Eigen Value	7.80	3.44
Percent Variance Explained	35.42	15.64
Cumulative Percent	35.42	51.07

PC 1: X^2 = 104.49, df = 8, P = <.0001

PC 2: F = 5.41, df = 8, 165, P = <.0001

Ochrotomys nuttalli, *Peromyscus gossypinus*, and *Sorex longirostris* were largely associated with closed canopy, mature forests with high basal area, high densities of small diameter stems, and greater amounts of mid to high interval VC. *Cryptotis parva*, *Mus musculus*, *Peromyscus polionotus*, and *Sigmodon hispidus* showed greater associations with open canopy habitats with higher amounts of herbaceous ground cover and low interval vertical cover (Appendix B). In comparison to other species, *Blarina carolinensis* was intermediate in its association with habitats, using both of the above habitat types.

The first two components of the principal components analysis (PCA) explained more than 50% of the variation in the twenty-two habitat variables quantified (Table 3.5), and yielded interpretable dimensions of habitat variation. The first component accounted for 35.42% of the total variance and described an axis of increasing tree height, basal area and canopy cover, and decreasing ground cover. High values on the first component correspond to habitat indicative of mature forests with mid to high percentages of canopy coverage. The second component accounted for 15.64% of the total variance. As was the case with the first component, more than half of the habitat variables also were positively correlated with this component. However, the highest correlations on the second component were with small diameter stems with low to high vertical cover. The higher values on this component correspond with more open habitats with low canopy cover and greater amounts of vertical cover.

The habitat associations of each species were plotted on the first two principal components (PC) and based on Tukey-Kramer a posteriori tests, reveal two largely non-overlapping species groups defined by PC 1: those associated with more open-canopy habitats and those associated with closed-canopy, mature forest habitats (Fig. 3.1). *N. floridana*, *O. nuttalli*, *P. gossypinus*, and *S. longirostris* were all associated with closed-canopy, mature forests, while *C. parva*, *M. musculus*, *P. polionotus*, and *S. hispidus* were all associated with open-canopy habitats. The figure also reveals that some species are more specialized in their habitat selection, whereas others use more variable habitats. Based on F-tests on the variances of PC 1, *N. floridana, O. nuttalli*, and *S. longirostris* all show lower variability in their habitat selection (Table 3.6).

Species using open-canopy habitats demonstrated greater numbers of significant differences in their habitat associations. These species differed in their associations with VC1 ($X^2 = 8.11$, df = 3, P = .0438) and VC2 (F = 3.80, df = 3, 73, P = .0137) and ground cover components of grass (F = 3.66, df = 3, 73, P = .0162), woody stems ($X^2 = 9.28$, df = 3, P = .0258), woody vines ($X^2 = 13.80$, df = 3, P = .0032), herbaceous vines ($X^2 =$ 7.88, df = 3, P = .0485), and bare ground ($X^2 = 22.45$, df = 3, P = .0001).P3, P = .0485). In comparison to other open habitat species, *C. parva* was associated with higher mean densities of small diameter stems, while *M. musculus* and *S. hispidus* were associated with higher mean VC1 and VC2. *C. parva* was also associated with more grasses and woody vines, while *M. musculus* was associated with more forbs. *P. polionotus* was associated with more mean woody stems, herbaceous vines, and bare ground (Appendix B).

Species using closed-canopy, mature, wooded habitats demonstrated significant differences among themselves in their associations with canopy cover (F = 4.77, df = 3, 85, P =.0040) and density of small diameter stems (F = 3.55, df = 3, 85, P = .0177). *P. gossypinus* was associated with lower mean canopy cover, while *N. floridana* and

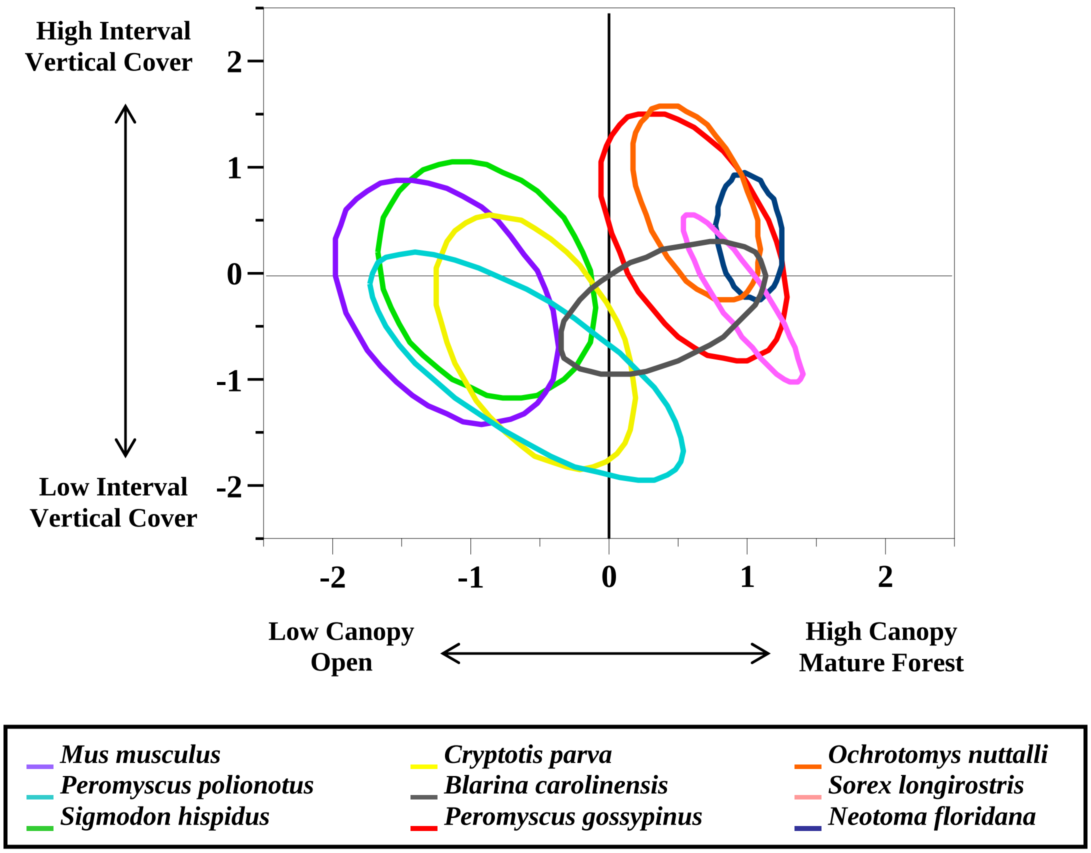

Figure 3.1. Small mammal habitat associations plotted on the first two principal components and circled with 50% confidence ellipses to show overlap and variability among species.

Table 3.6. Variations in small mammal habitat use in relation to habitat variables of the first two principal components.[a]

	Variances	
Species	**PC 1**	**PC 2**
Blarina carolinensis	0.3973	0.2838
Cryptotis parva	0.3724	1.0249
Mus musculus	0.4700	0.9480
Neotoma floridana	0.0408	0.2535
Ochrotomys nuttalli	0.1505	0.6055
Peromyscus gossypinus	0.3235	0.9904
Peromyscus polionotus	0.9301	0.8238
Sigmodon hispidus	0.4424	0.8863
Sorex longirostris	0.1350	0.4514

[a] *Reithrodontomys humulis* excluded due to n = 2.

O. nuttalli were associated with greater mean densities of small diameter stems. *S. longirostris* was associated with the lowest mean density of small diameter stems. Ground cover components associated with each of these species were largely woody stems, woody vines, and leaf litter (Appendix B).

Capture versus Non-Capture Trap Stations. **–** Within each habitat, small mammals were selective in their habitat use. Habitat variables associated with capture and non-capture trap stations within each habitat type differed in structural components (Table 3.7). Among open habitat types, agricultural field capture stations demonstrated more canopy cover, VC3-VC6, and litter, while non-capture stations had more bare ground. Old field capture stations were higher in VC5, while non-capture stations had greater basal area and more bare ground (Appendix C).

Among wooded habitat types, bottomland hardwoods, longleaf pine-wiregrass, pine flatwoods, and sandhills each showed fewer structural differences between capture and non-capture trap stations. Bottomland hardwood stations differed in VC2 and VC3 and woody stem ground cover. Longleaf pine-wiregrass stations differed in density of small diameter stems and woody stem ground cover while pine flatwoods stations differed in density of small diameter stems and VC2-VC4. Sandhill stations differed in forbs and other ground cover forms. In comparing structural differences for each of the above habitats, capture locations demonstrated higher quantities for each differing habitat variable. The exception is *other* ground cover forms in sandhill sites (Appendix C).

Wooded habitats demonstrating the greatest number of structural differences between capture and non-capture stations were orchards, pine plantations, and upland hardwoods. Orchard trap stations differed in canopy cover, densities of large diameter

Table 3.7. Habitat variables associated with small mammal capture and non-capture trap stations among different habitat types in Bulloch and Candler Counties, Georgia. Rows of values for each small mammal species are mean (± 1 SE).

	Old Field		**Clearcut [a]**		**Agricultural Field**	
Habitat Variable	**C**[b]	**NC**	**C**	**NC**	**C**	**NC**
% Canopy	1.2 (0.54)	3.6 (2.32)	5.9 (5.93)	18.0 (18.02)	11.6 (3.28)*	0.3 (0.28)*
% Basal Area (m^2/ha)	0.0 (0.00)*	0.7 (0.33)*	1.1 (1.1)	2.2 (0.00)	1.4 (0.58)	0.0 (0.00)
Stem Density (≥ 10-cm DBH)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.00 (0.00)	0.0 (0.00)
Stem Density (< 10-cm DBH)	0.14 (0.05)	6.0 (1.74)	0.32 (0.32)	1.0 (1.00)	0.03 (0.02)	0.0 (0.00)
Average DBH (≥ 10-cm)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
% Vertical Cover 1	85.4 (5.29)	86.3 (7.07)	98.7 (1.25)	81.3 (16.25)	94.1 (2.29)	82.5 (7.24)
% Vertical Cover 2	65.4 (7.11)	48.3 (9.33)	86.2 (13.75)	51.3 (21.25)	80.2 (5.95)	61.5 (12.44)
% Vertical Cover 3	48.1 (8.09)	30.5 (10.25)	60.0 (40.00)	13.8 (6.25)	58.1 (6.45)*	27.0 (9.41)*
% Vertical Cover 4	30.3 (6.14)	12.0 (4.52)	46.2 (41.20)	0.0 (0.00)	25.2 (4.59)*	4.75 (2.99)*
% Vertical Cover 5	16.1 (4.43)*	2.3 (1.73)*	43.7 (31.25)	0.0 (0.00)	11.8 (2.89)*	0.0 (0.00)*
% Vertical Cover 6	10.4 (3.80)	1.3 (1.00)	38.7 (31.25)	0.0 (0.00)	8.9 (2.18)*	0.0 (0.00)*
% Grass	49.8 (3.13)	49.3 (4.30)	19.5 (11.50)	15.5 (15.50)	15.8 (2.53)	11.4 (2.58)
% Sedge	0.4 (0.18)	0.1 (0.12)	0.0 (0.00)	0.0 (0.00)	1.3 (0.27)	1.8 (0.66)
% Forbs	15.1 (2.11)	10.2 (1.19)	3.6 (0.90)	2.3 (2.25)	38.7 (4.95)	30.6 (8.46)
% Woody Stems	5.1 (1.31)	1.9 (0.54)	16.7 (6.65)	8.4 (1.65)	7.0 (3.06)	16.0 (8.15)
% Woody Vines	5.9 (1.64)	5.5 (2.27)	16.2 (4.85)	10.5 (10.50)	1.6 (0.59)	0.4 (0.22)
% Herbaceous Vines	0.8 (0.28)	0.2 (0.20)	0.5 (0.50)	0.0 (0.00)	1.5 (0.37)	0.8 (0.66)
% Fern	0.1 (0.03)	0.0 (0.00)	2.0 (1.00)	3.0 (2.00)	0.0 (0.00)	0.0 (0.00)
% Other	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.2 (0.12)	0.4 (0.26)
% Bare Ground	6.7 (1.13)*	12.1 (2.42)*	10.4 (5.35)	15.0 (10.00)	22.3 (2.14)*	35.6 (2.91)*
% Litter	18.5 (1.88)	22.3 (3.52)	31.3 (3.75)	45.4 (17.90)	11.8 (2.38)*	2.8 (2.19)*
Litter Depth (cm)	1.2 (0.07)	1.2 (0.08)	2.5 (0.60)	2.7 (0.75)	0.9 (0.20)*	0.2 (0.15)*

[a] Clearcuts are excluded from statistical analysis because n = 2.
[b] **C** = capture site; **NC** = Non-capture site.
* = significant difference between habitat variables associated with capture and non-capture stations.

Table 3.7. (Continued)

	Orchard		Sandhill		Pine Plantation	
Habitat Variable	**C**	**NC**	**C**	**NC**	**C**	**NC**
% Canopy	38.1 (6.22)*	77.0 (2.02)*	45.9 (6.82)	52.6 (5.11)	51.0 (5.68)*	73.8 (6.34)*
% Basal Area (m^2/ha)	5.4 (1.12)	6.8 (1.11)	13.4 (1.99)	13.0 (1.61)	16.0 (2.85)	24.0 (3.73)
Stem Density (≥ 10-cm DBH)	0.0 (0.00)*	0.5 (0.19)*	0.02 (0.00)	2.4 (0.58)	0.05 (0.01)*	7.4 (1.36)*
Stem Density (< 10-cm DBH)	0.03 (0.01)	4.3 (1.54)	0.26 (0.06)	15.5 (3.21)	0.60 (0.09)	33.3 (11.20)
Average DBH (≥ 10-cm)	0.0 (0.00)	15.9 (10.41)	15.8 (3.27)	15.7 (2.76)	15.7 (2.83)	18.1 (1.88)
% Vertical Cover 1	86.3 (2.68)	78.8 (6.50)	48.5 (6.34)	43.8 (8.96)	61.1 (7.52)	41.0 (11.94)
% Vertical Cover 2	57.5 (5.20)	40.0 (6.75)	22.3 (5.04)	33.0 (5.66)	51.8 (6.77)*	25.0 (8.90)*
% Vertical Cover 3	19.3 (6.11)	16.3 (8.03)	17.3 (4.06)	23.0 (4.06)	50.5 (5.51)*	23.5 (8.73)*
% Vertical Cover 4	10.2 (5.08)	8.8 (5.20)	16.9 (5.60)	25.8 (6.33)	48.5 (5.25)*	23.0 (5.81)*
% Vertical Cover 5	12.5 (3.57)	5.6 (3.68)	21.0 (6.77)	33.5 (6.23)	46.4 (5.56)	29.3 (5.66)*
% Vertical Cover 6	6.8 (2.52)	1.9 (1.23)	20.2 (6.72)	28.0 (5.32)	48.4 (5.23)*	23.5 (6.03)*
% Grass	58.2 (5.93)*	29.5 (4.09)*	24.5 (4.28)	12.4 (1.70)	16.3 (3.96)*	4.2 (1.97)*
% Sedge	1.5 (0.58)*	3.3 (0.44)*	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
% Forbs	10.4 (1.80)	10.6 (1.55)	6.0 (0.78)*	2.5 (1.32)*	4.3 (1.05)	3.3 (1.05)
% Woody Stems	4.3 (1.27)	4.8 (1.95)	11.3 (1.14)	8.2 (1.27)	13.3 (1.68)	8.9 (2.83)
% Woody Vines	5.7 (2.39)	5.6 (2.31)	0.5 (0.20)	0.4 (0.17)	5.6 (1.14)	6.6 (2.75)
% Herbaceous Vines	0.6 (0.30)	0.3 (0.16)	2.2 (0.93)	1.9 (0.60)	0.1 (0.05)*	0.4 (0.18)*
% Fern	0.0 (0.00)	0.0 (0.00)	0.8 (0.60)	1.4 (1.00)	0.7 (0.28)	0.3 (0.25)
% Other	0.0 (0.00)	0.1 (0.08)	0.1 (0.08)*	0.9 (0.47)*	0.1 (0.05)	0.2 (0.11)
% Bare Ground	2.7 (1.25)	4.7 (1.48)	14.2 (2.98)	16.7 (4.34)	3.6 (1.13)	2.9 (1.99)
% Litter	16.6 (1.77)*	41.3 (4.39)*	40.5 (6.58)	55.6 (7.40)	55.7 (4.77)	63.3 (9.06)
Litter Depth (cm)	1.3 (0.14)*	2.5 (0.24)*	2.6 (0.36)	2.7 (0.36)	2.4 (0.31)	2.1 (0.28)

Table 3.7. (Continued)

Habitat Variable	Pine Flatwoods		Longleaf Pine-Wiregrass		Upland Hardwood	
	C	NC	C	NC	C	NC
% Canopy	59.6 (4.84)	70.7 (13.81)	60.8 (3.01)	62.6 (4.87)	76.5 (3.69)	79.5 (3.35)
% Basal Area (m²/ha)	32.8 (2.97)	30.0 (7.17)	21.1 (1.45)	20.2 (3.65)	30.9 (2.62)*	21.1 (2.26)*
Stem Density (≥ 10-cm DBH)	0.05 (0.01)	5.5 (0.87)	0.03 (0.00)	3.7 (0.91)	0.05 (0.00)	5.2 (0.33)
Stem Density (< 10-cm DBH)	0.53 (0.08)*	9.0 (2.52)*	0.37 (0.05)*	15.3 (3.29)*	0.63 (0.10)*	28.9 (4.20)*
Average DBH (≥ 10-cm)	23.5 (3.09)	26.7 (1.80)	22.0 (1.92)	24.2 (1.79)	20.6 (1.14)	22.8 (3.37)
% Vertical Cover 1	66.9 (5.28)	55.0 (4.82)	71.6 (3.81)	57.8 (5.16)	57.8 (4.53)*	37.0 (3.74)*
% Vertical Cover 2	49.6 (5.17)*	24.4 (0.78)*	42.3 (3.34)	32.5 (5.34)	53.9 (3.55)*	22.8 (2.85)*
% Vertical Cover 3	38.5 (4.57)*	15.6 (2.44)*	33.1 (3.72)	25.3 (6.21)	54.9 (3.49)*	17.3 (5.10)*
% Vertical Cover 4	28.1 (3.88)*	9.4 (3.16)*	27.7 (3.36)	23.0 (5.96)	52.1 (5.44)*	20.8 (7.67)*
% Vertical Cover 5	24.6 (5.48)	11.3 (3.44)	27.8 (3.76)	21.8 (4.64)	50.0 (5.94)*	12.8 (3.30)*
% Vertical Cover 6	21.5 (4.91)	8.8 (2.87)	27.0 (4.21)	14.8 (3.11)	48.5 (6.00)*	12.8 (3.08)*
% Grass	1.7 (1.01)	8.0 (5.03)	11.5 (2.48)	8.7 (4.40)	0.6 (0.30)	1.4 (0.68)
% Sedge	0.0 (0.00)	0.0 (0.00)	0.1 (0.03)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
% Forbs	0.9 (0.80)	3.9 (2.21)	3.8 (0.75)	2.1 (0.58)	0.3 (0.11)	0.6 (0.32)
% Woody Stems	19.9 (1.10)	17.6 (2.04)	16.4 (0.93)*	10.4 (2.20)*	15.8 (1.58)	12.3 (1.04)
% Woody Vines	3.6 (0.69)	5.1 (1.24)	4.4 (0.66)	2.70 (1.03)	8.5 (1.47)	6.0 (0.88)
% Herbaceous Vines	0.1 (0.07)	0.8 (0.49)	1.4 (0.39)	0.9 (0.40)	0.0 (0.00)	0.2 (0.18)
% Fern	1.2 (0.66)	3.2 (1.31)	4.3 (0.82)	2.1 (1.03)	1.1 (0.83)	0.0 (0.00)
% Other	1.0 (0.82)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.2 (0.22)	0.0 (0.00)
% Bare Ground	2.1 (1.35)	4.8 (3.11)	5.3 (1.71)	0.2 (0.17)	2.6 (1.08)	1.1 (0.58)
% Litter	69.7 (4.70)	56.7 (10.22)	52.6 (4.78)	65.4 (4.16)	71.7 (1.49)*	78.6 (1.51)*
Litter Depth (cm)	3.5 (0.28)	3.9 (0.77)	2.5 (0.22)	2.7 (0.29)	3.1 (0.12)*	2.6 (0.24)*

Table 3.7. (Continued)

	Bottomland Hardwood	
Habitat Variable	**C**	**NC**
% Canopy	79.7 (2.66)	83.3 (2.00)
% Basal Area (m²/ha)	41.5 (2.64)	37.5 (3.90)
Stem Density (≥ 10-cm DBH)	0.08 (0.01)	9.2 (1.01)
Stem Density (< 10-cm DBH)	0.53 (0.07)	30.4 (6.99)
Average DBH (≥ 10-cm)	25.8 (1.83)	23.0 (1.65)
% Vertical Cover 1	54.7 (5.05)	49.0 (7.54)
% Vertical Cover 2	49.5 (4.41)*	32.6 (5.59)*
% Vertical Cover 3	46.3 (4.47)*	28.8 (5.37)*
% Vertical Cover 4	42.7 (4.52)	32.8 (4.19)
% Vertical Cover 5	43.6 (5.61)	29.8 (6.11)
% Vertical Cover 6	44.3 (5.89)	27.3 (7.00)
% Grass	2.3 (0.55)	0.9 (0.40)
% Sedge	0.1 (0.07)	0.1 (0.08)
% Forbs	0.8 (0.40)	0.1 (0.08)
% Woody Stems	14.6 (1.05)*	10.9 (1.16)*
% Woody Vines	4.03 (0.63)	2.4 (0.88)
% Herbaceous Vines	1.1 (0.36)	0.3 (0.25)
% Fern	1.7 (0.53)	1.3 (0.49)
% Other	1.1 (0.45)	4.3 (2.77)
% Bare Ground	1.3 (0.40)	5.2 (1.92)
% Litter	72.3 (1.92)	74.3 (3.89)
Litter Depth (cm)	2.9 (0.13)	3.0 (0.20)

stems, and ground cover forms of grass, sedge and litter. Pine plantation trap stations differed in canopy cover, densities of large diameter stems, VC2-VC4 and VC6, and ground cover forms of grass and herbaceous vines. Upland hardwood trap stations differed in basal area, densities of small diameter stems, VC1-VC6 and ground cover in the form of litter. Except for grass, orchard non-capture stations were higher in each of these differing habitat variables. Non-capture stations within pine plantations were higher in canopy cover, densities of large diameter stems and herbaceous vines, while capture stations were higher in vertical cover and grass. Upland hardwood capture stations were higher in all differing habitat variables except litter (Appendix C).

Land Cover Associations. – The largest quantities of available land cover throughout the Bulloch/Candler landscape were cultivated/exposed earth, evergreen forest, and forested wetland, respectively. Low-density urban and clearcut/sparse were the next highest classes of available land cover (Figure 3.2). Overall, among species, there were no strong differences in land cover associated with trap site buffers (Table 3.8).

Among land cover classes, each species showed some differences in their individual associations with available land cover (Table 3.9). *M. musculus* and *S. hispidus* were associated with higher mean percentages of cultivated/exposed earth, but lower mean percentages of evergreen forest and forested wetland. *S. hispidus* was also associated with higher mean percentages of hardwood forest, while *M. musculus* was associated with lower mean percentages of open water. *C. parva* associated with lower mean percentages of forested wetland and *S. longirostris* associated with higher mean percentages of evergreen forest. *B. carolinensis*, *N. floridana*, *P. gossypinus*,

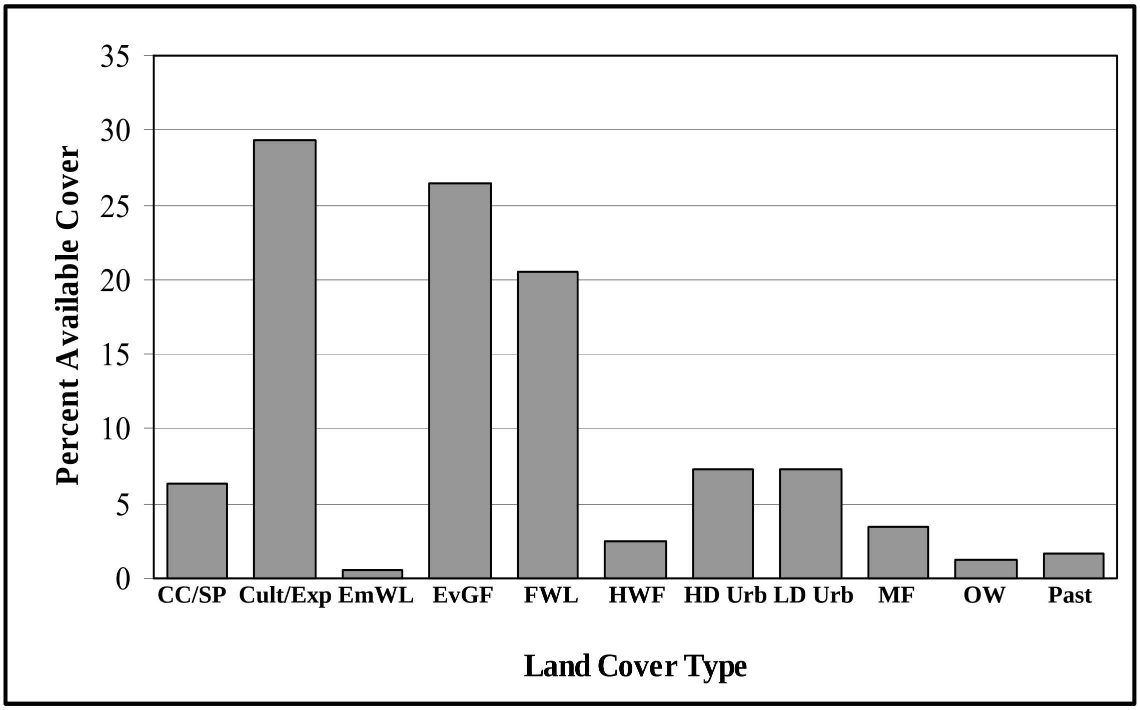

Figure 3.2. Combined land cover classes and available land cover for Bulloch and Candler Counties, Georgia.

Table 3.8. Differences in land cover classes associated with small mammal trap sites in Bulloch and Candler Counties, Georgia.

	One-way ANOVA (df = 2)		Kruskal-Wallis test (df = 8)	
Land Cover Class	***F***	***P***	X^2	***P***
Clearcut/Sparse*	1.05	.4003	-----	------
Cultivated/Exposed Earth*	2.66	.0103	-----	------
Emergent Wetland*	1.18	.3163	-----	------
Evergreen Forest	-----	------	25.29	.0048
Forested Wetland*	0.97	.4630	-----	------
Hardwood Forest	-----	------	11.68	.1660
High Density Urban*	0.53	.8306	-----	------
Low Density Urban	-----	------	23.17	.0032
Mixed Forest*	0.73	.6675	-----	------
Open Water*	0.77	.6278	-----	------
Pasture	-----	------	5.93	.6551

* Variables that meet assumptions of equal variance.

Table 3.9. Comparisons of available percentages of land cover types for the Bulloch/Candler landscape and percent land cover for 500-m radius buffers surrounding small mammal trap sites. Rows of values for each small mammal species are mean (± 1 SE).

Land Cover Type	**% Available**	***B. carolinensis*** (df = 7)	***C. parva*** (df = 6)	***M. musculus*** (df = 16)	***N. floridana*** (df = 8)	***O. nuttalli*** (df = 10)
Clearcut/Sparse	6.4	5.0 (1.00)	5.4 (0.99)	4.6 (1.13)	7.2 (1.34)	7.9 (1.06)
Cultivated/Exposed Earth	29.3	16.8 (7.12)	28.7 (6.67)	43.1 (4.65)*	35.4 (6.01)	31.6 (4.30)
Emergent Wetland	0.6	1.2 (0.45)	0.6 (0.52)	1.2 (0.43)	0.3 (0.22)	1.1 (0.40)
Evergreen Forest	26.5	32.2 (5.96)	21.9 (5.51)	16.4 (2.08)*	25.2 (3.84)	25.9 (3.17)
Forested Wetland	20.5	17.9 (4.24)	9.7 (2.25)*	13.5 (2.11)*	15.9 (3.52)	18.6 (3.47)
Hardwood Forest	2.5	6.2 (1.62)*	4.6 (1.78)	2.7 (0.56)	5.9 (1.40)*	4.4 (1.25)
High Density Urban	7.3	0.1 (0.11)	1.1 (0.82)	0.5 (0.35)	0.0 (0.00)	0.0 (0.00)
Low Density Urban	7.3	13.1 (9.31)	22.9 (10.81)	2.8 (1.34)	15.9 (4.62)	4.6 (1.26)*
Mixed Forest	3.5	3.7 (0.89)	3.1 (1.09)	2.1 (0.43)	2.7 (0.91)	4.8 (1.33)
Open Water	1.3	2.9 (0.86)	2.0 (0.79)	1.1 (0.48)*	1.9 (0.65)	2.1 (0.82)
Pasture	1.7	0.8 (0.83)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.5 (0.53)*

* = significant differences between land cover types associated with small mammal species and percentage of available land cover at the landscape scale.

Table 3.9. (Continued)

Land Cover Class	**% Available**	***P. gossypinus*** (df = 34)	***P. polionotus*** (df = 12)	***S. hispidus*** (df = 17)	***S. longirostris*** (df = 3)
Clearcut/Sparse	6.4	6.9 (0.88)	5.8 (0.87)	5.4 (0.97)	3.9 (1.11)
Cultivated/Exposed Earth	29.3	25.8 (3.70)	36.5 (5.50)	37.8 (4.16)*	11.2 (9.19)
Emergent Wetland	0.6	0.4 (0.19)*	1.3 (0.32)	0.3 (0.18)	0.6 (0.30)
Evergreen Forest	26.5	29.9 (2.63)	24.0 (3.32)	18.4 (2.25)*	43.8 (3.53)*
Forested Wetland	20.5	17.6 (1.90)	15.9 (2.58)	11.3 (3.91)*	19.4 (6.81)
Hardwood Forest	2.5	5.3 (0.79)*	6.9 (1.47)*	4.9 (0.85)*	9.3 (1.36)*
High Density Urban	7.3	0.3 (0.34)	0.0 (0.00)	0.5 (0.33)	0.0 (0.00)
Low Density Urban	7.3	3.7 (1.00)	6.7 (2.06)*	11.1 (11.03)	14.5 (4.44)*
Mixed Forest	3.5	4.0 (0.81)*	3.6 (0.74)	3.1 (0.58)	4.6 (1.41)
Open Water	1.3	1.9 (0.49)	1.7 (0.55)	2.2 (0.54)	3.8 (1.16)
Pasture	1.7	0.2 (0.19)	0.5 (0.51)*	0.0 (0.00)	0.0 (0.00)

P. polionotus, and *S. longirostris* all associated with higher mean percentages of hardwood forest. *P. polionotus* also associated with higher mean percentages of emergent wetland and mixed forest. *O. nuttalli*, *P. polionotus* and *S. longirostris* associated with lower mean percentages of low-density urban and *O. nuttalli* and *P. polionotus* associated with lower mean percentages of pasture as well. All species associations with clearcut/sparse and high-density urban land cover were proportional to available quantities within the landscape (Appendix D).

CHAPTER 4

DISCUSSION

I captured ten species of small mammals within an agricultural landscape in southeast Georgia. Of these, the most common were three insectivores (*Blarina carolinensis*, *Cryptotis parva*, *Sorex longirostris*) and six rodents (*Mus musculus*, *Neotoma floridana*, *Ochrotomys nuttalli*, *Peromyscus gossypinus*, *Peromyscus polionotus*, and *Sigmodon hispidus*). In terms of habitat use, these species make up two distinct groups: open-habitat species and forest species. Within the fragmented landscape I studied, open-habitat species use a wider range of habitats, whereas forest species are more specialized in their habitat use.

Species Habitat Associations. – The primary objective of this study was to quantify patterns of small mammal habitat use in an agricultural landscape of southeast Georgia. Among species inventoried, I found two patterns: (1) small mammals formed two habitat groups, and (2) some small mammals displayed more restricted habitat needs.

Small mammal associations with specific habitat types and habitat variables quantified in this study were largely consistent with what is known regarding the natural history of each small mammal species inventoried. Based on general habitat use, these species formed two specific groups: open-habitat species and woodland species.   The open-habitat species group is composed of *M. musculus*, *P. polionotus*, *S. hispidus*, and *C. parva*. The woodland species group is composed of *P. gossypinus*, *O. nuttalli*, *S. longirostris*, and *N. floridana*.

Among open-habitat species, *C. parva* and *P. polionotus* showed the greatest structural variability. *C. parva* is commonly found in various early successional habitats, such as old fields, clearcuts and pine plantations (Whitaker 1974). Although in this study *C. parva* was most abundant in old fields, the variability this species demonstrated in habitat use was largely because of its presence along field edges and early successional habitat edges of pine plantations. Edge habitats with greater amounts of canopy cover, decaying leaf litter and debris result in greater moisture retention and create more favorable habitat conditions for invertebrates, a primary food source for shrews. The fact that this species readily uses forest edges also suggests that it can disperse readily across a fragmented landscape.

The variability in habitat use of *P. polionotus* is largely due to its presence in open woodlands, such as sandhills and fire-managed longleaf pine-wiregrass communities. However, it was most abundant in agricultural fields, particularly in the vicinity of field edges. Regular disturbances, such as cultivation and frequent burning regimes create favorable habitat conditions for this species (Golley 1962). Although regular-burned sandhill habitats are becoming increasingly scarce and isolated, the ability of *P. polionotus* to use early successional fields suggests that this species is also to be flexible in its habitat use and movements within a fragmented landscape.

S. hispidus and *M. musculus* demonstrated the least variability in habitat use among open-habitat species. The minor associations these species showed with woodland habitats were mainly due to their presence in field edges and fallow pecan orchards. *S. hispidus* also demonstrated some association with frequently burned longleaf pine-wiregrass habitats and pine plantations containing patches of early successional habitat.

Among woodland species, *P. gossypinus* demonstrated the greatest variability in the structure of the habitats it used. Largely considered a woodland species, *P. gossypinus* also is a habitat generalist, and its presence among eight of ten habitat types sampled is reflective of that generalist nature, as is its greater relative abundances within six of ten habitat types sampled. Although the greatest numbers of *P. gossypinus* occurred within woodland habitats, its greater variability in habitat use in comparison to other woodland small mammal species can be attributed to its presence within more open woodland areas, such as longleaf pine-wiregrass communities, sandhills and various aged stands of pine plantations. This species' summer diet largely consists of animal matter, which explains its mid-summer to early fall presence in the edges of agricultural fields, clearcuts and early successional stages of pine plantations (Calhoun 1941). In addition, the greater variability in habitat use of *P. gossypinus* was a result of seasonal differences in foliage among wooded habitats during times of peak abundances (winter months).

N. floridana, *O. nuttalli* and *S. longirostris* associations with greater amounts of canopy cover and high densities of small diameter stems are reflective of their more specific habitat requirements. Regarding habitat use of *O. nuttalli*, the main factor thought to control its distribution within habitats is the presence of dense underbrush (Goodpaster and Hoffmeister 1954). This dense cover not only provides travel and escape cover, but also provides adequate sites and materials for nests and feeding platforms (Linzey and Packard 1977). Furthermore, studies by Gentry et al. (1968) and Pearson (1953) suggest that *P. gossypinus* may inhibit terrestrial movements of *O.*

nuttalli, and the presence of dense underbrush may provide for the coexistence of these two species in areas where they are sympatric.

Among these more specialized small mammal species, *N. floridana and S. longirostris* demonstrated the highest degree of specialization in their habitat use. In comparing within-site habitat use for both species with habitat types that historically made up the landscape of southeast Georgia, these species showed close associations with pristine bottomland hardwoods. Habitat selection in *N. floridana* is closely correlated with availability of cover, which offers materials and sites for house construction (Wiley 1980). In agricultural landscapes of southeast Georgia, mature, hardwood forests with greater amounts of canopy cover and patches of dense mid-story are more likely to provide these necessary habitat requirements. However, these forest types represent only 14% of the Bulloch/Candler landscape. Thus, *N. floridana* appears to have relatively little habitat available in a fragmented landscape, and it may experience problems in moving between isolated patches of habitat.

Although *S. longirostris* is classified as a habitat generalist (French 1980), the results of my study showed otherwise. As mentioned previously, this species is highly selective in its habitat use and was closely associated with more historically characteristic bottomland hardwood types. However, it is interesting that *S. longirostris* was most abundant in longleaf pine-wiregrass habitats, which are typically a dry habitat type. Because of many years of fire suppression and inadequate burning regimes, many of these habitat types are presently characterized by high basal area, high percentages of canopy cover, greater densities of mid-story trees and shrubs, and thick mats of accumulated leaf litter. With the exception of species composition, such habitat patches of longleaf pine-wiregrass may be structurally similar to bottomland hardwood sites.

It is also possible that drought conditions played a role in the degree of habitat specialization demonstrated by *S. longirostris*. Their habitat use would have become more dependent on cooler, moist conditions that support greater abundances of invertebrates, a major food source for shrews. Increased amounts of shade resulting in cooler temperatures and greater moisture retention would have created more favorable microclimates for achieving homeostasis and attracting invertebrates, the primary food source of shrews.

Habitat Comparisons. – Among habitat types inventoried in this study, differences in habitat structure were expected. In comparing woodland habitats, the most obvious factors contributing to these differences are the easily observed structural variations in monocultures, such as pecan orchards and pine plantations and the often sparse, more open sandhills. However, when these data are excluded from the analysis, the results are essentially the same (no significant differences in only six habitat variables, three of which are ground cover forms). Therefore, species composition and distribution of plant communities, season, stand age and soil type in pine-dominated versus hardwood-dominated habitats and monocultures versus natural habitats are largely responsible for these differences.

Because of greater similarities among open-habitat types, fewer differences in habitat structure were expected. Higher mean canopy cover and basal area in agricultural fields versus old fields resulted in greater capture success of small mammal species along agricultural field margins adjacent to woodlands. While small mammals do use old field margins, greater food and cover availability resulting from higher densities of grasses and forbs throughout these habitat types allow for species to use more of the interior. Differences in amounts of bare ground for these two habitat types are largely a result of row crops (soybeans and peanuts) and clean farming practices (row cultivation and herbicide use) typical of modern day agricultural fields (Appendix A).

Capture versus Non-capture Trap Stations. – In addition to patterns of habitat use by individual species, I also asked what habitat features were associated with trap stations where I captured small mammals. Non-capture trap stations among open habitats were largely characterized by less ground cover. Less ground cover and canopy associated with non-capture stations in agricultural fields resulted from a combination of farming practices and greater distances from field edges bordering woodlands. Higher basal area associated with non-capture stations of old fields are probably the result of varying stages of succession among these habitats. Furthermore, shading effects and competition for nutrients within these later successional stage old fields resulted in sparse patches of ground cover. Greater amounts of bare ground within old fields in early successional stages were probably a result of variations in soil nutrients and moisture, and competition between plant species. Because reduced cover probably increases predation risks and may decrease food availability, small mammals may have been reluctant to use these areas within open habitats.

In woodland habitats, non-capture stations tended to have less mid-interval vertical cover, lower amounts of ground cover types and lower densities of small diameter stems. In comparison, capture stations demonstrated higher quantities of each of these habitat variables. Also, woodland habitats demonstrating the greatest number of structural differences between capture and non-capture stations were orchards, pine plantations, and upland hardwoods. Less mid-interval vertical cover resulting from lower densities of small diameter stems and fewer low-growing woody plant forms may increase predation risks, thus hampering small mammal movement between areas within the habitat. Higher amounts of other growth forms associated with non-capture stations in sandhills seems unimportant, but thick mats of lichen (*Cladonia* spp.) are typical of these areas and may influence movements of small mammal species.

Greater differences in habitat structure associated with non-capture stations in pecan orchards and pine plantations are the result of less diversity, which is common among monocultures. Much like old field non-capture stations, higher amounts of canopy, higher densities of large diameter stems and more leaf litter resulted in less grass and forbs ground cover forms among non-capture stations in pecan orchards. Because of the dominance of open-habitat small mammal species within pecan orchards, these locations would have been less attractive. Habitat components associated with non-capture locations in pine plantations in this study are a result of varying stages of succession. Pine plantations are often species and structurally diverse habitats during the early stages of succession. However, diversity decreases with stand age and once the canopy closes and shading greatly reduces ground cover forms, these habitats become somewhat sterile environments (Langley and Shure 1980). Greater differences in non-capture locations between these habitats and naturally occurring woodland habitats used in this study are largely due to maturity of habitats and fewer changes occurring that would alter the habitat structure.

Land Cover Associations. – The greatest amounts of land cover within the Bulloch/Candler landscape are cultivated/exposed earth and evergreen forest, most of which is pine monoculture. Although there were some differences in land cover associations between species, these differences are simply reflective of the habitat types with which these species have been historically associated. However, in comparing land cover associated with small mammal trap sites to land cover available at the landscape scale, within a short distance (500-m radius) of the trap sites, the landscape around sites used by small mammals is similar to that of the landscape as a whole. These results indicate that suitable habitats from which more specialized species have to choose have been reduced to small fragments that are limited in spatial scale; these habitats do not occur in sufficiently larger patches to have a distinctive landscape signature. Thus, species using a narrow range of forested habitats (e.g., *N. floridana, S. longirostris*) are possibly at risk from the negative impacts of habitat fragmentation.

Species Numbers and Relative Abundances. – The overall number of individuals captured in this study was somewhat low in relation to trap nights as compared to other studies, but when conducting inventory studies and using transects as opposed to other trap arrays, one can often expect those numbers to be lower. Also, given what is known about the natural history of many small mammal species, environmental conditions often play a major role in the fluctuations of small mammal populations (Gentry et al. 1966, Smith et al. 1974). During the year this study was conducted and the preceding year, annual rainfall for the Bulloch/Candler landscape was 38.66 cm and 44.96 cm respectively, below the previous 30-year average (Southeast Regional Climate Center, 2004). Together, these factors resulted in somewhat lower than usual captures for a study of this scale.

The fact that *P. gossypinus* and *S. hispidus* captures were highest among rodent species is typical of small mammal habitat studies involving these species. According to Baker (1968), *Peromyscus* species are often the most common mammals in an area, while Golley (1962) states *S. hispidus* are probably the most abundant mammal in Georgia. Furthermore, trapping success for these species was greatest during times of their peak abundances. Cotton rats reach peak abundance during summer months in the southeastern United States (Odum, 1955) and cotton mice abundance peaks during winter months (Wolfe and Linzey 1977).

Relative species abundance was highest in old field habitats because of the high numbers of *S. hispidus* and *M. musculus* captures. Among the six small mammal species present within these habitats, relative abundances of these two species were significantly higher. In addition, early successional habitats such as old fields and clearcuts are often diverse in plant and invertebrate species, thus providing greater amounts of food during months in which small mammals more closely associated these habitats reach their peak abundances.

Relative species abundance was highest in longleaf pine-wiregrass habitats because of the high numbers of *P. gossypinus* captured. Among all other small mammal species within these communities, *P. gossypinus* demonstrated significantly higher relative abundances. While *P. polionotus* showed higher relative abundances in other habitat types, its relative abundance in longleaf pine-wiregrass habitats was second among all other small mammal species. However, *P. polionotus* were only present in longleaf pine- wiregrass communities that were currently under consistent burning regimes. Relative species abundances of *O. nuttalli* and *S. longirostris* also were highest in these habitats.

Management Implications. - My study reveals that small mammals in agricultural landscapes of southeast Georgia occupy a wide range of habitats. Furthermore, species with more specialized habitat use, especially *N. floridana*, *O. nuttalli*, and *S. longirostris*, should be more susceptible to large scale land conversions within these landscapes because they appear to use the narrowest range of habitats of the species sampled. As a result, future habitat management practices within this landscape should emphasize maximizing habitat structure associated with these species. For example, preserving more continuous, mature, hardwood habitats and establishing corridors between habitat fragments. Also, rather than converting land to pine monocultures, implementing management strategies such as restoring abandoned agricultural fields and clearcuts to native vegetation types. Finally, incentives to maintain large tracts of continuous habitats and less land development will also prove crucial to the maintenance of species within these habitats.

While this study provides conservationists with important information that will enable them to make appropriate management decisions pertaining to small mammals, more studies investigating the potential negative impacts of habitat fragmentation on small mammals are needed. As human populations continue to increase across the southeastern United States and large scale land conversions continue, such studies will prove crucial to the conservation of future biodiversity.

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APPENDICES

APPENDIX A. HABITAT VARIABLES, GROUND COVER, AND OBSERVED FREQUENCIES OF GROUND COVER ASSOCIATED WITH TEN HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA.

Table A.1. Habitat variables associated with small mammal trap sites in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	Old Field	Clearcut	Agricultural Field	Orchard	Sandhill	Pine Plantation	Pine Flatwoods
% Canopy	1.2 (0.54)	5.9 (5.93)	11.6 (3.28)	38.1 (6.22)	45.9 (6.82)	51.0 (5.68)	59.6 (4.84)
	0.0 - 6.7	0.0 - 11.9	0.0 - 48.0	13.7 - 62.3	4.3 - 88.0	7.9 - 82.6	38.6 - 90.4
Basal Area (m^2/ha)	0.0 (0.00)	1.1 (1.1)	1.4 (0.58)	5.4 (1.12)	13.4 (1.99)	16.0 (2.85)	32.8 (2.97)
	0.0 - 0.0	0.0 - 2.2	0.0 - 11.6	0.0 - 9.1	2.2 - 24.5	0.0 - 51.1	17.8 - 52.9
Stem Density (≥ 10-cm dbh)	0.0 (0.00)	0.0 (0.00)	0.00 (0.00)	0.0 (0.00)	0.02 (0.00)	0.05 (0.01)	0.05 (0.01)
	0.00 - 0.02	0.00 - 0.00	0.00 - 0.00	0.00 - 0.00	0.00 - 0.04	0.00 - 0.10	0.01 - 0.10
Stem Density (< 10-cm dbh)	0.14 (0.05)	0.32 (0.32)	0.03 (0.02)	0.03 (0.01)	0.26 (0.06)	0.60 (0.09)	0.53 (0.08)
	0.00 - 0.67	0.00 - 0.63	0.00 - 0.50	0.00 - 0.09	0.00 - 0.61	0.03 - 1.15	0.03 - 0.97
Average dbh (cm)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	15.8 (3.27)	15.7 (2.83)	23.5 (3.09)
	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 34.1	0.0 - 45.7	12.0 - 43.8
Vertical Cover 1[a]	85.4 (5.29)	98.7 (1.25)	94.1 (2.29)	86.3 (2.68)	48.5 (6.34)	61.1 (7.52)	66.9 (5.28)
	25.0 - 100	97.5 - 100	55.0 - 100	70.0 - 97.5	20.0 - 92.5	15.0 - 100	37.5 - 95.0
Vertical Cover 2	65.4 (7.11)	86.2 (13.75)	80.2 (5.95)	57.5 (5.20)	22.3 (5.04)	51.8 (6.77)	49.6 (5.17)
	0.0 - 100	72.5 - 100	0.0 - 100	40.0 - 90.0	5.0 - 62.5	2.5 - 97.5	25.0 - 82.5
Vertical Cover 3	48.1 (8.09)	60.0 (40.00)	58.1 (6.45)	19.3 (6.11)	17.3 (4.06)	50.5 (5.51)	38.5 (4.57)
	0.0 - 100	20.0 - 100	0.0 - 100	2.5 - 52.5	0 - 50.0	10.0 - 95.0	12.5 - 62.5
Vertical Cover 4	30.3 (6.14)	46.2 (41.20)	25.2 (4.59)	10.2 (5.08)	16.9 (5.60)	48.5 (5.25)	28.1 (3.88)
	0.0 - 97.5	5.0 - 87.5	0.0 - 75.0	0.0 - 42.5	0.0 - 55.0	5.0 - 87.5	5.0 - 57.5
Vertical Cover 5	16.1 (4.43)	43.7 (31.25)	11.8 (2.89)	12.5 (3.57)	21.0 (6.77)	46.4 (5.56)	24.6 (5.48)
	0.0 - 63.7	12.5 - 75.0	0.0 - 40.0	0.0 - 30.0	0.0 - 62.5	5.0 - 90.0	0.0 - 57.5
Vertical Cover 6	10.4 (3.80)	38.7 (31.25)	8.9 (2.18)	6.8 (2.52)	20.2 (6.72)	48.4 (5.23)	21.5 (4.91)
	0.0 - 67.5	7.5 - 70.0	0.0 - 27.5	0.0 - 22.5	0.0 - 65.0	7.5 - 90.0	0.0 - 60.0

[a] Vertical cover increments = 30.48 cm.

Table A.1. (Continued)

Habitat Variable	Longleaf Pine Wiregrass	Upland Hardwood	Bottomland Hardwood
% Canopy	60.8 (3.01) 27.2 - 90.1	76.5 (3.69) 51.6 - 97.9	79.7 (2.66) 39.2 - 95.1
Basal Area (m²/ha)	21.1 (1.45) 2.2 - 35.6	30.9 (2.62) 15.6 - 46.7	41.5 (2.64) 26.7 - 66.7
Stem Density (≥ 10-cm dbh)	0.03 (0.00) 0.00 - 0.09	0.05 (0.00) 0.03 - 0.08	0.08 (0.01) 0.01 - 0.12
Stem Density (< 10-cm dbh)	0.37 (0.05) 0.00 - 1.04	0.63 (0.10) 0.12 - 1.88	0.53 (0.07) 0.09 - 1.25
Average dbh (cm)	22.0 (1.92) 0.0 - 41.5	20.6 (1.14) 12.7 - 28.1	25.8 (1.83) 16.2 - 57.4
Vertical Cover 1	71.6 (3.81) 20.0 - 97.5	57.8 (4.53) 32.5 - 95.0	54.7 (5.05) 3.7 - 87.5
Vertical Cover 2	42.3 (3.34) 0.0 - 87.5	53.9 (3.55) 22.5 - 75.0	49.5 (4.41) 10.0 - 96.3
Vertical Cover 3	33.1 (3.72) 0.0 - 67.5	54.9 (3.49) 35.0 - 82.5	46.3 (4.47) 7.5 - 97.5
Vertical Cover 4	27.7 (3.36) 0.0 - 60.0	52.1 (5.44) 20.0 - 87.5	42.7 (4.52) 7.5 - 95.0
Vertical Cover 5	27.8 (3.76) 0.0 - 67.5	50.0 (5.94) 12.5 - 87.5	43.6 (5.61) 0.0 - 98.7
Vertical Cover 6	27.0 (4.21) 0.0 - 72.5	48.5 (6.00) 5.0 - 82.5	44.3 (5.89) 0.0 - 98.7

Table A.2. Ground cover forms and littler depth associated with small mammal trap sites in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	**Old Field**	**Clearcut**	**Agricultural Field**	**Orchard**	**Sandhill**	**Pine Plantation**	**Pine Flatwoods**
% Grass	49.8 (3.13)	19.5 (11.50)	15.8 (2.53)	58.2 (5.93)	24.5 (4.28)	16.3 (3.96)	1.7 (1.01)
	32.5 - 85.3	8.0 - 31.0	2.5 - 54.0	25.0 - 74.5	3.9 - 55.8	0 - 56.5	0.0 - 9.5
% Sedge	0.4 (0.18)	0.0 (0.00)	1.3 (0.27)	1.5 (0.58)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
	0.0 - 2.4	0.0 - 0.0	0.0 - 5.0	0.0 - 5.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
% Forbs	15.1 (2.11)	3.6 (0.90)	38.7 (4.95)	10.4 (1.80)	6.0 (0.78)	4.3 (1.05)	0.9 (0.80)
	6.2 - 32.5	2.7 - 4.5	0.0 - 81.5	3.5 - 20.5	0.6 - 10.5	0.0 - 12.2	0.0 - 9.6
% Woody Stems	5.1 (1.31)	16.7 (6.65)	7.0 (3.06)	4.3 (1.27)	11.3 (1.14)	13.3 (1.68)	19.9 (1.10)
	0.0 - 16.5	10.0 - 23.3	0.0 - 62.5	0.0 - 10.0	5.0 - 20.0	2.0 - 30.0	14.4 - 26.2
% Woody Vines	5.9 (1.64)	16.2 (4.85)	1.6 (0.59)	5.7 (2.39)	0.5 (0.20)	5.6 (1.14)	3.6 (0.69)
	0.0 - 20.0	11.3 - 21.0	0.0 - 13.0	0.0 - 20.5	0.0 - 1.8	0.0 - 20.2	1.0 - 10.0
% Herbaceous Vines	0.8 (0.28)	0.5 (0.50)	1.5 (0.37)	0.6 (0.30)	2.2 (0.93)	0.1 (0.05)	0.1 (0.07)
	0.0 - 3.0	0.0 - 1.0	0.0 - 7.4	0.0 - 2.5	0.0 - 9.0	0.0 - 1.0	0.0 - 0.8
% Fern	0.1 (0.03)	2.0 (1.00)	0.0 (0.00)	0.0 (0.00)	0.8 (0.60)	0.7 (0.28)	1.2 (0.66)
	0.0 - 0.4	1.0 - 3.0	0.0 - 0.0	0.0 - 0.0	0.0 - 7.1	0.0 - 3.5	0.0 - 6.7
% Fungi/Lichens	0.0 (0.00)	0.0 (0.00)	0.2 (0.12)	0.0 (0.00)	0.1 (0.08)	0.1 (0.05)	1.0 (0.82)
	0.0 - 0.0	0.0 - 0.0	0.0 - 2.5	0.0 - 0.0	0.0 - 0.9	0.0 - 0.8	0.0 - 10.0
% Bare Ground	6.7 (1.13)	10.4 (5.35)	22.3 (2.14)	2.7 (1.25)	14.2 (2.98)	3.6 (1.13)	2.1 (1.35)
	1.3 - 20.0	5.0 - 15.7	4.0 - 46.0	0.0 - 13.0	0.0 - 34.5	0.0 - 14.2	0.0 - 16.3
% Litter	18.5 (1.88)	31.3 (3.75)	11.8 (2.38)	16.6 (1.77)	40.5 (6.58)	55.7 (4.77)	69.7 (4.70)
	1.2 - 34.0	27.5 - 35.0	0.0 - 39.0	8.0 - 28.0	10.0 - 88.3	23.2 - 89.4	21.7 - 82.6
Litter Depth (cm)	1.2 (0.07)	2.5 (0.60)	0.9 (0.20)	1.3 (0.14)	2.6 (0.36)	2.4 (0.31)	3.5 (0.28)
	1.0 - 1.9	1.9 - 3.1	0.0 - 4.5	0.7 - 2.0	0.6 - 4.9	1.0 - 5.2	1.2 - 4.8

Table A.2. (Continued)

Habitat Variable	Longleaf Pine Wiregrass	Upland Hardwood	Bottomland Hardwood
% Grass	11.5 (2.48) 0.0 - 44.2	0.6 (0.30) 0 - 5.0	2.3 (0.55) 0.0 - 7.1
% Sedge	0.1 (0.03) 0.0 - 0.8	0.0 (0.00) 0.0 - 0.0	0.1 (0.07) 0.0 - 1.2
% Forbs	3.8 (0.75) 0.0 - 12.5	0.3 (0.11) 0.0 - 1.0	0.8 (0.40) 0.0 - 6.2
% Woody Stems	16.4 (0.93) 7.9 - 29.6	15.8 (1.58) 5.0 - 27.0	14.6 (1.05) 3.2 - 22.5
% Woody Vines	4.4 (0.66) 0.0 - 14.8	8.5 (1.47) 1.4 - 18.2	4.03 (0.63) 0.5 - 9.4
% Herbaceous Vines	1.4 (0.39) 0.0 - 8.8	0.0 (0.00) 0.0 - 0.0	1.1 (0.36) 0.0 - 4.5
% Fern	4.3 (0.82) 0.0 - 14.7	1.1 (0.83) 0.0 - 15.0	1.7 (0.53) 0.0 - 8.0
% Fungi/Lichens	0.0 (0.00) 0.0 - 0.9	0.2 (0.22) 0.0 - 4.0	1.1 (0.45) 0.0 - 8.2
% Bare Ground	5.3 (1.71) 0.0 - 30.6	2.6 (1.08) 0.0 - 11.7	1.3 (0.40) 0.0 - 8.0
% Litter	52.6 (4.78) 0.0 - 90.6	71.7 (1.49) 62.0 - 87.0	72.3 (1.92) 57.0 - 88.8
Litter Depth (cm)	2.5 (0.22) 0.0 - 4.1	3.1 (0.12) 2.0 - 3.8	2.9 (0.13) 1.8 - 3.9

Table A.3. Observed frequencies for ground cover forms associated with small mammal capture sites in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	**Old Field**	**Clearcut**	**Agricultural Field**	**Orchard**	**Sandhill**	**Pine Plantation**	**Pine Flatwoods**
(*f*) Grass	0.98 (0.01)	0.73 (0.08)	0.65 (0.06)	0.94 (0.04)	0.93 (0.04)	0.55 (0.08)	0.14 (0.07)
	0.81 - 1.00	0.65 - 0.80	0.20 - 1.00	0.70 - 1.00	0.56 - 1.00	0.00 - 1.00	0.00 - 0.75
(*f*) Sedge	0.08 (0.04)	0.00 (0.00)	0.21 (0.04)	0.23 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	0.00 - 0.53	0.00 - 0.00	0.00 - 0.80	0.00 - 0.70	0.00 - 0.00	0.00 - 0.00	0.00 - 0.00
(*f*) Forbs	0.88 (0.03)	0.40 (0.11)	0.81 (0.06)	0.69 (0.07)	0.71 (0.04)	0.35 (0.08)	0.10 (0.08)
	0.65 - 1.00	0.29 - 0.50	0.00 - 1.00	0.40 - 1.00	0.11 - 1.00	0.00 - 0.90	0.00 - 1.00
(*f*) Woody Stems	0.38 (0.09)	0.94 (0.06)	0.18 (0.06)	0.27 (0.08)	0.82 (0.04)	0.76 (0.05)	0.96 (0.02)
	0.00 - 1.00	0.88 - 1.00	0.00 - 1.00	0.00 - 0.60	0.59 - 1.00	0.30 - 1.00	0.80 - 1.00
(*f*) Woody Vines	0.28 (0.08)	0.81 (0.01)	0.12 (0.03)	0.24 (0.09)	0.06 (0.03)	0.43 (0.06)	0.42 (0.07)
	0.00 - 0.88	0.80 - 0.82	0.00 - 0.50	0.00 - 0.80	0.00 - 0.29	0.00 - 0.96	0.10 - 0.83
(*f*) Herbaceous Vines	0.09 (0.03)	0.09 (0.09)	0.24 (0.06)	0.10 (0.06)	0.27 (0.10)	0.00 (0.00)	0.01 (0.01)
	0.00 - 0.30	0.00 - 0.17	0.00 - 1.00	0.00 - 0.50	0.00 - 1.00	0.00 - 0.01	0.00 - 0.17
(*f*) Fern	0.01 (0.00)	0.20 (0.10)	0.00 (0.00)	0.00 (0.00)	0.06 (0.05)	0.09 (0.04)	0.10 (0.05)
	0.00 - 0.40	0.10 - 0.29	0.00 - 0.00	0.00 - 0.00	0.00 - 0.59	0.00 - 0.53	0.00 - 0.50
(*f*) Other	0.00 (0.00)	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	0.05 (0.03)	0.00 (0.00)	0.05 (0.02)
	0.00 - 0.00	0.00 - 0.00	0.00 - 0.30	0.00 - 0.00	0.00 - 0.29	0.00 - 0.04	0.00 - 0.25
(*f*) Bare Ground	0.42 (0.05)	0.44 (0.04)	0.83 (0.04)	0.13 (0.07)	0.50 (0.09)	0.21 (0.06)	0.10 (0.07)
	0.05 - 1.00	0.40 - 0.47	0.30 - 1.00	0.00 - 0.80	0.00 - 1.00	0.00 - 0.76	0.00 - 0.83
(*f*) Litter	0.86 (0.06)	0.91 (0.09)	0.31 (0.05)	0.74 (0.05)	0.99 (0.01)	0.92 (0.03)	1.00 (0.00)
	0.06 - 1.00	0.82 - 1.00	0.00 - 0.80	0.40 - 0.90	0.88 - 1.00	0.60 - 1.00	1.00 - 1.00

Table A.3. (Continued)

Habitat Variable	Longleaf Pine Wiregrass	Upland Hardwood	Bottomland Hardwood
(*f*) Grass	0.50 (0.07)	0.05 (0.02)	0.23 (0.05)
	0.00 -1.00	0.00 - 0.30	0.00 - 0.79
(*f*) Sedge	0.01 (0.01)	0.00 (0.00)	0.02 (0.02)
	0.00 - 0.17	0.00 - 0.00	0.00 - 0.24
(*f*) Forbs	0.41 (0.07)	0.06 (0.03)	0.10 (0.04)
	0.00 - 1.00	0.00 - 0.40	0.00 - 0.65
(*f*) Woody Stems	0.91 (0.03)	0.85 (0.05)	0.92 (0.03)
	0.30 - 1.00	0.25 - 1.00	0.59 - 1.00
(*f*) Woody Vines	0.44 (0.06)	0.52 (0.08)	0.53 (0.05)
	0.00 - 1.00	0.00 - 1.00	0.10 - 0.94
(*f*) Herbaceous Vines	0.20 (0.05)	0.00 (0.00)	0.18 (0.06)
	0.00 - 0.94	0.00 - 0.00	0.00 - 0.80
(*f*) Fern	0.37 (0.07)	0.04 (0.02)	0.18 (0.05)
	0.00 - 1.00	0.00 - 0.28	0.00 - 0.68
(*f*) Other	0.00 (0.00)	0.01 (0.01)	0.10 (0.03)
	0.00 - 0.12	0.00 - 0.20	0.00 - 0.56
(*f*) Bare Ground	0.22 (0.07)	0.07 (0.03)	0.11 (0.03)
	0.00 - 1.00	0.00 - 0.60	0.00 -0.53
(*f*) Litter	0.91 (0.04)	0.97 (0.01)	0.99 (0.00)
	0.00 - 1.00	0.88 - 1.00	0.94 - 1.00

APPENDIX B. HABITAT VARIABLES, GROUND COVER, AND OBSERVED FREQUENCIES OF GROUND COVER ASSOCIATED WITH TEN SPECIES OF SMALL MAMMALS INVENTORIED IN THIS STUDY IN BULLOCH AND CANDLER COUNTIES, GEORGIA.

Table B.1. Habitat variables associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	*B. carolinensis*	*C. parva*	*M. musculus*	*N. floridana*	*O. nuttalli*	*P. gossypinus*
% Canopy	47.3 (12.20)	7.6 (3.55)	15.5 (5.19)	79.4 (3.65)	77.8 (4.71)	62.7 (2.58)
	0 - 85.2	0 - 25.4	0 - 78.1	52.7 - 92.5	40.9 - 97.9	0 - 97.9
Basal Area (m^2/ha)	18.1 (5.66)	1.6 (1.26)	3.3 (1.36)	37.1 (3.73)	22.9 (2.79)	28.2 (1.86)
	0 - 41.2	0 - 8.9	0 - 24.5	15.6 - 62.0	6.7 - 43.7	2.2 - 66.7
Stem Density (≥ 10-cm dbh)	2.6 (0.99)	0.6 (0.57)	1.0 (0.40)	7.2 (0.80)	4.0 (0.84)	4.6 (0.42)
	0 - 8.0	0 - 4.0	0 - 7.0	3.0 - 12.0	0 - 10.0	0 - 12.0
Stem Density (< 10-cm dbh)	31.4 (9.10)	20.0 (11.39)	4.4 (2.69)	66.8 (9.90)	77.8 (7.98)	49.3 (4.54)
	0 - 71.0	0 - 69.0	0 - 58.0	21.0 - 125.0	30.0 - 115.0	0 - 188.0
Average DBH (cm)	17.5 (4.26)	1.6 (1.64)	1.3 (0.91)	22.8 (2.15)	19.0 (3.55)	21.4 (1.52)
	0 - 30.0	0 - 11.5	0 - 16.8	12.0 - 33.8	0 - 45.7	0 - 57.4
Vertical Cover 1[a]	55.6 (7.92)	57.1 (13.64)	90.3 (3.60)	51.8 (6.83)	66.3 (6.85)	64.5 (3.05)
	17.5 - 95.0	17.5 - 100.0	37.5 - 100.0	10.0 - 87.5	25.0 - 97.5	3.8 - 100.0
Vertical Cover 2	40.0 (2.67)	37.1 (14.15)	70.4 (6.93)	46.6 (4.51)	49.0 (5.53)	52.7 (3.11)
	30.0 - 52.5	0 - 97.5	0 - 100.0	30.0 - 75.0	12.5 - 82.5	0 - 97.5
Vertical Cover 3	32.2 (6.69)	31.8 (11.85)	49.3 (7.94)	44.3 (4.03)	48.6 (4.87)	46.1 (2.93)
	2.5 52.5	0 - 80.0	0 - 100.0	22.5 - 70.0	17.5 - 77.5	0 - 97.5
Vertical Cover 4	25 (5.82)	22.9 (8.08)	25.8 (5.82)	40.7 (3.09)	46.9 (5.27)	41.0 (3.17)
	0 - 47.5	0 - 47.5	0 - 97.5	25.0 - 55.0	17.5 - 87.5	0 - 95.0
Vertical Cover 5	27.8 (5.83)	16.8 (6.81)	15.1 (4.67)	45.2 (4.45)	51.7 (5.47)	38.4 (3.50)
	0 - 50.0	0 - 50.0	0 - 77.5	17.5 - 65.0	10.0 - 87.5	0 - 98.7
Vertical Cover 6	24.4 (6.17)	15.0 (8.18)	11.5 (4.56)	44.9 (6.80)	50.9 (4.44)	38.4 (3.56)
	0 - 60.0	0 - 60.0	0 - 90.0	15.0 - 90.0	30.0 - 72.5	0 - 98.7

[a] Vertical cover increments = 30.48 cm.

Table B.1. (Continued)

Habitat Variable	***P. polionotus***	***S. hispidus***	***S. longirostris***
% Canopy	24.9 (4.50) 0 - 54.2	24.9 (5.13) 0 - 89.1	76.1 (3.23) 64.1 - 86.2
Basal Area (m^2/ha)	7.9 (1.91) 0 - 24.5	5.5 (1.93) 0 - 46.7	30.1 (5.56) 15.6 - 50.4
Stem Density (≥ 10-cm dbh)	1.6 (0.51) 0 - 10.0	1.0 (0.40) 0 - 7.0	5.0 (0.93) 2.0 - 8.0
Stem Density (< 10-cm dbh)	9.6 (3.41) 0 - 58.0	17.4 (5.02) 0 - 73.0	39.7 (7.86) 22.0 - 71.0
Average DBH (cm)	11.7 (2.77) 0 - 33.8	3.5 (1.56) 0 - 32.3	21.9 (2.31) 14.6 - 30.0
Vertical Cover 1	79.6 (5.77) 15.0 - 100.0	88.1 (3.61) 25.0 - 100.0	54.2 (7.74) 25.0 - 80.0
Vertical Cover 2	48.8 (7.55) 5.0 - 100.0	69.9 (4.93) 30.0 - 100.0	37.5 (7.10) 10.0 - 57.5
Vertical Cover 3	31.5 (7.40) 0 - 100.0	47.7 (6.31) 2.5 - 100.0	30.8 (7.89) 7.5 - 52.5
Vertical Cover 4	14.8 (5.01) 0 - 75.0	30.6 (5.13) 0 - 97.5	27.9 (5.89) 10.0 - 47.5
Vertical Cover 5	7.3 (3.08) 0 - 60.0	21.8 (4.01) 0 - 75.0	30.4 (7.53) 0 - 55.0
Vertical Cover 6	5.5 (2.85) 0 - 57.5	18.1 (3.92) 0 - 70.0	23.3 (6.67) 0 - 50.0

Table B.2. Ground cover forms and littler depth associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	***B. carolinensis***	***C. parva***	***M. musculus***	***N. floridana***	***O. nuttalli***	***P. gossypinus***
% Grass	13.9 (6.15)	49.6 (8.08)	35.0 (5.10)	1.6 (0.78)	6.4 (2.80)	5.5 (1.18)
	0 - 45.2	23.6 - 85.3	2.5 - 74.5	0 - 6.2	0 - 37.7	0 - 37.6
% Sedge	0.2 (0.15)	0.4 (0.34)	0.7 (0.26)	0.0 (0.00)	0.0 (0.00)	0.0 (0.03)
	0 - 1.2	0 - 2.4	0 - 5.0	0 - 0	0 - 0	0 - 1.2
% Forbs	4.6 (1.55)	10.9 (2.85)	29.6 (5.49)	0.0 (0.03)	1.3 (0.44)	2.0 (0.63)
	0 - 12.2	5.0 - 27.0	2.0 - 81.5	0 - 0.3	0 - 5.0	0 - 34.0
% Woody Stems	13.0 (1.04)	8.0 (2.53)	3.4 (1.09)	16.1 (1.53)	16.8 (1.51)	15.6 (0.79)
	7.9 - 16.8	0 - 16.5	0 - 18.3	8.6 - 22.8	7.2 - 27.0	4.0 - 30.0
% Woody Vines	5.6 (1.04)	7.1 (3.07)	2.5 (0.97)	4.4 (0.92)	4.8 (1.13)	5.9 (0.70)
	0 - 8.2	0 - 20.0	0 - 20.0	1.0 - 10.0	0 - 15.4	0 - 21.0
% Herbaceous Vines	0.5 (0.27)	0.4 (0.43)	1.2 (0.39)	1.0 (0.52)	0.6 (0.34)	0.3 (0.10)
	0 - 1.8	0 - 3.0	0 - 7.4	0 - 4.5	0 - 4.2	0 - 4.5
% Fern	1.3 (1.05)	0.1 (0.09)	0.0 (0.02)	1.5 (0.75)	1.7 (0.94)	2.0 (0.50)
	0 - 8.5	0 - 0.6	0 - 0.4	0 - 8.0	0 - 12.1	0 - 15.0
% Fungi/Lichens	0.2 (0.13)	0.0 (0.00)	0.2 (0.13)	0.6 (0.54)	0.1 (0.07)	0.6 (0.23)
	0 - 0.9	0 - 0	0 - 2.5	0 - 6.0	0 - 0.9	0 - 10.0
% Bare Ground	5.2 (2.39)	2.7 (0.85)	12.9 (2.45)	1.5 (0.70)	2.4 (1.25)	2.6 (0.63)
	0 - 19.0	0 - 19.0	0 - 45.0	0 - 8.0	0 - 13.7	0 - 19.4
% Litter	55.2 (7.25)	22.5 (5.67)	15.5 (3.10)	73.2 (3.04)	65.9 (3.90)	65.5 (2.09)
	26.7 - 76.8	1.2 - 46.0	0 - 62.9	57.0 - 88.4	33.0 - 88.3	21.7 - 90.6
Litter Depth (cm)	2.7 (0.43)	1.4 (0.17)	1.1 (0.20)	2.8 (0.15)	3.2 (0.31)	3.0 (0.12)
	1.0 - 4.0	1.0 - 4.0	0 - 4.5	2.0 - 3.6	1.3 - 5.2	1.2 - 5.2

Table B.2. (Continued)

Habitat Variable	***P. polionotus***	***S. hispidus***	***S. longirostris***
% Grass	22.3 (3.23) 5.0 - 55.8	36.7 (4.22) 0 - 74.5	2.5 (1.19) 0 - 7.9
% Sedge	0.8 (0.29) 0 - 5.0	0.7 (0.22) 0 - 5.0	0.0 (0.00) 0 - 0
% Forbs	17.8 (4.52) 0 - 72.5	17.1 (2.95) 0 - 60.0	1.5 (0.66) 0 - 3.5
% Woody Stems	14.0 (3.57) 0 - 62.5	7.4 (1.59) 0 - 25.8	13.7 (2.19) 3.2 - 18.3
% Woody Vines	0.3 (0.14) 0 - 2.0	5.3 (1.30) 0 - 20.5	5.3 (0.84) 1.8 - 8.0
% Herbaceous Vines	2.8 (0.72) 0 - 9.0	0.9 (0.25) 0 - 5.0	0.8 (0.31) 0 - 1.8
% Fern	1.7 (0.66) 0 - 9.2	0.7 (0.38) 0 - 9.2	2.5 (1.43) 0 - 8.8
% Fungi/Lichens	0.1 (0.07) 0 - 1.5	0.0 (0.00) 0 - 0	0.0 (0.00) 0 - 0
% Bare Ground	22.5 (2.57) 2.4 - 46.0	9.2 (1.62) 0 - 27.0	2.0 (1.95) 0 - 11.7
% Litter	17.6 (4.24) 0 - 78.5	22.8 (3.21) 0 - 73.2	72.0 (4.60) 54.7 - 88.8
Litter Depth (cm)	1.2 (0.24) 0 - 3.6	1.4 (0.15) 0 - 3.4	3.5 (0.26) 2.2 - 3.9

Table B.3. Observed frequencies for ground cover forms associated with capture trap stations of small mammals in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	***B. carolinensis***	***C. parva***	***M. musculus***	***N. floridana***	***O. nuttalli***	***P. gossypinus***
(*f*) Grass	0.47 (0.13)	0.92 (0.07)	0.79 (0.06)	0.14 (0.06)	0.39 (0.09)	0.30 (0.05)
	0 - 1.00	0.52 - 1.00	0.20 - 1.00	0 - 0.53	0 - 0.82	0 - 1.00
(*f*) Sedge	0.03 (0.03)	0.09 (0.07)	0.12 (0.04)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)
	0 - 0.24	0 - 0.53	0 - 0.80	0 - 0	0 - 0	0 - 0.24
(*f*) Forbs	0.45 (0.13)	0.75 (0.07)	0.85 (0.04)	0.01 (0.01)	0.19 (0.06)	0.19 (0.04)
	0 - 0.89	0.50 - 1.00	0 - 0.53	0.30 - 1.00	0 - 0.06	0 - 0.67
(*f*) Woody Stems	0.83 (0.06)	0.47 (0.14)	0.23 (0.07)	0.94 (0.04)	0.89 (0.06)	0.88 (0.02)
	0.56 - 1.00	0 - 1.00	0 - 0.88	0.59 - 1.00	0.30 - 1.00	0.25 - 1.00
(*f*) Woody Vines	0.51 (0.13)	0.25 (0.13)	0.15 (0.05)	0.51 (0.07)	0.51 (0.09)	0.48 (0.04)
	0 - 0.88	0 - 0.88	0 - 0.88	0.10 - 0.94	0 - 1.00	0 - 1.00
(*f*) Herbaceous Vines	0.09 (0.04)	0.04 (0.04)	0.18 (0.06)	0.17 (0.09)	0.12 (0.06)	0.05 (0.02)
	0 - 0.29	0 - 0.30	0 - 1.00	0 - 0.80	0 - 0.80	0 - 0.60
(*f*) Fern	0.12 (0.09)	0.01 (0.01)	0.00 (0.00)	0.15 (0.07)	0.16 (0.08)	0.15 (0.03)
	0 - 0.71	0 - 0.06	0 - 0.04	0 - 0.60	0 - 0.88	0 - 0.94
(*f*) Fungi/Lichens	0.02 (0.02)	0.00 (0.00)	0.03 (0.02)	0.03 (0.02)	0.02 (0.01)	0.05 (0.01)
	0 - 0.12	0 - 0	0 - 0.30	0 - 0.20	0 - 0.17	0 - 0.56
(*f*) Bare Ground	0.19 (0.08)	0.18 (0.06)	0.59 (0.08)	0.08 (0.02)	0.10 (0.05)	0.14 (0.03)
	0 - 0.67	0 - 0.41	0 - 1.00	0 - 0.20	0 - 0.64	0 - 0.83
(*f*) Litter	0.94 (0.03)	0.77 (0.13)	0.56 (0.08)	0.99 (0.01)	0.99 (0.00)	0.99 (0.01)
	0.72 - 1.00	0.06 - 1.00	0 - 1.00	0.94 - 1.00	0.94 - 1.00	0.60 - 1.00

Table B.3. (Continued)

Habitat Variable	***P. polionotus***	***S. hispidus***	***S. longirostris***
(*f*) Grass	0.86 (0.05) 0.20 - 1.00	0.82 (0.06) 0 - 1.00	0.27 (0.11) 0 - 0.71
(*f*) Sedge	0.13 (0.05) 0 - 0.67	0.12 (0.04) 0 - 0.70	0.00 (0.00) 0 - 0
(*f*) Forbs	0.80 (0.07) 0 - 1.00	0.74 (0.05) 0 - 1.00	0.23 (0.10) 0 - 1.00
(*f*) Woody Stems	0.60 (0.09) 0 - 1.00	0.40 (0.07) 0 - 1.00	0.96 (0.03) 0.88 - 1.00
(*f*) Woody Vines	0.03 (0.02) 0 - 0.24	0.27 (0.06) 0 - 0.88	0.66 (0.08) 0.29 - 0.82
(*f*) Herbaceous Vines	0.33 (0.08) 0 - 1.00	0.15 (0.04) 0 - 1.00	0.11 (0.04) 0 - 0.29
(*f*) Fern	0.17 (0.07) 0 - 1.00	0.07 (0.04) 0 - 1.00	0.22 (0.13) 0 - 0.82
(*f*) Fungi/Lichens	0.03 (0.02) 0 - 0.30	0.00 (0.00) 0 - 0	0.00 (0.00) 0 - 0
(*f*) Bare Ground	0.77 (0.06) 0.18 - 1.00	0.45 (0.06) 0 - 1.00	0.02 (0.02) 0 - 0.12
(*f*) Litter	0.62 (0.09) 0 - 1.00	0.73 (0.05) 0 - 1.00	0.98 (0.02) 0.88 - 1.00

APPENDIX C. HABITAT VARIABLES AND GROUND COVER ASSOCIATED WITH CAPTURE AND NON-CAPTURE TRAP STATIONS WITHIN TEN HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA.

Table C.1. Habitat variables associated with non-capture trap stations in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	Old Field	Clearcut	Agricultural Field	Orchard	Sandhill	Pine Plantation	Pine Flatwoods
% Canopy	3.6 (2.32)	18.0 (18.02)	0.3 (0.28)	77.0 (2.02)	52.6 (5.11)	73.8 (6.34)	70.7
	0.0 - 22.5	0.0 - 36.0	0.0 - 2.76	70.2 - 84.9	21.8 - 74.3	29.0 - 93.0	30.3 - 89.1
Basal Area (m^2/ha)	0.7 (0.33)	2.2 (0.00)	0.0 (0.00)	6.8 (1.11)	13.0 (1.61)	24.0 (3.73)	30.0
	0.0 - 2.2	2.2 - 2.2	0.0 - 0.0	4.4 - 11.6	6.7 - 22.2	6.7 - 43.7	11.1 - 42.2
Stem Density (≥ 10-cm dbh)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.5 (0.19)	2.4 (0.58)	7.4 (1.36)	5.5 (0.87)
	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0 - 1.0	0.0 - 6.0	1.0 - 14.0	2.0 - 8.0
Stem Density (< 10-cm dbh)	6.0 (1.74)	1.0 (1.00)	0.0 (0.00)	4.3 (1.54)	15.5 (3.21)	33.3 (11.20)	9.0 (2.52)
	0.0 - 15.0	0.0 - 2.0	0.0 - 0.0	1.0 - 11.0	0.0 - 34.0	0.0 - 108.0	1.0 - 17.0
Average dbh (cm)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	15.9 (10.41)	15.7 (2.76)	18.1 (1.88)	26.7
	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 -63.6	0.0 -33.3	10.5 -26.0	21.8 -29.6
Vertical Cover 1[a]	86.3 (7.07)	81.3 (16.25)	82.5 (7.24)	78.8 (6.50)	43.8 (8.96)	41.0 (11.94)	55.0
	25.0 - 100	65.0 - 97.5	42.5 - 100	50.0 - 95.0	20.0 - 97.5	0.0 - 92.5	40.0 - 75.0
Vertical Cover 2	48.3 (9.33)	51.3 (21.25)	61.5 (12.44)	40.0 (6.75)	33.0 (5.66)	25.0 (8.90)	24.4
	10.0 - 100	30.0 - 72.5	0.0 - 100	17.5 - 67.5	10.0 - 72.5	0.0 - 87.5	22.5 - 27.5
Vertical Cover 3	30.5 (10.25)	13.8 (6.25)	27.0 (9.41)	16.3 (8.03)	23.0 (4.06)	23.5 (8.73)	15.6
	2.5 - 100	7.5 - 20.0	0.0 - 25.0	0.0 - 52.5	7.5 - 45.0	0.0 - 82.5	5.0 - 22.5
Vertical Cover 4	12.0 (4.52)	0.0 (0.00)	4.75 (2.99)	8.8 (5.20)	25.8 (6.33)	23.0 (5.81)	9.4 (3.16)
	0.0 - 37.5	0.0 - 0.0	0.0 - 25.0	0.0 - 32.5	0.0 - 65.0	0.0 - 52.5	0.0 - 22.5
Vertical Cover 5	2.3 (1.73)	0.0 (0.00)	0.0 (0.00)	5.6 (3.68)	33.5 (6.23)	29.3 (5.66)	11.3
	0.0 - 17.5	0.0 - 0.0	0.0 - 0.0	0.0 - 22.5	0.0 - 60.0	0.0 - 52.5	0.0 - 22.5
Vertical Cover 6	1.3 (1.00)	0.0 (0.00)	0.0 (0.00)	1.9 (1.23)	28.0 (5.32)	23.5 (6.03)	8.8 (2.87)
	0.0 - 10.0	0.0 - 0.0	0.0 - 0.0	0.0 -7.5	0.0 - 52.5	0.1 - 60.0	0.0 - 17.5

[a] Vertical cover increments = 30.48 cm.

Table C.1. (Continued)

Habitat Variable	Longleaf Pine Wiregrass	Upland Hardwood	Bottomland Hardwood
% Canopy	62.6 (4.87) 31.6 - 79.2	79.5 (3.35) 60.1 - 93.5	83.3 (2.00) 69.8 - 93.8
Basal Area (m²/ha)	20.2 (3.65) 11.1 - 51.1	21.1 (2.26) 13.3 - 35.6	37.5 (3.90) 22.2 - 62.2
Stem Density (≥ 10-cm dbh)	3.7 (0.91) 1.0 - 10.0	5.2 (0.33) 4.0 - 7.0	9.2 (1.01) 0.05 - 0.15
Stem Density (< 10-cm dbh)	15.3 (3.29) 3.0 - 28.0	28.9 (4.20) 12.0 - 48.0	30.4 (6.99) 2.0 - 79.0
Average dbh (cm)	24.2 (1.79) 10.0 -30.2	22.8 (3.37) 13.4 -42.9	23.0 (1.65) 15.3 - 31.9
Vertical Cover 1	57.8 (5.16) 40.0 - 82.5	37.0 (3.74) 22.5 - 52.5	49.0 (7.54) 20.0 - 85.0
Vertical Cover 2	32.5 (5.34) 12.5 - 67.5	22.8 (2.85) 10.0 - 40.0	32.6 (5.59) 5.0 - 57.5
Vertical Cover 3	25.3 (6.21) 2.5 - 55.0	17.3 (5.10) 7.5 - 55.0	28.8 (5.37) 5.0 - 55.0
Vertical Cover 4	23.0 (5.96) 0.0 - 45.0	20.8 (7.67) 2.5 - 77.5	32.8 (4.19) 10.0 - 52.5
Vertical Cover 5	21.8 (4.64) 5.0 - 40.0	12.8 (3.30) 2.5 - 30.0	29.8 (6.11) 2.5 - 57.5
Vertical Cover 6	14.8 (3.11) 5.0 - 37.5	12.8 (3.08) 2.5 - 37.5	27.3 (7.00) 5.0 - 60.0

Table C.2. Ground cover forms and littler depth associated with non-capture trap stations in Bulloch and Candler Counties, Georgia. Rows of values corresponding with each habitat variable are mean (± 1 SE) and range, respectively.

Habitat Variable	Old Field	Clearcut	Agricultural Field	Orchard	Sandhill	Pine Plantation	Pine Flatwoods
% Grass	49.3 (4.30)	15.5 (15.50)	11.4 (2.58)	29.5 (4.09)	12.4 (1.70)	4.2 (1.97)	8.0 (5.03)
	30.0 - 70.0	0.0 - 31.0	2.5 - 25.0	20.0 - 47.0	6.7 - 26.0	0.0 - 15.0	0.0 - 31.0
% Sedge	0.1 (0.12)	0.0 (0.00)	1.8 (0.66)	3.3 (0.44)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
	0.0 - 1.2	0.0 - 0.0	0.0 - 5.0	1.7 - 5.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
% Forbs	10.2 (1.19)	2.3 (2.25)	30.6 (8.46)	10.6 (1.55)	2.5 (1.32)	3.3 (1.05)	3.9 (2.21)
	4.1 - 16.0	0.0 - 4.5	0.0 - 74.0	6.0 - 17.0	0.0 - 14.0	0.2 - 11.0	0.0 - 14.0
% Woody Stems	1.9 (0.54)	8.4 (1.65)	16.0 (8.15)	4.8 (1.95)	8.2 (1.27)	8.9 (2.83)	17.6 (2.04)
	0.0 - 5.0	6.7 - 10.0	0.0 - 55.0	0.0 - 13.3	5.0 - 15.9	0.5 - 32.0	10.8 - 25.0
% Woody Vines	5.5 (2.27)	10.5 (10.50)	0.4 (0.22)	5.6 (2.31)	0.4 (0.17)	6.6 (2.75)	5.1 (1.24)
	0.0 - 20.0	0.0 - 21.0	0.0 - 2.0	0.8 - 16.0	0.0 - 1.3	0.0 - 29.0	3.0 - 10.8
% Herbaceous Vines	0.2 (0.20)	0.0 (0.00)	0.8 (0.66)	0.3 (0.16)	1.9 (0.60)	0.4 (0.18)	0.8 (0.49)
	0.0 - 2.0	0.0 - 0.0	0 - 6.7	0.0 - 1.0	0.0 - 6.0	0.0 - 1.5	0.0 - 3.0
% Fern	0.0 (0.00)	3.0 (2.00)	0.0 (0.00)	0.0 (0.00)	1.4 (1.00)	0.3 (0.25)	3.2 (1.31)
	0.0 - 0.0	1.0 - 5.0	0.0 - 0.0	0.0 - 0.0	0.0 - 10.0	0.0 - 2.5	0.0 - 8.3
% Other	0.0 (0.00)	0.0 (0.00)	0.4 (0.26)	0.1 (0.08)	0.9 (0.47)	0.2 (0.11)	0.0 (0.00)
	0.0 - 0.0	0.0 - 0.0	0.0 - 2.5	0.0 - 0.5	0.0 - 3.9	0.0 - 1.0	0.0 - 0.0
% Bare Ground	12.1 (2.42)	15.0 (10.00)	35.6 (2.91)	4.7 (1.48)	16.7 (4.34)	2.9 (1.99)	4.8 (3.11)
	2.0 - 25.0	5.0 - 25.0	22.5 - 55.0	0.0 - 10.0	1.3 - 36.0	0.0 - 20.0	0.0 - 19.0
% Litter	22.3 (3.52)	45.4 (17.90)	2.8 (2.19)	41.3 (4.39)	55.6 (7.40)	63.3 (9.06)	56.7 (10.22)
	6.0 - 42.0	27.5 - 63.3	0.0 - 22.0	25.0 - 55.0	0.0 - 81.6	1.0 - 93.0	11.0 - 76.7
Litter Depth (cm)	1.2 (0.08)	2.7 (0.75)	0.2 (0.15)	2.5 (0.24)	2.7 (0.36)	2.1 (0.28)	3.9 (0.77)
	1.0 - 1.5	1.9 - 3.4	0.0 - 1.2	1.8 - 3.2	0.0 - 4.2	0.0 - 3.0	0.7 - 6.0

Table C.2. (Continued)

Habitat Variable	Longleaf Pine Wiregrass	Upland Hardwood	Bottomland Hardwood
% Grass	8.7 (4.40) 0.0 - 40.9	1.4 (0.68) 0.0 - 5.0	0.9 (0.40) 0.0 - 3.3
% Sedge	0.0 (0.00) 0.0 - 0.2	0.0 (0.00) 0.0 - 0.0	0.1 (0.08) 0.0 - 0.8
% Forbs	2.1 (0.58) 0.0 - 5.8	0.6 (0.32) 0.0 - 3.0	0.1 (0.08) 0.0 - 0.8
% Woody Stems	10.4 (2.20) 0.8 - 24.2	12.3 (1.04) 8.0 - 18.3	10.9 (1.16) 2.7 - 15.0
% Woody Vines	2.70 (1.03) 0.0 - 8.3	6.0 (0.88) 3.0 - 10.0	2.4 (0.88) 0.0 - 8.3
% Herbaceous	0.9 (0.40) 0.0 - 3.3	0.2 (0.18) 0.0 - 1.8	0.3 (0.25) 0 - 2.5
% Fern	2.1 (1.03) 0.0 - 8.0	0.0 (0.00) 0.0 - 0.0	1.3 (0.49) 0.0 - 5.0
% Other	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0	4.3 (2.77) 0.0 - 21.7
% Bare Ground	0.2 (0.17) 0.0 - 1.7	1.1 (0.58) 0.0 - 4.0	5.2 (1.92) 0.0 - 15.8
% Litter	65.4 (4.16) 41.7 - 83.5	78.6 (1.51) 72.5 - 85.0	74.3 (3.89) 48.3 - 87.5
Litter Depth (cm)	2.7 (0.29) 1.7 - 4.6	2.6 (0.24) 1.4 - 3.7	3.0 (0.20) 2.2 - 4.4

APPENDIX D. LAND COVER CLASSES AND PERCENTAGES FOR 500-METER RADIUS HABITAT BUFFERS SURROUNDING SMALL MAMMAL TRAP SITES IN BULLOCH AND CANDLER COUNTIES, GEORGIA.

Land Cover Class	***B. carolinensis***	***C. parva***	***M. musculus***	***N. floridana***	***O. nuttalli***	***P. gossypinus***
Clearcut/Sparse	5.0 (1.00) 1.5 - 9.9	5.4 (0.99) 2.0 - 8.9	4.6 (1.13) 0.1 - 17.0	7.2 (1.34) 1.6 - 12.8	7.9 (1.06) 2.5 - 13.3	6.9 (0.88) 0.8 - 24.7
Cultivated/Exposed Earth	16.8 (7.12) 1.2 - 53.2	28.7 (6.67) 3.3 - 53.2	43.1 (4.65) 3.3 - 71.9	35.4 (6.01) 1.2 - 55.7	31.6 (4.30) 7.6 - 48.4	25.8 (3.70) 0.0 - 67.2
Emergent Wetland	1.2 (0.45) 0.0 - 3.8	0.6 (0.52) 0.0 - 3.7	1.2 (0.43) 0.0 - 3.8	0.3 (0.22) 0.0 - 3.7	1.1 (0.40) 0.0 - 2.2	0.4 (0.19) 0.0 - 9.3
Evergreen Forest	32.2 (5.96) 6.6 - 50.5	21.9 (5.51) 6.6 - 42.5	16.4 (2.08) 6.3 - 39.3	25.2 (3.84) 7.2 - 39.9	25.9 (3.17) 10.4 - 47.7	29.9 (2.63) 6.9 - 61.1
Forested Wetland	17.9 (4.24) 4.3 - 34.4	9.7 (2.25) 2.7 - 19.2	13.5 (2.11) 1.7 - 34.2	15.9 (3.52) 4.3 - 34.4	18.6 (3.47) 4.3 - 38.1	17.6 (1.90) 2.1 - 40.0
Hardwood Forest	6.2 (1.62) 0.4 - 12.2	4.6 (1.78) 0.4 - 12.8	2.7 (0.56) 0.2 - 7.1	5.9 (1.40) 0.5 - 10.8	4.4 (1.25) 0.2 - 12.0	5.3 (0.79) 0.0 - 17.0
High Density Urban	0.1 (0.11) 0.0 - 0.9	1.1 (0.82) 0.0 - 5.9	0.5 (0.35) 0.0 - 5.9	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0	0.3 (0.34) 0.0 - 11.7
Low Density Urban	13.1 (9.31) 0.0 - 78.1	22.9 (10.81) 0.1 - 78.1	2.8 (1.34) 2.2 - 78.1	15.9 (4.62) 0.0 -10.6	4.6 (1.26) 0.0 - 9.0	3.7 (1.00) 0.0 - 74.2
Mixed Forest	3.7 (0.89) 1.1 - 7.2	3.1 (1.09) 0.8 - 7.5	2.1 (0.43) 0.0 - 5.5	2.7 (0.91) 0.7 - 7.9	4.8 (1.33) 0.6 - 14.9	4.0 (0.81) 0.0 - 24.1
Open Water	2.9 (0.86) 0.4 - 6.0	2.0 (0.79) 0.1 - 5.7	1.1 (0.48) 0.0 - 7.6	1.9 (0.65) 0.3 - 6.0	2.1 (0.82) 0.0 - 9.7	1.9 (0.49) 0.0 - 12.9
Pasture	0.8 (0.83) 0.0 - 6.6	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0	0.5 (0.53) 0.0 - 5.9	0.2 (0.19) 0.0 - 6.7

APPENDIX D. (CONTINUED)

Land Cover Class	***P. polionotus***	***R. humulis***	***S. hispidus***	***S. longirostris***
Clearcut/Sparse	5.8 (0.87) 0.6 - 10.4	5.9 (1.58) 4.4 - 7.5	5.4 (0.97) 0.6 - 17.0	3.9 (1.11) 1.5 - 6.5
Cultivated/Exposed Earth	36.5 (5.50) 6.4 - 68.4	21.7 (9.57) 12.1 - 31.3	37.8 (4.16) 3.0 - 71.9	11.2 (9.19) 1.2 - 38.7
Emergent Wetland	1.3 (0.32) 0.0 - 4.1	0.8 (0.38) 0.1 - 0.5	0.3 (0.18) 0.0 - 4.1	0.6 (0.30) 0.0 - 1.9
Evergreen Forest	24.0 (3.32) 6.3 - 40.4	32.9 (9.51) 23.5 - 42.5	18.4 (2.25) 6.6 - 46.2	43.8 (3.53) 35.8 - 50.5
Forested Wetland	15.9 (2.58) 3.5 - 34.2	11.3 (3.91) 7.4 - 15.3	11.3 (3.91) 1.7 - 34.2	19.4 (6.81) 4.3 - 34.4
Hardwood Forest	6.9 (1.47) 0.7 - 19.3	8.9 (3.94) 4.9 - 12.8	4.9 (0.85) 0.4 - 11.6	9.3 (1.36) 6.0 - 12.2
High Density Urban	0.0 (0.00) 0.0 - 0.0	0.2 (0.18) 0.0 - 0.4	0.5 (0.33) 0.0 - 5.9	0.0 (0.00) 0.0 - 0.0
Low Density Urban	6.7 (2.06) 0.0 - 8.7	4.4 (0.73) 0.1 - 22.2	11.1 (11.03) 0.0 - 78.1	14.5 (4.44) 0.0 - 6.4
Mixed Forest	3.6 (0.74) 0.5 - 8.8	5.3 (2.17) 3.2 - 7.5	3.1 (0.58) 0.0 - 8.5	4.6 (1.41) 1.5 - 7.2
Open Water	1.7 (0.55) 0.0 - 5.7	2.2 (0.51) 1.7 - 2.7	2.2 (0.54) 0.0 - 7.6	3.8 (1.16) 1.6 - 6.0
Pasture	0.5 (0.51) 0.0 - 6.7	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0	0.0 (0.00) 0.0 - 0.0

APPENDIX E. PLANT SPECIES COMPOSITION FOR TEN DIFFERENT HABITAT TYPES SAMPLED FOR SMALL MAMMALS IN BULLOCH AND CANDLER COUNTIES, GEORGIA.

Habitat Type	Species Composition
Agricultural Field	**Woody Plants:** *Campsis radicans, Rubus* spp., *Sida spinosa.* **Herb Layer:** *Amaranthus spinosus, Ambrosia* spp., *Aster* spp., *Bromus* spp., *Cenchrus longispinus, Chenopodium album, Conyza canadensis, Croton capitatus, C. glandulosus, Cynodon dactylon, Cyperus* spp., *Dactyloctenium aegyptium, Desmodium tortuosum, Digitaria* spp., *Eupatorium capillifolium, Euphorbia* spp., *Helenium amarum, Heterotheca subaxillaris, Ipomoea* spp., *Jacquemontia tamnifolia, Mollugo verticillata, Panicum* spp., *Paspalum dilatatum, Paspalum notatum, Passiflora incarnata, Portulaca oleracea, Polygonum* spp., *Richardia scabra, Rumex acetosella, R. hastatulus, Senna obtusifolia, S. occidentalis, Solanum carolinense, S. americanum, Solidago* spp., *Sorghum halepense, Stellaria media, Triodia flava, Verbena brasiliensis.*
Bottomland Hardwood	**Woody Plants:** *Acer rubrum, Alnus serrulata, Ampelopsis arborea, Aralia spinosa, Aronia arbutifolia, Arundinaria gigantea, Berchemia scandens, Betula nigra, Bignonia capreolata, Callicarpa americana, Campsis radicans, Carpinus caroliniana, Carya aquatica, C. ovata, C. tomentosa, Cephalanthus occidentalis, Clethra alnifolia, Cliftonia monophylla, Crataegus sp., Cyrilla racemiflora, Fagus grandifolia, Fraxinus caroliniana, Gelsemium sempervirens, Hypericum tetrapetalum, Ilex coriaceae, I. decidua, I. opaca, Itea virginica, Ligustrum sinense, Liquidambar styraciflua, Liriodendron tulipifera, Lonicera japonica, Lyonia lucida, Magnolia grandiflora, M. virginiana, Morus rubra, Myrica cerifera, Nyssa aquatica, N. sylvatica, Parthenocissus quinquefolia, Persea borbonia, Pinus elliottii, P. glabra, P. taeda, Prunus serotina, Quercus alba, Q. falcata var. pagodifolia, Q. laurifolia, Q. lyrata, Q. michauxii, Q. nigra, Rhododendron canescens, Sabal minor, Sambucus canadensis, Smilax laurifolia, S. walteri, Taxodium ascendens, T. distichum, Tilia americana, Toxicodendron radicans, Viburnum nudum, V. rufidulum, Vitis aestivalis, V. rotundifolia.* **Herb Layer:** *Aster* spp., *Athyrium asplenioides, Boehmeria cylindrica, Carex sp., Chasmanthium* spp., *Cyperus* spp., *Desmodium viridiflorum, Elephantopus carolinianus, Heteranthera reniformis, Juncus* spp., *Mitchella repens, Ptridium aquilinum, Saururus cernuus, Sphagnum* sp., *Verbena* sp., *Woodwardia areolata, W. virginiana.*

APPENDIX E. (CONTINUED)

Habitat Type	Species Composition
Clearcut	**Woody Plants:** *Acer rubrum, Aralia spinosa, Baccharis halimifolia, Callicarpa Americana, Clethra alnifolia, Gelsemium sempervirens, Ilex opaca, Liquidambar styraciflua, Magnolia virginiana, Myrica cerifera, Nyssa sylvatica* var. *sylvatica, Parthenocissus quinquefolia, Pinus taeda, Prunus serotina, Quercus alba, Q. falcata, Q. nigra, Rhododendron canescens, Rhus* sp., *Rubus* sp., *Sassafras albidum, Symplocos tinctoria, Smilax* sp., *Toxicodendron radicans, Ulmus alata, Vaccinium arboreum, V. elliotti, Vaccinium* sp., *Vitis rotundifolia.* **Herb Layer:** *Andropogon* spp., *Aster* spp., *Cyperus* spp., *Digitaria* spp., *Elephantopus tomentosus, Eupatorium capillifolium, Ipomoea* spp., *Panicum* spp., *Phytolacca americana, Polygonum* sp., *Ptridium aquilinum, Senna obtusifolia, Taraxacum officinale.*
Longleaf Pine - Wiregrass	**Woody Plants:** *Acer rubrum, Asimina triloba, Callicarpa americana, Chrysobalanus oblongifolius, Cornus florida, Crataegus flava, C. uniflora, Diospyros virginiana, Gaylusaccia dumosa, Gelsemium sempervirens, Hypericum galioides, H. hypericoides, Ilex glabra, Ligustrum sinense, Liquidambar styraciflua, Malus angustifolia, Myrica cerifera, Nyssa sylvatica var. sylvatica, Osmanthus americanus, Persea borbonia, Pinus palustris, P. taeda, Prunus serotina, Prunus umbellata, Quercus falcata, Q. incana, Q. laevis, Q. marilandica, Q. nigra, Q. stellata, Rhus copallina, R. vernix, Rubus* sp., *Sassafras albidum, Smilax bona-nox, S. glauca, S. pumila, Symplocos tinctoria, Toxicodendron quercifolia, T. radicans, Vaccinium arboreum, V. myrsinites, V. stamineum, Vitis rotundifolia.* **Herb Layer:** *Acalypha gracilens, Amsonia ciliata, Andropogon* sp., *Aeschynomene* sp., *Aristida beyrichiana, Asclepias tomentosa, A. tuberosa, Aster* sp., *Baptisia lanceolata, B. perfoliata, Chamaecristaa fasciculata, C. nictitans, Clematis reticulata, Clitoria mariana, Cnidoscolus stimulosus, Crotalaria* sp., *Desmodium rotundifolium, D. strictum, Desmodium* sp., *Dichanthelium aciculare, Dyschoriste oblongifolius, Eupatorium capillifolium, E. compositifolium, Galactia* spp., *Helianthemus carolinianum, Lespedeza bicolor, L. cuneata, L. hirta, L. procumbens, L. virginica, Liatris elegans, Mimosa quadrivalvis, Panicum* spp., *Paspalum notatum, Piriqueta caroliniana, Pityopsis graminifolia, Pteridium aqualinum, Rhynchosia reniformis, Rudbeckia* spp., *Scutellaria multiglandulosa, Sporobolus junceus, Stillingia sylvatica, Strophostyles umbellata, Stylisma* spp., *Stylosanthes biflora, Tephrosia virginiana, Yucca filamentosa.*

APPENDIX E. (C0NTINUED)

Habitat Type	Species Composition
Old Field	**Woody Plants:** *Baccharis halimifolia, Carya illinoensis, Diospyros virginiana, Hypericum reductum, H. galioides, H. hypericoides, Juniperus virginiana, Ligustrum sinense, Liquidambar styraciflua, Lonicera japonica, Myrica cerifera, Pinus elliottii, P. taeda, Prunus angustifolia, Prunus serotina, P. umbellata, Rhus copallina, Rubus* spp., *Sassafras albidum, Smilax* spp. **Herb Layer:** *Amaranthus* sp., *Ambrosia* spp., *Andropogon* spp., *Aster* spp., *Baptisia perfolata, Bromus* sp., *Chamaecrista fasciculata, C. nictitans, Cenchrus* sp., *Conyza canadensis, Croton* sp., *Cynodon dactylon, Cyperus* spp., *Daucus carota, Digitaria* spp., *Eragrostus spectabilis, E. hirsuta, Erigeron* spp., *Eupatorium capillifolium, E. compositifolium, Euthamia tenuifolia, Galactia volubilis, Gnaphalium obtusifolium, Helenium amarum, Helianthus* sp., *Heterotheca subaxillaris, Ipomoea* spp., *Lespedeza cuneata, L. procumbens, Panicum* spp., *Paspalum notatum, Ptridium aquilinum, Rhexia mariana, Rumex acetosella, Setaria* spp., *Sida spinosa, Solidago* spp., *Sorghum halepense, Taraxacum officinale, Triodia flava, Verbena brasiliensis, Vicia* spp.
Orchard	**Woody Plants:** *Albizia julibrissin, Ampelopsis arborea, Carya illinoensis, Ligustrum sinense, Lonicera japonica, Melia azedarach, Parthenocissus quinquefolia, Prunus caroliniana, P. serotina, Quercus nigra, Rubus* spp., *Sida spinosa.* **Herb Layer:** *Allium vineale, Amaranthus spinosus, Ambrosia* spp., *Andropogon* spp., *Bidens bipinnata, Cenchrus longispinus, Chenopodium album, Croton glandulosus, Cynodon dactylon, Cyperus* spp., *Digitaria* spp., *E. capillifolium, E. compositifolium, Gamochaeta purpurea, Geranium carolinianum, Gnaphalium obtusifolium, Heterotheca subaxillaris, Ipomoea* spp., *Lygodium japonicum, Oxalis stricta, O. violacea, Paspalum notatum, Passiflora incarnata, Phytolacca americana, Richardia scabra, Rumex acetosella, R. hastatulus, Senna obtusifolia, Setaria* spp., *Solanum carolinense, S. americanum, Solidago* spp., *Sonchus asper, Sorghum halepense, Vicia* spp.

APPENDIX E. (CONTINUED)

Habitat Type	Species Composition
Pine Flatwoods	**Woody Plants:** *Acer rubrum, Aronia arbutifolia, Asimina triloba, Bignonia capreolata, Callicarpa americana, Clethra alnifolia, Cyrilla racemiflora, Gaylusaccia dumosa, G. frondosa, Gelsemium sempervirens, Hypericum galioides, H. hypericoides, H. tetrapetalum, Ilex casseine, I. coriaceae, I. glabra, I. vomitoria, Liquidambar styraciflua, Liriodendron tulipifera, Lobelia brevifolia, Lyonia ferruginea, L. lucida, L. mariana, Magnolia virginiana, Myrica cerifera, Nyssa sylvatica var. sylvatica, Pinus elliottii, P. palustris, P. serotina, Persea borbonia, Quercus laurifolia, Q. nigra, Q. virginiana, Rhododendron canescens, Rhus copallina, Rubus* spp., *Serenoa repens, Smilax glauca, S. rotundifolia, S. smallii, Vaccinium elliottii, V. myrsinites, V. stamineum, Vitis rotundifolia.* **Herb Layer:** *Andropogon* spp., *Aristida beyrichiana, Asclepias tuberosa, Astragalus villosus, Chamaecrista fasciculata, Clitoria* sp., *Commelina communis, Ctenium aromaticum, Diodia virginiana, Dyschoriste oblongifolia, Elephantopus nudatus, Erianthus giganteus, Eryngium yuccifolium, Eupatorium capillifolium, E. compositifolium, E. rotundifolium, Eupatorium serotinum, Lespedeza hirta, Ludwigia alternifolia, Oenothera fruticosa, Paspalum notatum, Polygala lutea, P. nana, Pteridium aquilinum, Rhexia alifanus, R. mariana, R. virginica, Sabatia* sp., *Sarracenia flava, Sphagnum* sp., *Stylosanthes biflora, Syngonanthus flavidulus, Woodwardia areolata, W. virginiana, Xyris caroliniana.*
Pine Plantation	**Woody Plants:** *Acer rubrum, Albizia julibrissin, Ampelopsis arborea, Callicarpa americana, Carya illinoensis, Chrysobalanus oblongifolius, Clethra alnifolia, Cliftonia monophylla, Crataegus flava, Crotalaria* sp., *Croton capitatus, Cyrilla, Diospyros virginiana, Gelsemium sempervirens, Hypericum galioides, H. hypericoides, H. tetrapetalum, Liquidambar styraciflua, Ilex cassein, I. coreaceae, I. glabra, Lespedeza bicolor, Ligustrum sinense, Lonicera japonica, Melia azedarach, Myrica cerifera, Nyssa sylvatica* var. *sylvatica, Osmanthus americanus, Persea borbonia, Pinus elliottii, P. palustris, P. taeda, Prunus serotina, P. umbellata, Pueraria montana, Quercus falcata, Q. incana, Q. marilandica, Q. nigra, Q. stellata, Q. virginiana, Rhus copallina, Rubus* spp., *Sassafras albidum, Smilax* spp., *Vitis rotundifolium, Vaccinium arboreum.*

Habitat Type	Species Composition
Pine Plantation (Continued)	**Herb Layer:** *Ambrosia* spp., *Andropogon* spp., *Arachis* sp., *Aristida beyrichiana, Asclepius tuberosa, Asplenium platyneuron, Aster* spp., *Chamaecrista fasciculata, C. nictitans, Cladonia* sp., *Clitoria mariana, Cnidoscolus stimulosus, Cynodon dactylon, Desmodium* spp., *Diodia virginiana, Elephantopus* spp., *Eupatorium alba, E. capillifolium, E. rotundifolium, Opuntia humifusa, Oxalis stricta, Panicum, Paspalum notatum, Pityopsis graminifolia, Pteridium aqualinum, Rhexia* spp., *Solidago , Sorghum halepense, Stylisma* spp., *Yucca filamentosa.*
Sandhill	**Woody Plants:** *Asimina angustifolia, A. parviflora, Calamintha coccinea, Callicarpa americana, Carya glabra, Chrysobalanus oblongifolius, Crataegus flava, Crataegus uniflora, Diospyros virginiana, Gaylusaccia dumosa, Gelsemium sempervirens, Hypericum gentianoides, H. hypericoides, H. reductum, Liquidambar styraciflua, Myrica cerifera, Pinus elliottii, P. palustris, P. taeda, Prunus serotina, P. umbellata, Quercus incana, Q. laevis, Q. nigra, Q. stellata, Q. stellata var. margaretta, Rhus copallina, Sassafras albidum, Smilax pumila, Toxicodendron quercifolia, T. radicans, Vaccinium arboreum, Vaccinium stamineum, Vaccinim tenellum, Vitis rotundifolia.* **Herb Layer:** *Amsonia ciliata, Andropogon* spp., *Arenaria caroliniana, Aristida beyrichiana, Asclepias hemistrata, A. tomentosa, Balduina angustifolia, Baptisia lanceolata, B. perfoliata, Bonamia* sp., *Chamaecrista nictitans, Chrysopsis gossypina, Cladonia* sp., *Clitoria mariana, Cnidosculus stimulosis, Cuthbertia ornata, Cyperus spp., Dyschoriste oblongifolia, Elephantopus nudatus, Eriogonum tomentosum, Eupatorium compositifolium, E. rotundifolium, E. serotinum, Euphorbia* sp., *Galactia* sp., *Gnaphalium obtusifolium, Indigofera caroliniana, Ipomoea* sp., *Lespedeza hirta, L. procumbens, Liatris chapmanii, L. elegans, Lupinus diffusus, L. perennis, Mimosa quadrivalvis, Nolina brittoniana, Opuntia humifusa, Panicum* spp., *Paspalum notatum, Pityospsis graminifolia, Pteridium aqualinum, Rhynchosia reniformis, Scuttelaria multiglandulosa, Solidago* spp., *Sporobolus junceus, Stillingia sylvatica, Stylisma angustifolia, S. humistrata, Stylodon carolinensis, Tephrosia virginiana, Trichostema dichotomum, Viola pedata, Yucca filamentosa.*

APPENDIX E. (CONTINUED)

Habitat Type	Species Composition
Upland Hardwood	**Woody Plants:** *Acer rubrum, Ampelopsis arborea, Arundinaria gigantea, Bignonia capreolata, Callicarpa americana, Carya tomentosa, C. glabra, C. illinoensis, Castanea floridana, Cornus floridana, Diospyros virginiana, Fagus grandifolia, Gelsemium sempervirens, Hypericum hypericoides, Ilex opaca, I. glabra, Ligustrum sinense, Liquidambar styraciflua, Lonicera japonica, Malus angustifolia, Melia azedarach, Myrica cerifera, Nyssa sylvatica var. sylvatica, Osmanthus americanus, Persea borbonia, Pinus elliottii, Pinus echinata, P. palustris, P. taeda, Prunus serotina, Quercus alba, Q. falcata, Q. incana, Q. nigra, Q. stellata, Rhamnus caroliniana, Rubus spp., Sassafras albidum, Smilax glauca, S. rotundifolia, Symplocos tinctoria, Toxicodendron radicans, Vaccinium arborea, V. elliottii, V. stamineum, Vitis rotundifolia.* **Herb Layer:** *Asplenium platyneuron, Elephantopus tomentosa, Pteridium aqualinum, Scutellaria integrifolia, Trillium* sp.*, Viola* sp.