Small Mammal Habitat Utilization of a Feedstock Agroforest System in the Mississippi Alluvial Plain

A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Forest Resources

by

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University of Arkansas-Monticello, 2011

August 2013

University of Arkansas-Monticello

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ABSTRACT

In recent years, there has been an increasing effort to expand the production and use of biofuels to ease our dependence on foreign oil. A concern associated with the expansion of bioenergy feedstock production is that marginal land currently forested or managed for wildlife habitat in conservation programs will be converted to corn or soybean production due to high market values of these crops. Cottonwood (*Populus deltoides*)-switchgrass (*Panicum virgatum*) agroforests could provide suitable habitat for a number of wildlife species on this type of land while providing needed bioenergy feedstocks. Small mammals are ecologically important for a variety of reasons, and play a vital role in the enhancement and preservation of biological diversity. Little is known about how small mammals would utilize these biofuel feedstock agroforest systems. I used multivariate analysis to describe variation in composition and abundance of small mammals within a feedstock agroforest system in the Mississippi Alluvial Plain in southeast Arkansas. I used canonical correspondence analysis (CCA) in program to produce ordination diagrams. I recorded 261 individuals of 5 taxa of small mammals across 4 seasons combined. House mouse (*Mus musculus*) accounted for 63.98% of individuals captured, hispid cotton rat (*Sigmodon hispidus*) accounted for 16.48% of individuals captured, marsh rice rat (*Oryzomys palustris*) and *Peromyscus* sp. accounted for 9.78% each of individuals captured, and fulvous harvest mouse (*Reithrodontomys fulvescens*) accounted for 0.38% of individuals captured. Canonical correspondence analysis of habitat variables and small mammal captures for all seasons combined resulted in a partial CCA with explanatory variables accounting for 34.3% of the total variation among captures. Down woody debris, water, canopy cover, and presence of trees exerted the greatest influence

on capture rates. Canonical correspondence analysis of plant species and small mammal captures for all seasons combined resulted in a partial CCA with explanatory variables accounting for 32.6% of the total variation among captures. Cottonwood trees, Johnson grass (*Sorghum halepense*), soybeans (*Glycine max*), and switchgrass exerted the greatest influence on capture rates. To achieve the greatest biodiversity in a feedstock agroforest, I recommend the following. Plant alley cropped cottonwood and switchgrass combination stands to maximize plant heterogeneity. Minimize use of herbicides and other weed control measures to allow plants important to small mammals to grow within cottonwood stands. Leave woody debris, which is important to some small mammals, on site after harvest of cottonwood stands.

ACKNOWLEDGMENTS

First, I thank God for the vision and strength He gave me to pursue a graduate degree. The completion of this project would have been possible without Him. I thank my wife for her support and sacrifices, which allowed me to pursue my dream of a postgraduate education. I send thanks to my Major Professor, Dr. Don White, Jr., for his support, guidance, assistance, and friendship. I also thank my Graduate Committee members, Dr. Rob Kissell and Dr. John Hunt, for their constructive comments during different phases of this project. A special thanks to Chris Watt for his assistance with field work and other aspects of this project. I thank Allan Humphrey for his assistance in the field as well. I am grateful to Dr. Karen Fawley and Dr. Marvin Fawley for their assistance with plant identification. I was my pleasure working with all of you.

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INTRODUCTION

Within the past decade there has been a growing effort to expand the production of biofuel feedstocks to reduce U.S. dependence on foreign oil imports and to slow global climate change (Tenenbaum 2008). Biofuels are fuels produced by fermenting the sugars in biomass to produce ethanol, or by enzymatic hydrolysis or synthesis gas fermentation to produce cellulosic ethanol (Bies, 2006). Biomass can come from several sources, such as forestry residues, agricultural crops and residues, wood, animal and livestock wastes, and municipal wastes (Bies, 2006). A recent concern associated with the expansion of bioenergy feedstock production in the Lower Mississippi Alluvial Valley is conversion of marginal-quality land currently forested or managed for wildlife habitat to high-value corn or soybean production (Tenenbaum 2008). A growing trend is to produce biomass with non-food source agroforest crops, such as switchgrass (*Panicum virgatum*) and cottonwood trees (*Populus deltoides*).

Cottonwood-switchgrass agroforests, while providing fiber for bioenergy production, could simultaneously provide suitable habitat for a number of wildlife species on marginal-quality land. Wildlife species diversity (Schiller and Tolbert 1996), especially species that depend on early successional forests (Wesley et al. 1981), could potentially benefit from the presence of agroforests on marginal-quality land currently predominated by row crops.

Small mammals are ecologically important for several reasons. They serve as a primary prey base for many avian, reptilian, and mammalian predators (Carey and Johnson 1995). Many small mammal species consume insects detrimental to human land uses (Carey and Johnson 1995). Several species facilitate dispersal of fungal spores that

form root-inhabiting ectomycorrhizae, which are required by many plants for nutrient procurement, water absorption, and protection from root pathogens (Maser et al. 1978). In some circumstances, small mammals impact regeneration of plants through seed consumption and dispersal (Plucinski and Hunter 2001, Vander Wall et al. 2001). A few species of small mammals also influence hydrological processes and nutrient cycling with their burrowing activities (Laundre and Reynolds 1993).

Little is known about how wildlife populations will respond to and utilize biofuel feedstock agroforest systems. Christian et al. (1997) found that avian abundance and species richness was greater in short-rotation poplar (*Populus* sp.) plantations than in adjacent row crop or small grain fields. Initial trials in Iowa investigating use of switchgrass for biomass production have indicated that abundances of conservation priority grassland bird species were greater in marginal croplands supporting production of switchgrass than conventional row crops (Murray et al. 2002). Substantial knowledge exists on multi-scale small mammal habitat relationships, but data on effects of different types, intensities, and spatial arrangements of feedstock agroforest systems on small mammals do not exist and are urgently needed.

STUDY OBJECTIVES

In this study, I used multivariate analysis to describe variation in composition and abundance of small mammals within a feedstock agroforest system in the Mississippi Alluvial Plain in southeast Arkansas. I hypothesized habitat heterogeneity was ordered in space along a gradient that results in a simplified small mammal community with fewer, more abundant species, within the cottonwood, switchgrass, and soybean treatments with the lowest environmental variability.

LITERATURE REVIEW

Small Mammal Use of Agroforests

Little is known about the impacts of a cottonwood-switchgrass agroforest on small mammal populations. To my knowledge, with the exception of Robinson (2012) and Schwer (2011), little research has been conducted on small mammal habitat use of a cottonwood-switchgrass agroforest managed for biofuel production. Robinson (2012) found that small mammal species abundance and diversity was greater in cottonwood-switchgrass agroforests compared to row-crops of soybeans on three sites in the Lower Mississippi Alluvial Valley. Schwer (2011) found that switchgrass stands managed as a renewable energy crop have the potential to be viable wildlife habitat for some small mammal species in Kentucky. Research has been conducted, however, on use by small mammals of tallgrass prairies where switchgrass was a dominant species. Lemen and Clausen (1984), for example, found that mowing had species-specific affects on small mammal populations in tall-grass prairie ecosystems in Nebraska. Kaufman and Kaufman (2008), Kaufman et al. (2000), and Sietman et al. (1994) found that hay harvesting within a tallgrass prairie had a negative effect on small mammal populations in Kansas. Kaufman et al. (2000) and Kirsch (1997) found that house mice (*Mus musculus*) were commonly captured in croplands, but Kaufman et al. (2000), Kirsch (1997), and Kaufman and Kaufman (1990) showed house mice tended to avoid grassland habitat. Clark et al. (1987) captured a large number of white-footed mice (*Peromyscus leucopus*) in tallgrass prairie habitat.

Research has also been conducted on small mammal use of poplar (*Populus* sp.) stands. Christian et al. (1997) showed that small mammal species diversity and

abundance was greater in monocultural hybrid poplar plantations compared to row crops, but lower than in mixed species forests. By comparing capture rates of small mammals between different types of short rotation stands and surrounding habitats, Giordano and Meriggi (2009) found that short rotation poplar plantations were suitable habitat for small mammal communities.

Habitat Use

Small mammal species occurrence is correlated with environmental factors that collectively define vegetation type (Jameson 1949, Miller and Getz 1977, Dueser and Shugart 1978, Grant and Birney 1979, Morris 1979, Doyle 1987). Coppeto et al. (2006) found that variations in small mammal population abundances could be better explained by macrohabitat features, such as forest type, than by microhabitat features. Bellows et al. (2001) found that there was no difference in small mammal abundance among 5 macrohabitat types, and canonical correspondence analysis revealed only 27% of variation of small mammal distribution was attributable to microhabitat variables. Bowne et al. (1999), however, found that microhabitat variables influenced movement patterns of hispid cotton-rats (*Sigmodon hispidus*). Schweiger et al. (2000) found that *S. hispidus* distributions were associated with early successional vegetation, while *P. leucopus* preferred large blocks of vegetation dominated by woody plants. Schweiger et al. (2000) also suggested that landscape-level vegetation structure and composition at least partially explained small mammal distributions.

Peromyscus leucopus has been reported to be associated with vertical heterogeneous habitat and woody vegetation (Kaufman et al. 2000, Clark et al. 1987). Kaufman et al. (2000) reported *P. leucopus* preferred woodlands over herbaceous

vegetation and Sietman et al. (1994) reported associations with habitats that contained woody vegetation over native tallgrass prairie.

Peromyscus maniculatus are considered to be habitat generalists (Elliott and Root 2006, Block et al. 1999). Stallman and Best (1996) and Fleharty and Navo (1983) found that *P. maniculatus* do not rely on herbaceous ground cover for protection, but instead excavate extensive burrow systems in Iowa and Kansas. Barbour and Davis (1974) reported *P. maniculatus* commonly occupied crop land, grasslands, and weed fields in Kentucky. Williams et al. (2002) found that structure of mammal assemblages was closely related to vegetation structure within and between habitats, and over all spatial scales examined, using a multi-scale approach.

Lambert et al. (2006) found that many small mammal species showed increased abundances with habitat features indicative of edge-affected or disturbed habitats, such as number of vines per tree, mean log size, number of logs, and volume of downed woody debris, and found negative relationships with understory openness, understory woody-stem density, tree density, and tree size.

Several researchers have reported that vegetative structure complexity is positively correlated with abundance and diversity of small mammals (Olson and Brewer 2003, Peles and Barrett 1996, Germano and Lawhead 1986, Johnson 1986, Pizzimenti and De Salle 1981). Due to the numerous small mammal species that are likely present on my study site, and conflicting literature on what habitat variables are important to small mammal assemblages, it is difficult to predict which habitat variables may be important to small mammals in the Mississippi Alluvial Plain.

METHODS

Study Site

My study site was located on the Rohwer Division of the Southeast Research and Extension Center (hereafter "the Center") located 3.2 km north of Rohwer, in Desha County, Arkansas (Figure 1). The Center is approximately 336 ha and consists almost entirely of cropland. The Center is located in a region generally considered marginal-quality cropland. This study was part of a larger study with the goal of developing economically and ecologically sustainable agroforest systems that produce cellulosic bioenergy feedstocks in the Lower Mississippi Alluvial Valley.

My study site consisted of 15 study plots (5 90 x 90 m and 10 30 x 90 m) planted in varying percentages of cottonwood trees, switchgrass, and soy beans (*Glycine max*) (Figure 2). Due to the small size of the 30 x 90 m plots, and to maintain consistency with a previous small mammal study on this site (Robinson 2012), only the 5 90 x 90 m plots were utilized for trapping small mammals in this observational study. The 30 x 90 plots were used for other bioenergy studies. All plots were extensively managed for weed control using herbicides and mechanical methods based on criteria in a concurrent bioenergy study. Plots consisted of 100% switchgrass (S1-3), 100% cottonwood (W1-3), 70% switchgrass, 30% cottonwood (SW1-3), 70% cottonwood, 30% switchgrass (WS1-3), and 100% soybeans (C1-3) (Figure 2). Combination plots (SW1-3 and WS1-3) were alley cropped (i.e., cottonwood trees and switchgrass were planted in alternating strips 15 m and 30 m wide). Cottonwood stands were approximately 4 years old and well established. Switchgrass, however, had multiple years of crop failure but had improved survival rates for the year of this study. Figure 3 shows an alley cropped

cottonwood/switchgrass stand typical of plots on this site. The remainder of the Center was predominately row-crops with the exception of the abandoned fish ponds immediately north of the feedstock plots. The abandoned fish ponds contain an abundance of vegetation and contained varying amounts of water throughout the year. Vegetation present in the row-crop areas changed drastically throughout the year and is displayed as digitized maps of general vegetation type by season in figures 4-7.

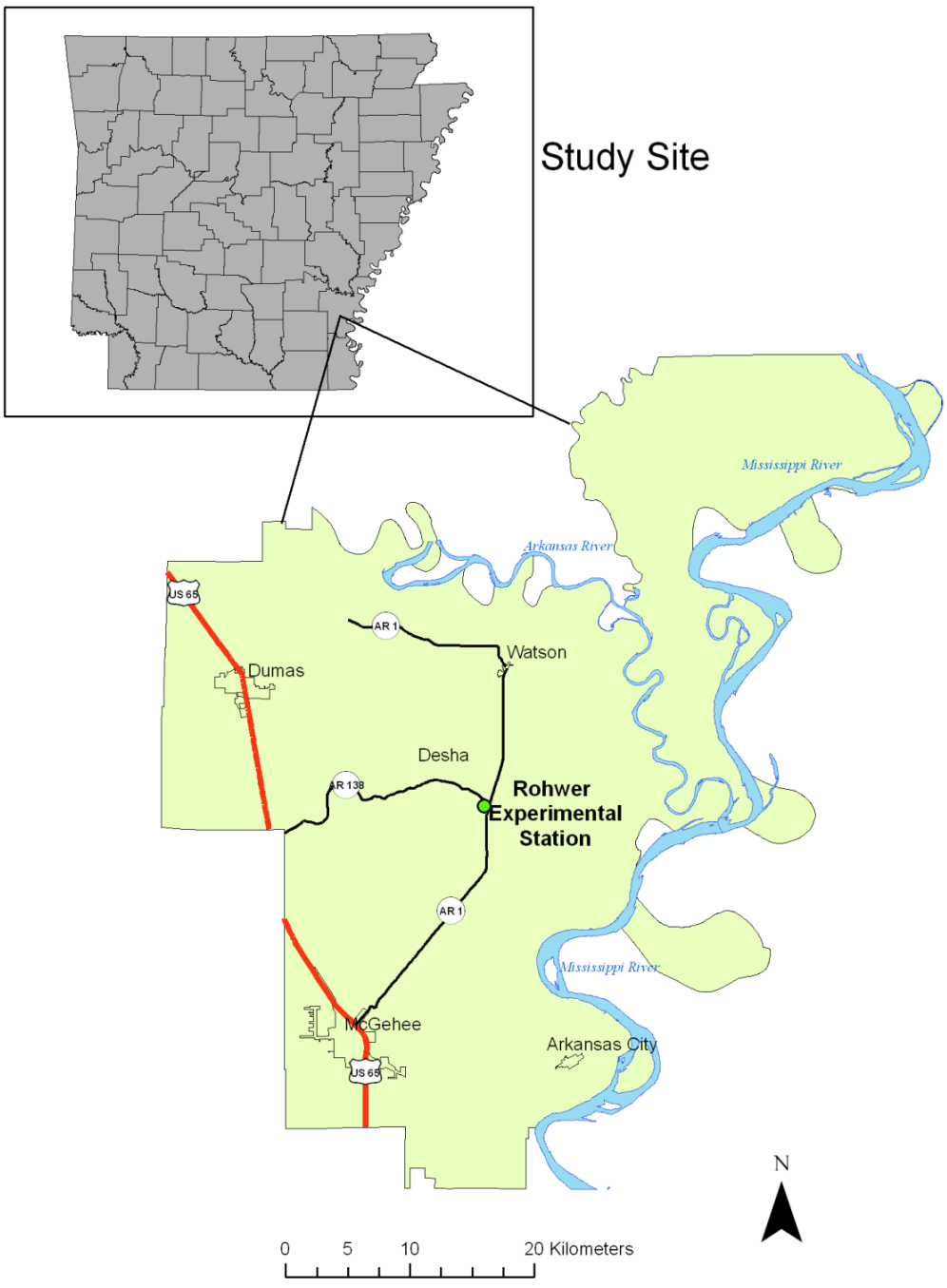

Figure 1. Location of the Rohwer Division of the Southeast Research and Extension Center, Desha County, Arkansas, 2012.

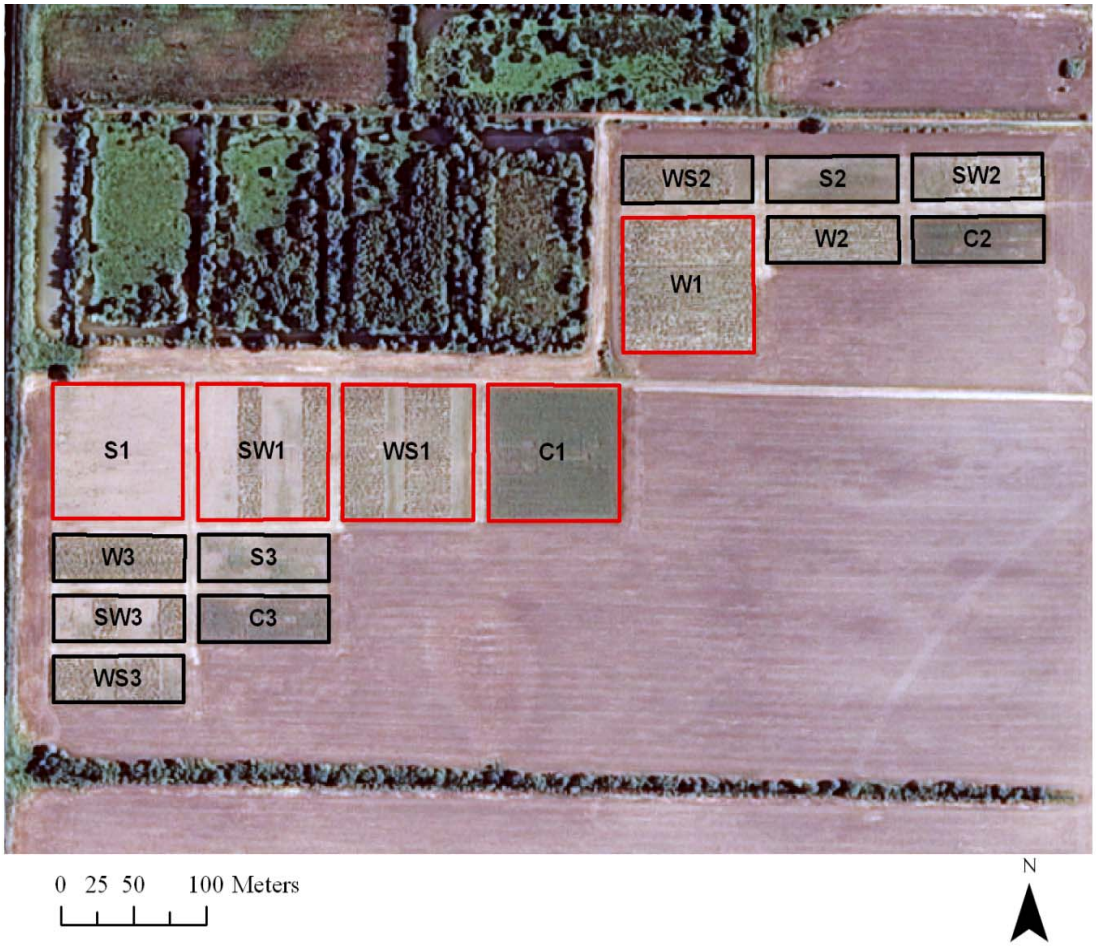

Figure 2. Arrangement of experimental plots. S1-3 = 100% switch grass; SW1-3 = 70% switch grass, 30% cottonwood; WS1-3 = 70% cottonwood, 30% switch grass; W1-3 = 100% cottonwood; and C1-3 = 100% soybeans. Small mammals were trapped in plots W1, S1, SW1, WS1, and C1 only (plots highlighted in red).

Figure 3. Typical alley cropped cottonwood/switchgrass plot summer 2012.

Figure 4. General vegetation types for 500 m buffers around feedstock plots for winter 2012. Red lines indicate dirt roads.

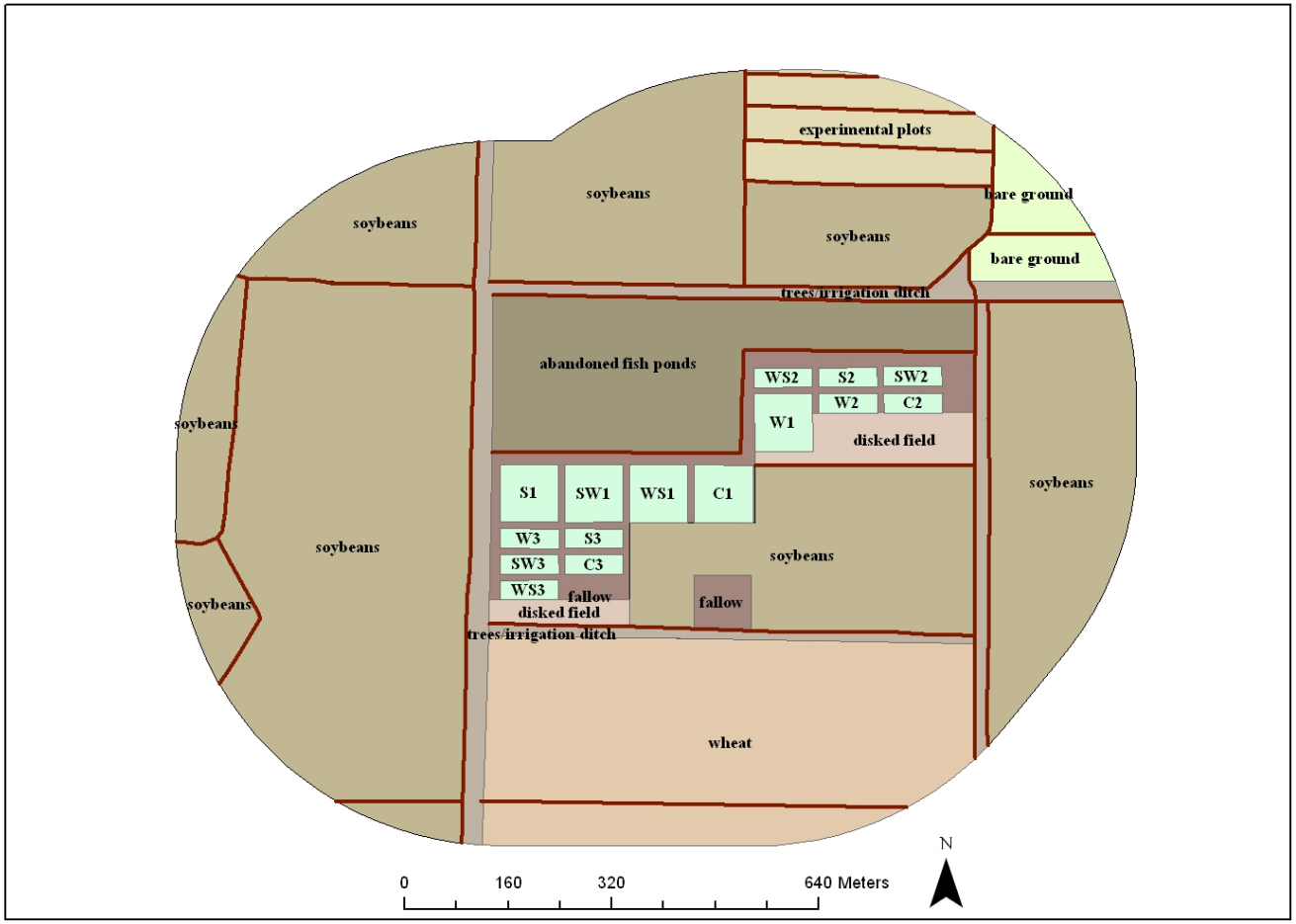

Figure 5. General vegetation types for 500 m buffers around feedstock plots for spring 2012. Red lines indicate dirt roads.

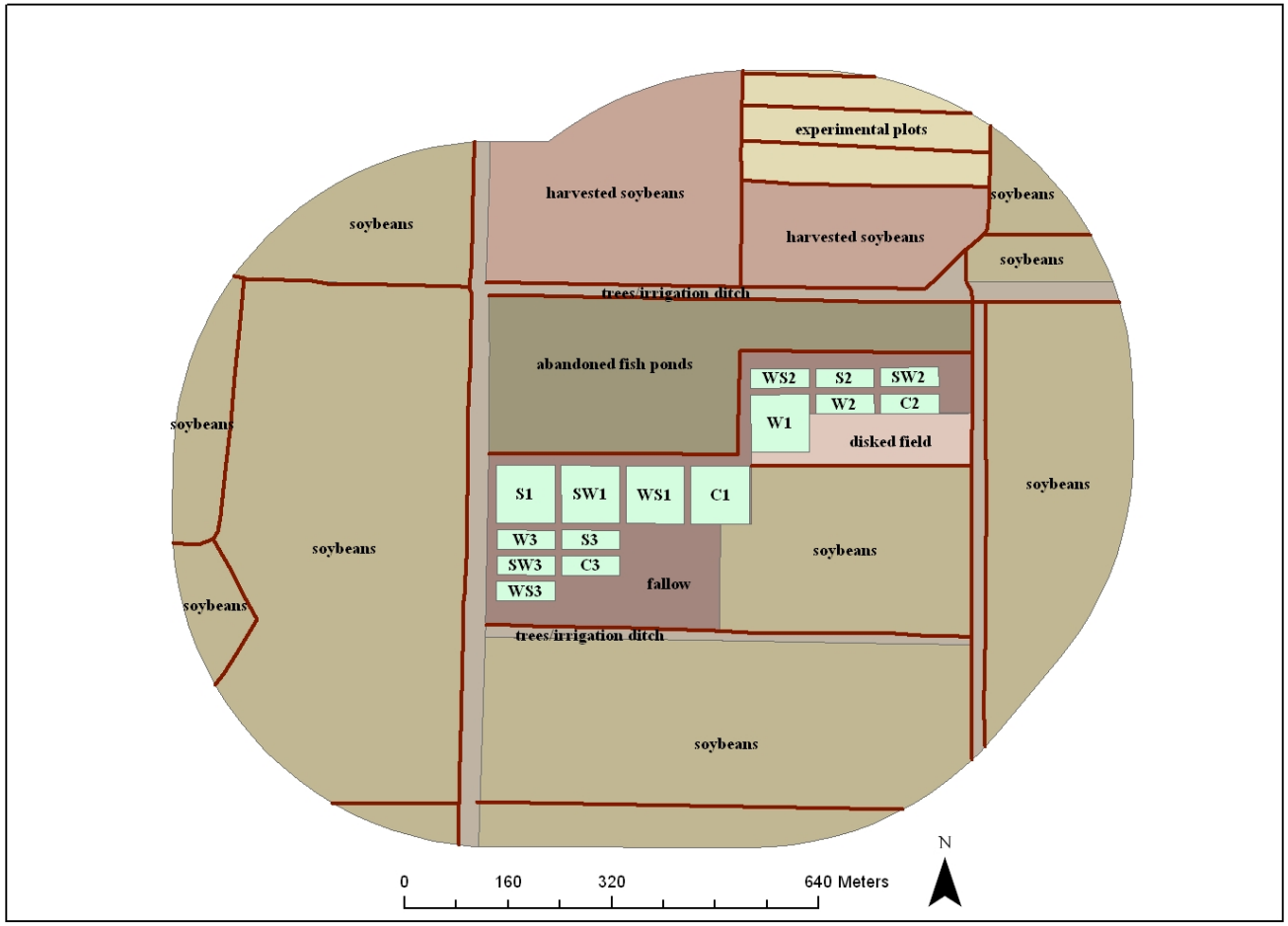

Figure 6. General vegetation types for 500 m buffers around feedstock plots for summer 2012. Red lines indicate dirt roads.

Figure 7. General vegetation types for 500 m buffers around feedstock plots for fall 2012. Red lines indicate dirt roads.

Trapping

Small mammals were captured using Sherman live traps (7.6 x 9 x 23 cm; Sherman 1941). A trapping grid consisted of 36 traps set in each 90 x 90 m plot (Figure 8). Traps were set 15 m apart and were 7.5 m from the edge of the plot (Figure 8). Trapping was conducted 4 times (once per season) beginning winter (January) 2012 and ending fall (October) 2012. Traps were set for 5 consecutive nights, yielding 900 possible trap nights per season. I adjusted available trap nights by subtracting empty sprung traps and traps containing recaptured animals. Traps were baited with oatmeal and checked each morning at dawn. During periods of high temperatures, traps were closed each morning and opened the same evening to eliminate daytime captures. During times of cold temperatures, cotton was placed in the traps to aid heat retention and reduce mortality.

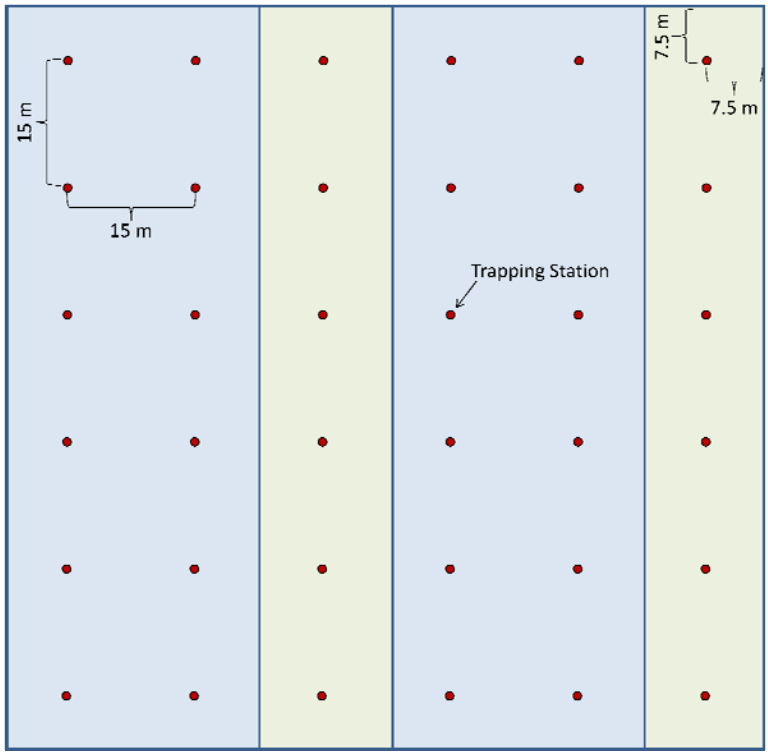

Figure 8. Small mammal trap placement in a 90 x 90 m alley-cropped plot.

Biological Data Collection

Captured animals were identified to species (genera in the case of *Peromyscus* sp.) using physical characteristics (i.e., pelage coloration, tail length, body mass and length, and incisor morphology). Species, age (juvenile or adult), body mass (g), sex, breeding condition, fate (e.g., tagged and released, recaptured and released, or dead in trap), plot type, and trap number were recorded for each individual captured. Each individual was fitted with a uniquely numbered metal ear tag prior to release. These capture and handling methods were approved by the Institutional Animal Care and Use Committee at the University of Arkansas-Monticello, permit number 200601.

Small Mammal Habitat Utilization

Since the relative importance of various habitat features to the small mammals on the study site was unknown, habitat data were collected dealing with as many aspects of the vegetation that I considered biologically relevant to small mammals. In total, 46 habitat variables were measured (Table 1). Vegetation sampling was conducted at successful trap stations only and within a maximum of 6 of the 36 small mammal trapping stations on each plot (Figure 9). I chose trap stations to be sampled based on trapping success (e.g., a trap that captured 4 animals in 5 nights of trapping was chosen over a trap that captured 1 animal in 5 nights). Limiting the amount of trap stations sampled to 6 allowed for adequate sampling of the rather homogenous vegetation, while eliminating the excessive time and manpower required to sample every successful trapping station.

A 2 x 2 m quadrat with a nested 1 x 1 m quadrat centered on a trapping station was used to quantify vegetation composition. The habitat variables I measured are listed and defined in Table 1.

Table 1. Habitat variables measured on habitat plots. Ocular estimations were based on the Daubenmire Scale 0-5, 6-25, 26-50, 51-75, 76-95, and 96-100.

Mnemonic	Units	Description
1x1 m quadrat		
SPECIESCOV*X*	%	Ocular estimate of the percentage ground cover of each plant species in the plot. *X* denotes the unique number assigned to each species.
2x2 m quadrat		
HERBLIVE	%	Ocular estimate of the percentage ground cover of living herbaceous plants in the plot.
HERBDEAD	%	Ocular estimate of the percentage ground cover of dead herbaceous plants in the plot.
GRASSLIVE	%	Ocular estimate of the percentage ground cover of living grasses in the plot.
GRASSDEAD	%	Ocular estimate of the percentage ground cover of dead grasses in the plot.

TREELIVE	%	Ocular estimate of the percentage ground cover of living trees in the plot.
TREEDEAD	%	Ocular estimate of the percentage ground cover of dead trees in the plot.
SHRUBLIVE	%	Ocular estimate of the percentage ground cover of living shrubs in the plot.
SHRUBDEAD	%	Ocular estimate of the percentage ground cover of dead shrubs in the plot.
VINELIVE	%	Ocular estimate of the percentage ground cover of living vines in the plot.
VINEDEAD	%	Ocular estimate of the percentage ground cover of dead vines in the plot.
BAREGROUND	%	Ocular estimate of the percentage ground cover of bare ground in the plot.
LITTER	%	Ocular estimate of the percentage ground cover of litter in the plot.
WATER	%	Ocular estimate of the percentage ground cover of water in the plot.
MEANVEGHT	cm	Mean height of vegetation in the plot.
MAXVEGHT	cm	Maximum height of vegetation in the plot.
TREEHT	m	Height of tree in plot.
TREEDBHT	cm	DBH of tree in plot.
LITTERDEPTH	cm	Mean depth of litter in plot.
Density board		
DBG1WIN	%	Ocular estimate of the percentage vegetation density at ground level 1 m from trap station within trap transects. Estimated by placing a 0.25 m^2 density board at ground level 1 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DBG1BTW	%	Ocular estimate of the percentage vegetation density at ground level 1 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at ground level 1 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DBG2WIN	%	Ocular estimate of the percentage vegetation density at ground level 2 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at ground level 2 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DBG2BTW	%	Ocular estimate of the percentage vegetation density at ground level 2 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at ground level 2 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DBG5WIN	%	Ocular estimate of the percentage vegetation density at ground level 5 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at ground level 5 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DBG5BTW	%	Ocular estimate of the percentage vegetation density at ground level 5 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at ground level 5 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.

DB11WIN	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 1 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1 m above ground level 1 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB11BTW	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 1 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1 m above ground level and 1 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DB12WIN	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 2 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1 m above ground level 2 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB12BTW	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 2 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1 m above ground level and 2 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DB15WIN	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 5 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1 m above ground level 5 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB15BTW	%	Ocular estimate of the percentage vegetation density at 1 m above ground level and 5 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1 m above ground level and 5 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DB1.51WIN	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 1 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level 1 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB1.51BTW	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 1 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level and 1 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
DB1.52WIN	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 2 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level 2 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB1.52BTW	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 2 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level and 2 m from trap station and perpendicular to the trap transect estimating the

		percentage of the board covered by vegetation.
DB1.55WIN	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 5 m from trap station within trap transect. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level 5 m from trap station and from within the trap transect estimating the percentage of the board covered by vegetation.
DB1.55BTW	%	Ocular estimate of the percentage vegetation density at 1.5 m above ground level and 5 m from trap station between trap transects. Estimated by placing a 0.25 m^2 density board at 1.5 m above ground level and 5 m from trap station and perpendicular to the trap transect estimating the percentage of the board covered by vegetation.
7.5-m radius plot		
DWDLENGTH	cm	Length of down woody debris >2.54 cm in diameter.
DWDDIA	cm	Diameter of down woody debris.
Other		
CANCOV	%	Canopy coverage. Estimate of overstory cover of trees with value representing the number of dots (0-96) covered by vegetation from a densiometer held at approximately waist high directly over trap station.
DISTCOV	m	Distance from plot to nearest vegetation that could hide a rodent.
DISTWATER	m	Distance from plot to nearest water.
SOILTEMP	^oC	Temperature of soil at a depth of 2.5 cm.

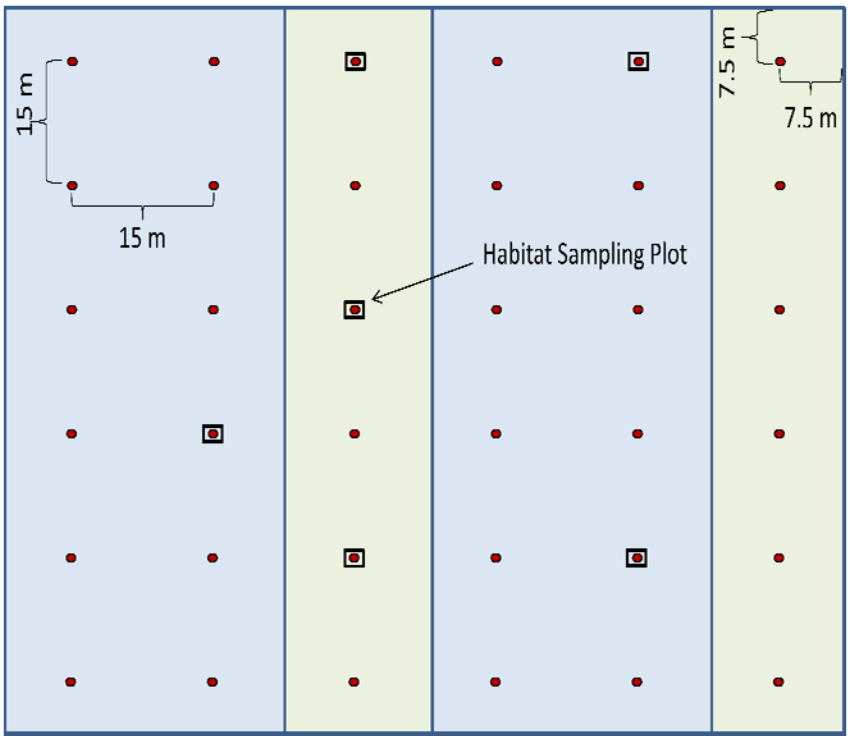

Figure 9. Trapping grid in a 90 x 90 m alley-cropped plot with squares indicating habitat sampling plots. Actual plots sampled were determined by capture success.

Data Analysis

Shannon's diversity index (Shannon 1948), and total number of individuals captured per 100 trap nights were calculated for each treatment during each season, as well as all seasons combined. The Shannon diversity index was calculated as follows:

$$H = -\sum p_i \, ln \;\; p_i$$

where p_i = proportion of individuals in plot of species *i.*

Canonical Correspondence Analysis (CCA) is a widely used direct-gradient ordination technique in ecological studies that simultaneously displays sample-by-species-by-environmental parameter correlations. CCA uses a repetitive algorithm of reciprocal averaging of sample scores and species scores (with an extra step of repetitive

refinement of sample score prediction from the various measured habitat parameters, using multiple regression), until the scores stabilize. I used CCA to describe the overall relationships and relative importance of local habitat parameters to the small mammal community. CCA examines variation in community composition by constraining the species or site ordination axes to be linear combinations of environmental variables. In this way I was able to identify strength of various environmental variables in explaining small mammal community composition among the treatments and control plots.

Because my habitat variables were measured using a number of different scales, data were standardized to unit variance prior to analysis. Small mammal counts were log-transformed ($\log_{10}$ [N+1]) and abundances of rare species were downweighted in proportion to their frequency (Hill 1979). Transformations were performed to prevent extremely abundant or extremely rare species from having undue influence on the ordination (Gauch 1982). CANOCO Version 5.0® (ter Braak and Ŝmilauer 2012) was used to conduct the analyses.

Three separate CCA analyses were performed in program CANOCO. Measured habitat parameters, plant species, and plant family were entered separately into the 3 analyses as explanatory variables. Small mammal species were entered into each analysis as response variables. Plot treatments (W1, S1, WS1, SW1, C1) were entered as supplementary (passive) variables. Season (winter, spring, summer, fall) was entered as covariates (covariables in earlier CANOCO versions). Covariates were partialled out (eliminated) from the ordination resulting in partial ordination, or in this case partial CCA (ter Braak and Ŝmilauer 2012).

Initial variable reduction was conducted using Pearson's Correlations in SAS (SAS Institute Inc. 2008). Variables with a correlation > 0.500 were omitted from the CCA analysis. Additional variable reduction was accomplished using manual forward selection in CANOCO and by examining variance inflation factors (VIF) for each variable. For the forward selection process, variables with a *P*-value > 0.05 were not included in the analysis. Variables with a VIF >10.0 were also omitted. To reduce influence of rare environmental variables on the analysis, a variable must have been collected in at least 5% of the habitat plots to have been included in the analysis.

Summary statistics of the partial CCA analyses were produced by CANOCO and include eigenvalues, explained cumulative variation, and explained fitted cumulative variation. Eigenvalues are a measure (between 0 and 1) of importance for each calculated axis (ter Braak and Ŝmilauer 2012). Explained cumulative variation is the cumulative percentage variance in the response data explained by each axis (ter Braak and Ŝmilauer 2012). Explained fitted cumulative variation is the cumulative percentage variance in the fitted response data explained by each axis (ter Braak and Ŝmilauer 2012). Summary statistics tables displayed columns for 4 axes. The first 3 axes are canonical; the 4^{th} is unconstrained and is used for determining the explained and explained fitted variations. (ter Braak and Ŝmilauer 2012).

Ordination methods such as CCA also produce ordination diagrams, in this case, biplots. Ordination diagrams display environmental variables (explanatory/supplementary variables) as arrows, and species (response variables) as symbols (triangle).
General guidelines for interpreting ordination diagrams are provided below. Examples refer to Figure 10.

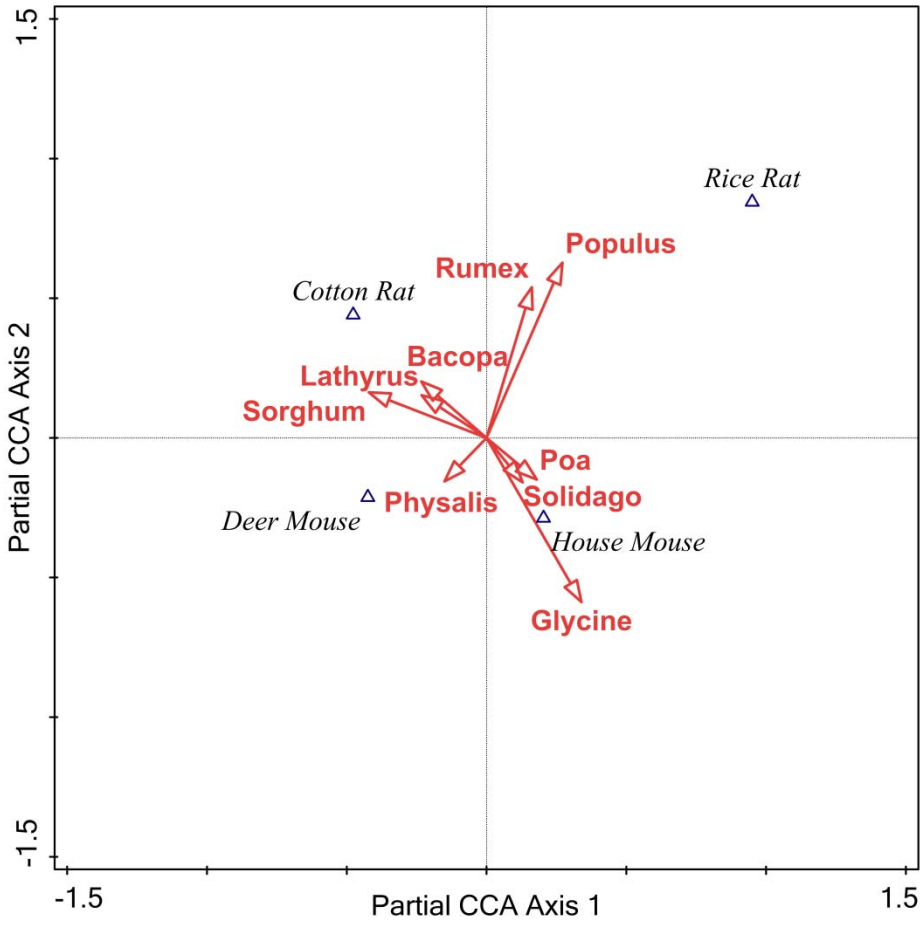

Figure 10. Sample partial CCA ordination diagram showing environmental variables (arrows) and species (triangles).

1. Distance between species symbols is proportional to the dissimilarity between the species. Species that are nearer are more similar than species which are farther apart. Example: Deer mouse is more similar to house mouse than rice rat.
2. The length of environmental variable arrows corresponds to the amount of variation explained by the variable. Example: Populus has a stronger association with community composition than Physalis.
3. The correlation between environmental variables, and between environmental variables and ordination axes is inversely proportional to the angle between the

arrows. Angles < 90° correspond to positive correlation; right angles correspond to no correlation; and angles > 90° correspond to negative correlation. Example: Populus is positively correlated with Rumex and negatively correlated with Physalis.

4. The strength of the relationship between variables displayed as arrows and species displayed as symbols can be estimated by drawing a line perpendicular to the arrow through the symbol. Lines that intersect arrows farther away from plot center indicate a stronger relationship. Example: Rice rat is more associated with Populus than any other species.
5. Arrows display positive values only. Arrows may be extended in the opposite direction to interpret negative relationships (Lepš and Šmilauer 2003). Example: Cotton rat is negatively associated with Glycine.

RESULTS

I recorded 261 individuals of 5 taxa for all seasons combined Table 2. House mouse (*Mus musculus*) accounted for 63.98% of individuals captured, hispid cotton rat (*Sigmodon hispidus*) accounted for 16.48% of individuals captured, marsh rice rat (*Oryzomys palustris*) and deer mouse (*Peromyscus* spp.) accounted for 9.78% each of individuals captured, and fulvous harvest mouse (*Reithrodontomys fulvescens*) accounted for 0.38% of individuals captured across all seasons combined. Treatment S1 had the greatest number of individuals captured per 100 trap nights, but had the next to lowest diversity index for all seasons combined. Treatment SW1 had the greatest diversity index and the 2nd greatest number of individuals captured.

Table 2. All seasons combined 2012 small mammal trapping results, number of individuals captured per 100 trap nights (TNs), and Shannon's Diversity Index.

	Treatment					
Species	(C1)	(S1)	(SW1)	(W1)	(WS1)	Total
Mus musculus	35	63	34	6	29	167
Oryzomys palustris	0	10	6	0	9	25
Peromyscus spp.	0	8	8	7	2	25
Reithrodontomys fulvescens	0	1	0	0	0	1
Sigmodon hispidus	0	8	8	15	12	43
Total	**35**	**90**	**56**	**28**	**52**	**261**
Number of ind./100 TNs	5.22	14.26	8.54	4.02	7.73	7.84
Shannon Index	0	0.72	1.10	1.01	1.09	0.77

For the winter trapping session treatment S1 had the greatest number of individuals captured per 100 trap nights, but had the next to lowest diversity index (Table 3). Treatment W1 had the greatest diversity index, but had the fewest number of individuals captured.

Table 3. Winter 2012 small mammal trapping results, number of individuals captured per 100 trap nights (TNs), and Shannon's Diversity Index.

	Treatment					
Species	(C1)	(S1)	(SW1)	(W1)	(WS1)	Total
Mus musculus	14	37	16	4	12	83
Oryzomys palustris	0	1	3	0	3	7
Peromyscus spp.	0	6	5	6	1	18
Reithrodontomys fulvescens	0	0	0	0	0	0
Sigmodon hispidus	0	0	0	2	0	2
Total	**14**	**44**	**24**	**12**	**16**	**110**
Number of ind./100 TNs	9.15	32.35	16.90	7.10	10.00	14.47
Shannon Index	0	0.50	0.86	1.01	0.70	0.76

Treatment SW1 had the greatest number of individuals captured per 100 trap nights, and had the 2nd greatest diversity index for the spring session (Table 4). Treatment W1 had the greatest diversity index, and had the 2nd greatest number of individuals captured.

Table 4. Spring 2012 small mammal trapping results and Shannon's Diversity Index.

	Treatment					
Species	(C1)	(S1)	(SW1)	(W1)	(WS1)	Total
Mus musculus	0	0	4	1	2	7
Oryzomys palustris	0	0	1	0	0	1
Peromyscus spp.	0	0	0	1	0	1
Reithrodontomys fulvescens	0	0	0	0	0	0
Sigmodon hispidus	0	0	0	0	0	0
Total	**0**	**0**	**5**	**2**	**2**	**9**
Number of ind./100 TNs	0	0	2.81	1.11	1.12	1.01
Shannon Index	0	0	0.50	0.69	0	0.68

Treatment C1 had the greatest number of individuals captured per 100 trap nights, but the diversity index was 0 for the summer trapping session (Table 5). Treatment S1 had the greatest diversity index, but had the fewest number of individuals captured.

Table 5. Summer 2012 small mammal trapping results and Shannon's Diversity Index.

	Treatment					
Species	(C1)	(S1)	(SW1)	(W1)	(WS1)	Total
Mus musculus	14	2	6	1	9	32
Oryzomys palustris	0	0	0	0	0	0
Peromyscus spp.	0	0	0	0	0	0
Reithrodontomys fulvescens	0	0	0	0	0	0
Sigmodon hispidus	0	2	2	7	4	15
Total	**14**	**4**	**8**	**8**	**13**	**47**
Number of ind./100 TNs	8.28	2.26	4.55	4.52	7.39	5.37
Shannon Index	0	0.69	0.56	0.38	0.62	0.66

Treatment S1 had the greatest number of individuals captured per 100 trap nights, but had the 3rd greatest diversity index for the fall session (Table 6). Treatment SW1 had the greatest diversity index, and had the 3rd highest number of individuals captured.

Table 6. Fall 2012 small mammal trapping results and Shannon's Diversity Index.

	Treatment					
Species	(C1)	(S1)	(SW1)	(W1)	WS1)	Total
Mus musculus	7	24	8	0	6	45
Oryzomys palustris	0	9	2	0	6	17
Peromyscus spp.	0	2	3	0	1	6
Reithrodontomys fulvescens	0	1	0	0	0	1
Sigmodon hispidus	0	6	6	6	8	26
Total	**7**	**42**	**19**	**6**	**21**	**95**
Number of ind./100 TNs	4.00	30.22	11.95	3.51	13.21	11.83
Shannon Index	0	0.84	1.26	0	1.23	0.88

Canonical correspondence analysis of habitat variables and small mammal captures for all seasons combined resulted in a partial CCA with supplementary variables. The explanatory variables accounted for 34.32% of total variation among captures (Table 7). Ordination diagram of habitat variables shows the relationship between 7 habitat variables and 3 species and 1 genus of small mammals (Figure 11A) and 5 treatment variables and 3 species and 1 genus of small mammals (Figure 11B) on partial CCA axes 1 and 2. Axis 1 and 2 explains (displays) 32.39% of total variation and 94.37% of total fitted variation among capture rates. Axis 1 roughly represented a gradient of vegetation height with trees to left side of the diagram to bare ground on the right. Axis 2 roughly correlated to a moisture gradient with dry plots at the bottom and plots containing water at the top of the diagram. Habitat variables having the greatest influence on small mammal captures were down woody debris length (DWDLENGHT), water (WATER), trees (TREELIVE), and canopy cover (CANCOV). Marsh rice rats were associated with DWDLENGHT and WATER. Cotton rats were associated with TREELIVE and CANCOV, grasses (GRASSLIVE) and vegetation density (DBG5WIN), while house mice showed a negative relationship with the same variables. Deer mice showed a negative relationship to DWDLENGHT. Cotton rats were associated with treatment W1 and house mice were strongly associated with treatment C1. Treatments W1 and C1 also had the greatest influence on small mammal captures.

Table 7. Summary statistics for CCA of habitat variables and small mammal captures.

Statistic	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Eigenvalues	0.2517	0.1791	0.0257	0.3437
Explained variation (cumulative)	18.93	32.39	34.32	60.17
Explained fitted variation (cumulative)	55.14	94.37	100	

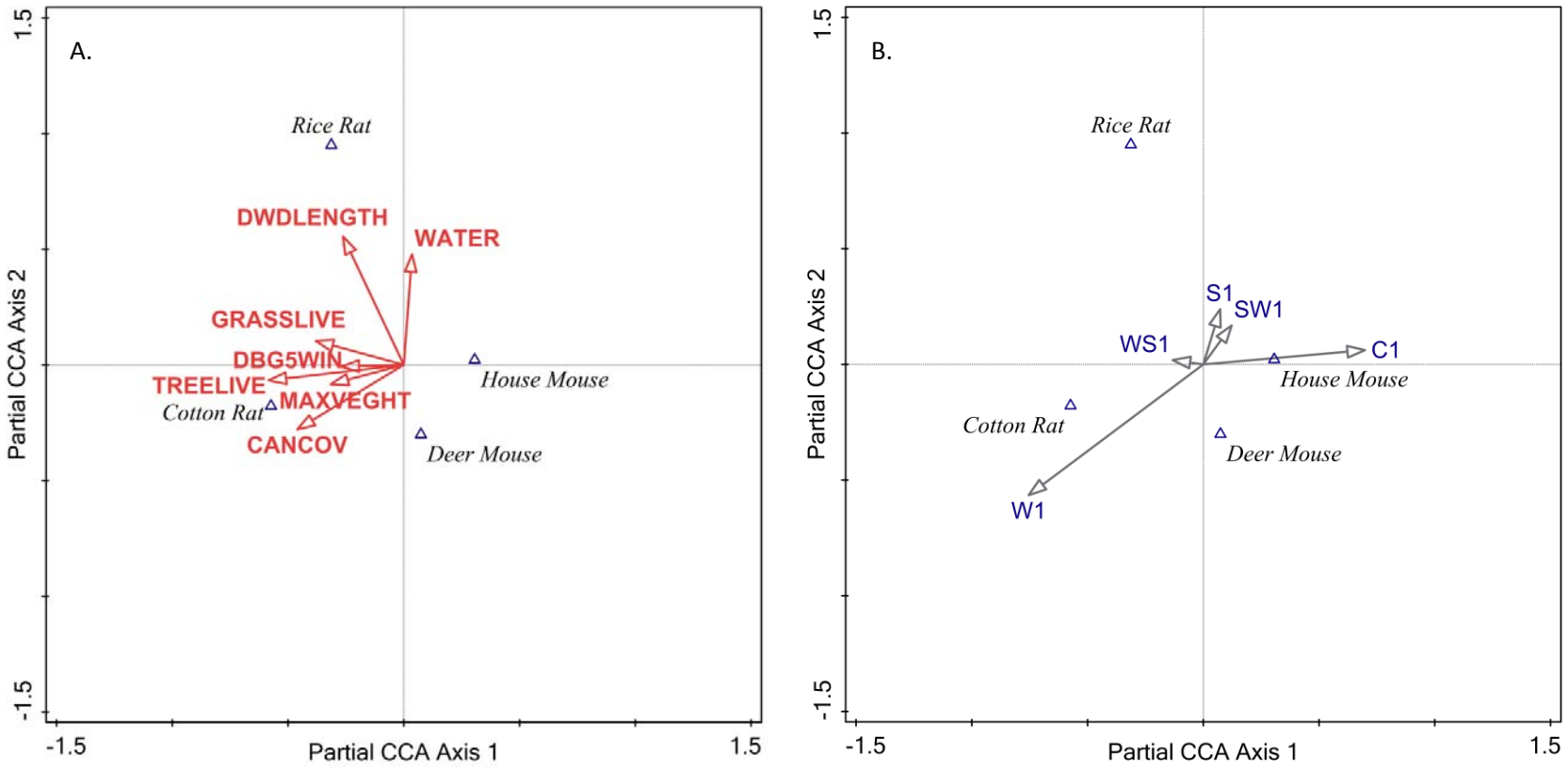

Figure 11. Relationship among 7 habitat variables and 3 species and 1 genus of small mammals (A.), and 5 treatment variables and 3 species and 1 genus of small mammals (B.) on partial CCA axes 1 and 2. Treatment variables (W1, S1, WS1, SW1, C1) were entered in the analysis as passive (supplementary) variables. Partial CCA axis 1 roughly represents a gradient of vegetation height with trees to left side of the diagram to bare ground on the right. Partial CCA axis 2 roughly correlates to a moisture gradient with dry plots at the bottom and plots with water present at the top of the diagram.

Canonical correspondence analysis of plant species and small mammal captures for all seasons combined resulted in a partial CCA with supplementary variables. The explanatory variables accounted for 32.58% of total variation among captures (Table 8). Ordination diagram of plant species shows the relationship between 5 plant species and 3 species and 1 genus of small mammals (Figure 12A) and 5 treatment variables and 3 species and 1 genus of small mammals (Figure 12B) on partial CCA axes 1 and 2. Axis 1 and 2 explains (displays) 26.92% of total variation and 82.63% of total fitted variation among capture rates. Axis 1 roughly represents a gradient of vegetation height with trees to right side of the diagram to bare ground on the left. The gradient represented by axis 2 is not readily discernible from the given data. Plant species having the greatest influence on small mammal captures were soybeans, cottonwood, and Johnson grass (*Sorghum halepense*). Rice rats were associated with cottonwood and switchgrass, while deer mice showed a negative relationship with those plant species. House mice were associated with soybeans and annual bluegrass, while cotton rats showed a negative relationship with those plant species and a positive relationship with Johnson grass. Cotton rats were associated with treatment W1 and house mice were strongly associated with treatment C1. Treatments W1 and C1 also had the greatest influence on small mammal captures.

Table 8. Summary statistics for CCA of plant species variables and small mammal captures.

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.2133	0.1447	0.0753	0.3838
Explained variation (cumulative)	16.04	26.92	32.58	61.44
Explained fitted variation (cumulative)	49.23	82.63	100	

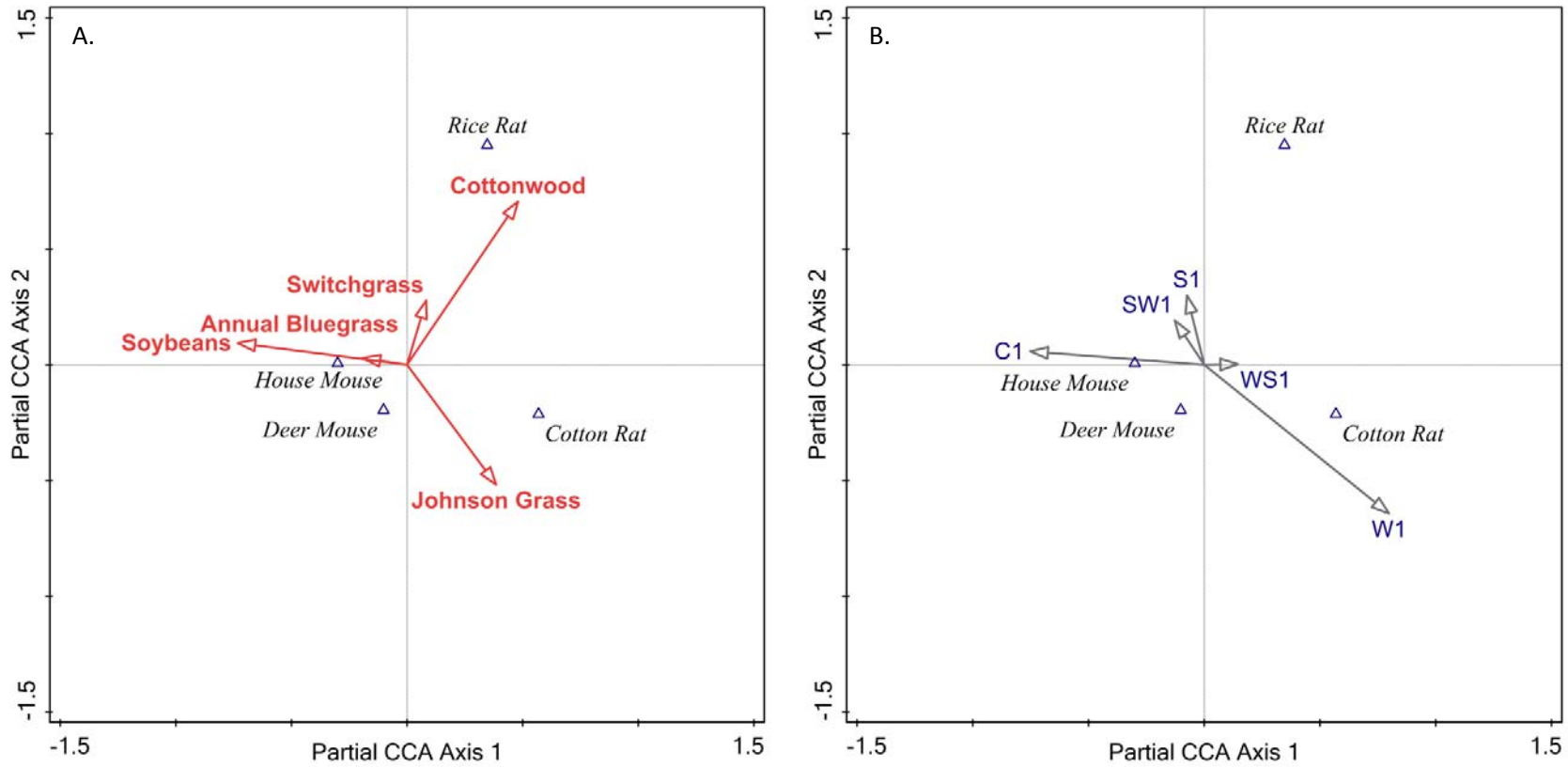

Figure 12. Relationship among 5 plant species variables and 3 species and 1 genus of small mammals (A.), and 5 treatment variables and 3 species and 1 genus of small mammals (B.) on partial CCA axes 1 and 2. Treatment variables (W1, S1, WS1, SW1, C1) were entered in the analysis as passive (supplementary) variables. Partial CCA axis 1 roughly represents a gradient of vegetation height with trees to right side of the diagram to bare ground on the left. Partial CCA axis 2 is not readily discernible from the given data.

Canonical correspondence analysis of plant families and small mammal captures for all seasons combined resulted in a partial CCA with supplementary variables. The explanatory variables accounted for 25.67% of total variation among captures (Table 9). Ordination diagram of plant species shows the relationship between 3 plant families and 3 species and 1 genus of small mammals (Figure 13A) and 5 treatment variables and 3 species and 1 genus of small mammals (Figure 13B) on partial CCA axes 1 and 2. Axis 1 and 2 explains (displays) 22.11% of total variation and 86.14% of total fitted variation among capture rates. The gradient represented by axis 1 or axis 2 is not readily discernible from the given data. Plant families having the greatest influence on small mammal captures were Fabaceae, Salicaceae, and Poaceae. House mice were associated with Fabaceae. Rice rats were associated with Salicaceae, while deer mice showed a negative relationship with Salicaceae. Cotton rats were associated with Poaceae. Cotton rats were associated with treatment W1 and house mice strongly associated with treatment C1. Treatments W1 and C1 also had the greatest influence on small mammal captures.

Table 9. Summary statistics for CCA of plant family variables and small mammal captures.

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.1903	0.1038	0.0473	0.4665
Explained variation (cumulative)	14.31	22.11	25.67	60.74
Explained fitted variation (cumulative)	55.75	86.14	100	

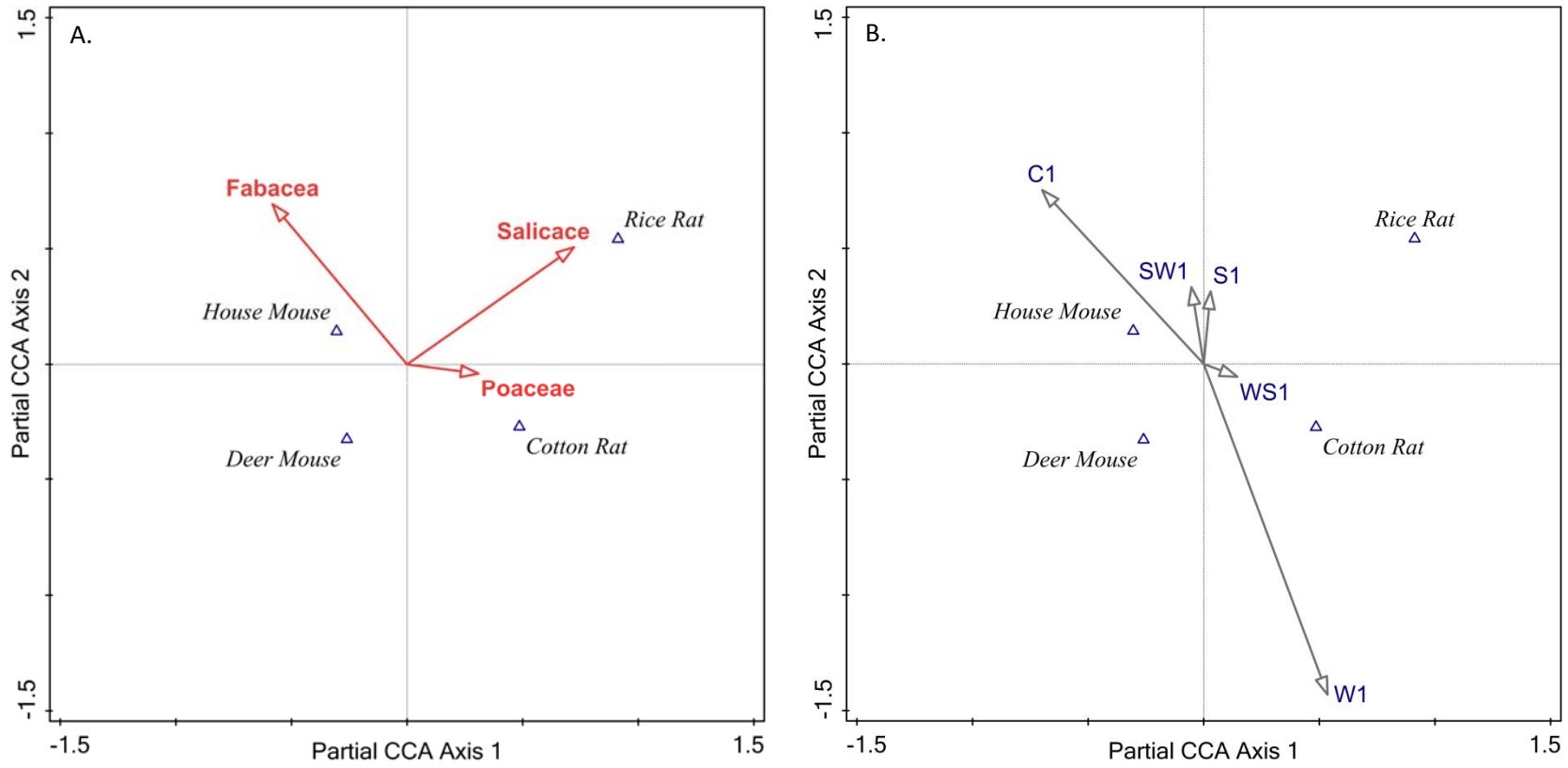

Figure 13. Relationship among 3 plant family variables and 3 species and 1 genus of small mammals (A.), and 5 treatment variables and 3 species and 1 genus of small mammals (B.) on partial CCA axes 1 and 2. Treatment variables (W1, S1, WS1, SW1, C1) were entered in the analysis as passive (supplementary) variables. Partial CCA axes 1 and 2 are not readily discernible from the given data.

DISCUSSION

Whether a bioenergy crop represents a net gain or loss of habitat depends upon the type of land that is being replaced (Fargione et al. 2009), the crop being produced (e.g., corn versus switchgrass) and the wildlife species in question (Rupp et al. 2012). In this study, the bioenergy crop replaced a row crop with very little plant diversity. It is clear from the results of the diversity indices that the cottonwood/switchgrass plots offer greater small mammal diversity than the soybean row crops. As expected, small mammal diversity increased with increased plant diversity. However, small mammal diversity is likely still lower than on more natural sites. According to the range maps by Sealander and Heidt (1990) the range of at least 17 species of small mammals occurs within the study site. While likely not directly comparable to my study area, Tappe et al. (1994) and Perry and Thill (2005) each recorded 9 species and 1 genus of small mammals in mixed pine hardwood stands in western Arkansas.

Capture rates differed greatly between seasons, but can mostly be attributed to annual population cycles. Stickel (1979) and Taitt and Krebs (1983) have shown that many small mammal populations experience relatively low population density in spring, an increasing density through fall, and then a steady decline through winter caused by a decrease in reproduction. While not quantified in this study, another possible explanation for the varied capture rates is the change by season in general vegetation type surrounding the agroforest plots. Maps of 500 m buffers around the plots display how standard agricultural practices drastically alter vegetation composition and structure between seasons. For instance, a large area southeast of the plots was left fallow and was covered with vegetation in the winter which could provide suitable habitat. In the spring

the same area was planted in soybeans, likely altering the composition and abundance of the small mammal community. These unknown effects of adjacent land practices should be a focus of future studies, by either attempting to quantify the effects or by attempting to eliminate them.

CANOCO results suggest there are a number of habitat variables that influenced capture success of small mammals. Down woody debris, water, canopy cover, the presence of trees, the presence of live grass, vegetation density, and vegetation height were shown to be the measured habitat variables that influences capture rates. Presence of soybeans, cottonwood trees, switchgrass, annual bluegrass (*Poa annua*), and Johnson grass, along with the plant families Fabaceae, Poaceae, and Salicaceae, also influenced capture rates.

Down woody debris, even though there was very little on the site, was shown to have a significant influence on capture rates. The importance of woody debris to small mammals has been well documented. Barnum et al. (1992), McMillan and Kaufman (1995), and McCay (2000) have indicated that small mammals selectively use down logs for travel. Removing all wood residue to use as feedstock during harvest of cottonwood stands would reduce the availability of woody debris in the next rotation.

Presence of water influenced the capture success of marsh rice rats. Sealander and Heidt (1990) list the marsh rice rat as semi-aquatic. There were no marsh rice rats captured during the summer trapping session when no water was present in the plots. During the other trapping sessions there was varying amounts of water present. Marsh rice rats were captured in treatments S1, SW1, and WS1, but not in W1. Treatment W1 is slightly elevated compared to the other treatments and did not hold water as readily as

the other treatment plots. This could explain the lack of capture success of marsh rice rats in treatment W1. The presence of the abandoned fish ponds directly adjacent to the treatment plots likely influenced the presence of marsh rice rats on the study site. Feedstock plots may have had little influence on the presence of this species; rather, presence of water on the plots allowed them to venture out of the abandoned fish ponds.

Trees and canopy cover exerted influence on capture success of hispid cotton rats. Hispid cotton rats are known to inhabit areas where suitable cover is present (Sealander and Heidt 1990). They are rarely found in forested areas; however, they do occur along forest edges (Sealander and Heidt 1990). The small size of the experimental plots more closely resembles a forest edge than a forest setting, and may explain the apparent deviation from their usual natural history. Another explanation could be presence of Johnson grass in part of the W1 plot. Vegetation height and density, and presence of Johnson grass also influenced capture success of hispid cotton rats. An area of treatment W1 was apparently not sprayed with herbicide and had abundant growth of Johnson grass and other vegetation not found in the remainder of the plot or in cottonwood portions of SW1 and WS1. The majority of hispid cotton rats captured were in this area of treatment W1.

Treatment plots were extensively managed using herbicides and mechanical weed control to maximize bioenergy feedstock production. It is doubtful that a feedstock producer would expend this amount of resources on an operational crop, thus allowing for greater plant heterogeneity. Should this be the case, the potential small-mammal diversity in a feedstock production crop could be greater than the results of this study indicate. For instance Johnson grass, which was shown to exert significant influence on

capture rates, might be more abundant with more conservative applications of herbicide among the cottonwood trees. In turn, this would likely increase vegetation density which was also shown to influence capture rates. Also, the spacing of cottonwood trees would have an effect on vegetation density. Figure14 shows intensively managed experimental cottonwood plots at the Center with little understory vegetation. Figure 15, in comparison, shows a nearby cottonwood plantation managed for traditional wood products with a wider tree spacing and abundant understory vegetation.

Figure 14. Intensively managed experimental cottonwood plot at the Center during spring 2013.

Figure 15. Cottonwood stand managed for traditional wood products located in Desha County Arkansas during spring 2013.

Presence of cottonwood trees, switchgrass, Johnson grass, annual bluegrass, and soybeans influenced capture rates. Marsh rice rats were associated with cottonwood trees, yet no marsh rice rats were captured in treatment W1. The cottonwood sections of WS1 and SW1 tended to hold more water and were the areas where the majority of marsh rice rats were captured. Marsh rice rats were also slightly associated with switchgrass. Unfortunately, there was difficulty establishing switchgrass stands on this site. The switchgrass stands were only partially established when this project began and additional switchgrass plugs were added in the spring of 2012. The marsh rice rats captured in switchgrass stands, again, could be because of the water present in those plots. Because of the poor establishment of the switchgrass stands it is difficult to draw any solid conclusions about the influence of switchgrass on the small mammal assemblages. After the switchgrass is well established it would likely grow much taller and denser shading out competing vegetation. This could have positive or negative effects on small mammal diversity. Hispid cotton rats and *Peromyscus* sp. were associated with Johnson grass which was only found in the area apparently untreated with herbicide. House mice and *Peromyscus* sp. were associated with annual bluegrass. House mice were the only species captured in the soybean plot.

Plant families Fabaceae, Poaceae, Salicaceae, and Solanaceae influenced capture rates of small mammals. Hispid cotton rats and marsh rice rats were associated with Poaceae and Salicaceae (grasses and trees). House mice were associated with Fabaceae (beans).

Ordination diagrams with treatments as supplementary variables for all 3 analyses show house mice strongly associated with treatment C1 and hispid cotton rats associated

with treatment W1. House mice were the only species captured in treatment C1. The majority of hispid cotton rats were captured in treatment W1. The other species and treatments show little correlation. This may be due, in part, to the fact that capture locations in treatment WS1 and SW1 were not analyzed using the specific vegetation association they were located in. In other words, they were analyzed as WS1 or SW1 instead of switchgrass/SW1 or cottonwood/SW1. Some capture locations were in the switchgrass and some in the cottonwood trees, but were both analyzed as SW1 or WS1.

As expected, small mammal diversity increased with increased plant diversity. There were a number of factors that likely influenced capture success. Some factors, such as the ever-changing general habitat type around the plots, were impossible to quantify. There is little doubt that cottonwood and switchgrass feedstock plantations would provide more suitable habitat for small mammals than the soybean row crops it would replace. However, a study on large scale feedstock plantations is necessary to eliminate variables unaccounted for in this study and truly understand the factors influencing small mammal habitat utilizations of these feedstock agroforests.

RECOMMENDATIONS

To achieve the greatest biodiversity in a feedstock agroforest, I recommend the following.

1. Plant alley cropped cottonwood and switchgrass combination stands to maximize plant heterogeneity.
2. Minimize use of herbicides and other weed control measures to allow plants important to small mammals to grow within cottonwood stands.
3. Leave some woody debris, which is important to some small mammals, on site after harvest.
4. Future studies should be conducted on large feedstock stands to minimize the effects of adjacent land practices on study results. Future studies should also be multi-year and include effects of feedstock harvest on small mammal populations.

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APPENDIX

Table A1. List of plant species collected in agroforest plots for all seasons 2012.

Family	Genus	Species	Common Name
Amaranthaceae	*Amaranthes*	*blitoides*	Prostrate Amaranth
Asteraceae	*Baccharis*	*halimifolia*	Baccharis
Asteraceae	*Conyza*	*canadensis*	Horseweed
Asteraceae	*Eupatorium*	*capillifolium*	Dogfennel
Asteraceae	*Gnaphalium*	*purpureum*	Purple Cudweed
Asteraceae	*Lactuca*	*serriola*	Prickly Lettuce
Asteraceae	*Solidago*	sp.	--
Asteraceae	*Sonchus*	*asper*	Spiny Sow Thistle
Asteraceae	*Symphyotrichum*	*divaricatum*	Purple Aster
Asteraceae	*Vernonia*	*gigantea*	Giant Ironweed
Brassicaceae	*Cardamine*	*hisuta*	Hairy Bittercress
Caryophyllaceae	*Minuartia*	*patula*	Glade Sandwort
Clusiaceae	*Hypericum*	*labocarpum*	--
Convolvulaceae	*Ipomoea*	sp.	Morning Glory
Fabaceae	*Glycine*	*max*	Soybean
Fabaceae	*Sesbania*	*macrocarpa*	Coffeebean
Fabaceae	*Vicia*	*tetrasperma*	Smooth Vetch
Juncaceae	*Juncus*	*diffusissimus*	Slimpod Rush
Lamiaceae	*Lamium*	*amplexicaule*	Henbit
Fabaceae	*Lathyrus*	sp.	--
Poaceae	*Brachiaria*	*platyphylla*	Broadleaf Signal Grass
Poaceae	*Echinochloa*	*colona*	Jungle Rice
Poaceae	*Panicum*	*virgatum*	Switchgrass
Poaceae	*Poa*	*annua*	Annual Bluegrass
Poaceae	*Sorghum*	*halepense*	Johnson Grass
Polygonaceae	*Brunnichia*	*ovata*	Buckwheat Vine
Polygonaceae	*Polygonum*	*pensylvanicum*	Smartweed
Polygonaceae	*Rumex*	*crispus*	Curly Dock
Polygonaceae	*Rumex*	*hastatulus*	Heartwing Sorrel
Ranunculaceae	*Ranunculus*	sp.	--
Rosaceae	--	--	--
Salicaceae	*Populus*	*deltoides*	Cottonwood
Scrophulariaceae	*Bacopa*	*monnieri*	Water Hyssop
Scrophulariaceae	*Veronica*	*peregrina*	Neckweed
Solanaceae	*Physalis*	*angulate*	Cutleaf Groundcherry
Verbenaceae	*Verbena*	*brasiliensis*	Brazilian Vervain