SMALL MAMMAL COMMUNITY ASSOCIATIONS AND HABITAT USE AT PEA RIDGE NATIONAL MILITARY PARK, BENTON COUNTY, ARKANSAS

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by

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Abstract- *Juniperus virginiana* L. (Eastern Red Cedar) is a fire-intolerant tree species that has been invading and altering grassland ecosystems throughout the American Great Plains and Midwest. To see how Eastern Red Cedar encroachment affects small mammal communities, we surveyed small mammals using live-trapping and mark-recapture methods in Eastern Red Cedar forest and 5 other habitats common to the Ozark region. Additionally, we compared the microhabitat use of presumed juniper obligate *Peromyscus attwateri* Baird (Texas Mouse) and its conspecific *P. leucopus* Rafinesque (White-Footed Mouse). We ran over 7000 trap-nights and found that the small mammal species composition in Eastern Red Cedar was comparable to local mixed oak forests but lower than warm-season grasslands and oldfields. We encountered no small mammal species endemic to Eastern Red Cedar forest. Texas Mice were using Eastern Red Cedar sites more than oak and used areas with high vertical structure while White-Footed Mice showed a slightly increased use of areas with high litter ground cover.

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INTRODUCTION

Invasion of grassland communities by woody plant species is a global concern (Archer et al. 1995). Throughout the world encroachment of trees and shrubs has been caused by fire suppression and increases in livestock grazing over the past 150 years (Brown and Carter 1998). Increased woody vegetation leads to increased erosion (Grover and Musick 1990), enlarged plant and soil carbon (Hibbard et al 2003) and nitrogen (Wheeler et al. 2007) stocks, and altered flow of water through the ecosystem (Huxman et al 2005). This in turn leads to decreased diversity of many organisms, including herbaceous plants (Gehring and Bragg 1992), birds (Sirami et al. 2009, Coppedge et al. 2001), and small mammals (Horncastle et al. 2005). Ultimately, encroachment of woody plants into grassland habitats leads to ecosystem deterioration and simplification.

In parts of the central United States, invasion of grasslands is happening as *Juniperus virginiana* L. (Eastern Red Cedar) converts native grassland into forested habitat (Coppedge et al. 2001, Engle et al. 1996). Horncastle et al. (2005) also found that Eastern Red Cedar-dominated habitats not only support small mammal communities that are smaller and less diverse than native prairie, but the communities are smaller and less diverse than adjacent cross timbers forest habitats. Alteration of the small mammal community is a concern for land managers given the importance of small mammals in an ecosystem. Small mammals are an integral component in the food web by acting as both predator and prey for a variety of organisms (Kaufman et al. 1998). Small mammals contribute to dispersal of seeds (Siepielski and Benkman 2008) and fungal spores (Maser et al. 1978). They also act as hosts for a variety of diseases (Gubler et al. 2001) and loss of small mammal biodiversity results in greater Lyme disease risk for humans and wildlife (Schmidt and Ostfeld 2001). Some fossorial small mammals, such as pocket gophers, directly affect soil fertility, which in turn alters the plant community (Huntly and Inouye 1988).

Loss of biodiversity and alteration of ecosystem processes are concerns for the staff at Pea Ridge National Military Park (PERI) in Benton County, Arkansas. The park is part of the Springfield Plateau in the Ozark Highlands and is largely made up of Post Oak (*Quercus stellate* Wagenh.)-Blackjack Oak (*Q. marilandica* Muenchh.) and oak-hickory forests with pockets of warm and cool-season grasslands (Dale and Smith 1983, James 2008). Unfortunately, over the past 150 years, Eastern Red Cedar has expanded from covering ≤1% of PERI to between 15-26% of the park in 2007 (James 2008, Young et al. 2007). Park staff have implemented mechanical thinning and prescribed burning to reduce Eastern Red Cedar land cover and encourage the establishment of warm season grasses to recreate the oak-savanna habitat present pre-colonization (Eads 2005). To better understand the wildlife communities at PERI and to establish baseline information to compare the effects of land management practices on said communities, PERI staff has implemented a small mammal monitoring program (Eads 2005). Small mammals are a nearly ubiquitous and easily surveyed group of organisms that respond quickly to changes in the environment, and thus serve as a good metric to measure how mechanical thinning and prescribed fire are affecting the wildlife at PERI. (Francl and Small 2013, Kirkland 1990).

While the small mammal communities of the various oak forests of the Ozarks have been fairly well documented, the communities of grassland and Eastern Red Cedar habitats have been largely uncharacterized (Douglas 2010). In the nearby Great Plains, the small mammal communities of the warm-season, tallgrass prairie are dominated by *Peromyscus maniculatus* Wagner. (Deer Mouse), *Sigmodon hispidus* Say and Ord. (Hispid Cotton Rat), and Harvest mice (*Reithrodontomys* spp.) (Horncastle et al. 2005, Matlack et al. 2008). Cool-season grasslands dominated by exotic forage grasses in other parts of the country tend to have a similar species composition, but a lower abundance (Coley et al. 1999). There is some evidence that *Reithrodontomys montanus* Baird (Plains Harvest Mouse), a species of special concern in Arkansas, may be more abundant in cool-season grasslands than other grassland types (AGFC 2013, James et al. 1979). In the forests of the Ozarks and Ouachita Mountains, most small mammal communities are predominantly *P. leucopus* Rafinesque (White-Footed Mouse) with occasional *Neotoma floridana* Ord. (Eastern Woodrat) and *Ochrotomys nuttalli* Harlan (Golden Harvest Mouse) (Douglas 2010, Perry and Thill 2005).

White-Footed Mice are also the most abundant small species encountered in most Eastern Red Cedar forests of the Great Plains (Horncastle et al. 2005, Matlack 2008); however *Peromyscus attwateri* J.A. Allen (Texas Mouse) dominates the small mammal community in juniper habitat along rocky bluffs, cliffs, and outcrops (Schmidly 1974). The Texas Mouse is found throughout central and northeastern Texas, eastern Oklahoma, and the western end of the Interior Highlands of Arkansas, Missouri, and Kansas (Schmidly 1974). During the Xerothermic maximum roughly 6000 BCE, the Texas Mouse likely had a much larger range until climate changes around 2000 BCE caused landscape changes that resulted in fragmentation of suitable habitat and the present isolation of Texas Mouse populations (Sugg et al. 1990). Habitat fragmentation is a problem for Texas Mice as it increases the extinction rate of small mammals (Fischer and Lindenmayer 2007) and can also alter small mammal movement and spatial patterning (Wolff et al. 1997). There is little to no movement between adjacent populations of Texas mice in the Ozark and Ouachita Mountains, which could limit the ability of Texas mice to recolonize areas they have been extirpated from (Sugg et al. 1990). Additionally, laboratory tests show White-Footed Mice, which can also dominate small mammal communities in Eastern Red

Cedar stands (Seagle 1985), competitively displace Texas Mice under laboratory conditions (Brown 1964).

The purpose of my studies was to characterize the small mammal communities of 6 distinct Ozark habitats to see if Eastern Red Cedar contains a unique small mammal community and to evaluate the differential habitat use of Texas and White-Footed mice. My first chapter addresses the former objective and is intended for submission for publication to the *Journal of Mammalogy* (possibly changing target journal) with Dr. David G. Krementz as coauthor. My second chapter addresses the latter objective and is not intended for submission for publication in its current form.

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CHAPTER I

SMALL MAMMAL COMMUNITY ASSOCIATIONS OF PEA RIDGE NATIONAL MILITARY PARK, ARKANSAS

Abstract- *Juniperus virginiana* L. (Eastern Red Cedar) is a fire-intolerant tree species that has been invading and altering grassland ecosystems throughout the American Great Plains and Midwest. Many land managers are interested in removing Eastern Red Cedar to restore native grasslands. As a metric of habitat health, we surveyed small mammals using mark-recapture methods in Eastern Red Cedar forest and 5 other habitats common to the Ozark region. We ran over 7000 trap-nights and found that the small mammal species composition in Eastern Red

Cedar was comparable to local mixed oak forests but lower than warm-season grasslands and oldfields. We encountered no small mammal species endemic to Eastern Red Cedar forest. We found that Eastern Red Cedar forest has no unique species and a less diverse small mammal community than the grasslands it replaces. Renovating former grasslands invaded by Eastern Red Cedar should increase small mammal species diversity at the local scale.

Introduction

Anthropogenic disruption of natural fire regimes has resulted in Eastern Red Cedar invading and converting native grasslands both in the Eastern and Central United States into forested habitats (Coppedge et al. 2001, Engle et al. 1996, Owensby et al. 1973). Increases in woody vegetation can lead to increased erosion (Grover and Musick 1990), enlarged plant and soil carbon (Hibbard et al. 2003) and nitrogen (Wheeler et al. 2007) stocks, and altered flow of water through the ecosystem (Huxman et al 2005). This in turn leads to decreased diversity of many organisms, including herbaceous plants (Gehring and Bragg 1992), birds (Sirami et al. 2009, Coppedge et al. 2001), and small mammals (Horncastle et al. 2005, Matlack et al. 2008). Many organizations, from The Nature Conservancy to the U.S. Fish and Wildlife Service, advocate removing Eastern Red Cedar to restore and protect native grasslands (Drake and Todd 2002, TNC 2014, USFWS 2013). Horncastle (2005) and Matlack (2008) found that the small mammal communities of Eastern Red Cedar-dominated habitat in the Great Plains are less diverse and contain no unique species compared to the native tallgrass prairie and cross-timbers woodland. However, no one has looked to see if this holds true in highly variable landforms, such as the Ozark Mountains, where multiple distinct habitats can occur in close proximity.

The Ozark region of the United States is a unique and diverse landscape encompassing a variety of habitats, from hardwood forests and savannas to grassy glades and fens (USGS 2013). Roughly 160 species of plants and animals are endemic to the region (USGS 2013). To conserve and better manage this environment, land stewards must first understand the composition of the distinct plant and animal communities present. Small mammals are a nearly ubiquitous and easily surveyed group of organisms that respond quickly to changes in the environment (Francl and Small 2013, Kirkland 1990). Small mammals are also an integral component of many terrestrial communities by acting as both predator and prey for a variety of organisms (Kaufman et al. 1998), contributing to the dispersal of seeds (Siepielski and Benkman 2008) and fungal spores (Maser et al. 1978), and by acting as hosts for an assortment of diseases (Gubler et al. 2001). As such, small mammal communities can be used to characterize and describe the health of an ecosystem.

Scientists have been studying the small mammals of the Ozarks since the early twentieth century (Jackson 1907). Researchers have usually concentrated on surveying the various mixed hardwood forests common to the area (Douglas 2010, Fantz and Renken 2005, Gram et al. 2001) though Brown (1964) worked in Eastern Red Cedar glades and Nelson (2007) sampled warm-season grasslands. No one has studied the small mammal fauna of 3 Ozark habitats in particular: cool-season grassland dominated by *Festuca arundinacea* Schreb. (Tall Fescue) and *Agrostis giganteum* Roth. (Redtop), warm-season grassland dominated by *Sorghastrum nutans* [L.] Nash. (Indiangrass) and *Andropogon gerardii* Vitman, (Big Bluestem), and Eastern Red Cedar forest. Mammalogists have described the small mammal communities of these habitats in other parts of the country though. Recently, researchers studying how Eastern Red Cedar encroachment into tallgrass prairie changes small mammal communities in Kansas (Matlack et al. 2008) and

Oklahoma (Horncastle et al. 2005) found that *Peromyscus maniculatus* Wagner (Deer Mouse), *Sigmodon hispidus* Say and Ord (Hispid Cotton Rat), and *Reithrodontomys* spp. (harvest mice) dominated the grasslands while Deer Mice and *P. leucopus* Rafinesque (White-Footed Mouse) dominated the Eastern Red Cedar forest small mammal community.

We wanted to characterize the small mammal communities of 6 distinct habitats in the Ozarks and compare them to one another in terms of species abundances, richness, and diversity. In particular, we wanted to see if any small mammal species are found only in Eastern Red Cedar forest or if the habitat has a unique small mammal community. We chose Eastern Red Cedar forest, Post oak-Blackjack oak forest consisting largely of *Quercus stellata* Wagenh. (Post oak) and *Q. marilandica* Muenchh. (Blackjack oak), oak-hickory forest consisting mostly of mixed oaks other Post and Blackjack oaks (James 2008), warm-season grassland, cool-season grassland, and oldfields. Both Brown (1964) and Horncastle et al. (2005) found differences in the small mammal species composition between Eastern Red Cedar and mixed oak forest, so we predicted that we would find similar differences. Matlack (2008) and Ring (1999) caused us to predict that the warm-season grassland and oldfield sites will have different communities due to the increased availability of woody vegetation in the latter habitat. Tall fescue occasionally lives in association with an endophytic fungus, *Acremonium coenophialum* Morgan-Jones & Gams, that decreases nutrient availability in the plant (Bush and Buckner 1973), which in turn results in decreased small mammal abundance (Coley 1995). Thus we expect the cool-season grasslands to have a different small mammal community composition than the other grassland habitats.

Field Site Description

Pea Ridge National Military Park (PERI) lies in northwestern Arkansas on the Springfield Plateau, a component of the Ozark Highlands (Nelson 2005). Topography varies considerably throughout the park, with differences in elevation, slope, and aspect over small spatial scales (Pietz 2009). The climate is classified as humid subtropical (Koppen Climate Classification System) with average temperature ranging from 0.1^{o} C in February to 25.3^{o} C in July (Weatherbase 2013). Within the 1740ha park are 5 main habitat types: Post oak-Blackjack oak forest, oak-hickory forest (James 2008), warm-season grassland (Dale and Smith 1983), oldfield, and cool-season grassland (NPS 2005). In recent decades, Eastern Red Cedar has invaded and transformed significant sections of the park from one of the aforementioned grassland habitat types into an Eastern Red Cedar-dominated forest (N. Moore, NPS, personal communication).

Methods

Based on dominant overstory tree species as described in Eyre (1980), we divided forested habitat throughout PERI into Eastern Red Cedar forest and the 2 native hardwood forest types: Post Oak forest and oak-hickory forest. Unforested habitat was divided into warm-season grassland, cool-season grassland, and oldfield based on specific composition of the grasses and amount of woody vegetation.

We selected sample sites to survey small mammals in each of the 6 habitat types from permanent sample locations established by Pietz (2009). We selected each site randomly from a subset of the permanent sample sites based on habitat type and whether the site was adversely affected by some feature (e.g., nearby road or recent prescribed burn). From each site we set out a line of traps in a random direction. We surveyed 12 sites, or 2 sites in each habitat, in autumn

(Sep-Nov 2012). We added 3 more sites, 1 in each of the forested habitats, in order to better discern the differences in small mammal communities among those habitats. This made 15 sites for the winter (Dec-Feb 2013), spring (Mar-May 2013), and summer (Jun-Aug 2013) surveys. Traps were set in the evening and checked in the morning for 5 consecutive nights. We ran trap transects each night in 2 habitat types and we varied the order of sites sampled each season.

Based on the sampling scheme of Pearson and Ruggiero (2003), at each site we set out a trap transect of 25 trap stations consisting of Sherman (8 X 9 X 23 cm) and Tomahawk #202 live capture traps. The first trap was placed 15m from the sampling site and each successive trap was 10 m away. Where large (dbh >20cm), living trees were available we secured the Tomahawk traps, 1 to a tree, ~3m up the bole either horizontally if there was a branch or vertically if there was not. Otherwise, we placed a Tomahawk trap on the ground at the 1st, 5th, 9th, and 13th trap stations. A fitted, tan vinyl covering was attached to each trap with safety pins for camouflage and to protect captured animals from inclement weather. Polyester batting was added to each trap for warmth and we baited the traps with balls of peanut butter, molasses, and oats to target *Glaucomys volans* L. (Southern Flying Squirrels, Bowman et al. 2005). At the remaining 21 stations, we placed 1 Sherman trap per station. We baited the Sherman traps with a mixture of peanut butter and whole oats as well as a piece of polyester batting to provide insulation.

During the spring and summer sessions we added pitfall traps to our sampling scheme. We checked and closed traps in the morning and set them in the evening. We oriented the pitfall trap array in a cross-type design. The design consisted of a central pitfall with 4 drift fences (~30 cm tall) extending in each cardinal direction 10 m from the center pit with additional pitfalls placed at the end of each fence. Pitfalls traps are 2-gallon buckets buried with their tops even with the ground. We baited pitfall traps with cat food to prevent captured shrews from starving (J.S. Millar, University of Western Ontario, personal communication) and the top was covered with an elevated cover board to allow small mammals to fall into the pit while excluding larger animals. We located the pitfall trap array at the start of the sampling transect. We ran the pitfalls for 5 consecutive nights per plot, inverting the cover boards during the day to close the traps, and checked them every morning and evening.

To detect the presence of larger animals, a single motion-activated game camera was placed adjacent to the trapping line ~1m up on the bole of a tree or fencepost. Roughly 40g of deer corn was broadcast within the line of sight of the camera. Game camera results are presented in Appendix A.

We handled captured small mammals following the handling guidelines of Sikes et al. (2011) as approved by the University of Arkansas Institutional Animal Care and Use Committee (permit # 13001). We identified mammals to species using Sealander and Height (1990). Due to difficulties with discriminating between *Peromyscus leucopus* Rafinesque (White-footed mouse) and *P. maniculatus* Wagner (Deer Mouse) in the field we classified them as *Peromyscus* spp. (Rich et al. 1996). We recorded the weight, sex, and relative age, when possible, of all individuals. We marked captured mice with #1005-1 monel ear tags and shrews with 0.24 cm diameter leg bands to identify recaptures. We took picture vouchers of all distinct mammal species trapped. We entered all animals that expired in traps into the University of Arkansas J. William Fulbright College of Arts and Sciences Museum.

We calculated species richness within each transect and habitat type with the program SPECRICH2 (Rexstad and Burnham 1991). SPECRICH2 implements the jackknife estimator for model M_h (White et al. 1978). Compared to other methods, this model better accounts for differing detection probabilities among species and for the possibility that some species may not be sampled. We also calculated Pielou's evenness (Pielou 1969) and the Shannon diversity index (Shannon 1949) using Microsoft Excel 2010. For both metrics we estimated abundance using the bias-adjusted Lincoln-Peterson method, which minimizes the Lincoln-Peterson method's trend to overestimate abundances in situations where the estimated abundance is lower than the sum of captures for the first and second trap periods (Williams et al. 2002). We set the first trap period as the first 3 nights of trapping and the second period as the last 2 nights as this produced the most even grouping of captures between trap periods. We included animals that died in the traps in our estimates if they were caught during the second trap period or no new individuals were captured during the second trap period; otherwise they were excluded.

To test for differences in community composition among habitat types we conducted a permutational analysis of variance (PERMANOVA) test on a Bray-Curtis dissimilarity matrix made up of bias-adjusted Lincoln-Peterson estimates of species abundances by transect. PERMANOVA has been shown to be both more powerful at detecting changes in community structure and more robust in the face of data with heterogeneous distributions than other multivariate tests such as analysis of similarity (ANOSIM) and the Mantel test (Anderson and Walsh 2013). Since trap lines are better suited to estimating species richness than abundance (Pearson and Ruggiero 2003), we chose a Bray-Curtis dissimilarity matrix as it emphasizes species richness more than abundance (Anderson and Walsh 2013; Clarke et al. 2006). We conducted a PERMANOVA test among all habitats together, with all habitats grouped into forested or grassland, with just forested habitats, with just grassland habitats, and between each potential pair of habitats.

Results

We ran 5,780 Sherman trap nights, 1,112 Tomahawk trap nights, and 506 pit trap nights over 15 transects. We captured 271 individual small mammals belonging to 9 different species 475 times over the course of a year (Table 1). We excluded from our results 1 *Reithrodontomys* that we captured but could not identify to species. Three species (*Peromyscus* spp., *Peromyscus attwateri* J.A. Allen [Texas Mouse], and *Reithrodontomys fulvescens* J.A. Allen [Fulvous Harvest Mouse]) accounted for 85% of all captures and 80% of all individuals while we caught 3 species (*Blarina hlyophaga* Elliot [Elliot's Short-Tailed Shrew], *Glaucomys volans* L. [Southern Flying Squirrel], and *Reithrodontomys montanus* Baird [Plains Harvest Mouse]) 5 or fewer times each. *Peromyscus* spp. accounted for the largest number of captures (231) and number of individuals (114).

We had the greatest capture success in oldfield sites (12.10 captures per 100 trap-nights). Oak-hickory forest and cool-season grassland had low catch rates of 2.81 and 1.28 captures per 100 trap nights, respectively, while Eastern Red Cedar forest, Post Oak forest, and warm-season grassland all had above average catch success (9.05, 6.76, and 7.27 captures per 100 trap-nights, respectively). As for species specific catch per unit effort, we encountered only 1 species *Peromyscus* spp., in every habitat and their catch per unit effort varied between habitats from virtually 0 to 6.06. We found the Southern Flying Squirrel and Plains Harvest Mouse in only 1 habitat, Eastern Red Cedar forest and cool-season grassland, respectively. We found Elliot's Short-Tailed Shrews only in forested habitats while we caught Fulvous Harvest Mice, Hispid Cotton Rats, and *Cryptotis parva* Say (Least Shrew) exclusively in unforested habitats. We encountered *Ochrotomys nuttali* Harlan (Golden Harvest Mouse) and members of the 3 species of *Peromyscus* in both forested and unforested habitats, though in every case we captured more individuals in the former habitat.

All 3 unforested habitats had higher Shannon diversity indices than the most diverse forested habitat, Eastern Red Cedar forest (Table 2). Further, oldfields, warm-season grasslands, and cool-season grasslands had higher estimated species richness values as high or higher than those for Post Oak and oak-hickory forest. Pielou's evenness values reflect species richness, thus we found lower scores for species-poor oak-hickory and Post Oak forests than more speciose Eastern Red Cedar forest and oldfield. Cool-season grassland was the outlier with low species richness but high evenness. PERMANOVA tests of species composition among all habitats considered separately, between forested and grassland habitats, and among grassland habitats were different (p-values =0.001, 0.001, and 0.001, respectively). Pairwise comparisons among all forested habitats were not different (p=0.117) as were all pairwise comparisons between forest types (Table 3). All other comparisons except the oak-hickory forest/cool-season grassland pairing were different.

Discussion

Our results show that small mammal communities in the Ozarks are largely consistent with the established literature on small mammal habitat associations in other parts of the American Midwest. The Least shrew, Fulvous harvest mouse, Plains harvest mouse, Deer mouse, Hispid cotton rat (Stancampiano and Schnell 2004), and Elliot's short-tailed shrew (Thompson et al. 2011) are associated with open grassland habitat while the Southern Flying Squirrel (Bendel and Gates 1987), Golden Harvest Mouse (Christopher and Barrett 2006), Texas Mouse (Ethredge et al. 1989), and White-Footed Mouse (Kaufman et al. 1983) are associated with forest habitat. We found Elliot's short-tailed shrew exclusively in forest as opposed to grassland, but since we only caught 3 shrews we do not feel we can draw any conclusions.

Texas Mice predominantly use areas with rocky glades and cliffs, but we found individuals up to a kilometer from such habitats (Brown 1964, Ethredge et al. 1989). As such, Texas Mice may not be as tightly associated with rocky habitats as previously thought. The reduced association with rocky habitats at our study site might also be a consequence of PERI lying at the edge of the Texas Mouse's range (Schmidly 1974).

That oldfields and the other grasslands differ in their small mammal species composition is not surprising considering that low levels of woody vegetation in a grassland can provide habitat for both woodland and grassland small mammal species (Matlack et al. 2008, Swihart and Slade 1990). This explanation is borne out as all animals present that we caught at warm-season grassland sites we also caught in oldfield sites, as well as Texas mice, a woodland-associated species (Kaufman et al. 1983). We did capture a Golden Harvest Mouse, a species associated with hardwood forests (Christopher and Barrett 2006, Seagle 1985), in a warm-season grassland. Golden harvest mice build nests in trees, but will venture into forest edges to forage (Morzillo et al. 2003).

Small mammal surveys of cool-season and fescue-dominated grasslands tend to have lower capture rates and species richness than warm-season grasslands (Coley et al. 1999, Washburn and Seamans 2007). Our results bear this out, but 1 of the 4 species we caught in cool-season grasslands, the Prairie Harvest Mouse, is a species of special concern in Arkansas and we found it at both cool-season transects but nowhere else (AGFC 2013). The main concern for this species is that it belongs to the geographically distinct subspecies *R.m. griseus*, whose current range is unknown but likely shrinking (Benedict et al. 2000). This subspecies uses dry, upland habitat characterized by sparse grass and forb cover, and much of that has been destroyed (Panella 2012). The first records of Plains Harvest Mice in Arkansas came from captures in abandoned pastures composed of cool season Tall Fescue and *Cynodon dactylon* (L.) Pers. (Bermuda Grass) (James et al. 1979). James et al. (1979) postulates that Plains Harvest Mice are found in cool-season grasslands because it closely mimicks the upland sites with sparse, short grass that they are traditionally associated with. Additional research is needed to learn if this species and others actually prefer the less diverse but more abundant (Peterson et al. 2002) cool-season grasslands converted from the more diverse warm-season grasslands that spanned much of the American Midwest before the arrival of Europeans (Risser 1988).

We found no difference in species composition between cool-season grassland and oak-hickory forest, but this may result from the low number of captures in both habitats. The similarity among the 3 forested habitats is likely due to the low species richnesses and *Peromyscus* spp. composing 34%, 90%, and 92% of the individuals captured in Eastern Red Cedar, Post Oak, and oak-hickory forests, respectively. We only found 1 small mammal species endemic to a specific wooded habitat, Southern Flying Squirrel to Eastern Red Cedar forest. Because this is based only on a single capture and Southern Flying Squirrels use numerous forest types throughout the eastern United States, there were likely undetected squirrels in all forest types (Muul 1974).

Eastern Red Cedar encroachment and conversion of grasslands is a major problem throughout the American Midwest (Briggs et al. 2002) and many organizations are actively removing cedar from their lands (Drake and Todd 2002, TNC 2014, USFWS 2013). The small mammal community of Eastern Red Cedar forest is little different from the upland oak forests of the Ozarks, but it is less diverse than the warm-season grasslands and oldfields that are being replaced. While cool-season grasslands are less species rich than Eastern Red Cedar, the listed Plains Harvest Mouse is found only in that habitat and should thus be given special management consideration. Eastern Red Cedar forest has a less diverse and abundant small mammal community than the grassland habitats it supplants, and the species it does have are neither listed nor unique. Management action to convert Eastern Red Cedar forest back to ancestral warm-season grassland or oak savanna would likely be beneficial to the small mammal communities of the Ozarks.

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Table 1: Number of captures (and individuals) of small mammal species by habitat at Pea Ridge National Military Park, Benton County, Arkansas

Species	Cedar	Post-oak	Oak-hickory	Oldfield	Warm	Cool	Total
Elliot's Short-Tailed Shrew	-	1 (1)	2 (2)	-	-	-	3 (3)
Least Shrew	-	-	-	1 (1)	19 (19)	3 (3)	23 (23)
Southern Flying Squirrel	1 (1)	-	-	-	-	-	1 (1)
Golden Harvest Mouse	8 (6)	-	-	3 (1)	3 (1)	-	14 (8)
Texas Mouse	70 (30)	10 (4)	-	9 (4)	-	-	89 (38)
Peromyscus spp.	37 (19)	95 (45)	39 (23)	43 (18)	13 (7)	4 (2)	231 (114)
Fulvous Harvest Mouse	-	-	-	53 (39)	22 (20)	1 (1)	76 (60)
Plains Harvest Mouse	-	-	-	-	-	5 (4)	5 (4)
Hispid Cotton Rat	-	-	-	15 (7)	18 (13)	-	33 (20)
Total	116 (56)	106 (50)	41 (25)	124 (70)	75 (60)	13 (10)	475 (271)

Table 2: Based upon the modified Lincoln-Peterson estimate of species abundance, species richness, Shannon index of diversity, and Pielou's evenness for each habitat at Pea Ridge National Military Park, Benton County, Arkansas.

Habitat	Richness	Diversity	Evenness
Cedar	6 (1.7)	1.03	0.75
Post Oak	4 (1.2)	0.37	0.34
Oak-hickory	3 (1.2)	0.24	0.35
Oldfield	6 (2.1)	1.03	0.57
Warm-season	7 (1.7)	1.20	0.74
Cool-season	4 (2.3)	1.24	0.89

Table 3: Pairwise PERMANOVA test results (p values) between habitats at Pea Ridge National Military Park, Benton County, Arkansas.

Habitat	Cedar	Post Oak	Oak-hickory	Oldfield	Warm-season
Post Oak	0.12				
Oak-hickory	0.07	0.22			
Oldfield	0.001*	0.004*	0.005*		
Warm-season	0.001*	0.001*	0.001*	0.03*	
Cool-season	0.003*	0.004*	0.08	0.002*	0.002*

APPENDIX A: NUMBER OF SITE DETECTIONS OF SPECIES BY GAME CAMERAS BY HABITAT

Number Of transects throughout the year of sampling where a species was detected

	White-Tailed Deer	Raccoon	Armadillo	Coyote	Other
Eastern Red Cedar	6	1	1	1	Rabbit (1)
Post oak	6	0	1	0	Fox squirrel (1) Gray Squirrel (1)
Oak-hickory	5	0	1	0	Flying squirrel (1) Blue Jay (1)
Oldfield	4	0	0	0	Crow (1)
Warm-season	3	0	1	1	None
Cool-season	5	2	0	0	Bobcat (1)

CHAPTER II

MICROHABITAT ASSOCIATIONS OF *PEROMYSCUS* MICE IN EASTERN RED CEDAR AND MIXED-OAK FOREST

Abstract- To what degree *Peromyscus attwateri* J. A. Allen (Texas Mouse) can use habitats other than the steep, rocky, juniper-dominated slopes the species is associated with is of conservation importance. Learning what other small mammal species the Texas Mouse can coexist with and if they utilize different aspects of the habitat could also help protect the species. We examined habitat use and microhabitat associations of Texas mice and two other *Peromyscus* species among *Juniperus virginiana* L. (Eastern Red Cedar), *Quercus stellata* Wangeneh. (Post Oak), and oak-hickory forests devoid of rocky substrate in the Arkansas Ozarks. We predominantly found Texas mice in Eastern Red Cedar stands along with *Peromyscus* spp. Texas mice and *Peromyscus* spp. used different aspects of the habitat, but the magnitude of the difference was small. The Texas Mouse can live away from rocky slopes and bluffs, but how it partitions resources with respect to other small mammals remain unclear.

Introduction

Compared to other members of the genus *Peromyscus*, little research has been conducted on Texas Mouse (*Peromyscus attwateri*) ecology. The Texas Mouse is found throughout central and northeastern Texas, eastern Oklahoma, and the western end of the Interior Highlands of Arkansas, Missouri, and Kansas (Schmidly 1974). This species is generally associated with rocky substrate, especially limestone bluffs and cliffs, as well as Ashe Juniper (*Juniperus asheii*) and Eastern Red Cedar (*J. virginiana*) (Brown 1964, Ethredge et al. 1991, Long 1961, Ring 1999). To what degree the Texas Mouse depends on rocky substrate and cedar stands appears to vary geographically. Brown (1964) and Lee (1999) found Texas Mice virtually only in cedar glades in the Ozarks of Missouri while in the Flint Hills of Kansas Long (1961) caught Texas mice on limestone bluffs dominated by blackjack oak (*Quercus marilandica*). Blair (1938) found

Texas mice in limestone ravines dominated by Shumard (*Q. shumardii*) and chinquapin (*Q. muhlenbergii*) oaks. Ethredge (1989) believed that the Texas Mouse is more of a habitat generalist within the Ashe Juniper communities of Texas, but did not sample outside of that habitat. Montgomery (1974) found that the Texas Mouse he caught along the Cassatot River in Arkansas appeared to inhabit south-facing slopes regardless of substrate type or overstory vegetation. Sealander (1962) found that the Texas Mouse has a lower hemoglobin count in its blood, and concluded that the Texas Mouse might have a lower cold tolerance than other small mammal species within its range and potentially uses open, rocky areas because those habitats have a warmer microclimate.

The White-Footed Mouse (*Peromyscus leucopus*) also inhabits juniper-dominated habitats and may be able to competitively exclude the Texas Mouse (Brown 1964, Horncastle 2005, Matlack 2008, Seagle 1985). The concept that one species can prevent another from inhabiting the same habitat due to resource competition has been around since 1904 and has since been observed in various small mammals (Cameron 1964, Grinnel 1904, Hallett et al. 1983). In captivity, White-Footed mice will harass and kill Texas Mice kept in the same enclosure even when there are ample resources (Brown 1964). Outside of the Texas Mouse's range, which the range of the White-Footed Mouse completely envelops, White-Footed Mice are the most commonly encountered small mammal in Eastern Red Cedar forest (Matlack 2008, Seagle 1985). Brown (1964), Montgomery (1974), and Ring (1999) all predominantly caught Texas mice and White-footed mice in different habitats. Stancampiano and Caire (1995), however, caught both *Peromyscus* species in the same area, and occasionally the same trap. Texas and White-Footed mice can coexist alongside other ecologically similar species by using different resources in a habitat ((Ethridge et al. 1989, Seagle 1985). Under what conditions, if any, the Texas Mouse and White-Footed Mouse can coexist is currently unknown.

Knowing what habitats Texas mice use could be of conservation importance in the future if, as Brown (1964) and Ring (1999) found, the species is limited to juniper-dominated habitat with a rocky substrate. During the Xerothermic maximum roughly 6000 BCE, the Texas Mouse likely had a much larger range until climate changes around 2000 BCE resulted in landscape changes that resulted in fragmentation of suitable habitat and the present isolation of Texas Mouse populations (King 1981, Sugg et al. 1990).). Habitat fragmentation is a problem for Texas Mice as it increases the extinction rate of small mammals (Fischer and Lindenmayer 2007) and can also alter small mammal movement and spatial patterning (Wolff et al. 1997). While the species is currently listed as "Least Concern" by the International Union for the Conservation of Nature and Natural Resources (IUCN; Simpson and Ferrato 2013), habitat and resource specialization is associated with higher risks of extinction from habitat loss (McKinney 1997, Owens and Bennett 2000). There is little to no movement between adjacent populations of Texas mice in the Ozark and Ouachita Mountains, which could limit the ability of Texas mice to recolonize areas they have been extirpated from (Sugg et al. 1990).

Our objectives are to examine: a) if the Texas Mouse use forested habitats away from rocky outcrops, b) what microhabitat characteristics the Texas Mouse is using, and c) if the Texas and White-Footed mice are using different microhabitats. We predict that the Texas Mouse use forested habitats away from rocky substrate as a previous small mammal inventory at our study site found their only Texas Mouse away from the park's limestone bluffs (Johnsey and Mallinen 1971). Additionally, both Montgomery (1974) and Ring (1999) caught Texas mice in Arkansas away from rocky habitat. We also predict that Texas and White-Footed mice are using different microhabitats as both species have been found to be able to cohabit with other ecologically and phylogenetically similar species via niche differentiation (Ethridge et al. 1989, Seagle 1985). Specifically, we hypothesize that the Texas Mouse use south-facing slopes with less vertical structure and canopy cover due to their lower cold tolerance compared to White-Footed mice (Sealander 1962). We expect to find more Texas Mice where there is more Eastern Red Cedar and more White-Footed mice in areas with higher than average amounts of coarse woody debris and litter based on the findings of Dueser and Shugart (1978), Greenberg (2002), Matlack (2008) and Seagle (1985).

Field Site Description

Pea Ridge National Military Park (PERI) lies in northwestern Arkansas on the Springfield Plateau, a component of the Ozark Highlands (Nelson 2005). Topography varies considerably throughout the park, with differences in elevation, slope, and aspect over small spatial scales (Pietz 2009). The climate is classified as humid subtropical (Koppen Climate Classification System) with average temperature ranging from 0.1^{o} C in February to 25.3^{o} C in July (Weatherbase 2013). Within the 1,740 ha park are 5 main habitat types: Post oak (*Quercus stellata* Wagenh.)-Blackjack Oak (*Q. marilandica* Muenchh) forest, oak-hickory forest (James 2008), warm-season grassland (Dale and Smith 1983), oldfield, and cool-season grassland (NPS 2005). In recent decades, Eastern Red Cedar has invaded and transformed significant sections of the park from one of the aforementioned grassland habitat types into an Eastern Red Cedar-dominated forest (N. Moore, NPS, personal communication).

Methods

Based on dominant overstory tree species as described in Eyre (1980), we divided forested habitat throughout PERI into Eastern Red Cedar forest and the 2 native hardwood forest types, Post Oak forest and oak-hickory forest. We selected sample sites to survey small mammals in each of the 3 habitat types from permanent sample sites established by Pietz (2009) as the sites had a known aspect that we could use for our microhabitat analyses. We selected each site randomly from a subset of the permanent sample locations based on habitat type and whether the location was adversely affected by some feature (e.g., nearby road or recent prescribed burn). From each site we set out a line of traps in a random direction. We surveyed 9 sites, or 3 sites in each habitat, once each during the winter (Dec-Feb 2013), spring (Mar-May 2013), and summer (Jun-Aug 2013). We ran each transect for 5 nights and we varied the order of sites sampled each season.

Based on the sampling scheme of Pearson and Ruggiero (2003), at each site we set out a trap transect of 25 trap stations consisting of Sherman (~8 X 9 X 23cm) and Tomahawk #202 live capture traps. We placed the first trap 15m from the sampling site and each successive trap was 10m away. Where large (dbh>20cm), living trees were available we secured the Tomahawk traps, 1 to a tree, ~3m up the bole with the opening facing up. Otherwise, we placed a Tomahawk trap on the ground at the 1st, 5th, 9th, and 13th trap stations. A fitted, tan vinyl covering was attached to each trap with safety pins for camouflage and to protect captured animals from inclement weather. At the remaining 21 stations, we placed 1 Sherman trap per station. We baited the all traps with a mixture of peanut butter and whole oats as well as a piece of polyester batting to provide insulation. We checked and closed traps in the morning and set them in the evening.

We handled captured small mammals following the handling guidelines of Sikes et al. (2011) as approved by the University of Arkansas Institutional Animal Care and Use Committee (permit # 13001). We identified mammals to species using Sealander and Height (1990). We recorded the weight, sex, and relative age, when possible, of all individuals. We marked captured mice with #1005-1 monel ear tags and shrews with Federal #1 leg bands to identify recaptures. We took picture vouchers of all distinct mammal species trapped.

Every season we collected habitat data at 10 locations per transect (30 per habitat) to gauge available microhabitat features (available) and at every location where we caught a Texas Mouse or *Peromyscus* spp. to measure the microhabitat used. The first vegetation sampling location was at the start of the trapping line and we randomly selected the other sites from a georeferenced aerial photo using ArcGIS version 10.0 (ESRI 2011). If we ended up with more used than available samples, we collected vegetation data from additional random locations until we had as many available as used locations. We recorded the height and percent of board that was obscured by vegetation using a gridded density board (2 X 0.5-m backdrop) from a distance of 10 m in four cardinal directions around the plot's center (Nudds 1977). We estimated percent litter cover within a 0.5 x 0.5-m frame (Daubenmire 1959) in four cardinal directions at 5 m from the plot center. We measured percent overhead canopy cover using a convex spherical densitometer in all four cardinal directions at the plot center. Using a 10-factor wedge prism we estimated the basal area of both living trees and snags. We identified all living trees counted to species using Kirkman et al. (2007) and counted their contribution to the overall basal area.

To model microhabitat use in the Texas Mouse and *Peromyscus* spp., we used Generalized Linear Models (GLM) (R Version 9.3.2) to compare habitat at available and used locations where we caught each species being tested. Our models included all uncorrelated

(R^2<0.4) variables that had the highest probability of affecting the mice based on previously published research. To account for the possibility that the species' microhabitat use pattern differ from season to season we tested a GLM for each species and season, for a total of six total analyses.

We used Canonical Correspondence Analysis (CCA) to compare the microhabitat use by Texas mice and *Peromyscus* spp. CCA is effective at simplifying large environmental datasets and relating them to community structure when species response to an environmental gradient is unimodal and the researcher is only interested in how community structure is influenced by the variable measured (McCune et al. 2002). CCA is also more effective at comparing multiple species at a time and species with few observations (Guise et al. 1999). We wished to see if the same component explained the most variation in the Texas Mouse and *Peromyscus* spp. microhabitat use. We used the same covariates from the GLMs and lumped across gender and age.

Results

We ran 2,646 Sherman trap nights, 514 Tomahawk trap nights, and 281 pit trap nights over 9 transects. We captured 112 individual small mammals 240 times, including 159 captures of 79 *Peromyscus* spp. and 70 captures of 28 individual Texas mice. Juveniles made up 12 of the individuals we captured from each species. *Peromyscus* spp. was well represented in all habitats, but we only made 8 captures of Texas mice in Post Oak and none in oak-hickory (Table 1). We only encountered Texas mice in 4 transects (2 Eastern Red Cedar and 2 Post Oak) while *Peromyscus* spp. could be found on every transect line. The number of captures we made per transect varied from 69 (43 Texas Mouse, 20 *Peromyscus* spp., and 6 others) to 2 (1 *Peromyscus* spp. and 1 other). We collected habitat data from 288 “available” sites, 105 *Peromyscus* spp. capture sites, and 38 Texas Mouse capture sites (Table 2).

Texas Mice were consistently using areas with higher than average vertical vegetation structure and Eastern Red Cedar basal area in each season (Table 3). We found that litter and canopy cover, and vertical density during the spring were related to *Peromyscus* spp. use. In winter and summer, *Peromyscus* spp. habitat use was not related to any habitat covariates measured.

The CCA demonstrated that *Peromyscus* spp. and Texas mice are using different aspects of the habitat as they are responding to the two components differently (Fig. 1, Fig. 2, Fig. 3). Just like the GLMs showed, across all three seasons *Peromyscus* spp. is using areas with litter more than its availability while Texas mice are using areas with more Eastern Red Cedar and vertical structure. Unfortunately, among all three seasons the first two canonical axes never explain more than 15 % of the variability in the data. This indicates that the observed microhabitat associations and discrimination between microhabitat use of *Peromyscus* spp. and Texas mice are not strong.

Discussion

Texas mice do live away from rocky outcrops and are using different habitats than *Peromyscus* spp. We captured only 12% of our Texas Mouse outside of Eastern Red Cedar forest compared to capturing 77% of *Peromyscus* spp outside of Eastern Red Cedar forest. Brown (1964) and Ring (1999) both found similar patterns in the Ozarks where all but a few of the Texas mice they caught came from Eastern Red Cedar glades instead of mixed oak forests. Every Post Oak transect that we found Texas mice at was within 500m of Eastern Red Cedar forest, which is well within the dispersal range for other members of the *Peromyscus* genus

(King 1968). Also, captures of the Texas mice in Post Oak transects were not consistent. During the winter, half of the animals we trapped at one transect were Texas mice, but we never caught any more in spring or summer. We only caught Texas mice at one other Post Oak transect, and all but one of those captures occurred during summer. Finally, of the Texas mice we caught in Post Oak transects, we never recaptured a mouse from one season to the next, so it is possible that the Texas Mice we encountered had dispersed from the Eastern Red Cedar forest but could not establish themselves in the Post Oak forest.

Other studies have suggested that White-Footed and Deer mice are habitat generalists (Brannon 2005, King 1968, Seagle 1985) though the Deer Mouse subspecies found in the American Midwest, *P.m. bairdii* (Prairie Deer Mouse), is associated with grasslands (Horncastle 2005, King 1968, Matlack 2008). White-Footed mice use deciduous more than evergreen forest types, which may explain their lower numbers in Eastern Red Cedar stands. (Dueser and Shugart 1978). As we found *Peromyscus* spp. at every Eastern Red Cedar transect where we trapped a Texas Mouse, neither species appears to be excluding the other from that habitat.

Results from the GLM models and CCA imply that *Peromyscus* spp. and the Texas Mouse are responding to different aspects of the habitat: however, the variables we measured only weakly account for the species' local distributions. Either there is considerable niche overlap or the species are responding to different habitat aspects than the ones we measured. Other microhabitat features that are used by White-Footed and Deer Mouse include understory tree dispersion and woody plant diversity (Dueser and Shugart 1978), litter depth litter-soil depth (Seagle 1985), and slope (Stancampiano and Schnell 2004). The Texas Mouse has been described as more of a microhabitat generalist within juniper-dominated habitats (Ethredge et al 1989). Texas mice are morphologically and behaviorally adapted to living on trees and cliffs and can be frequently found climbing them, thus the positive association with vertical vegetation structure that we found makes sense (Ethredge 1989, Long 1961). We hypothesized that Texas mice would use south-facing areas with less vertical vegetation due to their supposed lower cold tolerance, but our results indicate that the mice are not as dependent on the warmth of direct sunlight as Sealander (1962) theorized.

There is no consensus on why the Texas Mouse uses juniper habitat. Though Texas mice consume more juniper berries than Deer or White-Footed mice (Brown 1964), the diets of the three species are virtually indistinguishable combinations of fruits, herbaceous plants, and arthropods (Stancampiano and Caire 1995) so habitat preference likely is not due to a preferred food source. Juniper habitat tends to be rocky, occasionally with cliffs and bluffs (Wells 1970), and Texas mice have large eyes and ears for navigating in dark fissures in cliffs (Long 1961) so the mice might be responding to the substrate and not the vegetation.

Other researchers have also found weak correlations between White-Footed mice microhabitat use and litter (Brannon 2005, Dueser and Shugart 1978, Ring 1999). Both Horncastle (2005) and Matlack (2008) noticed that White-Footed mice respond positively to increasing woody cover, up to a point. We did not observe this, possibly because the former also sampled unforested locations, thus creating a larger range of data, while the latter used remote sensing instead of *in situ* data collection. We may have observed a response to canopy cover, or another variable, had we differentiated White-Footed and Prairie Deer mice as they have different responses to canopy cover, and likely other habitat aspects (Horncastle 2005, Matlack 2008). We believe because White-Footed mice use forested habitat much more than the Prairie Deer Mouse the majority of the captures and habitat data collection sites were White-Footed

Mice. If Prairie Deer mice were as scarce at PERI as other researchers have found at their sites, the effect of lumping the two *Peromyscus* species was negligible.

Texas mice are not rocky substrate or cliff obligates, but we found that they use Eastern Red Cedar forests disproportionate to that tree's abundance. Texas mice and *Peromyscus* spp. can cohabit the same area and use slightly different aspects of the habitat. Texas mice use dense Eastern Red Cedar stands while *Peromyscus* spp. shows only a slight inclination towards patches of habitat with more litter than normal. The low variability in habitat use by both species that is explained by the habitat variables we measured indicates that our variables were not sufficient to describe the resource partitioning, or lack thereof, between the species. There is a need for studying the juvenile dispersal and other large-scale movement patterns of Texas mice to understand the species' ability to emigrate from one population to another and recolonize habitats they have been extirpated from. Our research suggests that neither the lack of rocky substrate nor the presence of other *Peromyscus* species precludes the presence of Texas Mouse populations.

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Table 1: Small mammal captures of *Peromyscus* spp. and Texas Mouse (*Peromyscus attwateri*) at Pea Ridge National Military Park, Benton County, Arkansas

Species	Eastern Red Cedar	Post Oak	Oak-hickory
Peromyscus spp.	37	89	33

Texas Mouse	62	8	0

Table 2: Habitat data collection sites by location type and season at Pea Ridge National Military Park, Benton County, Arkansas. *Peromyscus* spp. and Texas Mouse (*Peromyscus attwateri*) sites were collected at trap locations where we captured the species and available sites were randomly located sites within the forest stand that the trapping line was in

Type	Winter	Spring	Summer	Total
Available	91	107	90	288
Peromyscus spp.	27	43	35	105
Texas Mouse	8	22	8	38
Total	126	172	133	431

Table 3: Model selection results by season for Texas Mouse (*Peromyscus attwateri*) microhabitat use at Pea Ridge National Military Park, Benton County, Arkansas. Covariates represent vertical vegetation density, aspect of the slope, and Eastern Red Cedar basal area. Only models with a ΔAIC score of 2 or less are reported.

Season	Model	K*	AIC*	ΔAIC*	w_i^*
Winter	Vertical	1	52.4	0	0.445
	Aspect+Vertical	2	53.9	1.5	0.214
	Eastern Red Cedar+Vertical	2	54.1	1.7	0.191
Spring	Eastern Red Cedar+Vertical	2	149.9	0	0.557
	Aspect+Eastern Red Cedar+Vertical	3	151.5	1.6	0.242
Summer	Eastern Red Cedar+Vertical	2	24.4	0	0.271
	Eastern Red Cedar	1	24.7	0.3	0.236
	Aspect+Eastern Red Cedar+Vertical	3	25.4	1.1	0.163

*K – no. parameters, AIC –Akaike's Information Criterion, ΔAIC – difference in AIC relative to smallest value, w_i – AIC weight.

Table 4: Model selection results by season for *Peromyscus* spp. microhabitat use at Pea Ridge National Military Park, Benton County, Arkansas. Covariates represent canopy cover, percent ground cover by litter, and vertical vegetation density. Only models with a lower AIC than the Intercept and with a ΔAIC score of 2 or less and are reported.

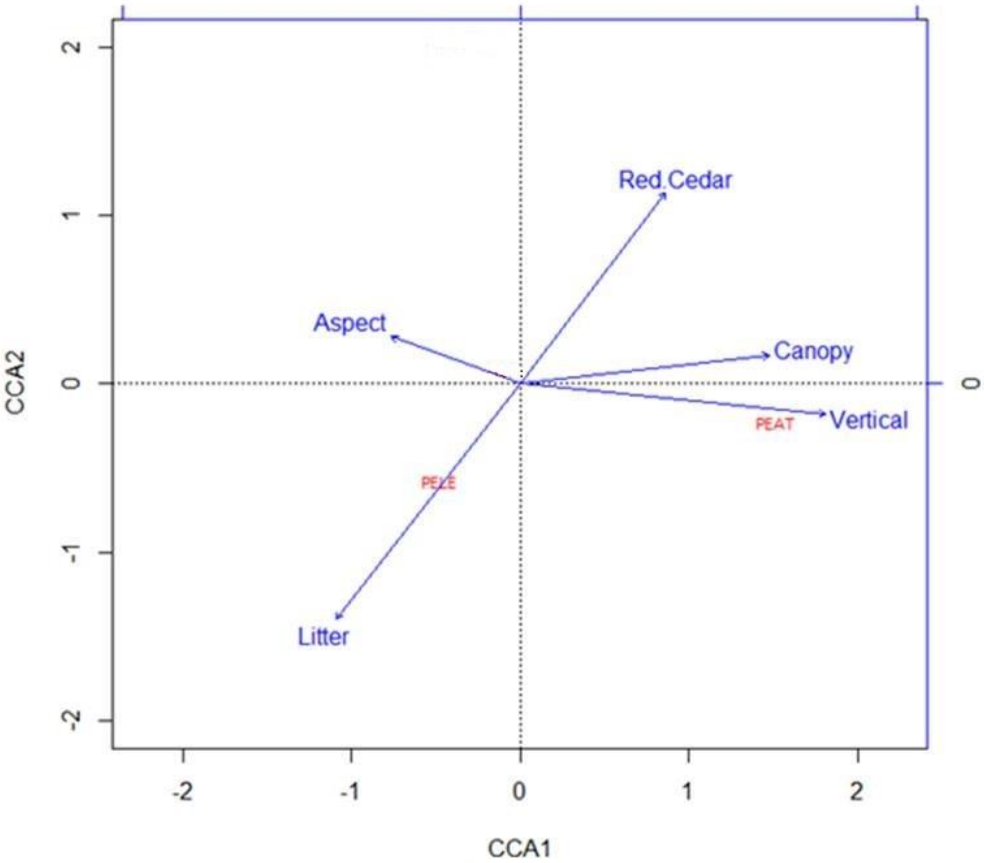
Season	Model	*K*	AIC	ΔAIC	w_i
Winter	Intercept	0	143.1	0	0.297
Spring	Litter	1	235.8	0	0.448
	Litter+Vertical	2	237.2	1.4	0.219
	Canopy+Litter	2	237.3	1.5	0.206
Summer	Intercept	0	199.1	0	0.517

[*] *K* – no. parameters, AIC –Akaike's Information Criterion, ΔAIC – difference in AIC relative to smallest value, w_i – AIC weight.

Figure 1: Ordinations graphs of Canonical Correspondence Analysis results relating small mammal species to microhabitat covariates during the winter trapping session. Covariates represent vertical vegetation density, aspect of the slope, canopy cover, percent ground cover by litter, and Eastern Red Cedar basal area.

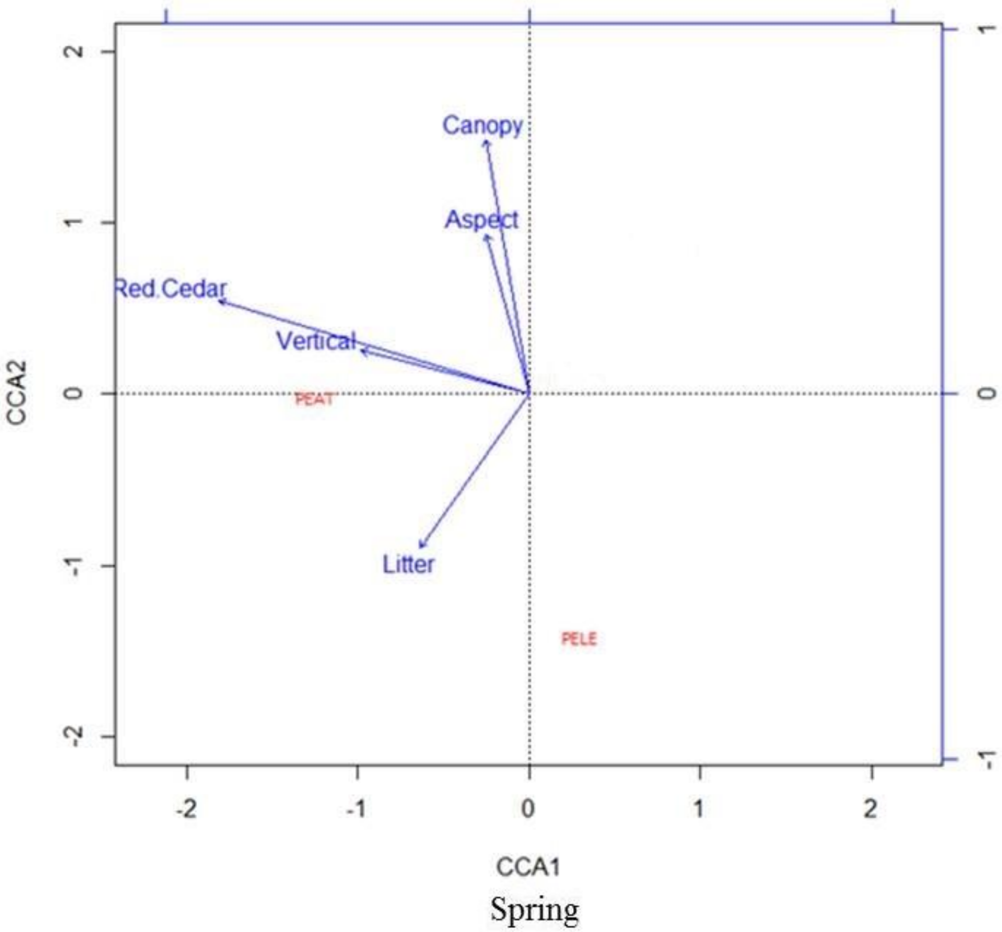
Figure 2: Ordinations graphs of Canonical Correspondence Analysis results relating small mammal species to microhabitat covariates during the spring trapping session. Covariates represent vertical vegetation density, aspect of the slope, canopy cover, percent ground cover by litter, and Eastern Red Cedar basal area.

Figure 3: Ordinations graphs of Canonical Correspondence Analysis results relating small mammal species to microhabitat covariates during the summer trapping session. Covariates represent vertical vegetation density, aspect of the slope, canopy cover, percent ground cover by litter, and Eastern Red Cedar basal area.



Winter

Figure 1


Canopy
Aspect
Red.Cedar
Vertical
PEAT
Litter
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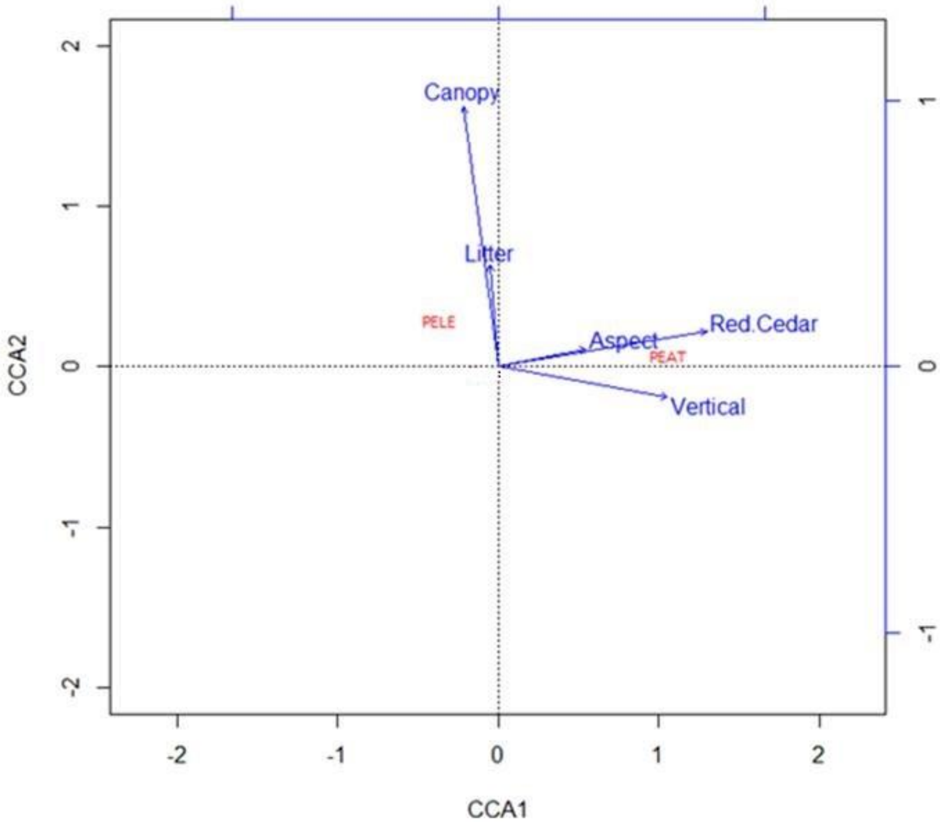
CCA2
CCA1
-2
-1
0
1
2
Spring

Figure 2



Summer

Figure 3

CONCLUSION

The small mammal community of Eastern Red Cedar forest is very similar to that found in upland oak forests of the Ozarks, but is less diverse than the warm-season grasslands or oldfields that it replaces. While cool-season grasslands are less species rich than Eastern Red Cedar, the listed Plains Harvest Mouse is found only in that habitat and should thus be given special management consideration. The grassland habitats we surveyed have roughly the same species composition as other nearby grasslands in the Great Plains and forests at PERI had virtually the same species as found in the cross-timbers of Oklahoma and Ouachita Mountains of central Arkansas (Horncastle et al. 2005, Matlack et al 2008, Perry and Thill 2005). Eastern Red Cedar forest has a less diverse and abundant small mammal community than the grassland habitats it replaces, and the species it does have are neither listed nor unique. Management action to convert Eastern Red Cedar forest back to ancestral warm-season grassland or oak savanna would likely be beneficial to the small mammal communities of the Ozarks, though it could be detrimental to Texas Mice.

Texas Mice are not rocky substrate or cliff obligates, but we found that they use Eastern Red Cedar forests disproportionate to that tree's abundance. Texas mice and *Peromyscus* spp. can cohabit the same area and use slightly different aspects of the habitat. Texas mice use dense Eastern Red Cedar stands while *Peromyscus* spp. shows only a slight inclination towards patches of habitat with more litter than normal. The low variability in habitat use by both species that is explained by the habitat covariates we measured indicates our variables were not sufficient to describe the resource partitioning, or lack thereof, between the species. There is a need for studying the juvenile dispersal and other large-scale movement patterns of Texas mice to understand the species' ability to emigrate from one population to another and recolonize habitats they have been extirpated from. Thankfully, our research shows that neither the lack of rocky substrate nor the presence of other *Peromyscus* species precludes the presence of Texas Mouse populations.

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