8-2000

The Relationship of Small Mammal Species to Habitat Variables in West-Central Georgia and East-Central Alabama

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Masters of Science in Environmental Science Program

The relationship of small mammal species to habitat variables in west-central Georgia and east-central Alabama

A Thesis in

Environmental Science

by

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Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science

August 2000

I have submitted this thesis in partial fulfillment of the requirements for the degree of Master of Science.

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Abstract

The objective of this investigation was to assess the impact of environmental variables upon small mammal species distribution in 60 plots on Fort Benning, Muscogee and Chattahoochee Counties, Georgia and Russell County, Alabama. The small mammal fieldwork was carried out in December of 1994 through January of 1995. The vegetation was inventoried in June through October of 1995. During this period, 235 small mammals were trapped in a total of 5950 trap nights. A total of 10 small mammal species and 234 plant species were identified. The small mammal species abundance's were determined by using snap trapping along the plot transect. The responses of the *Blarina carolinensis*, *Cryptotis parva*, *Oryzomys palustris*, *Reithrodontomys humulis*, *Peromyscus gossypinus*, *Peromyscus polionotus*, *Ochrotomys nuttalli*, *Sigmodon hispidus*, *Neotoma floridana*, and *Mus musculus* with respect to the the sand to clay ratio, percent slope, elevation, distance to water, number of burns, number of evergreen and deciduous species, number of grass species, number of forb species, canopy cover, understory, and percent bareground cover were evaluated and analyzed using a direct gradient analysis technique termed Canonical Correspondence Analysis (CCA). To evaluate the response of specific species with high abundance, a second analysis was performed to include only *Reithrodontomys humulis*, *Peromyscus gossypinus*, *Peromyscus polionotus*, and *Sigmodon hispidus*. The modified analysis was consistent with the first unmodified analysis with the exception of *Sigmodon*. The modified

analysis showed that the most important habitat characteristic for *Sigmodon* was a low degree of understory.

Perturbations to important microhabitat characteristics due to training or land management practices would change the distributions of several species. The four most important environmental variables with respect to how the small mammals responded to them were understory, canopy cover, the number of deciduous species, and percent bareground cover. Changes in land management practices like decreasing the frequency of burning or training practices such as the removal of vast tracts of trees would change the distribution of small mammals species.

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Acknowledgments

I'd like to acknowledge and thank several people and agencies that assisted me during the course of preparing this thesis. I'd like to thank two Columbus State University faculty members, Bill Birkhead and Julie Ballenger who offered support and assistance with my thesis. A special thanks goes to John Graham, of Berry College, who took the time to assist me with the statistical analysis. I wouldn't have completed my thesis without his guidance. I'd also like to thank the Directorate of Operations and Training and the Directorate of Public Works on Fort Benning, Georgia for their permission to use data from the installation for my thesis project. I'd like to acknowledge the Land Condition Trend Analysis Program (LCTA) and thank Theresa Davo for allowing me to access LCTA data and for assisting me numerous times during the course of my project.

Dedication

I'd like to dedicate my thesis to my parents Tom and Sue Kosky and my boyfriend John Gower. They have supported my educational endeavors and continually encouraged me to complete this project. I'd also like to dedicate my thesis to Art Cleveland, my thesis advisor, who tirelessly supported and guided this paper.

Introduction

The objective of this investigation was to correlate the microhabitat characteristics of the environment with small mammal species in 60 plots on Fort Benning, Georgia. The small mammal fieldwork was carried out in December of 1994 and January of 1995. The vegetation was inventoried in June through October of 1995. During this period, 234 small mammals were trapped during a total of 5950 trap nights. A total of 11 small mammal species and 235 plant species were identified. The small mammal species abundance's were determined by using snap trapping along the plot transect. To explore the relationship between the microhabitat and small mammal species, the following criteria were evaluated: percent bareground cover, distance to water, number of grass species, number of forb species, number of evergreen species, understory, canopy cover, sand to clay ratio, number of deciduous species, elevation, slope, number of burns from 1991-1995, and small mammal species abundance. Canonical correspondence analysis, a direct gradient analysis technique, was used to correlate the above environmental variables to abundance of the small mammals. The solution was a biplot that displayed the small mammal species distributions along the environmental axes.

Determining the dominant environmental gradients that influence the response of small mammals is of significant interest. Suites of variables have been suggested to be responsible for the distribution of small mammals within their geographic ranges. These include degree of understory, substrate moisture, water availability, canopy cover, forb cover, and herbaceous vegetation (Miller and Getz 1976, Geier and Best 1980, Holbrook 1978).

The investigation of small mammal species distributions and how they relate to their microhabitat has been studied in numerous diverse localities (Geier and Best 1980, Kaufman and Fleharty 1974, Holbrook 1978, M'Closkey and Fieldwick 1975, Martell and Radvanyi 1977, Armstrong 1977). However there has not been a detailed analysis of distributional patterns of small mammals on Army installations (Whitworth pers com). A variety of forest habitats and the combination of training and land management practices provided an exceptional opportunity to explore the relative importance of specific environmental variables and their relationship to small mammals.

Several multivariate techniques have been used to establish the relationship between specific environmental variables and small mammals including discriminate function analysis, correlation analysis, and cluster analysis (Holbrook 1978, Miller and Getz 1976, Armstrong 1977). CCA has also been used in several studies to describe plant community variation and to determine patterns of distribution of species along a disturbance gradient (Lyon and Sagers 1998, Dibble et al. 1999). Other studies used CCA to determined the relationship between freshwater macroinvertebrates and their habitat, and relate vegetation patterns to topography, fire-return intervals, and geologic parent material (Warrington *et al.* 1996, Batek *et al.* 1999). Although no studies were found using CCA and small mammals, it was an appropriate choice for this study because it is a direct gradient analysis technique that specifically illustrated the relationship between the distribution of species and their environment (ter Braak and Verdonschot 1995).

Study Area

Fort Benning is a United States Army training installation located in the southeastern United States about 100 miles southwest of Atlanta, Georgia (Figure 1). The installation lies south of Columbus, Georgia and southeast of Phenix City, Alabama (Figure 2). It encompasses about 182,00 acres (73,653 hectares), of which 169,500 acres (68,594 hectares) are located in Muscogee and Chattahoochee Counties, Georgia. A small part of the installation, about 500 acres (202 hectares), is in Marion County, Georgia. An additional 12,200 acres (4937 hectares) are located in Russell County, Alabama.

Historically, the longleaf pine community dominated the southeastern Coastal Plain. It is characterized as an open park-like pine barren composed of even and uneven-aged forests, woodlands, and savannas (Landers *et al.*1995). Longleaf pine is the chief tree species in this fire driven forest ecosystem (Landers *et al.* 1995). The groundcover is diverse consisting of grasses and very little understory hardwoods. The groundcover provides the fuel for regular fires; induced by lightning or by the Native Americans. The longleaf pine seedlings are resistant to fire damage while the hardwoods are less resistant. Wharton (1978) described the Coastal Plain Province as open canopy forest on sandhills and in deep sands on ridge tops. The canopy included oak species rarely over 4.572 meters high and may or may not have included longleaf pine. Leaf litter generally was absent, with lichens replacing it for ground cover. Cactus and yucca were among the herbaceous layer of plants present adapted for growth in dry conditions. The oak-hickory-pine forests of the Coastal Plain as described by William Bartram (Van Doren 1955) in 1776, enroute from Savannah to Augusta, as a level plain with loose soil and spacious high forests. He noted such species as hickory (*Carya spp.*) loblolly pine (*Pinus taeda*), short leaf pine (*Pinus echinata*), white oak (*Quercus alba*), sweetgum (*Liquidambar styraciflua*), and yellow poplar (*Liriodendron tulipifera*). He described the sand-hills as mostly forested with long leaf pine (*Pinus palustris*), numerous herbaceous plants, savannas, and clumps of evergreen and other trees such as Magnolia (*Magnolia grandiflora*), Viburnum, and Azalea.

The Chattahoochee River meanders through the western portion of the installation and separates the Georgia and Alabama sides. A unique aspect of the location of the installation is a zone of transition between the Piedmont Physiographic Province to the north and Coastal Plain to the south, known as the Fall Line. The Fall Line represents an area of rapids and falls in streams and rivers that demarcate the transition between the two physiographic provinces. The Fall Line transition influences the northern portion of Fort Benning. The result is a diversity of Piedmont and Coastal Plain-affected habitats and the associated occurrence of a variety of ecotonal plant and animal communities. This effect of location is not limited to terrestrial communities but also is reflected in the physical features and biotic composition of the streams that pass through or arise within the installation.

The major soils found on the installation are Troup, Nankin, Ailey, and Cowarts soils. The soils texture (Figure 3), was created by the U.S. Army

Engineering and Research Development Center Environmental Laboratory, Vicksburg, Mississippi using soil coverages obtained from the Conservation and Land Management Branches, Fort Benning, Georgia (U.S. Army 2000). For a more complete description of the soil coverages refer to Appendix A.

Figure 1. Map of the Southeastern United States. Fort Benning is located in west-central, Georgia.

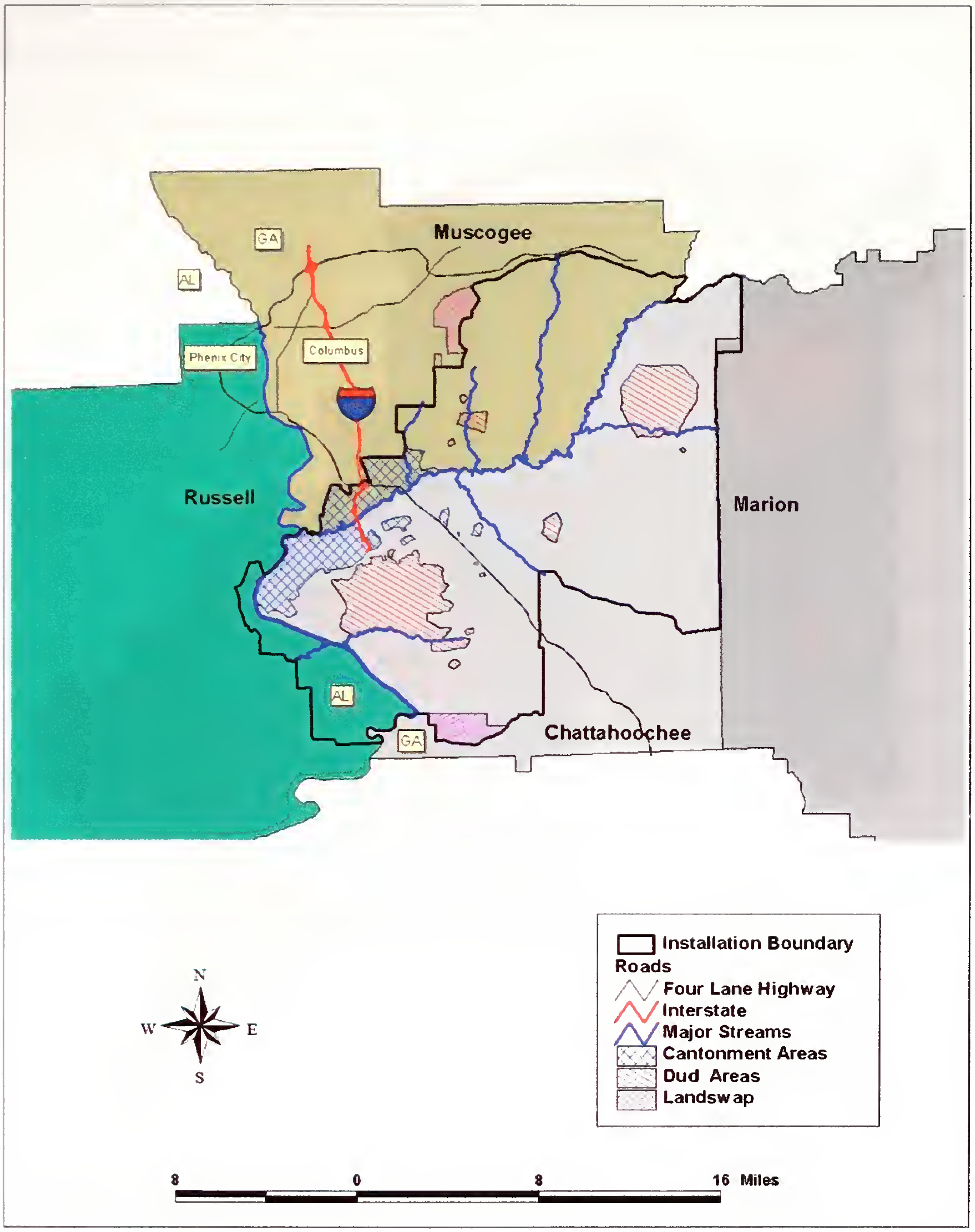


Figure 2. Specific site location of Fort Benning, Georgia.

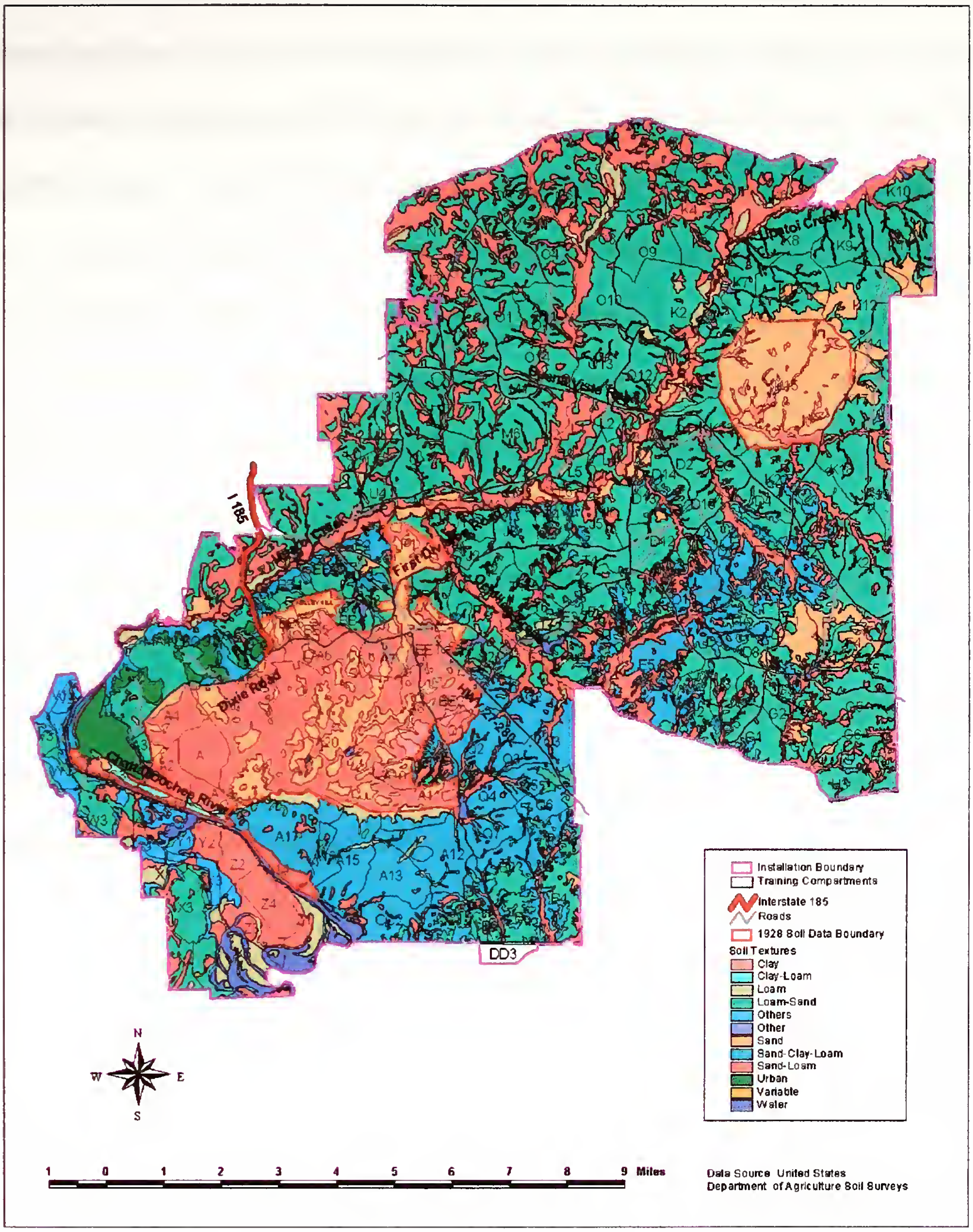


Figure 3. Soil texture map for Fort Benning, Georgia (U.S. Army 2000). See Appendix B for detailed explanation of how the map was produced.

Most of the installation is drained by Upatoi Creek a major tributary of the Chattahoochee River, which extends from the northeastern part of the state in the southern Appalachian Mountains and Blue Ridge Province to its junction with the Flint River. At the Florida-Georgia boundary the Flint and Chattahoochee River combine to become the Apalachicola River draining into the Gulf of Mexico at Apalachicola, Florida. A section of Fort Benning's southeastern area drains into the Flint River. (Figure 4). Tributaries of Upatoi Creek within Fort Benning include Ochillee, Randall, and Pine Knot Creeks. Oswichee Creek is a tributary of the Chattahoochee.

The land that Fort Benning now occupies was historically used in several capacities. Native American villages, farms, mills, and cotton plantations once occupied the current site of Fort Benning. Previous inhabitants influenced the landscape through agriculture, timber harvesting, burning and water impoundment's for mill operation (Elliot *et al.* 1995, and Kane 1998).

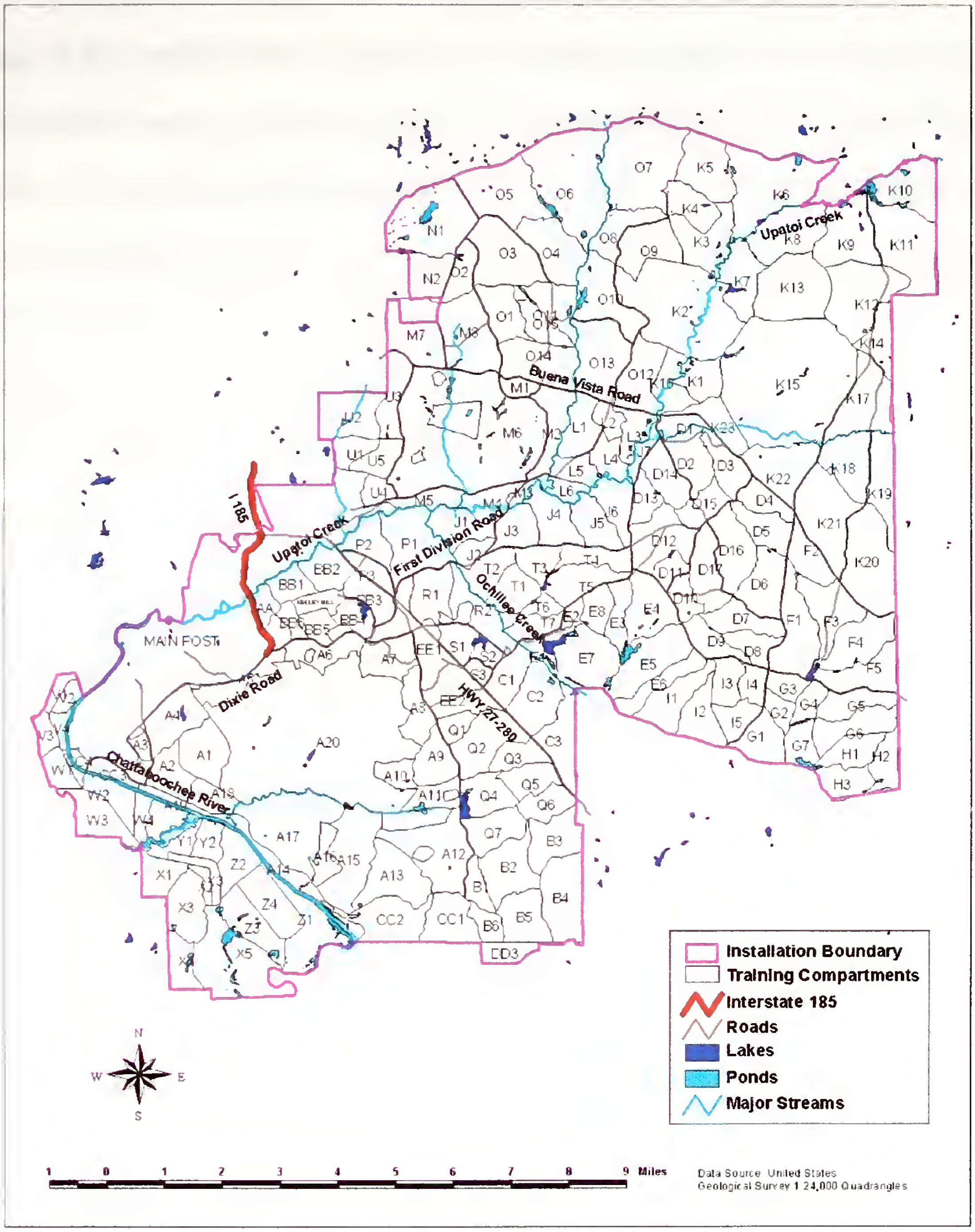
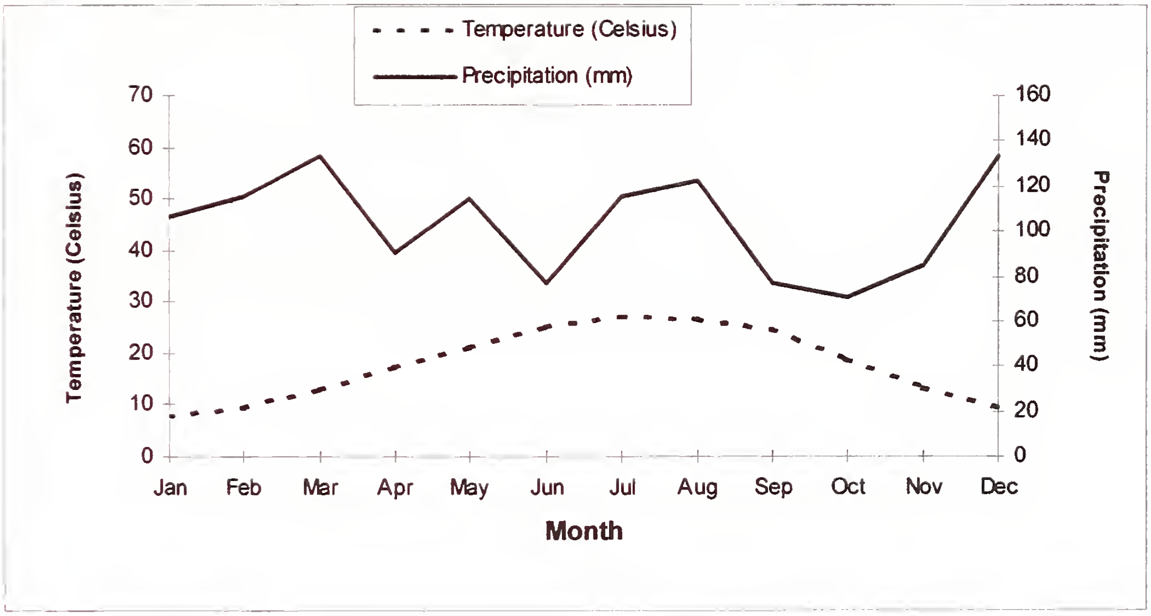


Figure 4. The major waters on Fort Benning, Georgia.

Hot humid summer months and cool temperatures with an occasional cold wave in the winter months characterize the climatic conditions on Fort Benning. Precipitation occurs regularly throughout the year with an annual average rainfall of 81-122 cm (Jones and Davo 1997). The average mean temperatures for the summer range from 23°-30° C and the average winter mean temperatures range from 4.0°-15° C (Jones and Davo 1997). The climate diagram, (Figure 5), illustrates the annual temperature pattern and precipitation (Jones and Davo 1997). Figures 6 and 7 summarize the mean monthly temperature and precipitation.

Figure 5. Climate diagram for Fort Benning, Georgia. It represents 32 years of data (1965-1996). Taken from Jones and Davo (1997).



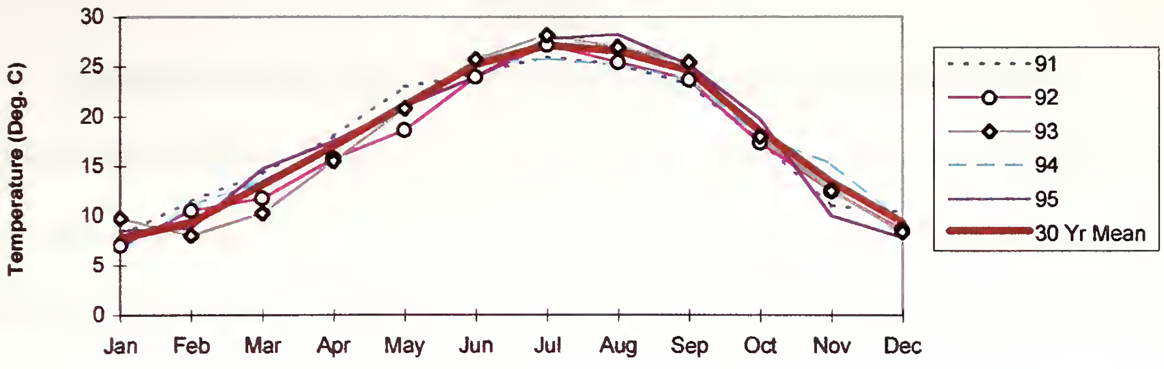


Figure 6. Mean monthly temperatures for 1991-1995 and the long-term average. Taken from Jones and Davo (1997).

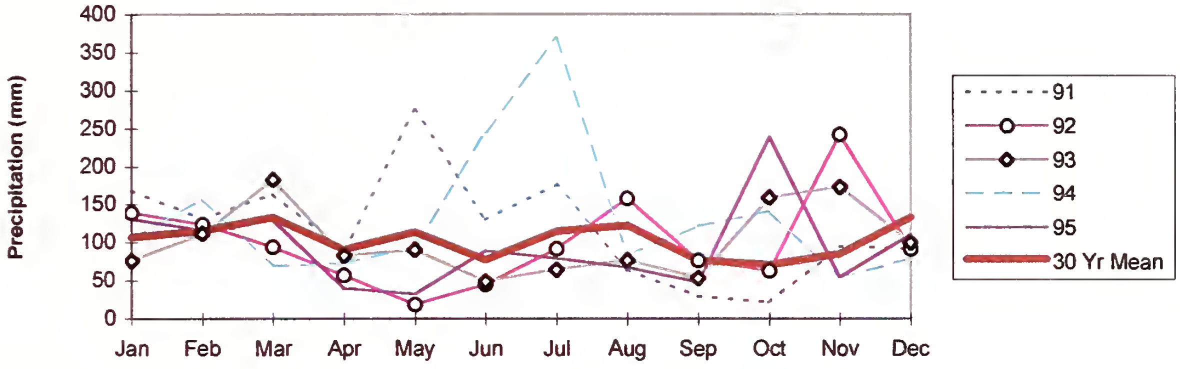


Figure 7. Mean monthly precipitation for 1991-1995 taken at Fort Benning 30-year mean. Taken from Jones and Davo (1997).

Methods

A small mammal survey and vegetation inventory was conducted on 60 plots on Fort Benning, Georgia in 1994 and 1995. (See Figure 8 for location of plots and Appendix C for a list of grid coordinates). The plots were established based on criteria developed by the U.S. Army Corps of Engineers, Engineering Research and Development Center Construction Engineering Research Laboratory (ERDC-CERL) for the Land Condition Trend Analysis (LCTA) program and were representative of the installation habitats as a whole. Each plot measured 6 meters by 100 meters. Data were collected in the following manner: the small mammals were trapped on each plot using snap traps in December of 1994 and January 1995 and a vegetation inventory was conducted in the summer of 1995 on each plot.

Canonical correspondence analysis (CCA) was used for the analysis of the environmental variables and small mammal species data. CCA is a direct gradient analysis procedure designed to extract the best synthetic gradients from species and environmental data by forming linear combinations of environmental variables that maximally distribute the species. Direct gradient analysis can be used for hypothesis testing or exploratory analysis. Since the analysis was not planned *a priori*, a hypothesis was not generated for this data and instead exploratory analysis was employed to correlate the environmental variables to the small mammals.

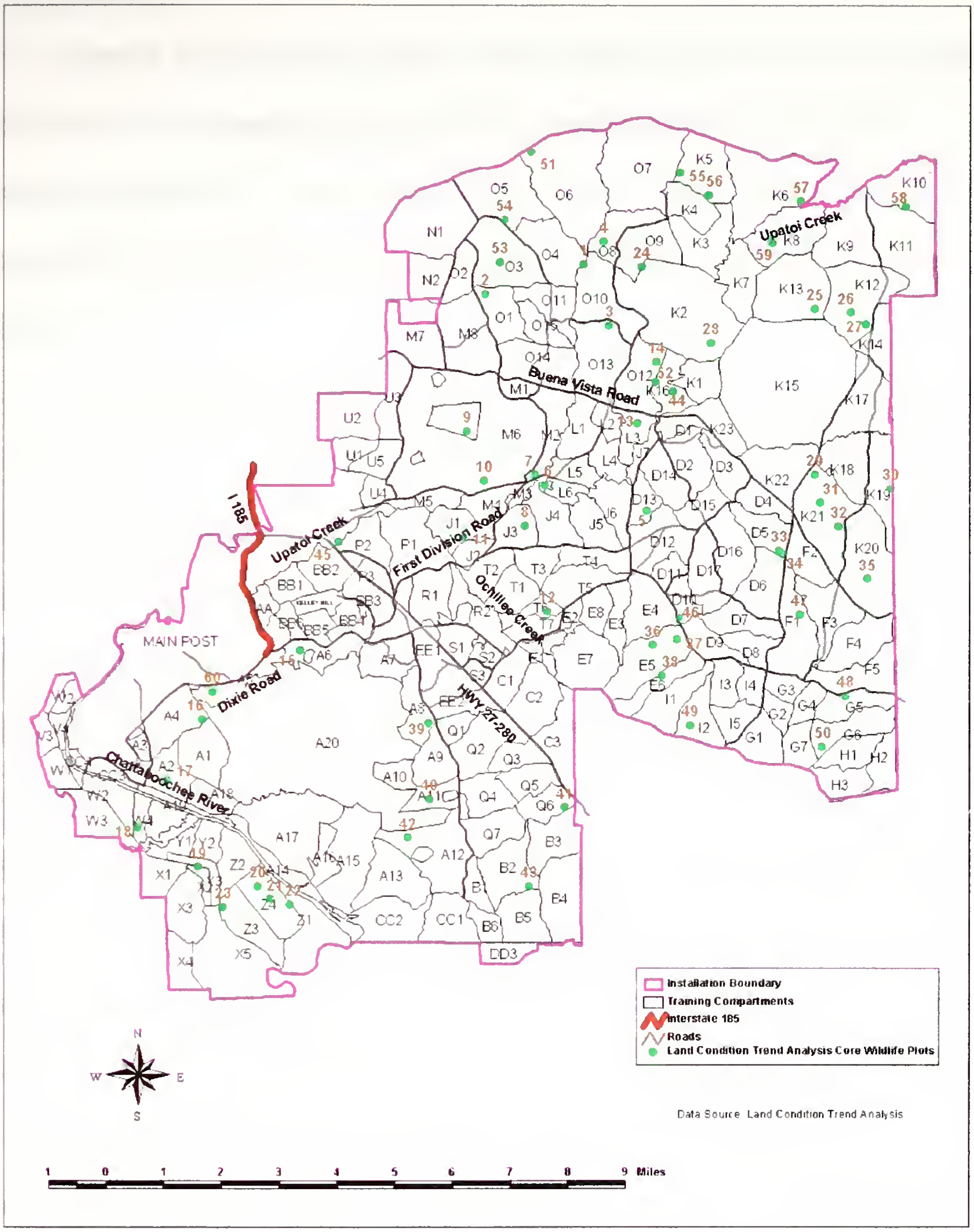


Figure 8. Land Condition Trend Analysis plots on Fort Benning, Georgia. Plots 1-60 are represented and were used for the small mammal survey in December of 1994 through January of 1995.

Field procedures

Methods for the Land Condition Trend Analysis Program (LCTA) included plot allocation and establishment, vegetation and land use inventory and monitoring of line transect and belt, and small mammal data collection procedures. For more information on LCTA methodology refer to Tazik *et al.* (1992).

Plot establishment included 200 core plots randomly assigned to their location based on land cover (1990 SPOT Image) and soil combination. The azimuth of each plot was randomly chosen but restricted the plot to the same soil series. The plot belt was 6 X 100 meters with permanent rods placed in the ground at 25-meter increments down the center of the plot from the zero point to the 100-meter point. A 100-meter tape transected the plot during a survey. Rubber tipped metal clips affixed the meter tape at each 25 meter increment beginning with the zero meter point. Four procedures documented the location of each plot. Three trees painted with an orange band, formed a triangulation around the zero meter point of each plot. The distance and azimuth from each orange-banded tree to the zero meter point recorded its location. General and specific maps and photographs documented the location of each plot. Photographs taken included a panoramic view of the line transect, taken from the zero meter point, a view approaching the plot, and a view approaching the plot from the road. The coordinates of each zero meter point were collected using a Global Positioning System (GPS).

Data collected along the 100 meter line transect included five entries each at 1 meter increments beginning with the 0.5 meter point and ending with the 100 meter point. The data collected included the location of the plant on the line transect, the height of the species, the genus and species of the plant, ground cover, and surface disturbance. Tables 1 and 2 detail the physical disturbance and ground cover parameters respectively. These data provided information about canopy cover, surface disturbance, and ground cover using a modified point intercept method.

A 1 meter rod placed on the meter tape flush with the ground was used to measure the herbaceous vegetation 1 meter or less in height. A telescoping range pole placed on the meter tape measured the woody vegetation greater than 1 meter in height. The plant species was also recorded. Vegetation that hit the range pole every 0.5 meter was recorded up to 8.5 meters. The top-most canopy species greater than 8.5 meters in height was also recorded. Any indication of disturbance was documented at each point. Surface soil disruption or crushed vegetation defined disturbance. Ground cover was recorded at each point. The entry for ground cover was based on the material on the ground that was directly beneath the 1 meter rod and 100 meter tape.

Table 1. Categories of Physical Disturbance Recorded on the Line Transect

Type	Code	Description
None	N	No evidence of physical disturbance to the soil surface or crushed vegetation
Road	R	Permanent or semi-permanent traffic route receiving periodic maintenance
Trail	T	Semi-permanent traffic route receiving no maintenance
Pass	P	A random vehicle track that does not follow an established traffic pattern
Other	O	Evidence of soil disturbance from nonvehicular sources such as excavation, demolition, bivouac activity, etc.

Tazik *et. al* 1992.

Table 2. Ground cover categories recorded on the line transect.

Category	Code	Description
Basal cover	*	That part of a plant where the leaves and/or stem join the roots at the soil surface. Vascular plants are recorded by species code.* Record microphytes as MOSS, LICHEN, or ALGAE.
Prostrate	*	Attached leaves, stems, stolons, etc. in contact with the soil surface away from the plant crown.
Dead wood	DW	Detached, fallen, woody material $\geq$ 2.5 cm in at least two dimensions.
Litter	LG, LF, LS, LT	Detached herbaceous plant parts of any size, and woody material $\geq$ 2.5 cm in at least two dimensions. The second letter code identifies the source of litter (ie., G=grass, F=forb).
Duff	DG, DF, DS, DT	Accumulations of litter $\geq$ 2.5 cm in depth. The second letter in the code identifies the source of the litter (i.e., G=grass, F=forb, S=shrub, and T=tree).
Rock	RO	Rock and other nonbiodegradable material > 7.5 cm in any dimension.
Gravel	GR	Gravel and other nonbiodegradable material > 2mm in any dimension and < 7.5 cm in all dimensions.
Bare Ground	BG	Exposed soil.

Tazik *et. al* 1992.

The belt inventory included four entries listing the species, its location with respect to the line transect, distance from the line transect, and its height. These data were collected at each point along the 100 meter transect point for which a woody plant occurred on the belt. The belt extended three meters on each side of the line transect and was 100 meters in length. Data collected on the belt was designed to depict the species composition, density, and height distribution of the woody vegetation. The height, species, and location of all woody species $\geq$ 1 meter were recorded on the belt. A telescoping range pole was used to measure the distance of the woody species from the line, the point on the line adjacent to that plant, and the height of the woody species. Live and dead woody species are recorded. Woody plants that generated compound stems, root sprouts, adventitious roots, or rhizomes were recorded as one plant. The tallest stem was used to record the height.

Small mammals were trapped on 60 of the 200 plots using 40 museum special snap traps and 10 rat traps per plot for a three week period during December 1994 through January 1995. Prior to data collection, a scientific collection permit was obtained from the Georgia Department of Natural Resources. The traps were placed parallel to the line transect of the plot at a distance of 15 meters on each side of the line transect. The traps were spaced at increments of approximately 7.5 meters. (See Appendix D for diagram of traps placement). The traps were set for 5950 trap nights using peanut butter and rolled oats as bait. The traps were set during the morning and afternoon of the first day. They were checked at the same time the following day and reset.

Finally, the traps were checked and picked up on the third day. All specimens collected were placed in a plastic sealable freezer bag marked with the species, date, plot number, and training area then frozen. The specimens were deposited at the Vertebrate Museum at Columbus State University, Columbus, Georgia and kept frozen until they were subsequently skeletonized.

Although the vegetation was collected within the 3 meter belt on either side of the line transect, the traps were placed parallel to the line transect at a distance of 15 meters on each side of the line transect at 7.5 meters increments. This procedure was designed for a broad number of DOD installations and should have been modified on Fort Benning to account for the fact that the microhabitat data collected within the three meter belt could vary from microhabitat data beyond the belt or the line transect.

Laboratory Procedures

In August 1998, the 1995 specimens were thawed, measured, and skeletonized to verify the species. Each specimen was thawed at room temperature under a ventilated hood and the total body length, tail length, left foot length, and ear length was measured in millimeters. These data were recorded and entered into a database. The skulls of the specimens were tagged with a catalog number, which indicated the plot number, trap night, and year. The specimen acronym representing the genus and species and the sex was also written on the tag. Each of the tagged specimens was placed in a box for storage. The skeletization procedure is that described by Hall (1955).

Data Analyses

To determine the association of environmental variables on species composition, Canonical Correspondence Analyses was performed on the 1995 data using Canoco for Windows, Version 4. (See Table 3 for an explanation of environmental variables). The linear combination of environmental variables adds the full power of regression to this ordination technique. The technique is derived from a species packing model in which species are assumed to have bell-shaped response surfaces with respect to compound environmental gradients (ter Braak, 1986). An ordination diagram is produced to display the variation in community composition as explained by the environmental variables. It also shows the distributions of the species along each environmental variable. The ordination diagram is a simple visual method to assess the relationship among the environmental variables and the species.

Table 3. Explanation of how the Environmental Variables were derived for analysis in 1995 CCA.

Environmental Variable	Point of Collection on LCTA 600 m^2 Plot	Explanation
Sand/Clay ratio	Data collected at 25 meter increments-5 total	Composite sample sent to the County Co-op extension, UGA
Percent Slope	Data collected at 25 meter increments-5 total	Clinometer is used to take measurement. Five measurements were averaged for use in analysis
Elevation (meters)	None	Taken from USGS topographic maps
Distance to Water (meters)	None	Calculated using Arcview
Number of Evergreen species	Data collected on line transect and belt	Calculated using SQL Base and Quest
Number of Deciduous species	Data collected on line transect and belt	Calculated using SQL Base and Quest
Number of Grass species	Data collected on line transect	Calculated using SQL Base and Quest
Number of Forb species	Data collected on line transect	Calculated using SQL Base and Quest
Canopy Cover	Data collected from line transect	Calculated using LCTA Front End Program using vegetation >4 meters
Understory	Data collected from line transect	Calculated using number of perennials via the LCTA Front End Program
Number of burns 1991-1995	Entire Plot	Calculated using SQL Base and Quest
Percent Bareground Cover	Data collected from line transect	Percentage calculated from data collected on 100 points using LCTA Front End Program

CCA is a technique that uses species abundance data and environmental data collected from plots. It is based on the Gaussian response curve (Figure 9).

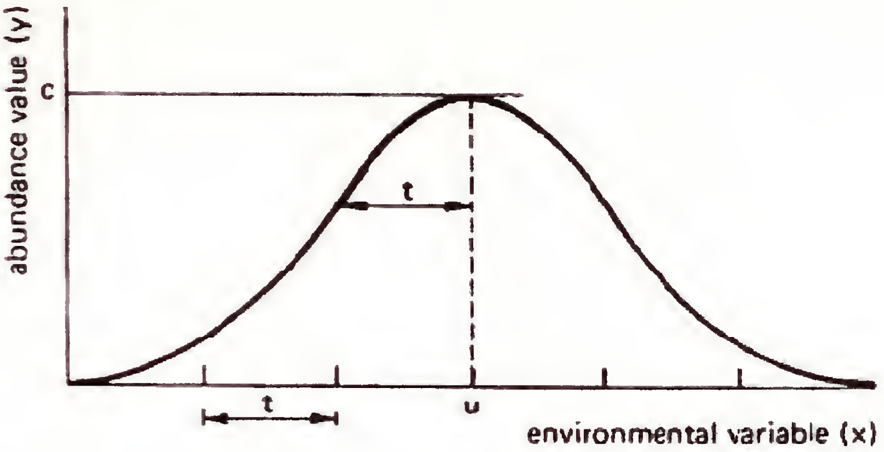


Figure 9. Gaussian curve exhibits a unimodal relation between the abundance (y) of a species and an environmental variable (x). Taken from ter Braak *et al.* (1988).

Synthetic gradients or ordination axes are generated from the environmental data that maximizes the niche separation among species. According to Shelford's Law of Tolerance (Shelford, 1911): species tend to thrive at a particular optimum so their numbers will be low or nonexistent outside of this optimum. The niche of a species is the result of many processes which are difficult to observe, but when community processes are observed from the standpoint of competition among species, a niche can be inferred. Species will separate themselves in an effort to minimize competition. A strong separation will create species partitioning along an environmental gradient. The composition of communities will change along an environmental gradient according to unimodal functions. Some species may fall outside the optimum and their response may be monotonic. Habitat space is multi-dimensional and species tend to be most abundant around an environmental optimum (ter Braak and Verdonschot 1995).

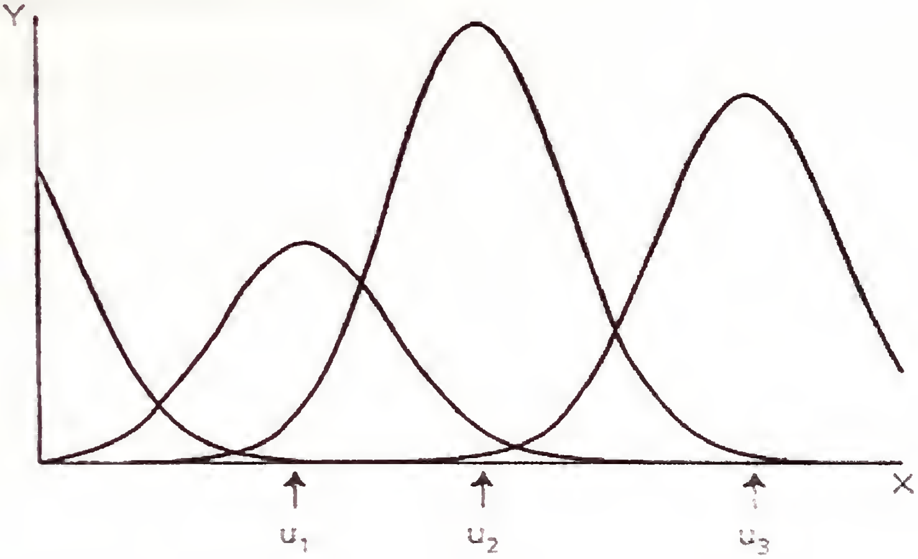


Figure 10. Unimodal curves for the expected abundance or response of three species against an environmental gradient (ter Braak *et al.* 1995). The U_x signify the environmental optimum of the species as estimated by the weighted average of the species.

The ordination diagram produced by CCA is explained by the following: Niche separation is indicated by the weighted variance of the species centroid, or weighted mean, where the average gradient values of the sites at which the species occur are the centroid. Species centroids indicate that the species scores are centered and standardized. The species' optimum, which is a unimodal curve, is illustrated in Figure 10. If the response curve of the species is symmetric, then the species centroid can be used as an estimate of the species relationship to the environmental gradient. The first ordination axis is derived from the first synthetic gradient. The eigenvalue of the ordination axis is the maximum amount of niche separation. The axes are a linear combination of the environmental variables that maximally separate the species niches. Each ordination axis that is generated is not correlated to the previously extracted axis or axes. The first few axes that are generated are usually sufficient to evaluate the relationship between the species and the environment since the eigenvalue will decrease as the number of axes generated increases (ter Braak and Verdonschot 1995). The ordination axes can be interpreted using the canonical coefficients and the intra-set correlations. Intra-set correlations are the correlation coefficient between the environmental variables and these ordination axes. Canonical coefficients are the ordination axes defined as linear combinations of the environmental variables through the equation that relates the ordination axis to the environmental variables. For a more detailed account of the mathematics, refer to ter Braak (1986).

According to ter Braak, (1986), the critical assumption is that the response of the species are unimodal and there exists of a single set of underlying environmental gradients to which all species respond. The procedure only guarantees that species dispersion is maximized and therefore models relative abundances. Palmer (1993) stated that CCA is robust to violations of the assumptions and it performed well with skewed species distributions. There was one limitation to CCA. It is assumed that the variables are measured without error and they are constant within a site. However

(Palmer and Dixon 1990) stated that this is a problem for direct gradient analysis in general and not a flaw specific to CCA.

The ordination diagrams produced by CCA are the crux of the procedure. The ordination diagram is a graph with the coordinate system formed by the ordination axes, which are the synthetic gradients extracted by CCA. The ordination diagram, or biplot, consists of the species points, site points, and arrows that represent the environmental variables. Table 4 summarizes the properties of the species-conditional CCA biplot.

Table 4. Properties of the species-conditional CCA biplot based on ter Braak (1995).

Scaling	Species Biplot Scaling
1. species x species	fitted relative abundances
2. species x species	chi-square distances
Quantitative Environmental Variables	
3. sites x species	values of environmental variables
4. species x environmental variables	weighted averages
environmental variables x environmental variables	correlations

The method chosen for this data was the biplot rule. According to ter Braak (1986), the arrows determine an axis in the diagram. The arrow can be extended in both directions in one's mind or on paper. From each species point a perpendicular is dropped to the environmental arrow. The endpoint of the perpendicular indicates the relative position of the center of the species with respect to that environmental arrow. Therefore they indicate the relative value of the weighted average of each species with respect to that environmental arrow.

The direction and length of the arrow have significant meaning in the biplot. The arrow points in the direction of maximum change in the value of the associated variable. The length represents the maximum rate of change for the associated variable. In relationship to the species' centroid, the arrows indicate the magnitude of species occurrence. The arrows indicate the magnitude of environmental variable that exists on the species sites (ter Braak and Verdonschot 1995). More specifically the length is equal to the multiple correlation of the variable with the displayed ordination axes and thus indicates how well the values of the variable are displayed in the biplot of sites and environmental variables; this property follows the fact that the coordinates of the arrow head are correlated with the axes and that the axes are uncorrelated. The length is also equal to the maximum rate of change of the variable; variables with short arrows do not vary much cross the diagram. The length is also equal to the magnitude of the effect that the corresponding variable has on the ordination scores while ignoring other variables (ter Braak and Verdonschot 1995).

Results

Gradient Analysis

The plots used in this analysis were located across an extensive range of environmental gradients. Tables 5 and 6 summarize the means, standard deviations, and the ranges of the 12 environmental variables used in the analysis for the unmodified and modified data.

Table 5. Environmental variables collected at 60 LCTA Plots and analyzed using canonical correspondence analysis. Data was collected on Fort Benning, Georgia during the summer, fall, and winter of 1995. Note that the means and standard deviations will be (usually slightly) different from a straightforward calculation of averages and standard deviations because the numbers used are weighted by species abundances.

Quantitative Variables	Mean	Standard Deviation	Maximum	Minimum
Sand/Clay ratio	6.18	3.66	15.1	0.2
Percent Slope	7.31	6.17	44.5	1.0
Elevation (meters)	171.83	104.09	351.0	2.0
Distance to Water (meters)	197.59	174.78	782.0	0.0
Number of Burns 91-95	1.17	0.93	3.0	0.0
Number of Evergreen species	2.29	1.26	6.0	0.0
Number of Deciduous species	8.64	5.09	24.0	0.0
Number of Grass species	3.36	1.81	8.0	0.0
Number of Forb species	3.36	1.81	8.0	0.0
Canopy Cover	35.16	29.95	98.0	0.0
Understory	63.48	23.38	99.0	13.0
Percent Bareground Cover	18.61	19.18	70.0	0.0

Table 6. Environmental variables collected at 60 LCTA Plots and analyzed using canonical correspondence analysis in a modified manner by deleting 6 of the original species. Data was collected on Fort Benning, Georgia during the summer, fall, and winter of 1995. Note that the means and standard deviations will be (usually slightly) different from a straightforward calculation of averages and standard deviations because the numbers used are weighted by species abundances.

Quantitative Variables	Mean	Standard Deviation	Maximum	Minimum
Sand/Clay ratio	6.20	3.47	15.1	0.2
Percent Slope	6.87	5.79	44.5	1.0
Elevation (meters)	166.92	102.49	351.0	2.0
Distance to Water (meters)	206.97	176.10	782.0	0.0
Number of Burns 91-95	1.19	0.94	3.0	0.0
Number of Evergreen species	2.19	1.18	6.0	0.0
Number of Deciduous species	8.43	5.06	24.0	0.0
Number of Grass species	3.37	1.82	8.0	0.0
Number of Forb species	3.37	1.82	8.0	0.0
Canopy Cover	34.74	30.27	98.0	0.0
Understory	62.81	23.65	99.0	13.0
Percent Bareground Cover	19.62	19.54	70.0	0.0

CCA was performed on 10 small mammal species with 12 environmental variables collected from 60 plots. (See Table 7 for a list of small mammal species and Appendix E for a list of plant species). The first two ordination axes for canonical coefficients and intra-set correlations were used to explore the approximate contribution of the environmental variables to the ordination axes for the data. Eigenvalues are listed in Table 8 to show the measure of importance of each axis. They range in value between 0 and 1. The first canonical axis accounted for 38.8% of the species-environment relation (eigenvalue=0.56), and the second axis accounted for 28.0% (eigenvalue=0.40). For abundance data, a low percentage of variation explained by the first two axes is relatively common and not too noisy for interpretation (ter Braak, 1998). The plots, small mammal species and environmental variables for the first two axes explained 30.7% of the variance in the species data. The first two axes accounted for 66.8% of the total variation in the species-environment relationship. The canonical coefficients and intra-set correlations are listed in Table 9. The solution to the analysis is displayed via the biplot. The scatter plots represent the environmental variables or the small mammals species as they are displayed in the biplot separately to simplify visualizing the solution. The biplot of species and environmental variables, the environmental variables scatter plot, and the small mammal species scatter plot are displayed in Figures 11, 12, and 13. See Appendices F and G for a listing by plot of environmental variables and small mammal species used in the analysis.

Once a biplot had been generated with all the small mammals and environmental variables, the analysis was run a second time removing all small mammals from the analysis except *P. gossypinus, P. polionotus, Reithrodontomys, and Sigmodon*. This was done to eliminate small mammals that had a low number of captures. The eigenvalues are listed in Table 8. The first canonical axis accounted for 56.9% of the species-environment relation (eigenvalue 0.525), and the second axis accounted for 37.8% (eigenvalue

0.348). The plots, small mammal species, and environmental variables for the first two axes explained 53.2% of the variance in the species data. The first two axes accounted or 94.7% of the total variation in the species-environment relationship. The canonical coefficients and intra-set correlations are listed in Table 10. The biplot for this analysis is displayed in Figure 14. The matrix used in the modified analysis for both the environmental variables and the small mammal species was the same as the unmodified analysis. The six small mammal species were removed before the analysis.

Species-environment relationship

The eigenvalues for the first two axis (Table 8) for both the modified and unmodified analysis indicated acceptable levels of separation of species scores along the measured environmental gradients. Eigenvalues >0.3 and the percentage explained by inertia (which is generally <10%) indicated a strong gradient in the data (ter Braak 1995). According to Palmer (1998), inertia is a measure of the total amount of variance in a data set. It is directly related to the physical concept of inertia, which is the tendency for an object in motion to stay in motion, and the tendency for an object at rest to stay at rest. For weighted averaging methods such as CCA, the inertia is related to the spread of species modes (or optima) in ordination space, rather than the variance in species abundance.

Table 7. Small mammal species, species code, and number of individuals used in canonical correspondence analysis. Specimens were collected on 60 plots on Fort Benning, Georgia in Muscogee, Chattahoochee, and Russell counties during the winter of 1994 and 1995.

Species Code	Genus	Species	Common Name	Number of specimens collected
BLCA	*Blarina*	*carolinensis*	Southern short-tailed shrew	1
CRPA	*Cryptotis*	*parva*	Least shrew	5
ORPA	*Oryzomys*	*palustris*	Marsh rice rat	3
REHU	*Reithrodontomys*	*humulis*	Eastern harvest mouse	23
PEGO	*Peromyscus*	*gossypinus*	Cotton mouse	55
PEPO	*Peromyscus*	*polionotus*	Oldfield mouse	82
OCNU	*Ochrotomys*	*nuttalii*	Golden mouse	7
SIHI	*Sigmodon*	*hispidus*	Hispid cotton rat	55
NEFL	*Neotoma*	*floridana*	Eastern woodrat	1
MUMU	*Mus*	*musculus*	House mouse	2

Nomenclature follows Whitaker and Hamilton (1998)

Table 8. Eigenvalues for axis 1 and 2 for both the initial analysis with 10 small mammal species modified analysis with 4 species. Small mammals were collected on 60 plots on Fort Benning, Georgia in Muscogee, Chattahoochee, and Russell counties during the winter of 1994 and 1995. Vegetation data was collected on the same plots in the summer and fall of 1995.

Eigenvalue for initial analysis Axis 1	Eigenvalue for initial analysis Axis 2	Eigenvalue for modified analysis with 4 species Axis 1	Eigenvalue for modified analysis with 4 species Axis 2
0.564	0.408	0.525	0.348

Table 9. Canonical coefficients which define the ordination axis as a linear combination of the environmental variables and intra-set correlations which are the correlation coefficients between the environmental variables and the ordination axes resulting from canonical correspondence analysis using data collected in the winter of 1994-1995 and summer and fall of 1995 from 60 plots on Fort Benning, Georgia.

Variable	Canonical Coefficients Axis 1	Canonical Coefficients Axis 2	Intra-set correlations Axis 1	Intra-set correlations Axis 2
Sand/Clay ratio	0.12	0.05	0.44	0.01
Percent Slope	-0.13	0.17	0.08	0.42
Elevation (meters)	0.20	-0.13	0.19	0.39
Distance to Water (meters)	-0.07	0.37	-0.21	0.39
Number of Burns	-0.10	-0.21	-0.46	-0.32
Number of Evergreens species	-0.11	-0.0	0.30	-0.32
Number of Deciduous species	0.58	0.27	0.87	-0.01
Number of Grass species	-0.09	0.10	-0.39	-0.15
Number of Forb species	0.0	0.0	-0.39	-0.15
Canopy Cover	0.49	0.76	0.77	-0.27
Understory	-0.10	-0.92	0.55	-0.59
Percent Bareground Cover	-0.0	0.60	-0.52	0.72

Table 10. Modified analysis using subset of small mammal species. Canonical coefficients which define the ordination axis as a linear combination of the environmental variables and intra-set correlations which are the correlation coefficients between the environmental variables and the ordination axes resulting from canonical correspondence analysis using data collected in the winter 1994-1995 and summer and fall of 1995 from 60 plots on Fort Benning, Georgia.

Variable	Canonical Coefficients Axis 1	Canonical Coefficients Axis 2	Intra-set correlations Axis 1	Intra-set correlations Axis 2
Sand/Clay ratio	0.10	0.07	0.37	0.01
Percent Slope	-0.16	0.08	0.03	0.33
Elevation (meters)	0.18	-0.15	0.13	0.34
Distance to Water (meters)	-0.10	0.39	-0.19	0.42
Number of Burns	-0.10	-0.20	-0.48	-0.26
Number of Evergreens species	-0.08	-0.00	0.25	-0.39
Number of Deciduous species	0.58	0.36	0.86	-0.00
Number of Grass species	-0.06	0.16	-0.42	-0.09
Number of Forb species	0.00	0.00	-0.42	-0.09
Canopy Cover	0.63	0.67	0.78	-0.35
Understory	-0.21	-0.99	0.53	-0.63
Percent Bareground Cover	0.06	0.56	-0.48	0.73

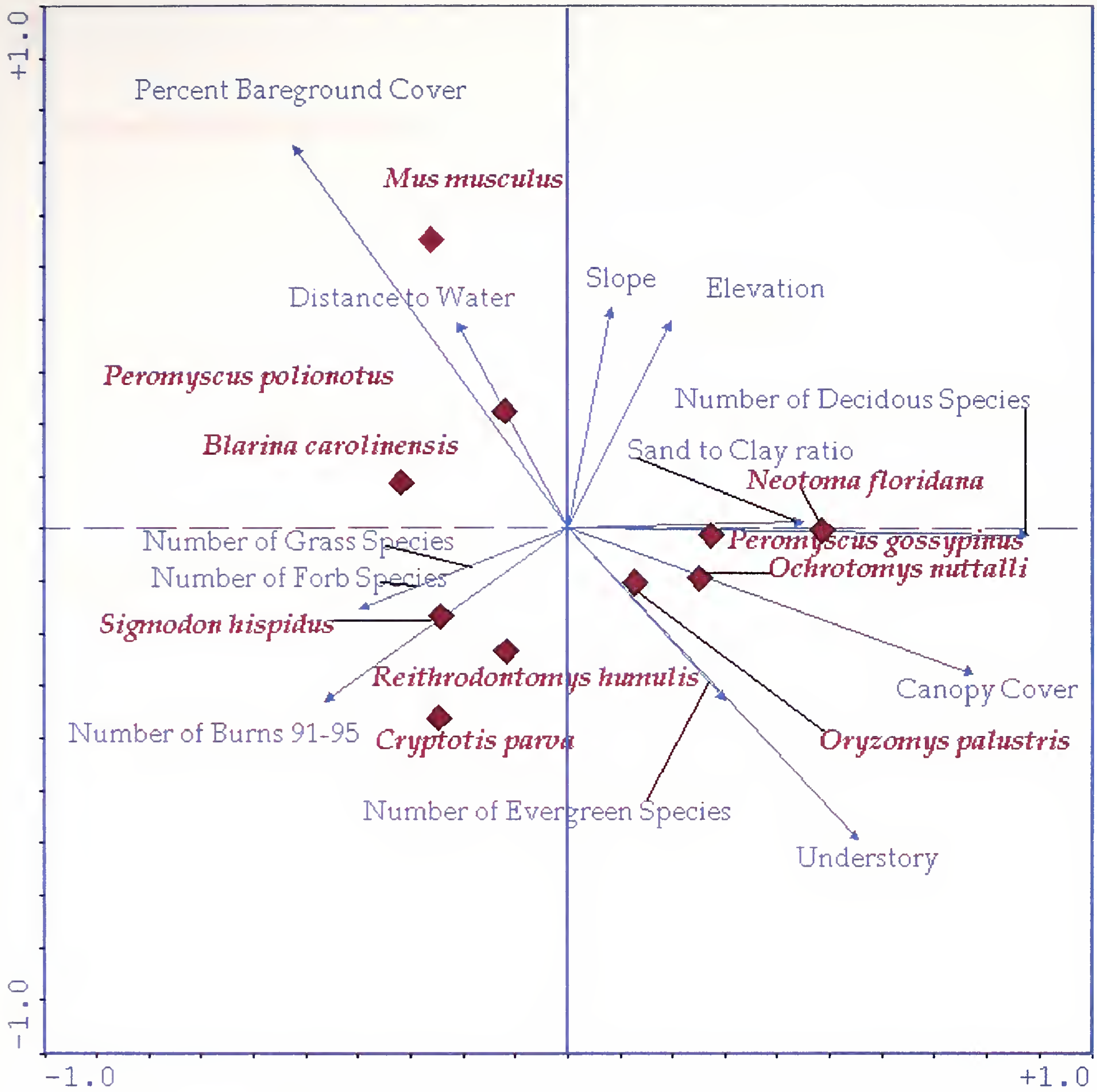


Figure 11. Biplot based on canonical correspondence analysis showing the first and second ordination axes including 60 plots, 10 small mammal species, and 12 environmental variables. Only the species represented by the diamonds and environmental variables represented by the arrows are shown. The biplot displays 31% of the inertia or weighted variance in the abundances and 73% of variance in the weighted averages and class totals of species with respect to the environmental variables. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.564 and 0.408 respectively. See figures 12 and 13 which are the same ordination presented separately to minimize clutter.

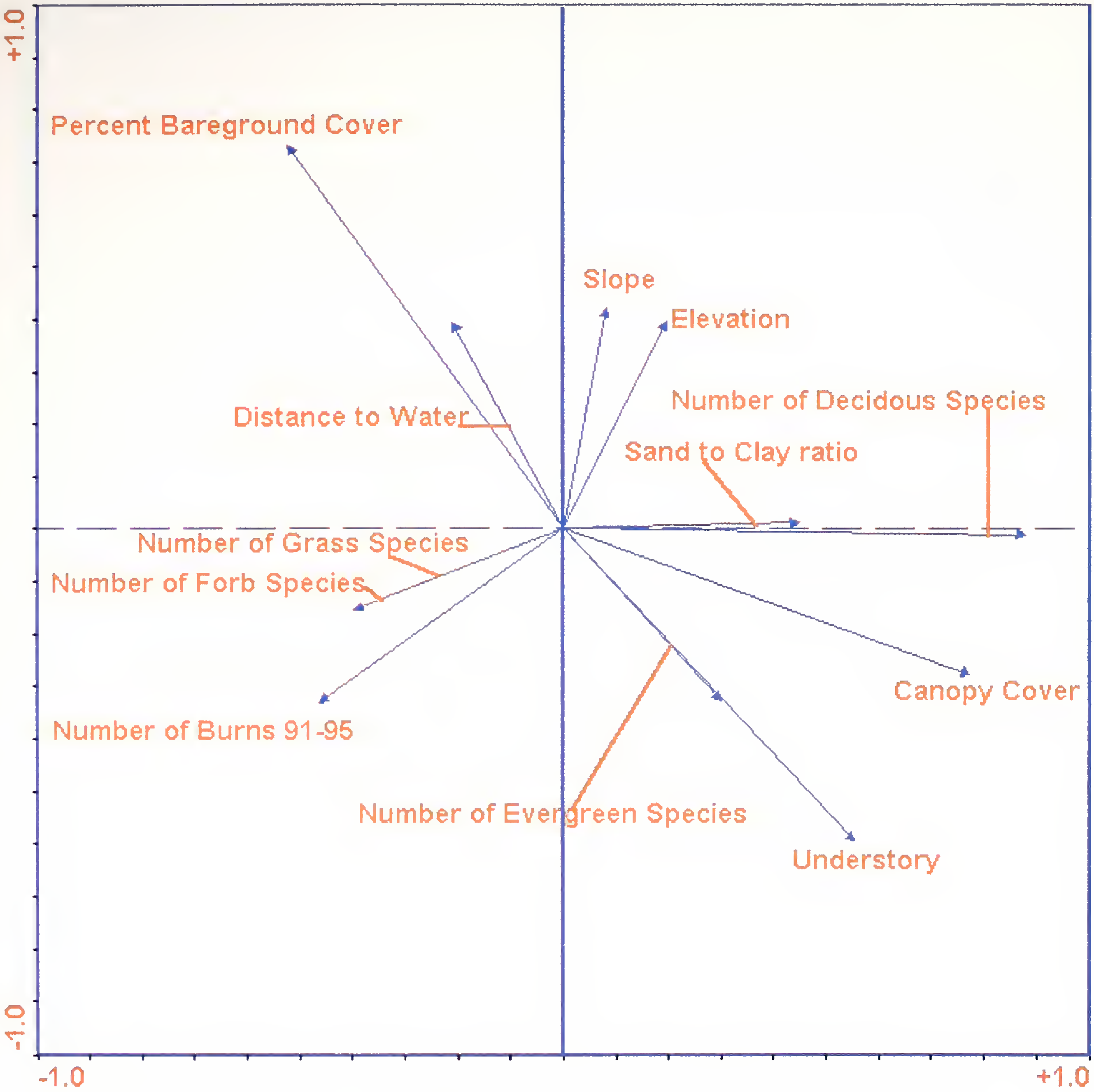


Figure 12. Environmental variables scatter plot based on 1995 canonical correspondence analysis showing the first and second ordination axes including 60 plots, 10 small mammal species, and 12 environmental variable. Only the species are shown. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.564 and 0.408 respectively.

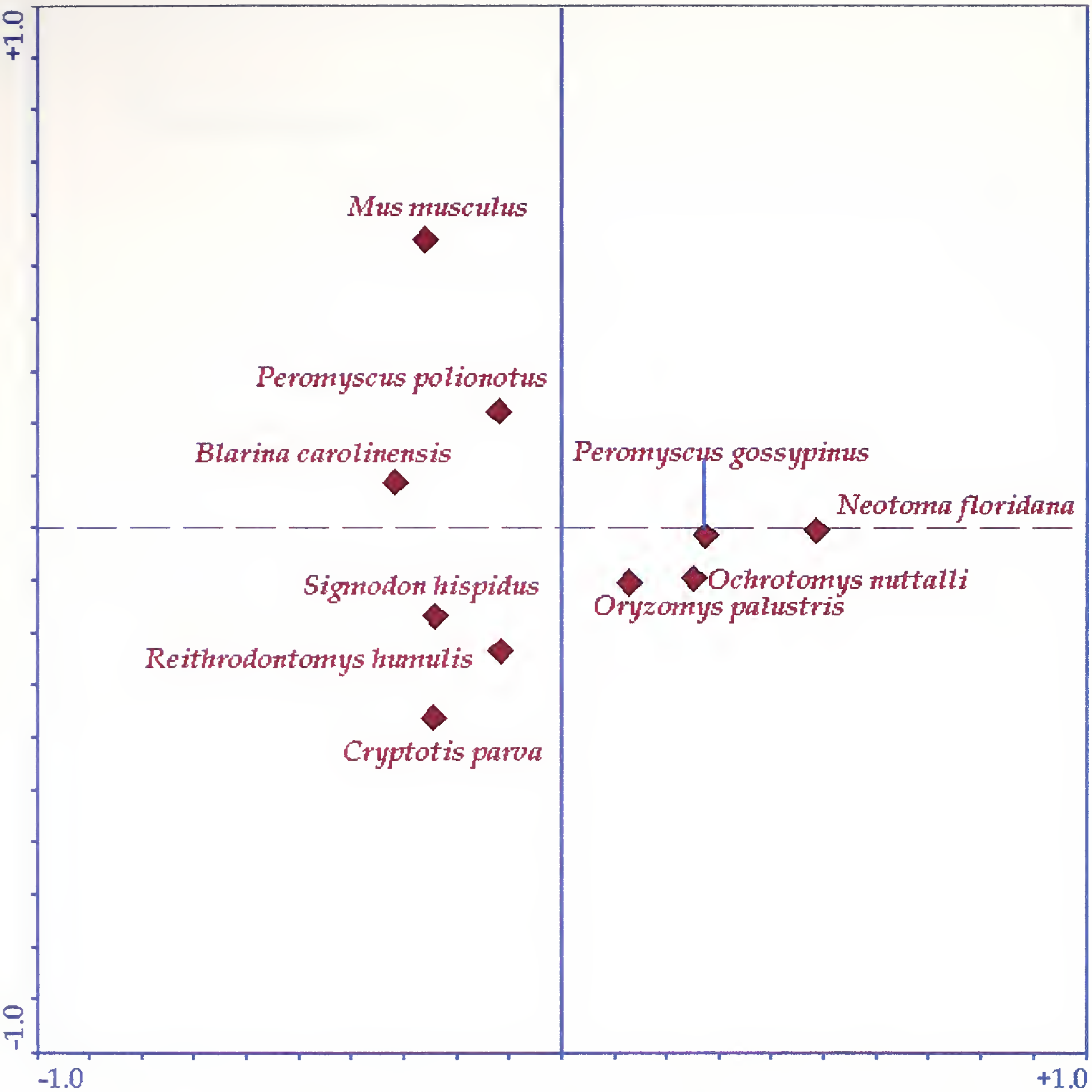


Figure 13. Species scatter plot based on 1995 canonical correspondence analysis showing the first and second ordination axes including 60 plots, 10 small mammal species, and 12 environmental variables. Only the species are shown. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.564 and 0.408 respectively.

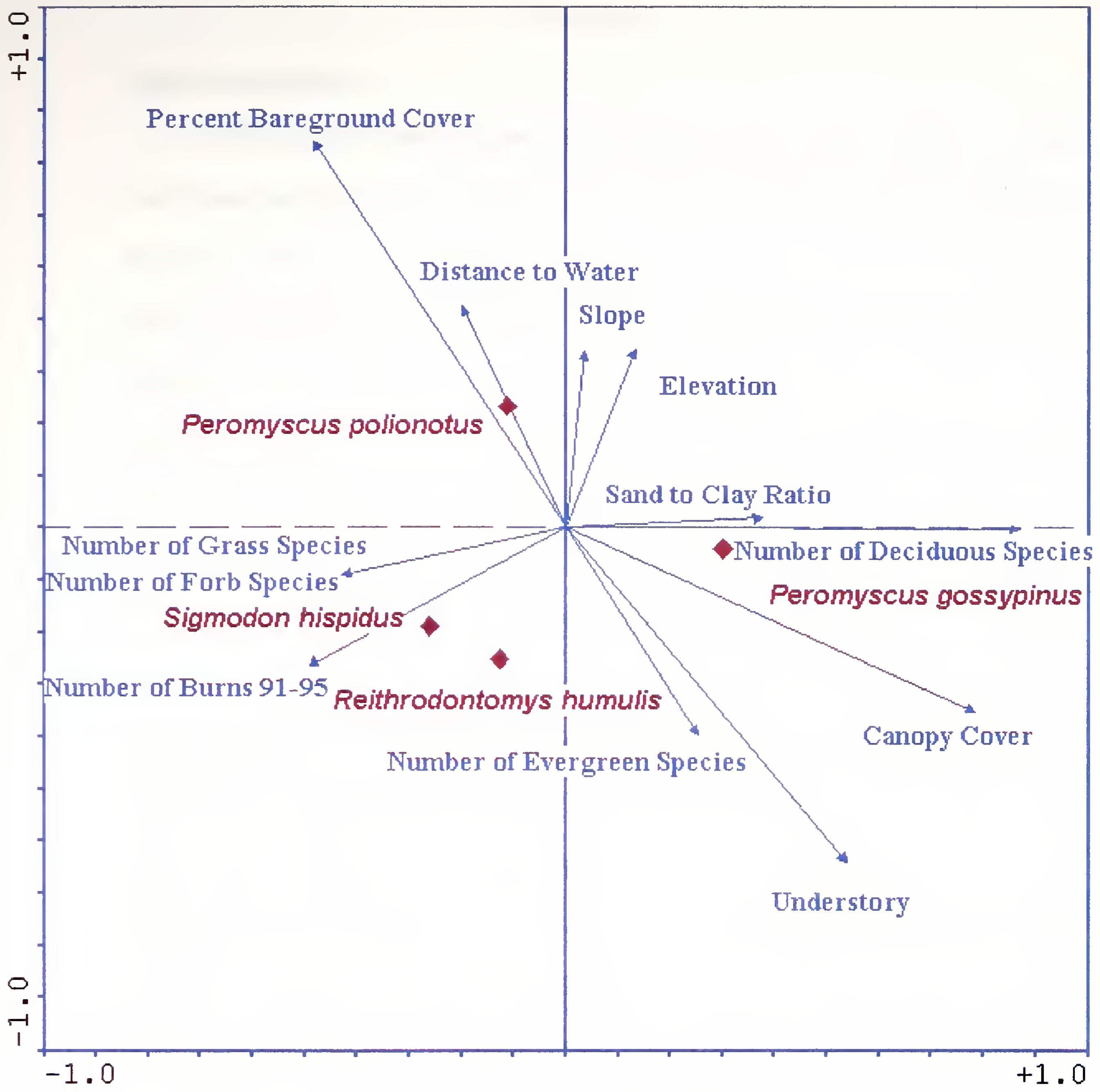


Figure 14. Biplot based on canonical correspondence analysis showing the first and second ordination axes including 60 plots, 4 small mammal species, and 12 environmental variables. Only the species represented by a diamond and environmental variables represented by the arrows are shown. The biplot displays 53% of the inertia or weighted variance in the abundances and 95 % of variance in the weighted averages and class totals of species with respect to the environmental variables. The eigenvalues of axis 1 (horizontal) and axis 2 (vertical) are 0.525 and 0.348 respectively.

Discussion

Species Associations

With respect to microhabitat use Whitaker and Hamilton (1998) reported that *Blarina carolinensis* had been poorly studied but they assumed it occupied the same habitat as *Blarina brevicauda*. *Blarina brevicauda* inhabits damp woods, wet meadows, and overgrown fields and constructs nests of grasses and shredded leaves. Golley *et al.* (1965) also found *B. brevicauda* in old fields. The ordination diagram (Figure 11). was used to interpret the relationship of *B. carolinensis* to the environmental variables. According to ter Braak (1986), from each species point a perpendicular is dropped to an environmental arrow to assess the relationship. The endpoint of the perpendicular indicates the relative position of the centers of the species distribution along the environmental arrow. (See appendix H for individual species biplots depicting the perpendicular). Therefore the endpoint approximates the value of the weighted average of the species with respect to the environmental arrow. From Figure 11, it can be inferred that *B. carolinensis* had a low weighted average with respect to slope, elevation, number of deciduous species, sand to clay ratio, canopy cover, understory, and number of evergreen species. These environmental variables do not contribute to *B. carolinensis'* choice of habitat. *Blarina carolinensis* had a high weighted average with respect to distance to water, percent bareground cover, number of grass species, number of forb species, and number of burns from 1991-1995. It can be inferred that *B. carolinensis* prefers a habitat with a moderate number of burns, number of grass and forb species, distance to water and a low percentage of bareground cover. The length of the arrow is also important when interpreting the ordination biplot. According to ter Braak (1986) it is equal to the rate of change in the weighted average. Longer arrows represent more important environmental variables and shorter arrows represent the less important ones. Therefore it can be inferred that the microhabitat characteristics that most influence *B. carolinensis*' choice of habitat are a low percentage of bareground cover.

Cryptotis occurs in a variety of habitats in the southeast, including pinewoods, old fields of weeds, and marshes (Whitaker and Hamilton 1998). Fields where the dominant vegetation is grasses and some weeds that form enough cover to allow movement in runways, is the preferred habitat according to Davis and Joeris (1945). *Cryptotis* generally occupies the same habitat as *Sigmodon hispidus.* Golley *et al.* (1965) found *Cryptotis* in old fields and roadsides. Briese and Smith (1974) also reported that *Cryptotis* had a preference for old fields and ecotones. The biplot indicated that in 1995 *Cryptotis* had a low weighted average with respect to slope, elevation, number of deciduous species, sand to clay ratio, percent bareground cover, distance to water, and canopy cover. It had a high weighted average with respect to the number of grass and forb species, number of burns from 1991-1995, the number of evergreen species, and understory. It can be inferred that a high number of grass, forb, and evergreen species and number of burns are microhabitat characteristics associated with *Cryptotis.* A moderate degree of understory is also an important characteristic. Considering the length of the environmental arrows it can be inferred that *Cryptotis* more specifically prefered sites with a moderate to dense understory, several evergreen species, and frequent burns. This supports the association of *Cryptotis* with pinewoods and grassy, weedy fields (Whitaker and Hamilton 1998). Frequent burns relate to the open pine stands that occur on the installation.

Golley, (1962) reported that *Oryzomys* is typically found in freshwater marshes and occasionally in dry uplands and constructs nests of leaves on the ground surface or in shallow burrows. Negus *et al.* (1961), described a similar habitat including old fields, bottomland forests, pineland, and mixed forests. The 1995 biplot indicated that *Oryzomys* had a high weighted average with respect to the number of deciduous and evergreen species, understory, canopy cover, and sand to clay ratio. It can be inferred that low sand to clay ratio, a low number of evergreen and deciduous species, an open canopy and low degree of understory are preferred microhabitat characteristics of *Oryzomys*. Considering the lengths of the arrows it can more specifically be inferred that *Oryzomys* is associated with a low degree of understory, an open canopy, and few deciduous species. This is consistent with both Negus *et al.* (1961) and Golley (1962).

Golley, (1962) and Golley *et al.* (1965), defined the distribution of *Reithrodontomys* as state wide, inhabiting the Blue Ridge Mountains, the Piedmont, and the Upper and Lower Coastal Plain but more specifically occurred in old fields and road sides. Howell (1954) reported finding *Reithrodontomys* in middle successional stage fields of predominately blue grass and golden rod. According to Stalling (1997), *Reithrodontomys* is commonly found in areas with dense vegetation low to the ground. It has also been reported that specific plant species composition is not an important descriptor of microhabitat (Cawthorn and Rose 1989). Both the modified and unmodified biplot for *Reithrodontomys* indicated it had a high weighted average with respect to understory, the number of evergreen species, the number of burns from 1991-1995, and the number of grass and forb species and canopy cover. It can be inferred that the microhabitat of *Reithrodontomys* has a moderate number of grass and forb species, a moderate number of burns, which is consistent with Stalling (1997). Considering the lengths of the arrows, a low degree of understory, an open canopy, and a moderate number of burns are the most important microhabitat characteristic. *Reithrodontomys* captures were about half that of *Sigmodon*. Golley *et al.* (1962) reported that when *Reithrodontomys* captures were high *Sigmodon* captures were low and vice versa. Kaye (1959) supported this finding and inferred a contentious relationship existed between the two species.

Peromyscus gossypinus primarily occupies river-bottom woodlands but also inhabit upland hardwood forests (Golley, 1962). Whitaker and Hamilton (1998), also stated that *P. gossypinus* is most abundant in river bottoms. They less frequently occupy pine-hardwood forests. Both the modified and unmodified biplot indicated that *P. gossypinus* had a high weighted average with respect to slope, elevation, sand to clay ratio, the number of evergreen and deciduous species, canopy cover, and understory. It can be inferred from both the modified and unmodified biplots, that the most important microhabitat characteristics are an open canopy, low degree of understory and few deciduous species. Few deciduous species and an open canopy are contrary to the literature.

According to Golley, (1962) and Golley *et al.* (1965), *P. polionotus* typically inhabits dry sandy areas including sandy floodplains in the foothills and fields in the early stages of old-field succession. *Peromyscus polionotus* had a high weighted average with respect to the number of grass and forb species, percent bareground cover, slope, elevation, and distance to water in both the unmodified and modified biplots. It can be inferred that the microhabitat of *P. poliontus* is a function of a low percentage of bareground cover, a moderate distance to water, a moderate slope, and low elevation. This is consistent with the findings of Golley, (1962) and Golley *et al.* (1965). Of these, the most important microhabitat characteristic is a low percentage of bareground cover.

Ochrotomys is confined to woodland habitat and construct nests several feet above ground in a tree or shrub (Golley, 1962). Whitaker and Hamilton (1998), explained that *Ochrotomys* are primarily arboreal and can climb to a height of thirty feet or more. Its nests are constructed with dead leaves, pine needles, and shredded bark at variable heights in a bush or nook of a tree. Goodpaster and Hoffmeister (1954) reported that honeysuckle is the preferred plant species at any elevation. It can be inferred from the biplot that a moderate sand to clay ratio, a moderate number of deciduous and evergreen and species, and a moderately open canopy and moderate degree of understory are important habitat characteristics for *Ochrotomys*. This is supported by Linzey and Packard (1977), who described the habitat of *Ochrotomys* as moist thickets, brushy areas in association with honeysuckle and greenbrier, in canebrakes and swampy woodlands, pine thickets, turkey-oak thickets and pine-oak woodlands. More specifically it can be inferred that of these, a moderate number of deciduous species, a moderately open canopy, and a moderate degree of understory are the most important microhabitat characteristics. Since an open canopy can allow the understory to become thick, this is consistent with a report by McCarley (1958), that indicated that the distribution of *Ochrotomys* is associated with density of understory.

Extensive research on *Sigmodon* has shown that habitat requirements include abundant grasses and forbs and sufficient dense cover to protect them from predation (Golley, 1962). According to Goertz (1964), the most important habitat component is moderate to dense stands of mid to high perennial grasses. More specifically they inhabit *Andropogon-Rubus-Helianthus* areas, *Smilax-Rubus* oldfields, fence rows, and railroad right-of-ways (Cleveland, 1979). The best general descriptor of habitat for *Sigmodon* is a well-drained area with abundant vegetative cover (Cleveland, 1979). Both the unmodified and modified biplots indicated that *Sigmodon* had a high weighted average with respect to the number of grass and forb species, and the number of burns from 1991-1995. However the modified biplot also indicated that a low number of evergreen species and a low degree of understory were also important microhabitat characteristics. Taking into consideration both biplots it can be inferred that a low degree of understory is the more important microhabitat characteristic for *Sigmodon*.

According to Whitaker and Hamilton (1998), *Neotoma* is found in low areas and swamps constructing nests of sticks, leaves, and rubbish along stream banks. As shown in the biplot, *Neotoma* displayed a low weighted average with respect to percent bareground cover, distance to water, number of grass and forb species, and number of burns from 1991-1995. *Neotoma* had a high weighted average with respect to several environmental variables including the slope, elevation, number of deciduous and evergreen species, canopy cover, and understory. It can be inferred that *Neotoma* is associated with a low slope, moderate elevation, a moderate number of deciduous species and high number of evergreen species, a moderately open canopy, and moderate understory. Considering the lengths of the environmental arrows it can be inferred that the more important microhabitat characteristics for *Neotoma* are a moderate number of deciduous species and understory, and a moderately open canopy. This is consistent with a study in Kansas by Fitch and Rainey (1956) that indicated that *Neotoma* had maximum abundance in areas with thick understory.

Mus occupy a variety of habitats but are often found in grassy fields and waste lands (Whitaker and Hamilton 1998). Golley *et al.* (1965) also found *Mus* in old fields. Geier and Best (1980) reported *Mus* was abundant in wet floodplains. An extensive study by Whitaker (1966), of the food choices of *Mus*, indicated that cover was important for *Mus* to become abundant. This supported the biplot, which indicated that *Mus* had a low weighted average with respect to all the environmental variables except percent bareground cover. More specifically *Mus* associated with habitat having a high percentage of bareground cover.

The modified analysis was very similar to the unmodified. The similarity is explained by the fact that species with a low number of captures did not contribute to the analysis as much as those that had a large number of captures. The unmodified biplot is trustworthy however; the placement of species with low abundance in the biplot is not as precise as those species with a high abundance. Therefore any conclusions based on the unmodified biplot about species with a low abundance would be subject to error.

Conclusions

The relationships between the small mammal species and the measured environmental variable were the same for the unmodified and the modified biplots with one exception. The habitat of *Reithrodontomys* was a function of a low degree of understory, an open canopy, and a moderate number of burns as indicated by both biplots. *Peromyscus gossypinus* was consistent in both biplots and related to few deciduous species, an open canopy, and a low degree of understory. Both the unmodified and the modified biplots showed that *Sigmodon* preferred microhabitat characteristics that included a high number of grass and forb species and a moderate number of burns. However the modified analysis also displayed the most important relationship was between *Sigmodon* and a low number of evergreen species and a low degree of understory. By removing the other species from the analysis, the results for *Sigmodon* showed additional important relationships with the number of evergreen species and understory.

Perturbations to important microhabitat characteristics due to training or land management practices would change the distributions of several species. The four most important environmental variables with respect to how the small mammals responded to them were understory, canopy cover, the number of deciduous species, and percent bareground cover. If the burning regime is altered to include less frequent burns, a thicker understory would result causing an increase in *Cryptotis, Neotoma, and Ochrotomys,* while causing a decrease in *Oryzomys, Reithrodontomys, P. gossypinus,* and *Sigmodon*. Increased thinning practices would result in a more open canopy causing an increase in *Oryzomys,* *Reithrodontomys*, and *P. gossypinus* while causing a decrease in *Ochrotomys* and *Neotoma*. There would be a similar response to training practices that removed vast tracts of trees such as the establishment of a tracked vehicle corridor. Predominately deciduous stands that are replaced with pine plantations would have an increase in *Cryptotis* and *Ochrotomys* and a decrease in *Neotoma*. Increased vehicular movement due to intense military operations would decrease the percent bareground cover and increase the presence of *B. carolinensis* and *P. polionotus* and decrease the presence of *Mus*.

Habitat characteristics are influenced by land management practices and training practices that occur on Fort Benning. Disturbance gradients composed of combinations of these land management and training practices could be detected using CCA. Land management practices such as thinning, burning, and clearcutting, contribute to the overall suitability of the landscape for small mammals. The intensity and type of training that occur on the installation also contribute to the habitat quality. An experimental design that addresses the effect of both land management practices and training impacts on small mammals may provide insight into the population dynamics and response of small mammals to different combinations of disturbance.

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Appendix A

List of Soils on Fort Benning

Plot Number	Soil Series Name	Soils Symbol		Plot Number	Soil Series Name	Soils Symbol
1	Eunola	EtA		37	Nankin	NkC3
2	Troup	TVD		38	Nankin	NkD3
3	Bibb	Bh		39		Unk
4	Troup	TVD		40		Unk
5	Troup	TrC		41	Nankin	NkD3
6	Toccoa	To		42	Nankin	NnE3
7	Wahee	WbA		43	Nankin	NkC3
8	Troup	TrC		44	Lakeland	LaB
9	Wagram	WaC		45	Toccoa	To
10	Troup	TVD		46	Nankin	NaB
11	Nankin	NaC		47	Lakeland	LaC
12	Nankin	NnE3		48	Orangeburg	OrB
13	Wagram	WaB		49	Nankin	NkD3
14	Ailey	AaC		50	Troup	TrD
15		Unk		51	Toccoa	To
16		Unk		52	Ailey	AaC
17	Nankin	NkC3		53	Pelham	Pm
18	Wickham	WhA		54	Wagram	WaC
19	Wickham	WhA		55	Ailey	AaC
20	Wickham	WhA		56	Troup	TrC
21	Wickham	WhA		57	Toccoa	To
22	Wickham	WhA		58	Cowarts	CwE
23	Wickham	WhA		59	Ailey	AaC
24	Ailey	AaC		60		Unk
25	Troup	TrC				
26	Lakeland	LaC				
27	Troup	TrB				
28	Ailey	AaB				
29	Troup	TrC				
30	Troup	TrC				
31	Bibb	Bh				
32	Bibb	Bh				
33	Nankin	NnE3				
34	Nankin	NnE3				
35	Troup	TrC				
36	Nankin	NkD3				

Appendix B

Explanation of the Soil texture map

The soil coverage was acquired from the Fort Benning, Georgia, Land Management and Conservation Branches. This coverage had data gaps and it is still currently a work in progress. The following USDA Soil Surveys were used as the base map.

Chattahoochee County, Georgia	Published 1997
Muscogee County, Georgia	Published 1983
Russell County, Alabama	Publication in Progress

The original soil coverage had several data gaps including mislabeled polygons, unlabeled polygons, and lacked soil polygons in the Impact Areas. In the modern soil surveys, areas considered to be exclusion zones were not mapped using modern soil survey methods or techniques. In order to fill the data gaps of the polygons that were left blank or mislabeled were corrected. Portions of the Chattahoochee County, Georgia soil survey that was conducted in 1924 and published in 1928, were manually digitized to fill in the exclusion areas. The soil texture coverage has the data for both the modern and 1928 soil survey.

Fort Benning lies within the USGS Hydrologic Unit Code (HUC) 03130003. This HUC boundary was obtained by downloading and assessing the shape file from the USGS Web Site.

The Alabama side of the base is currently being updated. The soil survey is scheduled to be in print at the end of the calendar year, and it should then be updated for more reliable data.

Soil textures were grouped in the following categories.

Surface Texture Groupings	Surface Texture Symbol	Original Soil Surface Textures *(As found in each surface texture grouping)*
Sand	**S**	(S) Sand (CS) Coarse Sand
Loamy Sand	**LS**	(LS) Loamy Sand
Sandy Loam	**SL**	(FSL) Fine Sandy Loam (SL) Sandy Loam (includes 1928 (M) Meadow category)
Loam	**L**	(L) Loam (SiL) Silty Loam
Sandy Clay Loam	**SCL**	(SCL) Sandy Clay Loam
Clay Loam	**CL**	(CL) Clay Loam (SiCL) Silty Clay Loam
Clay	**C**	(C) Clay
Variable	**P**	(P) Pits
Other	**O**	(O) Other – (i1928 survey - gullied lands)

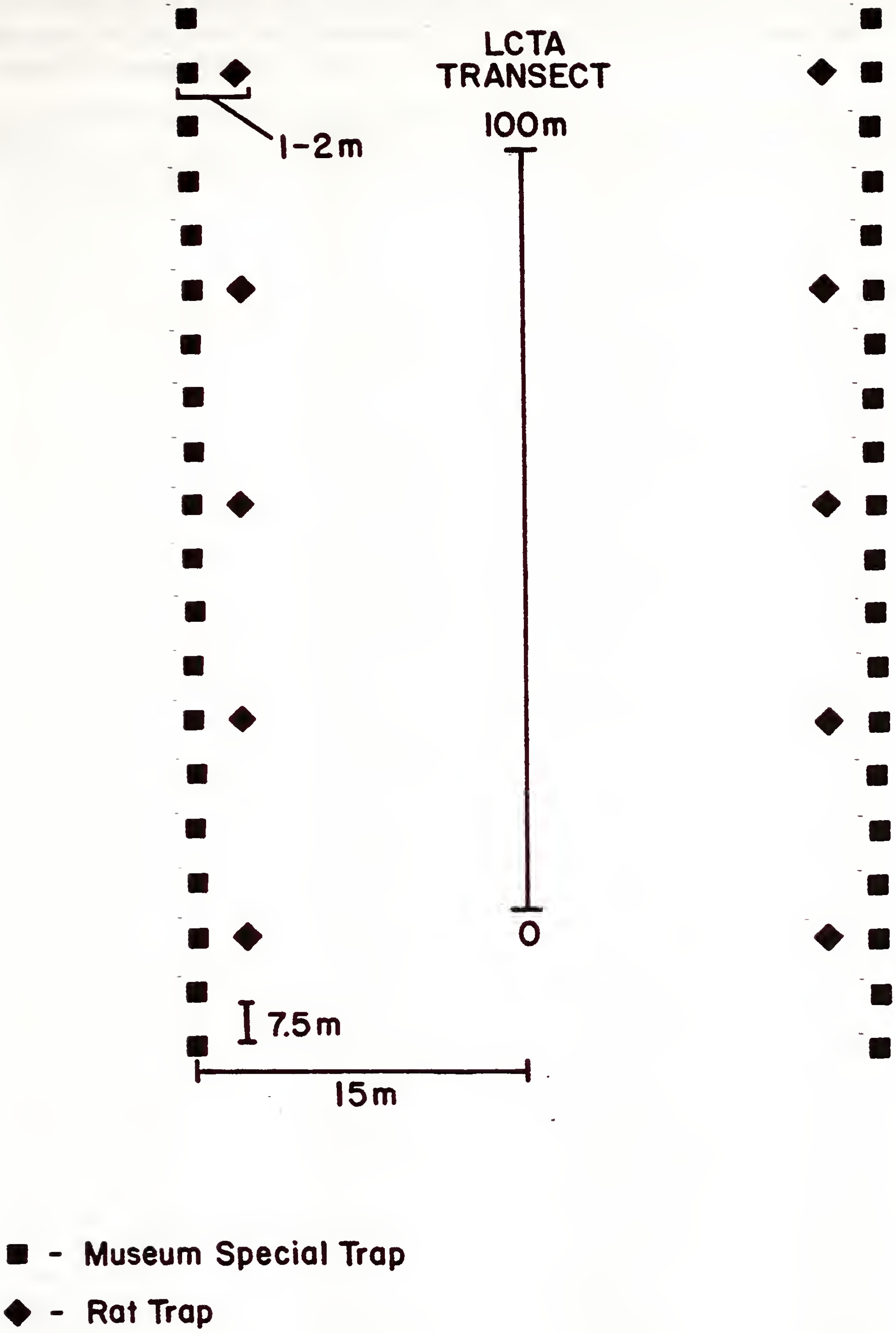
Appendix C

Grid Coordinates for Small Mammal Plots on Fort Benning, Georgia

Grid Coordinates are in Universal Transverse Mercator (UTM's)

Plot Number	dcme	dcmn		Plot Number	dcme	dcmn
1	708010	3597791		39	701873	3579607
2	704114	3596612		40	701910	3576613
3	709023	3595359		41	707267	3576285
4	708789	3598681		42	701060	3575087
5	710514	3588031		43	705873	3573162
6	706490	3589038		44	711552	3592754
7	706111	3589453		45	698312	3586760
8	705668	3587289		46	711790	3583790
9	703403	3591151		47	716570	3583950
10	704092	3589201		48	718382	3580716
11	703247	3586995		49	712216	3579565
12	706580	3584048		50	717477	3578703
13	710128	3591499		51	705932	3602250
14	710891	3593921		52	710860	3593143
15	696819	3582488		53	704683	3597851
16	692970	3579767		54	704874	3599544
17	691536	3577375		55	711803	3601439
18	690386	3575474		56	712928	3600527
19	692776	3573923		57	716619	3600284
20	695132	3573162		58	720764	3600096
21	695607	3572657		59	715471	3598642
22	696409	3572428		60	693372	3580854
23	693791	3572331				
24	710317	3597683				
25	717136	3596055				
26	718580	3595914				
27	719187	3595449				
28	713033	3594692				
29	717138	3589476				
30	720162	3588936				
31	717376	3588367				
32	718096	3587419				
33	715751	3586467				
34	715814	3586407				
35	719252	3585356				
36	710746	3582726				
37	711702	3582933				
38	711106	3581499				

Appendix D
Placement of traps parallel to the line transect



Appendix E

The following list contains the plant species recorded on the LCTA plots on Fort Benning in 1991 and 1995. Nomenclature follows the National Plant List of Scientific Names (USDA 1982).

Family	Genus	Species	USDA Code
EUPHORBIACEAE	*Acer*	*gracilens*	ACGR2
ACERACEAE	*Acer*	*negundo*	ACNE2
ACERACEAE	*Acer*	*rubrum*	ACRU
ACERACEAE	*Acer*	*saccharum*	ACSAF
HIPPOCASTANACEAE	*Aesculus*	*pavia*	AEPA
COMPOSITAE	*Ageratina*	*aromatica*	AGAR4
LEGUMINOSAE	*Albizia*	*julibrissin*	ALJU
BETULACEAE	*Alnus*	*serrulata*	ALSE2
COMPOSITAE	*Ambrosia*	*artemisiifolia*	AMAR2
ROSACEAE	*Amelanchier*	*arborea*	AMAR3
VITACEAE	*Ampelopsis*	*arborea*	AMAR5
APOCYNACEAE	*Amsonia*	*ciliata*	AMCI
GRAMINEAE	*Andropogon*	*ternarius*	ANTE2
GRAMINEAE	*Andropogon*	*virginicus*	ANVI2
SCROPHULARIACEAE	*Antirrhinum*	*virga*	ANVI5
LEGUMINOSAE	*Apios*	*americana*	APAM
ROSACEAE	*Aronia*	*arbutifolia*	ARAR7
GRAMINEAE	*Arundinaria*	*gigantea*	ARGI
CARYOPHYLLACEAE	*Arenaria*	*lanuginosa*	ARLA4
GRAMINEAE	*Aristida*	*longespica*	ARLO2
GRAMINEAE	*Aristida*	*purpurascens*	ARPU8
ARALIACEAE	*Aralia*	*spinosa*	ARSP2
GRAMINEAE	*Aristida*	*stricta*	ARST5
GRAMINEAE	*Aristida*	*tuberculosa*	ARTU
ARISTOLOCHIACEAE	*Asarum*	*arifolium*	ASAR10
ARISTOLOCHIACEAE	*Asarum*	*canadense*	ASCA
ASCLEPIADACEAE	*Asclepias*	*cordifolia*	ASCO
COMPOSITAE	*Aster*	*concolor*	ASCO2
COMPOSITAE	*Aster*	*dumosus*	ASDU
GUTTIFERAE	*Ascyrum*	*hypericoides*	ASHY
COMPOSITAE	*Aster*	*lateriflorus*	ASLA6
COMPOSITAE	*Aster*	*linariifolius*	ASLI2
ANNONACEAE	*Asimina*	*parviflora*	ASPA18
COMPOSITAE	*Aster*	*patens*	ASPA5
COMPOSITAE	*Aster*	*tortifolius*	ASTO6
ASCLEPIADACEAE	*Asclepias*	*tuberosa*	ASTU

POLYPODIACEAE	*Athyrium*	*filix-femina*	ATFIA2
SCROPHULARIACEAE	*Aureolaria*	*pectinata*	AUPE
LEGUMINOSAE	*Baptisia*	*lanceolata*	BALA3
RHAMNACEAE	*Berchemia*	*scandens*	BESC
URTICACEAE	*Boehmeria*	*cylindrica*	BOCY
SAPOTACEAE	*Bumelia*	*lanuginosa*	BULA
SAPOTACEAE	*Bumelia*	*lycioides*	BULY
VERBENACEAE	*Callicarpa*	*americana*	CAAM2
CYPERACEAE	*Carex*	*blanda*	CABL
CYPERACEAE	*Carex*	*bromoides*	CABR14
BETULACEAE	*Carpinus*	*caroliniana*	CACA18
JUGLANDACEAE	*Carya*	*cordiformis*	CACO15
LEGUMINOSAE	*Cassia*	*fasciculata*	CAFA
JUGLANDACEAE	*Carya*	*glabra*	CAGL8
JUGLANDACEAE	*Carya*	*illinoensis*	CAIL2
CYPERACEAE	*Carex*	*leptalea*	CALE10
LEGUMINOSAE	*Cassia*	*nictitans*	CANI4
JUGLANDACEAE	*Carya*	*ovata*	CAOV2
BIGNONIACEAE	*Campsis*	*radicans*	CARA2
JUGLANDACEAE	*Carya*	*tomentosa*	CATO6
CYPERACEAE	*Carex*	*venusta*	CAVE7
LEGUMINOSAE	*Cercis*	*canadensis*	CECA4
ULMACEAE	*Celtis*	*laevigata*	CELA
ULMACEAE	*Celtis*	*tenuifolia*	CETE
LEGUMINOSAE	*Centrosema*	*virginianum*	CEVI2
POLYPODIACEAE	*Cheilanthes*	*lanosa*	CHLA2
GRAMINEAE	*Chasmanthium*	*laxum*	CHLA6
GRAMINEAE	*Chasmanthium*	*sessiliflorum*	CHSE2
CLETHRACEAE	*Clethra*	*alnifolia*	CLAL3
LEGUMINOSAE	*Clitoria*	*mariana*	CLMA4
EUPHORBIACEAE	*Cnidoscolus*	*stimulosus*	CNST
CORNACEAE	*Cornus*	*asperifolia*	COAS2
LABIATAE	*Collinsonia*	*canadensis*	COCA4
COMPOSITAE	*Conoclinium*	*coelestinum*	COCO13
CORNACEAE	*Cornus*	*florida*	COFL2
CORNACEAE	*Cornus*	*foemina*	COFO
COMPOSITAE	*Coreopsis*	*major*	COMA6
ROSACEAE	*Crataegus*	*flava*	CRFL2
ROSACEAE	*Crataegus*	*marshallii*	CRMA5
ROSACEAE	*Crataegus*	*pulcherrima*	CRPU9
LEGUMINOSAE	*Crotalaria*	*rotundifolia*	CRRO5
ROSACEAE	*Crataegus*	*spathulata*	CRSP
ROSACEAE	*Crataegus*	*uniflora*	CRUN
ROSACEAE	*Crataegus*	*viridis*	CRVI2

GRAMINEAE	*Cynodon*	*dactylon*	CYDA
CYPERACEAE	*Cyperus*	*odoratus*	CYOD
CYPERACEAE	*Cyperus*	*plukenetii*	CYPL3
CYRILLACEAE	*Cyrilla*	*racemiflora*	CYRA
SAXIFRAGACEAE	*Decumaria*	*barbara*	DEBA4
LEGUMINOSAE	*Desmodium*	*ciliare*	DECI
LEGUMINOSAE	*Desmodium*	*lineatum*	DELI2
LEGUMINOSAE	*Desmodium*	*marilandicum*	DEMA2
LEGUMINOSAE	*Desmodium*	*paniculatum*	DEPA6
LEGUMINOSAE	*Desmodium*	*pauciflorum*	DEPA7
LEGUMINOSAE	*Desmodium*	*strictum*	DEST2
LEGUMINOSAE	*Desmodium*	*viridiflorum*	DEVI4
GRAMINEAE	*Dichanthelium*	*aciculare*	DIAC
GRAMINEAE	*Dichanthelium*	*acuminatum*	DIAC2
GRAMINEAE	*Dichanthelium*	*acuminatum*	DIACL
GRAMINEAE	*Dichanthelium*	*acuminatum*	DIACV2
GRAMINEAE	*Dichanthelium*	*boscii*	DIBO2
GRAMINEAE	*Dichanthelium*	.	DICHA2
GRAMINEAE	*Dichanthelium*	*dichotomum*	DIDI6
GRAMINEAE	*Dichanthelium*	*dichotomum*	DIDIE
GRAMINEAE	*Dichanthelium*	*dichotomum*	DIDIT
GRAMINEAE	*Dichanthelium*	*linearifolium*	DILI2
GRAMINEAE	*Dichanthelium*	*ovale*	DIOVA
GRAMINEAE	*Dichanthelium*	*sabulorum*	DISAP
GRAMINEAE	*Dichanthelium*	*scoparium*	DISC3
GRAMINEAE	*Dichanthelium*	*sphaerocarpon*	DISP2
RUBIACEAE	*Diodia*	*teres*	DITE2
EBENACEAE	*Diospyros*	*virginiana*	DIVI5
COMPOSITAE	*Elephantopus*	*tomentosus*	ELTO2
COMPOSITAE	*Erigeron*	*philadelphicus*	ERPH
COMPOSITAE	*Erigeron*	*strigosus*	ERST3
COMPOSITAE	*Eupatorium*	*album*	EUAL2
COMPOSITAE	*Eupatorium*	*capillifolium*	EUCA5
EUPHORBIACEAE	*Euphorbia*	*corollata*	EUCO10
COMPOSITAE	*Eupatorium*	*compositifolium*	EUCO7
COMPOSITAE	*Eupatorium*	*hyssopifolium*	EUHY
EUPHORBIACEAE	*Euphorbia*	*maculata*	EUMA7
COMPOSITAE	*Eupatorium*	*rotundifolium*	EURO4
COMPOSITAE	*Eupatorium*	*semiserratum*	EUSE
FAGACEAE	*Fagus*	*grandifolia*	FAGR
OLEACEAE	*Fraxinus*	*americana*	FRAM2
OLEACEAE	*Fraxinus*	*pennsylvanica*	FRPE
RUBIACEAE	*Galium*	*circaezans*	GACI2
RUBIACEAE	*Galium*	*hispidulum*	GAHI

LEGUMINOSAE	*Galactia*	*regularis*	GARE2
LEGUMINOSAE	*Galactia*	*volubilis*	GAVO
LOGANIACEAE	*Gelsemium*	*sempervirens*	GESE
GRAMINEAE	*Gymnopogon*	*ambiguus*	GYAM
STYRACACEAE	*Halesia*	*carolina*	HACA3
STYRACACEAE	*Halesia*	*diptera*	HADI3
HAMAMELIDACEAE	*Hamamelis*	*virginiana*	HAVI4
COMPOSITAE	*Helenium*	*amarum*	HEAM
COMPOSITAE	*Helianthus*	*angustifolius*	HEAN2
COMPOSITAE	*Heterotheca*	*graminifolia*	HEGR10
COMPOSITAE	*Helianthus*	*hirsutus*	HEHI2
COMPOSITAE	*Helianthus*	*microcephalus*	HEMI3
GUTTIFERAE	*Hypericum*	*gentianoides*	HYGE
AMARYLLIDACEAE	*Hypoxis*	*hirsuta*	HYHI2
AQUIFOLIACEAE	*Ilex*	*cassine*	ILCA
AQUIFOLIACEAE	*Ilex*	*coriacea*	ILCO
AQUIFOLIACEAE	*Ilex*	*decidua*	ILDE
AQUIFOLIACEAE	*Ilex*	*glabra*	ILGL
AQUIFOLIACEAE	*Ilex*	*opaca*	ILOP
AQUIFOLIACEAE	*Ilex*	*vomitoria*	ILVO
LEGUMINOSAE	*Indigofera*	*caroliniana*	INCA
CONVOLVULACEAE	*Ipomoea*	*pandurata*	IPPA
SAXIFRAGACEAE	*Itea*	*virginica*	ITVI
JUNCACEAE	*Juncus*	*acuminatus*	JUAC
JUGLANDACEAE	*Juglans*	*nigra*	JUNI
JUNCACEAE	*Juncus*	*trigonocarpus*	JUTR5
PINACEAE	*Juniperus*	*virginiana*	JUVI
ERICACEAE	*Kalmia*	*latifolia*	KALA
ERICACEAE	*Leucothoe*	*axillaris*	LEAX
LEGUMINOSAE	*Lespedeza*	*bicolor*	LEBI2
HYDROPHYLLACEAE	*Lemmonia*	*californica*	LECA
GRAMINEAE	*Leptoloma*	*cognatum*	LECO
LEGUMINOSAE	*Lespedeza*	*cuneata*	LECU
LEGUMINOSAE	*Lespedeza*	*hirta*	LEHI2
LEGUMINOSAE	*Lespedeza*	*intermedia*	LEIN2
LEGUMINOSAE	*Lespedeza*	*procumbens*	LEPR
CISTACEAE	*Lechea*	*racemulosa*	LERA
LEGUMINOSAE	*Lespedeza*	*repens*	LERE2
LEGUMINOSAE	*Lespedeza*	*stuevei*	LEST5
CISTACEAE	*Lechea*	*villosa*	LEVI
LEGUMINOSAE	*Lespedeza*	*virginica*	LEVI7
LAURACEAE	*Lindera*	*benzoin*	LIBE3
COMPOSITAE	*Liatris*	*elegans*	LIEL
OLEACEAE	*Ligustrum*	*sinense*	LISI

HAMAMELIDACEAE	*Liquidambar*	*styraciflua*	LIST2
COMPOSITAE	*Liatris*	*tenuifolia*	LITE6
MAGNOLIACEAE	*Liriodendron*	*tulipifera*	LITU
CAPRIFOLIACEAE	*Lonicera*	*japonica*	LOJA
CAPRIFOLIACEAE	*Lonicera*	*sempervirens*	LOSE
ONAGRACEAE	*Ludwigia*	*alternifolia*	LUAL2
ERICACEAE	*Lyonia*	*lucida*	LYLU3
ROSACEAE	*Malus*	*angustifolia*	MAAN3
MAGNOLIACEAE	*Magnolia*	*grandiflora*	MAGR4
MAGNOLIACEAE	*Magnolia*	*virginiana*	MAVI2
CARYOPHYLLACEAE	*Minuartia*	*groenlandica*	MIGR7
RUBIACEAE	*Mitchella*	*repens*	MIRE
MORACEAE	*Morus*	*rubra*	MORU2
MYRICACEAE	*Myrica*	*cerifera*	MYCE
MYRICACEAE	*Myrica*	*heterophylla*	MYHE
CORNACEAE	*Nyssa*	*sylvatica*	NYSY
ONAGRACEAE	*Oenothera*	*fruticosa*	OEFR
POLYPODIACEAE	*Onoclea*	*sensibilis*	ONSE
CACTACEAE	*Opuntia*	*humifusa*	OPHU
OLEACEAE	*Osmanthus*	*americanus*	OSAM
OSMUNDACEAE	*Osmunda*	*cinnamomea*	OSCI
OSMUNDACEAE	*Osmunda*	*regalis*	OSRE
BETULACEAE	*Ostrya*	*virginiana*	OSVI
ERICACEAE	*Oxydendrum*	*arboreum*	OXAR
GRAMINEAE	*Panicum*	*anceps*	PAAN
GRAMINEAE	*Panicum*	*anceps*	PAANR
PASSIFLORACEAE	*Passiflora*	*edulis*	PAED
GRAMINEAE	*Panicum*	*hallii*	PAHAF
CARYOPHYLLACEAE	*Paronychia*	*herniarioides*	PAHE6
GRAMINEAE	*Paspalum*	*laeve*	PALA10
GRAMINEAE	*Paspalum*	*notatum*	PANOS
VITACEAE	*Parthenocissus*	*quinquefolia*	PAQU2
GRAMINEAE	*Paspalum*	*setaceum*	PASEC2
GRAMINEAE	*Paspalum*	*urvillei*	PAUR2
GRAMINEAE	*Panicum*	*virgatum*	PAVI2
LAURACEAE	*Persea*	*borbonia*	PEBO
ARACEAE	*Peltandra*	*virginica*	PEVI
PINACEAE	*Pinus*	*echinata*	PIEC2
PINACEAE	*Pinus*	*elliottii*	PIEL
PINACEAE	*Picea*	*glauca*	PIGL
PINACEAE	*Pinus*	*glabra*	PIGL2
PINACEAE	*Pinus*	*palustris*	PIPA2
PINACEAE	*Pinus*	*serotina*	PISE
PINACEAE	*Pinus*	*taeda*	PITA

PLANTAGINACEAE	*Plantago*	*aristata*	PLAR3
PLANTAGINACEAE	*Plantago*	*lanceolata*	PLLA
COMPOSITAE	*Pluchea*	*purpurascens*	PLPU2
POLYPODIACEAE	*Polystichum*	*acrostichoides*	POAC4
POLYPODIACEAE	*Polypodium*	*polypodioides*	POPO6
LOGANIACEAE	*Polypremum*	*procumbens*	POPR4
ROSACEAE	*Prunus*	*americana*	PRAM
ROSACEAE	*Prunus*	*angustifolia*	PRAN3
ROSACEAE	*Prunus*	*serotina*	PRSE2
ROSACEAE	*Prunus*	*umbellata*	PRUM
POLYPODIACEAE	*Pteridium*	*aquilinum*	PTAQ
LEGUMINOSAE	*Pueraria*	*lobata*	PULO
FAGACEAE	*Quercus*	*alba*	QUAL
FAGACEAE	*Quercus*	*falcata*	QUFA
FAGACEAE	*Quercus*	*falcata*	QUFAP
FAGACEAE	*Quercus*	*incana*	QUIN
FAGACEAE	*Quercus*	*laevis*	QULA2
FAGACEAE	*Quercus*	*laurifolia*	QULA3
FAGACEAE	*Quercus*	*lyrata*	QULY
FAGACEAE	*Quercus*	*marilandica*	QUMA3
FAGACEAE	*Quercus*	*michauxii*	QUMI
FAGACEAE	*Quercus*	*nigra*	QUNI
FAGACEAE	*Quercus*	*phellos*	QUPH
FAGACEAE	*Quercus*	*rubra*	QURU
FAGACEAE	*Quercus*	*stellata*	QUST
FAGACEAE	*Quercus*	*stellata*	QUSTM
FAGACEAE	*Quercus*	*velutina*	QUVE
ERICACEAE	*Rhododendron*	*alabamense*	RHAL5
ERICACEAE	*Rhododendron*	*canescens*	RHCA7
ANACARDIACEAE	*Rhus*	*copallinum*	RHCO
MELASTOMATACEAE	*Rhexia*	*mariana*	RHMA
LEGUMINOSAE	*Rhynchosia*	*tomentosa*	RHTO3
CYPERACEAE	*Rhynchospora*	.	RHYNC3
LEGUMINOSAE	*Robinia*	*pseudoacacia*	ROPS
ROSACEAE	*Rubus*	*cuneifolius*	RUCU
LAURACEAE	*Sassafras*	*albidum*	SAAL5
PALMAE	*Sabal*	*minor*	SAMI8
LABIATAE	*Scutellaria*	*integrifolia*	SCIN2
LEGUMINOSAE	*Schrankia*	*microphylla*	SCMI
CYPERACEAE	*Scleria*	*triglomerata*	SCTR
SCROPHULARIACEAE	*Seymeria*	*cassioides*	SECA4
EUPHORBIACEAE	*Sebastiania*	*fruticosa*	SEFR
SCROPHULARIACEAE	*Seymeria*	*pectinata*	SEPE2
COMPOSITAE	*Silphium*	*asteriscus*	SIAS2

COMPOSITAE	*Silphium*	*compositum*	SICO5
LILIACEAE	*Smilax*	*bona-nox*	SMBO2
LILIACEAE	*Smilax*	*glauca*	SMGL
LILIACEAE	*Smilax*	*herbacea*	SMHE
LILIACEAE	*Smilax*	*laurifolia*	SMLA
LILIACEAE	*Smilax*	*pumila*	SMPU
LILIACEAE	*Smilax*	*rotundifolia*	SMRO
LILIACEAE	*Smilax*	*smallii*	SMSM
LILIACEAE	*Smilax*	*tamnoides*	SMTA2
SOLANACEAE	*Solanum*	*carolinense*	SOCA3
COMPOSITAE	*Solidago*	*canadensis*	SOCA6
GRAMINEAE	*Sorghum*	*halepense*	SOHA
COMPOSITAE	*Solidago*	*nemoralis*	SONE
GRAMINEAE	*Sorghastrum*	*nutans*	SONU2
COMPOSITAE	*Solidago*	*odora*	SOOD
GRAMINEAE	*Sporobolus*	*junceus*	SPJU
STYRACACEAE	*Styrax*	*americana*	STAM4
LEGUMINOSAE	*Stylosanthes*	*biflora*	STBI2
CONVOLVULACEAE	*Stylisma*	*humistrata*	STHU2
CONVOLVULACEAE	*Stylisma*	*patens*	STPA8
SYMPLOCACEAE	*Symplocos*	*tinctoria*	SYTI
LEGUMINOSAE	*Tephrosia*	*spicata*	TESP
LEGUMINOSAE	*Tephrosia*	*virginiana*	TEVI
TILIACEAE	*Tilia*	*americana*	TIAM
ANACARDIACEAE	*Toxicodendron*	*quercifolia*	TOQU
ANACARDIACEAE	*Toxicodendron*	*radicans*	TORA2
ANACARDIACEAE	*Toxicodendron*	*vernix*	TOVE
GRAMINEAE	*Triplasis*	*americana*	TRAM7
LEGUMINOSAE	*Trifolium*	*dubium*	TRDU2
COMMELINACEAE	*Tradescantia*	*ohiensis*	TROH
EUPHORBIACEAE	*Tragia*	*urens*	TRUR
TYPHACEAE	*Typha*	*latifolia*	TYLA
ULMACEAE	*Ulmus*	*alata*	ULAL
ULMACEAE	*Ulmus*	*americana*	ULAM
ULMACEAE	*Ulmus*	*rubra*	ULRU
ERICACEAE	*Vaccinium*	*arboreum*	VAAR
ERICACEAE	*Vaccinium*	*corymbosum*	VACO
ERICACEAE	*Vaccinium*	*elliottii*	VAEL
ERICACEAE	*Vaccinium*	*myrsinites*	VAMY3
ERICACEAE	*Vaccinium*	*stamineum*	VAST
COMPOSITAE	*Vernonia*	*angustifolia*	VEAN
VERBENACEAE	*Verbena*	*bracteata*	VEBR
VERBENACEAE	*Verbena*	*brasiliensis*	VEBR2
LEGUMINOSAE	*Vicia*	*hugeri*	VIHU

CAPRIFOLIACEAE	*Viburnum*	*nudum*	VINU
VITACEAE	*Vitis*	*rotundifolia*	VIRO3
CAPRIFOLIACEAE	*Viburnum*	*rufidulum*	VIRU
GRAMINEAE	*Vulpia*	*octoflora*	VUOC
CAMPANULACEAE	*Wahlenbergia*	*marginata*	WAMA
LEGUMINOSAE	*Wisteria*	*frutescens*	WIFR
POLYPODIACEAE	*Woodwardia*	*areolata*	WOAR
RANUNCULACEAE	*Xanthorhiza*	*simplicissima*	XASI
LILIACEAE	Yucca	*filamentosa*	YUFI
GRAMINEAE	*Zea*	*mays*	ZEMA

Appendix F
1995 Environmental Variables

Plot	Sand/ Clay ratio	Percent Slope	Elevation (meters)	Distance to Water (meters)	Number of Burns 91-95	Number of Evergreen species	Number of Deciduous species	Number of Grass species	Number of Forb species	Canopy Cover	Understory	Percent Bareground Cover
1	0.2	5	183	38	0	1	20	3	3	96	97	6
2	0.5	13	310	531	2	3	13	2	2	30	75	3
3	0.8	7	117	21	0	5	11	2	2	79	94	5
4	0.9	15	175	22	0	2	14	2	2	97	99	8
5	1.0	2	61	206	2	2	3	8	8	54	83	2
6	1.4	2	312	106	0	2	23	1	1	84	93	0
7	1.7	45	284	222	0	2	16	2	2	73	80	1
8	1.9	11	324	287	0	5	17	0	0	84	94	1
9	1.4	10	269	426	2	3	5	6	6	16	51	24
10	2.0	4	84	132	1	0	0	2	2	0	70	22
11	2.5	7	224	205	1	2	12	1	1	7	13	10
12	2.9	24	319	171	0	2	4	2	2	0	24	55
13	3.1	3	150	495	1	2	11	4	4	46	69	11
14	3.3	15	144	185	1	3	15	2	2	52	72	11
15	3.3	2	228	256	2	2	3	3	3	49	82	0
16	3.6	6	104	15	1	2	5	4	4	8	54	2
17	4.1	6	90	165	1	2	9	3	3	51	65	8
18	4.2	2	218	45	0	3	16	0	0	57	84	0
19	4.8	3	150	20	1	3	14	2	2	57	89	1
20	4.4	3	84	23	2	3	8	5	5	34	69	12
21	4.6	3	29	135	1	1	0	3	3	0	42	32
22	4.7	3	48	319	3	2	5	3	3	5	75	22
23	6.1	2	2	116	1	2	14	0	0	86	94	3
24	5.7	8	209	325	0	0	6	5	5	0	34	67
25	5.8	4	102	256	2	0	5	3	3	3	19	55
26	6.2	6	351	371	0	2	3	2	2	0	36	70

Plot	Sand/ Clay ratio	Percent Slope	Elevation (meters)	Distance to Water (meters)	Number of Burns 91-95	Number of Evergreen species	Number of Deciduous species	Number of Grass species	Number of Forb species	Canopy Cover	Understory	Percent Bareground Cover
27	5.4	4	325	782	3	2	7	7	7	30	71	41
28	6.2	5	85	220	2	2	12	3	3	16	50	31
29	7.1	7	217	38	1	1	9	3	3	15	46	48
30	7.1	9	279	261	0	1	9	3	3	36	74	23
31	7.8	6	250	0	1	6	10	1	1	98	99	9
32	8.2	4	169	13	0	2	10	2	2	96	98	0
33	8.5	6	283	118	0	3	15	2	2	85	98	1
34	8.9	8	267	146	1	5	12	1	1	87	94	0
35	8.8	27	312	265	0	5	11	0	0	89	94	2
36	7.3	5	41	264	0	3	24	2	2	65	84	3
37	6.0	6	243	309	0	1	16	0	0	86	89	8
38	8.8	11	184	103	0	0	14	1	1	98	99	0
39	9.5	7	308	295	2	4	11	6	6	36	84	1
40	11.1	1	55	34	0	2	12	1	1	97	98	1
41	9.8	14	303	19	1	2	12	0	0	84	91	0
42	10.0	11	285	283	2	3	2	6	6	61	89	8
43	10.0	16	282	60	0	1	15	8	8	34	85	12
44	10.5	3	101	101	0	2	6	2	2	10	35	14
45	11.8	3	89	94	0	5	22	1	1	93	97	1
46	11.2	2	343	235	1	0	12	1	1	24	39	4
47	11.5	9	202	161	2	1	5	4	4	25	48	24
48	12.0	11	301	653	3	3	4	8	8	71	82	7
49	11.7	5	172	505	0	3	15	2	2	95	97	1
50	12.2	7	193	63	1	3	7	8	8	18	58	4
51	12.4	6	217	22	1	3	10	2	2	94	97	5
52	12.7	9	14	346	1	4	20	3	3	87	90	1
53	12.9	4	170	15	0	3	9	4	4	70	95	3
54	11.5	12	75	263	2	2	5	4	4	16	77	26

Plot	Sand/ Clay	Slope	Elevation	Distance to Water	Number of Burns 91-95	Number of Evergreen	Number of Deciduous	Number of Grasses	Number of Forbs	Canopy Cover	Understory	Percent Bareground Cover
55	13.8	16	343	140	2	2	8	3	3	47	55	13
56	12.4	6	289	296	2	2	2	3	3	39	52	19
57	11.4	4	257	100	0	1	13	1	1	95	97	0
58	14.9	23	343	50	1	5	21	3	3	43	72	0
59	15.1	10	301	286	2	3	4	3	3	10	16	25
60	11.8	1	310	420	0	0	0	0	0	0	49	1

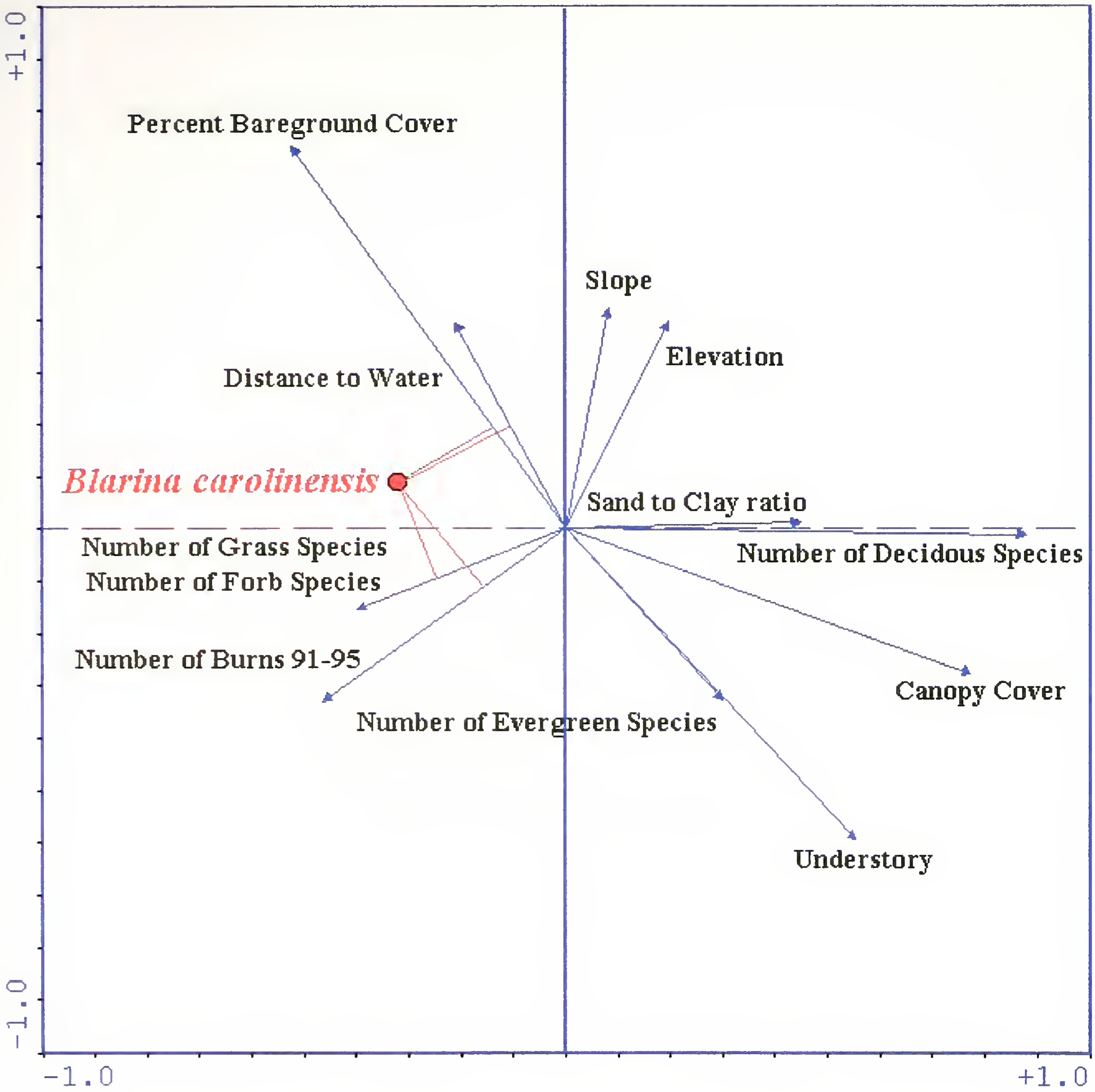
Appendix G
1995 Small Mammal Species

Plot	*Blarina carolinensis*	*Cryptotis parva*	*Mus musculus*	*Neotoma floridana*	*Ochrotomys nuttalli*	*Oryzomys palustris*	*Peromyscus gossypinus*	*Peromyscus polionotus*	*Reithrodontomys humulis*	*Sigmodon hispidus*
1	0	0	0	0	0	0	2	0	0	0
2	0	0	0	0	1	0	0	0	0	0
3	0	0	0	0	0	2	1	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	1	1	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	3	0	1
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	1	1	0	0
12	0	0	2	0	0	0	0	10	0	2
13	0	0	0	0	0	0	3	0	0	0
14	0	0	0	0	0	0	2	4	0	0
15	0	0	0	0	0	0	0	0	2	1
16	0	2	0	0	0	0	0	1	2	2
17	0	0	0	0	1	1	2	9	1	0
18	0	0	0	0	0	0	0	0	1	0
19	0	0	0	0	0	0	4	0	0	0
20	0	2	0	0	0	0	1	0	10	16
21	0	0	0	0	0	0	0	1	4	12
22	0	1	0	0	0	0	0	0	0	17
23	0	0	0	0	0	0	1	0	0	0
24	0	0	0	0	0	0	0	8	0	0
25	0	0	0	0	0	0	0	6	0	0
26	0	0	0	0	0	0	0	5	0	0
27	0	0	0	0	0	0	0	10	0	0
28	0	0	0	0	0	0	4	11	0	1
29	0	0	0	0	0	0	3	0	0	0
30	0	0	0	0	0	0	0	1	0	0

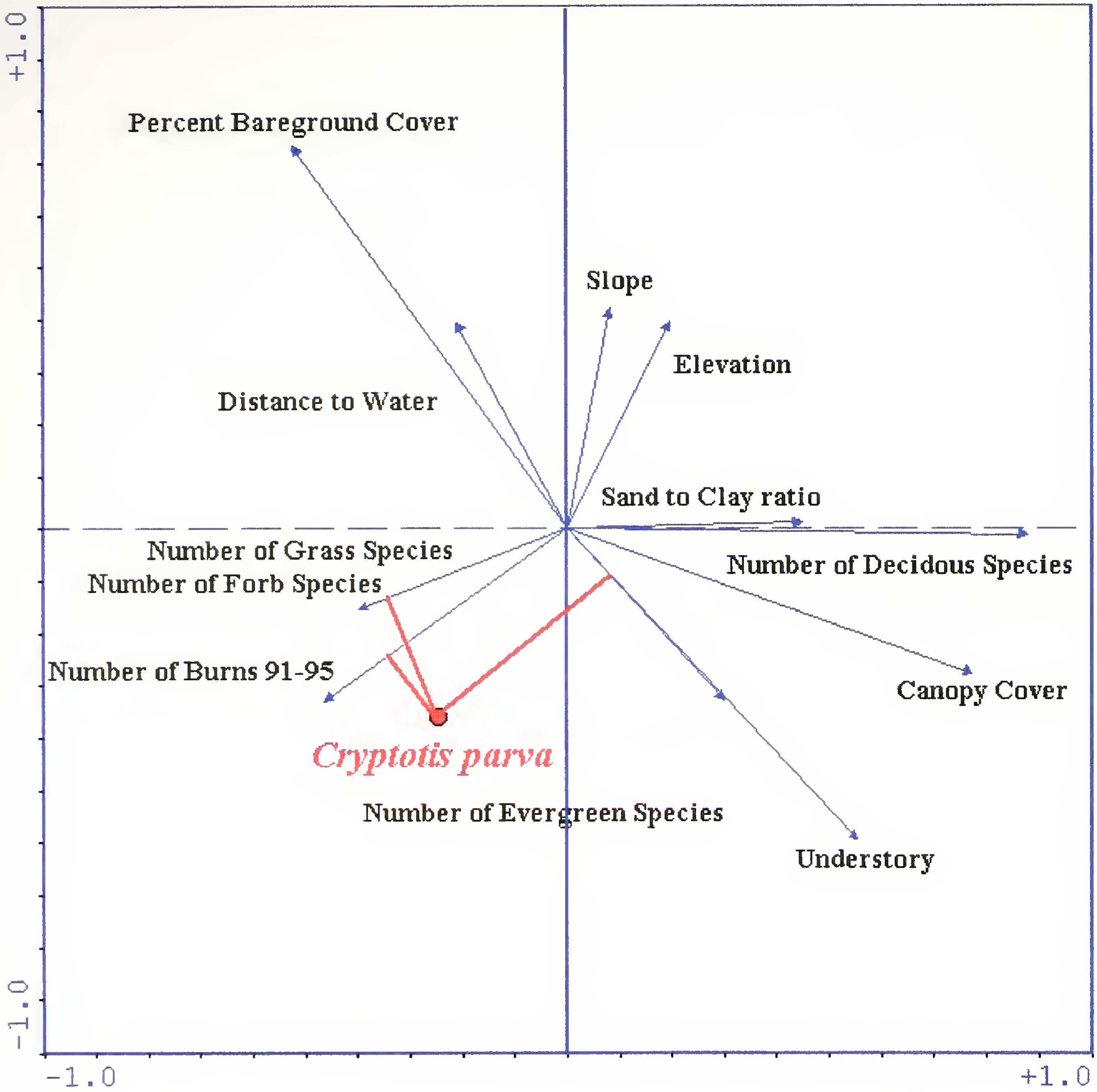
Plot	*Blarina carolinensis*	*Cryptotis parva*	*Mus musculus*	*Neotoma floridana*	*Ochrotomys nuttalli*	*Oryzomys palustris*	*Peromyscus gossypinus*	*Peromyscus polionotus*	*Reithrodontomys humulis*	*Sigmodon hispidus*
31	0	0	0	0	1	0	3	0	0	0
32	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	1	0	0	0
36	0	0	0	0	0	0	2	0	0	0
37	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	2	0	0	0
39	0	0	0	0	0	0	1	0	2	0
40	0	0	0	0	0	0	6	0	0	0
41	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	1
43	0	0	0	0	1	0	1	0	0	0
44	0	0	0	0	0	0	0	7	0	0
45	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	1	0	3	0	0	0
47	0	0	0	0	0	0	0	2	0	0
48	0	0	0	0	0	0	0	0	1	1
49	0	0	0	0	0	0	5	0	0	0
50	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	1	0	2	0	0	1
54	0	0	0	0	0	0	0	1	0	0
55	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	1	0	0	0
57	0	0	0	0	0	0	0	0	0	0
58	0	0	0	1	1	0	3	0	0	0
59	0	0	0	0	0	0	0	1	0	0
60	0	0	0	0	0	0	0	0	0	0

APPENDIX H

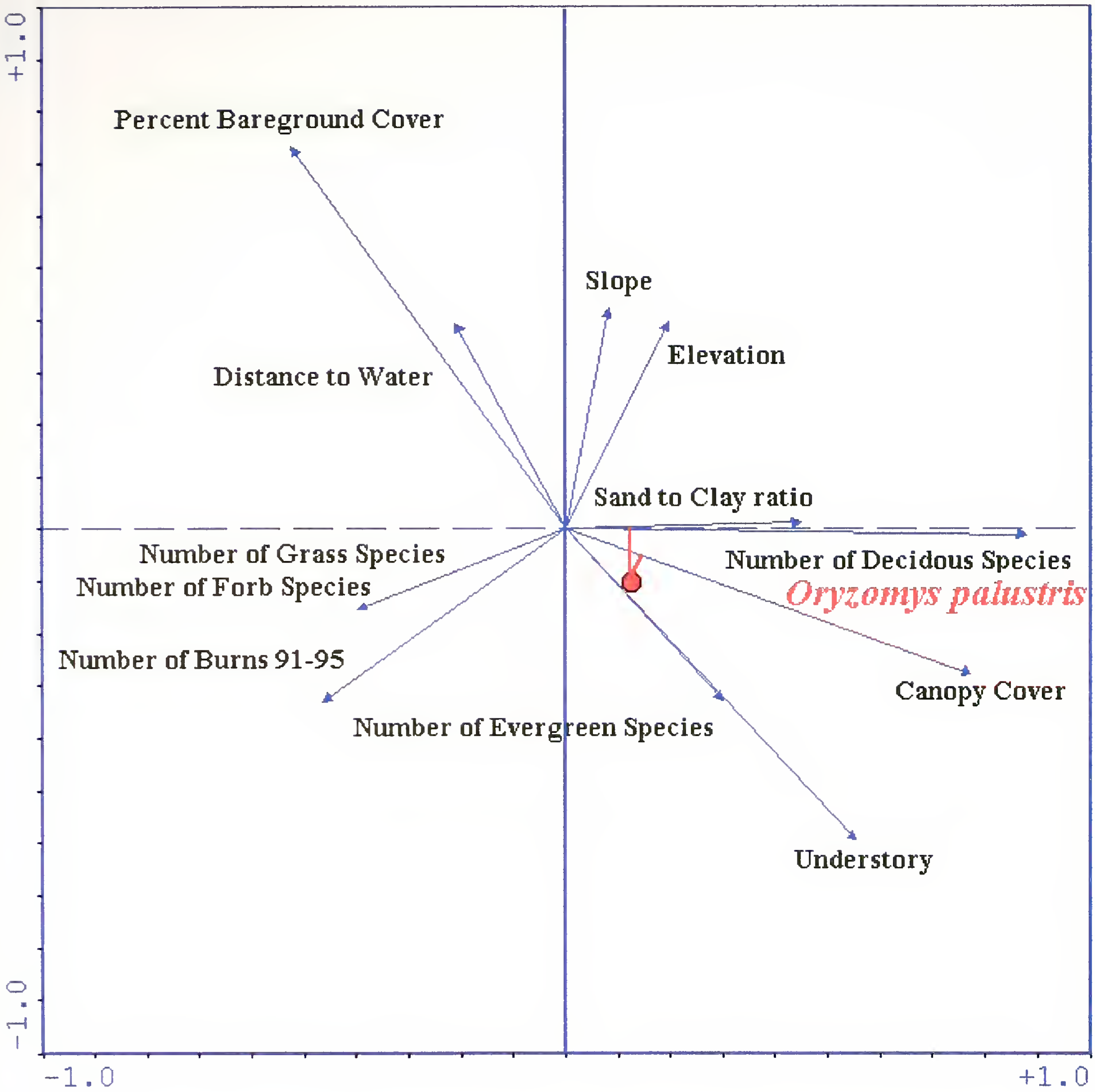
1995 Biplot showing perpendiculars from *Blarina* to the environmental arrows.



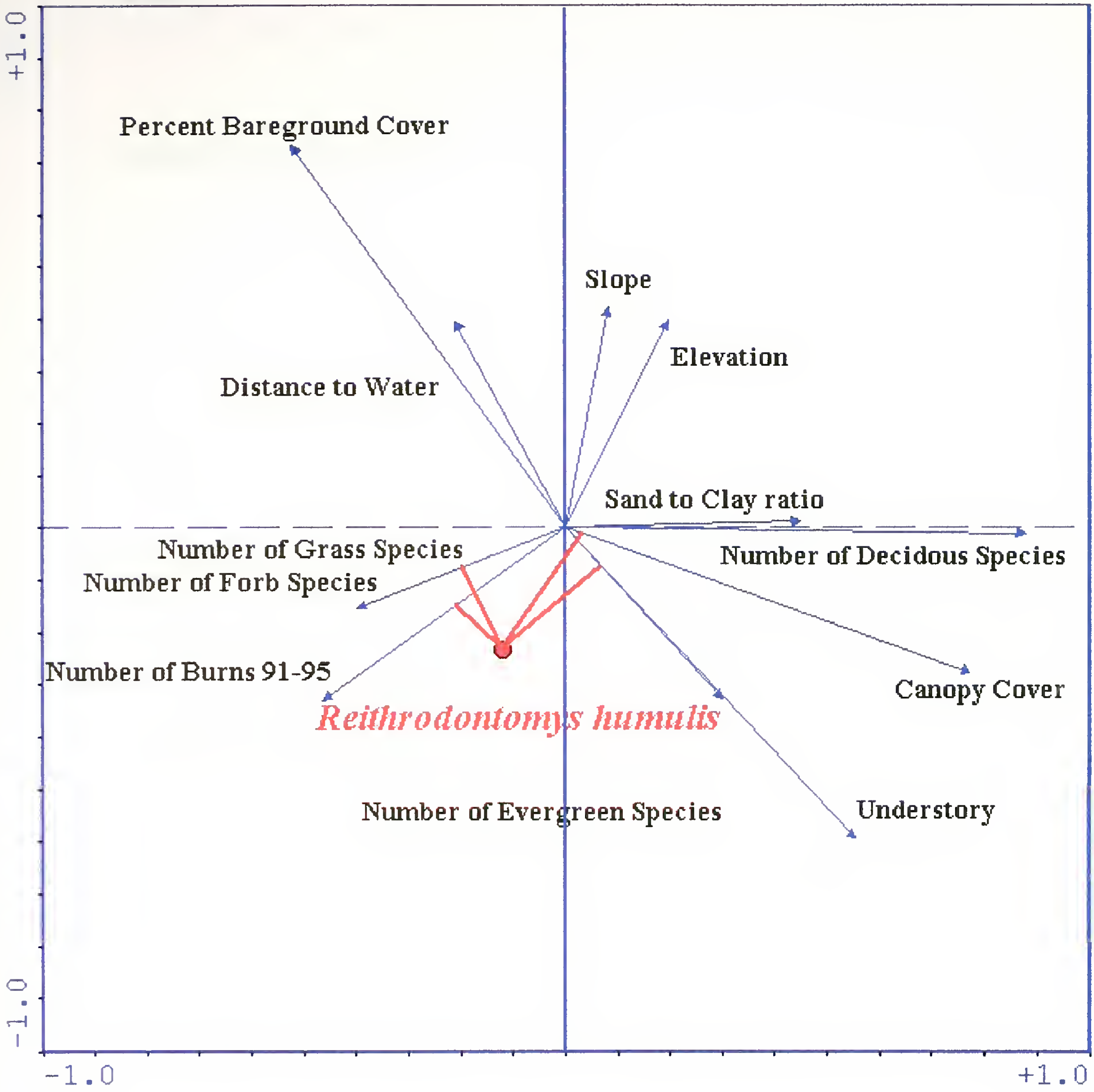
1995 Biplot showing perpendiculars from *Cryptotis* to the environmental arrows.



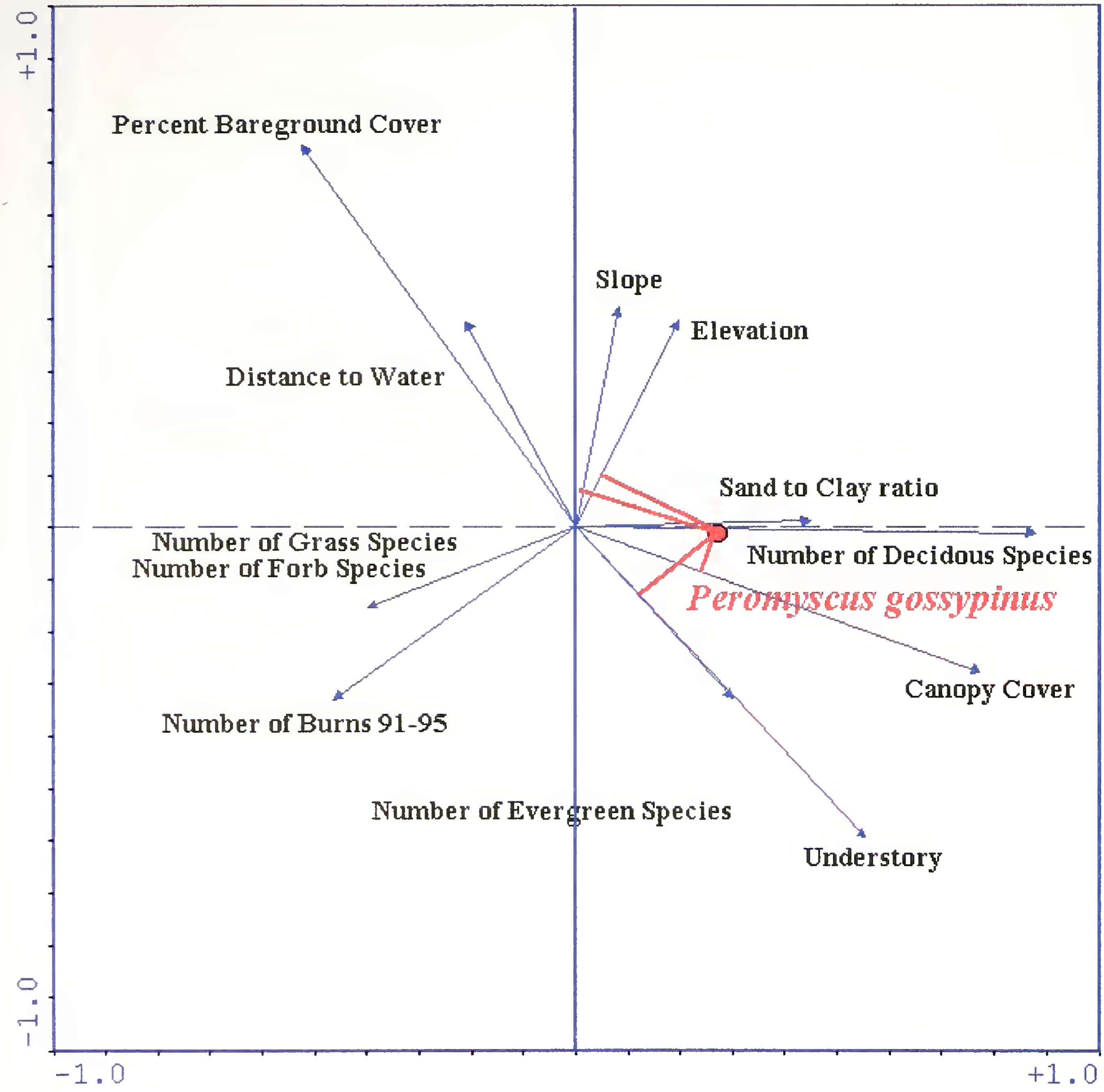
1995 Biplot showing perpendiculars from *Oryzomys* to the environmental arrows.



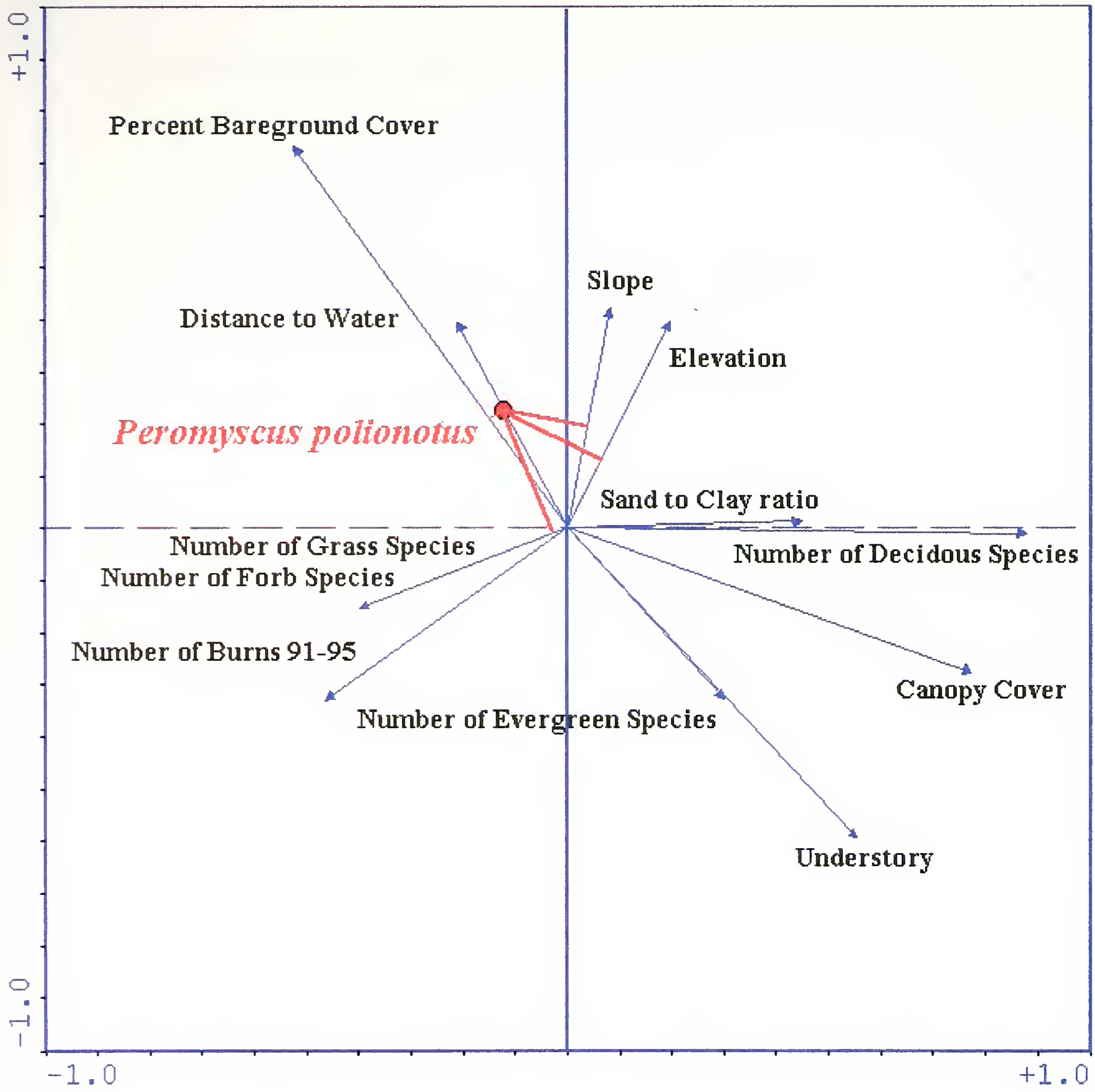
1995 Biplot showing perpendiculars from *Reithrodontomys* to the environmental arrows.



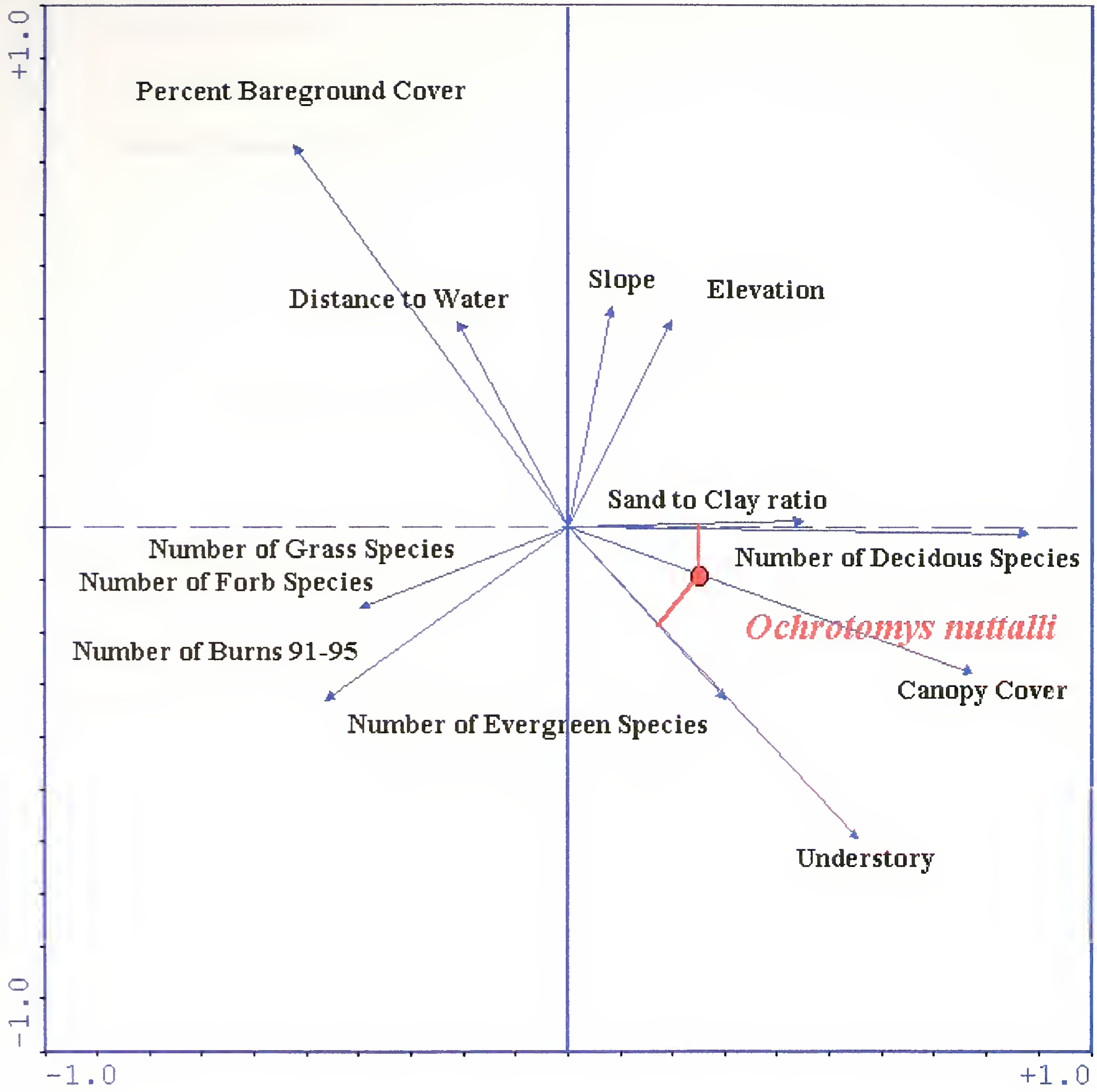
1995 Biplot showing perpendiculars for *P. gossypinus* to the environmental arrows.



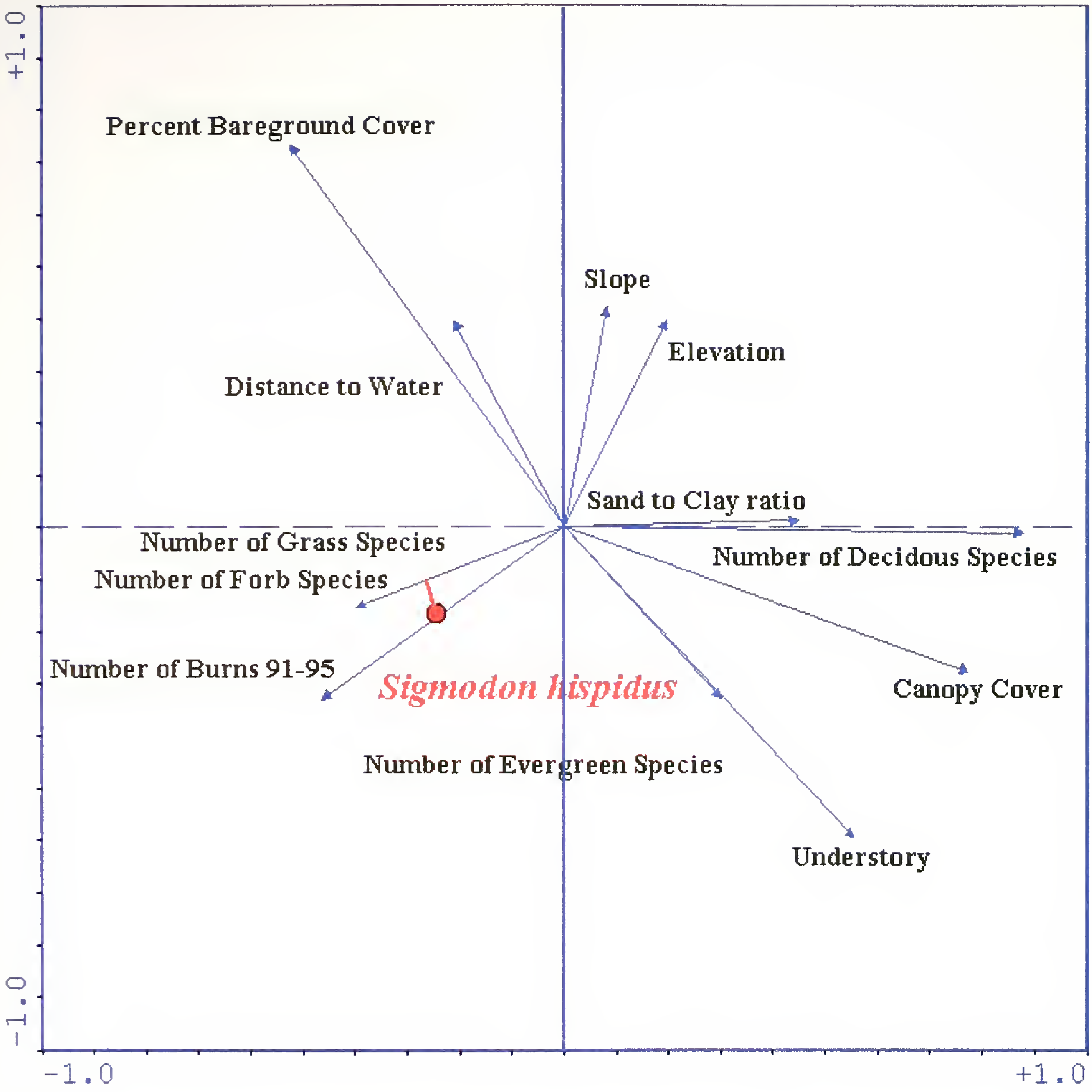
1995 Biplot showing perpendiculars from *P. polionotus* to the environmental arrows.



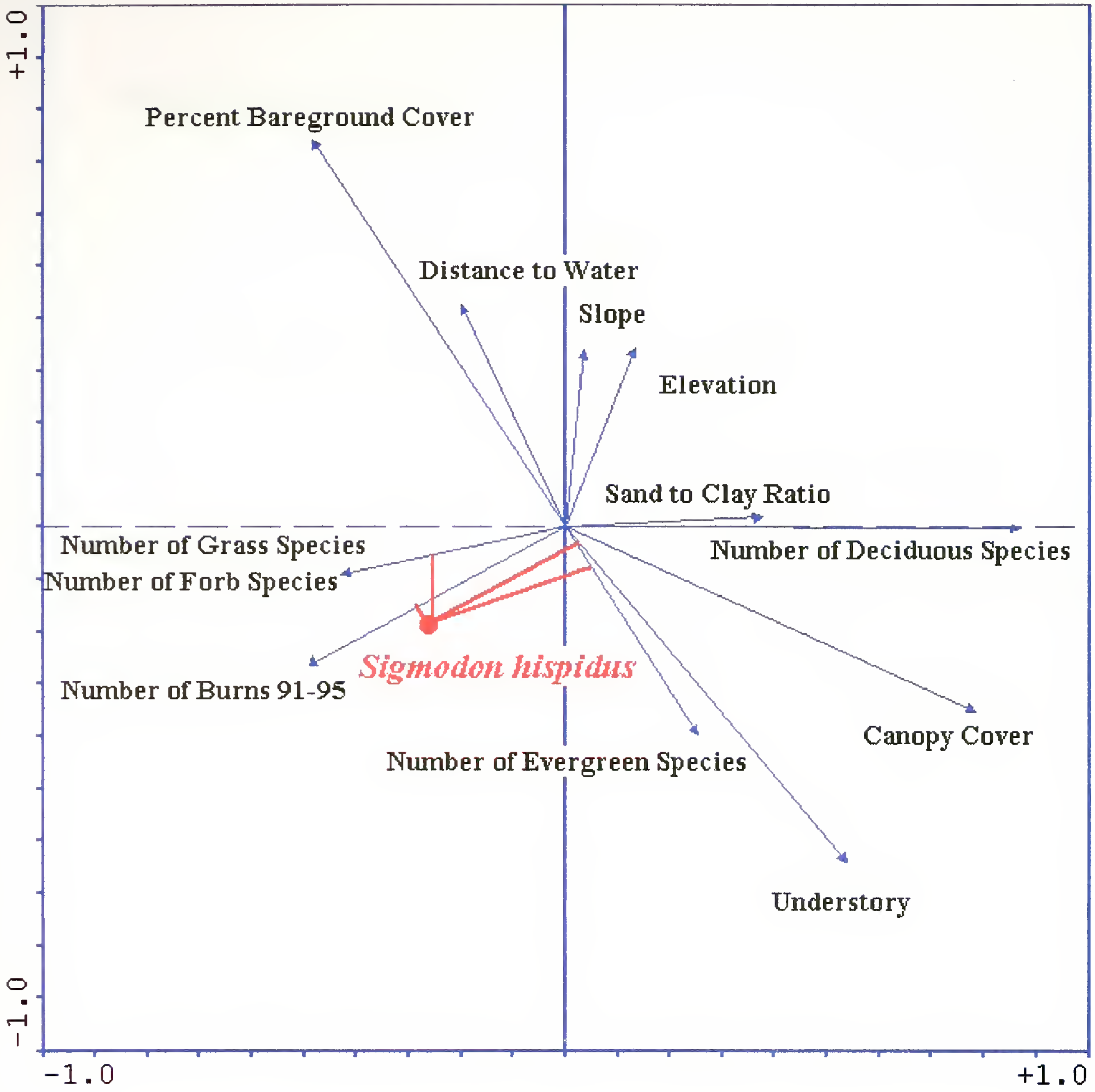
1995 Biplot showing perpendiculars for *Ochrotomys* to the environmental arrows.



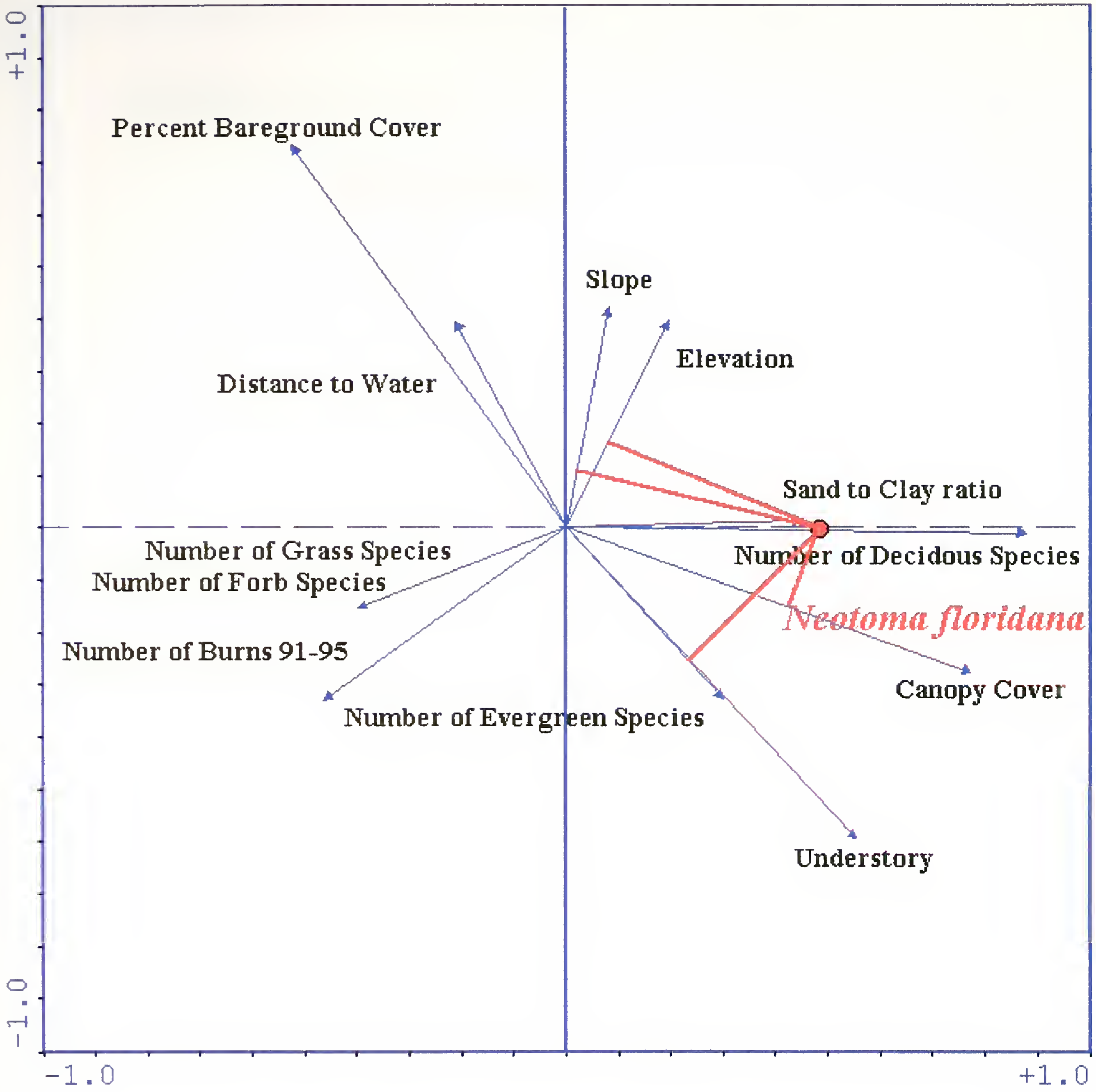
1995 Biplot using unmodified data showing perpendiculars from *Sigmodon* to the environmental arrows.



1995 Biplot using modified data showing perpendiculars from Sigmodon to the environmental arrows.



1995 Biplot showing perpendiculars from *Neotoma* to the environmental arrows.



1995 Biplot showing perpendiculars from *Mus* to environmental arrows.