MICROHABITAT SELECTION AND NATURAL HISTORY OF THREE SCORPIONS IN A PRESCRIBED FIRE MATRIX

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Abstract

Given the terrestrial nature of scorpions, they are likely to be impacted by fires in the grassland systems they occupy. To better understand such impacts, I studied the effect of seasonality of prescribed fire on microhabitat selection and compared scorpion abundance, richness, and diversity across fire treatments for *Centruroides vittatus, Vaejovis coahuilae,* and *V. russelli* at a site in the southeastern Great Plains. To assess microhabitat selection, I measured microhabitat variables for actual scorpion locations and random locations. Analysis of Variance was used to compare use versus availability to determine the influence of fire and season on microhabitat availability, use and selection. Diversity was calculated using modified Simpson's and Shannon-Wiener diversity indices. In addition, natural history was examined for *C. vittatus, V. coahuilae,* and *V. russelli*. Analysis of Variance was used to compare age structure and sexual dimorphism. Chi-square tests were used to determine if the sex ratio differed from 1:1. Regressions were used to determine if weather variables had an effect on abundance and diversity. *Centruroides vittatus* did not select for any aspect of its microhabitat, while *V. coahuilae* and *V. russelli* selected for a higher percentage of bare ground. *Vaejovis coahuilae* and total scorpion captures were highest in summer-burned plots and lowest in unburned plots while *C. vittatus* captures, diversity, and evenness were lowest in summer-burned plots and highest in unburned plots. Based on current trends, burning would seem to favor the burrowing species (*Vaejovis coahuilae*) at the expense of the climbing species (*Centruroides vittatus*). Results suggest that *C. vittatus, V. coahuilae,* and *V. russelli* are partitioning different aspects of their niches temporally, spatially, and morphologically.

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Chapter 1

MICROHABITAT SELECTION BY SCORPIONS IN A PRESCRIBED FIRE MATRIX

INTRODUCTION

North American prairies evolved under seasonal wildfires (Teague et al. 2008). These wildfires are known to enhance species richness and diversity, recycle nutrients and regulate succession, reduce woody species, and discourage the invasion of non-native plant species (Brockway et al. 2002). These effects are the result of how fire interacts with many physical and biological components of an ecosystem (Brockway et al. 2002). Thus, prescribed fire is crucial in the sustainability of grassland ecosystems.

Arachnids are a ubiquitous and conspicuous member of these fire-adapted grassland ecosystems (McClaran and Van Devender 1995). These organisms are nearly universally carnivorous, occupy intermediate trophic positions, and may be important in structuring communities, particularly invertebrate guilds (Churchill 1997, Lawrence and Wise 2000). However, few studies have directly addressed the effects of fire on these taxa (Freckman 1994, Moldenke et al. 1999).

Fire had a slight positive effect on the species richness of spiders in an Oregon forest (Koponen 2005). Also, fire seemed to favor ground-dwelling species, as species diversity and abundance of Gnaphosidae and Lycosidae were higher at the burned site (Koponen 2005). To date, a single study has been conducted on the responses of scorpions to prescribed fire in a grassland ecosystem. Smith and Morton (1990) found that at least 1 species of grassland scorpion, *Lychus alexandrinus*, persisted readily through fires in Australian grasslands. They hypothesized that, because of several aspects of their ecology, scorpions have the capacity to withstand the direct effect of fire disturbance as well as to take advantage of altered conditions that follow such disturbances. Scorpions are well established and adapted to grassland ecosystems and thus, may reach densities of 5000/ha and biomasses of 5-20 kg/ha (Polis et. al 1986). Most live in burrows or beneath persistent shelters (Polis 1988). They have extremely low metabolic rates and are able to eat large amounts of food and store excess energy from that food in the hepatopancreatic glands, making it possible for them to survive many months without food (Polis 1988). They are also long-lived. However, despite these facts and the fact that grasslands historically undergo frequent burning, the responses of scorpions to burning are largely unknown.

The families Vaejovidae and Buthidae are widespread in North America (Sissom and Hendrixson 2005). The family Vaejovidae is the largest scorpion family in North America and 146 species have been described on the continent (Sissom and Hendrixson 2005). The family Buthidae is the largest family worldwide and contains >90 genera and >900 species (Fet et al. 2000). Two species of Vaejovidae, *Vaejovis coahuilae* and *Vaejovis russelli*, and one species of Buthidae, *Centruroides vittatus*, are prominent in the southeastern Great Plains (Sissom and Hendrixson 2005, Shelley and Sissom 1995).

The life history information available for these 3 species is highly variable. While many studies have focused on *C. vittatus*, few studies have considered *V. coahuilae*, and, at this time, no studies have been conducted on the life history of *V. russelli*. *Vaejovi coahilae* is a burrowing species but little is known of the life history of *V. coahilae* and the information currently available is mostly the result of captive studies (Francke and Sissom 1984). Furthermore, only partial life history has been obtained from these captive studies because the scorpions frequently die before reaching sexual maturity (Francke and Sissom 1984).

Centruroides vittatus, a non-burrowing species, occurs in a variety of microhabitats in grasslands, deserts, and deciduous and pine forests. It inhabits rock crevices, canyon walls, and volcanic hills. They commonly enter houses and seek refuge under *Yucca* spp. and other available plant material. They occur from sea level to over 1800 m in the Guadalupe and Chisos Mountains of Texas as well as up to 2340 m among the mountains of Coahila, Mexico (Shelley and Sissom 1995).

Centruroides vittatus is also known to climb vegetation. Brown and O'Connell (2000) found that 20-25% of the scorpions they encountered were on vegetation and occurred at a height ranging from 2 cm to >75 cm. However, whether this is a predator avoidance behavior or a foraging response to higher prey abundance is not known (Brown and O'Connell 2000).

Given the terrestrial nature of scorpions, they are likely to be impacted by fires in the grassland systems they occupy. I also suspect that the effects of fire might be variable depending on life history. For example, the affinity for vegetation documented by *Centruroides vittatus* may make them more susceptible to fire than burrowing species, like *V. coahuilae* and *V. russelli*. Therefore, my objective was to examine the effect of seasonality of prescribed fire on the microhabitat selection of *C. vittatus, V. coahuilae,* and *V. russelli* at a site in the southeastern Great Plains. I also compared scorpion abundance, richness, and diversity across fire treatments.

STUDY AREA

Matador Wildlife Management Area

My specific study site is located within the 11,370-ha Matador Wildlife Management Area (WMA) in the central Rolling Plains of Cottle County, Texas (Hall et al. 2007; Figure I.1). The area was purchased in 1959 by the state of Texas with Pittman-Robertson funds and is managed by the Wildlife Division of Texas Parks and Wildlife Department (Richardson et al. 1974). Climate is characterized by dry winters and hot summers. Average annual rainfall is about 56 cm and bimodal with peaks occurring first during May and June and second during September and October (Carlson et al. 1990, Richardson et al. 1974). Topography ranges from riparian plains to gently rolling hills and steep-walled canyons (Richardson et al. 1974). The area is traversed by the confluence of the Middle and South Pease Rivers (Hall et al. 2007, Spears et al. 2002). The dominant soil association on the area is Miles (fine-loamy, mixed, thermic, alfisols) and Springer (coarse-loamy, mixed, thermic, alfisols) with nearly level to strongly sloping, deep, coarse textured to moderately coarse textured soils on outwash plains (Richardson et al. 1974).

The primary woody vegetation found on the Matador WMA includes honey mesquite (*Prosopis glandulosa*), sand sagebrush (*Artemisia filifolia*), shinnery oak (*Quercus havardii*), sand plum (*Prunus angustifolia*), prairie acacia (*Acacia angustissima*), redberry juniper (*Juniperus pinchoti*), eastern cottonwood (*Populus deltoids*), western soapberry (*Sapindus drummondii*), and netleaf hackberry (*Celtiss occidentalis*, Spears et al. 2002). Dominant grasses on the area include sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), purple three-awn (*Aristida purpurea*), little bluestem (*Andropogon scoparius*), Japanese brome (*Bromus japonicus*), and plains bristlegrass (*Setaria leucopila*). Dominant forb species include western ragweed (*Ambrosia psilostachya*), plantain (*Plantago* spp.), common sunflower (*Helianthus annuus*), and lamb's quarters (*Chenopodium album*, Hall 2005).

METHODS

Burning and Experimental Design

My specific study site was located in Headquarters Pasture (Figure I.1) and consisted of 273 ha of sand sagebrush–honey mesquite shrubland. The site is divided into 15 plots, each approximately 400 m^2 in size. There are 5 replicates of the treatment; each replicate consists of 3 plots. These plots are arranged into 5 blocks of 3 plots each. Within a block, plots were randomly assigned to a treatment: summer-burned, winter-burned, and unburned (Figure I.2). Summer-burned plots were burned in August 2005 and 2008. Winter-burned plots were burned in February 2005 and 2009.

Microhabitat Data Collection

I sampled for scorpions during 2-week periods each month from July to September 2008 and May to September 2009. Each sampling period started 1 week before the new moon and ended 1 week after the new moon. Within each sampling period, each plot was intensively searched for 1 person-hour of search time using a blacklight to locate scorpions (Stahnke 1972).

At each scorpion encounter, I assessed microhabitat characteristics using a 10 cm x 10 cm quadrat frame. This quadrat was placed over the area the scorpion occupied when first sighted. Each scorpion was captured. A portable weather station (Kestrel Meters, Sylvin Lake, Michigan, USA) was used to record air temperature, wind speed, and humidity at ground level of the frame. Substrate temperature was recorded using an infrared thermometer (Raynger ST, Raytek, Santa Cruz, California, USA). Inside the frame, percent cover was estimated for rock, bare soil, grass, forbs, woody vegetation, and litter. The combined percentages of vegetation cover could exceed 100% because of the 3-dimensional nature of the vegetation. Vegetation height in the quadrat was measured, however, I didn’t begin collecting vegetation height data until 2009. Estimations were made by the same observer to ensure consistency.

After recording habitat data for the actual scorpion location, I acquired a random location. To acquire a random point, I threw the frame over my shoulder for a distance of approximately 2 to 3 m. At this point, I recorded the same parameters as I did for the actual scorpion locations.

The location of each scorpion was recorded with a global positioning system (GPS; E-trex, Garmin Limited, Olathe, Kansas, USA) to an accuracy of $\leq$ 4 m. Sex, age (juvenile, subadult, or adult), and species were recorded for each scorpion. Prosoma/Mesosoma length, metasoma length, total length, telson/aculus length, and pedipalp length were also recorded for each scorpion. Scorpions were released at the site of capture.

Statistical Analysis

To assess microhabitat selection, actual scorpion points were categorized as “use” and random points were categorized as “availability”. I used Analysis of Variance (ANOVA) in the Statistical Analysis System (SAS Institute, Cary, North Carolina, USA) to compare use versus availability of microhabitat variables for *Centruroides vitattus*, *Vaejovis coahuilae*, and *Vaejovis russelli*. The same comparisons were made for sex and age (= juvenile, subadult, adult) within each species.

I also used ANOVA to compare use among species to determine if scorpions use microhabitat differently and to compare availability to determine if the burning treatments influenced microhabitat availability. Use and availability were analyzed with treatment and period (month/year) as main effects and treatment*period interaction.

For each intensive search within each plot, scorpion species diversity was calculated using both modified Simpson's and Shannon-Wiener diversity indices (Magurran 1988). Shannon's diversity index was calculated as:

$$- \Sigma \, p_i \ln p_i$$

where p_i is the proportion of individuals found in the *i*th species. Modified Simpson's diversity index was calculated as:

$$1 - \Sigma \, p_i^2$$

Data for scorpion abundances (= number of scorpions captured in 1 person-hour of search time in a plot) and diversities were analyzed using Analysis of Variance (ANOVA) in SAS (SAS Institute, Cary, North Carolina, USA) with treatment and period (month/year) as main effects and treatment*period interaction. For all analyses, I used block as a main effect to help control for among block variation. All statistical comparisons were considered significant at $\alpha=0.05$.

RESULTS

Microhabitat Availability

Treatment effects--Substrate temperature was higher in summer-burned than unburned plots (p=0.069) and higher in winter-burned than unburned plots (p=0.017); substrate temperature did not differ significantly between summer-burned and winter-burned plots (p=0.609, Table I.30). Wind speed was higher in summer-burned than unburned plots (p=0.005) and higher in winter-burned than in unburned plots (p=0.059);

wind speed did not differ significantly between summer-burned and winter-burned plots (p=0.280). Percentage of bare ground was higher in summer-burned than unburned plots (p<0.001) or winter-burned plots (p=0.027) and higher in winter-burned than unburned plots (p<0.001). Percentage of grass cover was higher in summer-burned than unburned plots (p=0.013) and higher in winter-burned than unburned plots (p=0.037); percentage of grass did not differ significantly between summer-burned and winter-burned plots (p=0.609). Percentage of forb cover was higher in unburned than in summer-burned (p=0.029) or winter-burned (p<0.001) plots; percentage of forb cover did not differ significantly between summer-burned and winter-burned plots (p=0.242). Percentage of litter cover was higher in unburned than in summer-burned (p<0.001) or winter-burned (p<0.001) plots and higher in winter-burned than summer-burned plots (p=0.024). Air temperature (p=0.901), humidity (p=0.579), percentage of rock (p=0.611), percentage of woody cover (p=0.163), and vegetation height (p=0.440) did not vary among treatments (Table I.30).

Period effects--Substrate temperature differed significantly among all periods (p<0.001) with few exceptions (Table I.31). Substrate temperatures were higher in June 2009 than in July 2008 (p<0.001) and lower in June 2009 than in July 2009 (p=0.022). Substrate temperatures were higher in May 2009 than in September 2009 (p<0.001; Table I.31).

Air temperature differed significantly among all periods (p<0.001) with few exceptions (Table I.31). Air temperatures were higher in August 2008 than in July 2008 (p=0.001) or July 2009 (p=0.001). Air temperatures were higher in September 2008 than in May 2009 (p=0.003). Air temperatures did not differ between July 2008 and July 2009 (p=0.909), June 2009 and May 2009 (p=0.091), or June 2009 and September 2008 (p=0.192; Table I.31).

Wind speed differed significantly among all periods (p<0.001) with few exceptions (Table I.31). Wind speed was lower in August 2008 than in July 2008 (p=0.003), July 2009 (p<0.001), or May 2009 (p=0.010) and higher in August 2008 than in September 2008 (p=0.014). Wind speed was lower in September 2009 than in July 2008 (p=0.004) and 2009 (p=0.020) and higher in September 2009 than in May 2009 (p=0.037). Wind speed was higher in June 2009 than in July 2009 (p<0.001) or May 2009 (p=0.004). Wind speed did not differ between July 2008 and July 2009 (p=0.442), July 2008 and May 2009 (p=0.659), July 2009 and May 2009 (p=0.898), or June 2009 and September 2009 (p=0.645; Table I.31).

Humidity differed significantly among all periods (p<0.001) with few exceptions (Table I.31). Humidity was higher in July 2008 than August 2008 (p=0.051) and higher in June 2009 than July 2009 (p=0.005). Humidity was higher in July 2008 than July 2009 (p=0.068) and higher in September 2009 than in September 2008 (p=0.074). Humidity did not differ between August 2009 and May 2009 ($p=0.286$) or July 2008 and June 2009 ($p=0.189$; Table I.31).

Percentage of bare ground was lower in July 2008 than any other period ($p<0.001$, Table I.31). Percentage of bare ground was lower in August 2008 than in August 2009 ($p<0.001$), July 2009 ($p<0.001$), June 2009 ($p<0.001$), May 2009 ($p<0.001$), and September 2009 ($p=0.030$). Percentage of bare ground was lower in September 2008 than in August 2009 ($p<0.001$), July 2009 ($p<0.001$), June 2009 ($p<0.001$), May 2009 ($p<0.001$), and September 2009 ($p=0.001$). Percentage of bare ground was higher in May 2009 than in July 2009 ($p=0.017$) or June 2009 ($p=0.056$) and higher in May 2009 than in September 2009 ($p=0.031$). Percentage of bare ground was higher in May 2009 than August 2009 ($p=0.074$). Percentage of bare ground did not differ between August 2008 and September 2008 ($p=0.105$), August 2009 and July 2009 ($p=0.369$), August 2009 and June 2009 ($p=0.663$), August 2009 and September 2009 ($p=0.352$), July 2009 and June 2009 ($p=0.760$), July 2009 and September 2009 ($p=0.750$), or June 2009 and September 2009 ($p=0.602$; Table I.31).

Percentage of grass cover was lower in September 2008 than August 2008 ($p=0.0006$), July 2008 ($p<0.0001$) and 2009 ($p=0.010$), June 2009 ($p=0.0006$), and September 2009 ($p=0.024$, Table I.31). Percentage of grass cover was lower in August 2009 than August 2008 ($p=0.019$), July 2008 ($p=0.0007$), and June 2009 ($p=0.010$).

Percentage of grass cover was lower in May 2009 than July 2008 (p=0.015) and June 2009 (p=0.042; Table I.31).

Percentage of forb cover was higher in June 2009 than August 2008 and 2009 (p<0.001), July 2008 and 2009 (p<0.001), September 2008 (p<0.001), and September 2009 (p=0.003, Table I.31). Percentage of forb cover was higher in May 2009 than August 2008 and 2009 (p<0.001), July 2008 and 2009 (p<0.001), September 2008 (p<0.001), and September 2009 (p=0.004). Percentage of forb cover did not differ between June 2009 and May 2009 (p=0.907). Percentage of forb cover was higher in September 2009 than August 2008 (p=0.049; Table I.31).

Percentage of litter cover differed significantly among all periods (p<0.001) with few exceptions. Percentage of litter cover was lower in August 2008 than in July 2008 (p<0.001), higher in August 2009 than in May 2009 (p=0.020), higher in July 2008 than September 2008 (p=0.020), higher in July 2009 than June 2009 (p=0.001), higher in July 2009 than May 2009 (p=0.082), and higher in September 2009 than June 2009 (p=0.032). Percentage of litter cover did not differ between August 2008 and September 2008 (p=0.158), August 2009 and July 2009 (p=0.461), August 2009 and September 2009 (p=0.428), July 2009 and September 2009 (p=0.772), June 2009 and May 2009 (p=0.315), or May 2009 and September 2009 (p=0.259; Table I.31).

Vegetation height was greater in June 2009 than August 2009 (p<0.001), July 2009 (p=0.020), May 2009 (p=0.017), and September 2009 (p=0.004); higher in July

2009 than August 2009 (p=0.002); and greater in May 2009 than August 2009 (p=0.091). Vegetation height did not differ between August 2009 and September 2009 (p=0.439), July 2009 and May 2009 (p=0.552), July 2009 and September 2009 (p=0.191), or May 2009 and September 2009 (p=0.514; Table I.31).

Percentage of rock (p=0.546) and percentage of woody cover (p=0.774) did not vary among sampling periods (Table I.31).

Interactions--I detected a treatment*period interaction for substrate temperature (F=17.38; p<0.001; Table I.32). Substrate temperatures were highest in August 2009 (p≤0.021) and lowest in September 2008 (p≤0.014), May 2009 (p≤0.036), and September 2009 (p≤0.036, Table I.32).

Substrate temperature did not differ by treatment in July 2008 and May 2009 (p≥0.364, Table I.32). In August 2008, substrate temperature did not differ between unburned and winter-burned (p=0.087) plots; however, substrate temperature was higher in summer-burned than unburned (p=0.005) or winter-burned (p<0.001) plots. In September 2008, substrate temperature was higher in unburned than summer-burned (p=0.014) or winter-burned (p<0.001) plots and higher in summer-burned than winter-burned (p<0.001) plots. In June 2009, substrate temperatures did not differ between summer-burned and winter-burned (p=0.060) plots; however, substrate temperature was lower in unburned than summer-burned (p=0.016) or winter-burned (p<0.001). In July 2009, substrate temperature did not differ between summer-burned and unburned plots (p=0.852); however, substrate temperatures were higher in winter-burned (p<0.001) than summer-burned or unburned plots. In August 2009, substrate temperatures did not differ between summer-burned and unburned plots (p=0.468); however, substrate temperatures were higher in winter-burned than summer burned (p<0.001) or unburned (p=0.051) plots. In September 2009, substrate temperatures did not differ between summer-burned and unburned plots (p=0.107) or winter-burned plots (p=0.488); however, substrate temperatures were higher in winter-burned than unburned plots (p=0.013; Table I.32).

I detected a treatment*period interaction for wind speed (F=4.06; p<0.001; Table I.33). Wind speeds were highest in August 2009 (p≤0.003) and lowest in September 2008 (p≤0.045, Table I.33).

Wind speed did not differ by treatment in August 2008, September 2008, and May 2009 (p≥0.145, Table I.33). In July 2008, wind speed did not differ between unburned and winter-burned plots (p=0.145); however, wind speed was higher in summer-burned than unburned (p=0.045) or winter-burned (p<0.001) plots. In June 2009, wind speed did not differ between summer-burned and unburned (p=0.146) plots or summer-burned and winter-burned (0.071) plots; however, wind speed was higher in winter-burned than unburned plots (p=0.002). In July 2009, wind speed did not differ between unburned and winter-burned plots (p=0.977); however, wind speed was lower in summer-burned than unburned (p=0.005) or winter-burned (p=0.004) plots. In August 2009, wind speed did not differ between unburned and winter-burned (p=0.697) plots;

however, wind speed was higher in summer-burned than unburned ($p<0.001$) or winter-burned ($p<0.001$) plots. In September 2009, wind speed did not differ between winter-burned and summer-burned ($p=0.116$) or winter-burned and unburned ($p=0.467$) plots; however, wind speed was higher in summer-burned than unburned ($p=0.016$) plots (Table I.33).

I detected a treatment*period interaction for humidity ($F=3.85$; $p<0.001$; Table I.34). In summer-burned and unburned plots, humidity was highest in September 2009 ($p\leq0.011$) and lowest in May 2009 ($p<0.001$). In winter-burned plots, humidity was highest in September 2008 ($p<0.001$) and lowest in August 2009 ($p\leq0.020$, Table I.34).

Humidity did not differ by treatment in July 2008, May 2009, August 2009, and September 2009 ($p\geq0.077$, Table I.34). In August 2008, humidity did not differ between unburned and winter-burned ($p=0.105$) plots; however, humidity was lower in summer-burned than unburned ($p=0.010$) or winter-burned ($p<0.001$) plots. In September 2008, humidity did not differ between summer-burned and winter-burned ($p=0.278$) plots; however, humidity was lower in unburned plots than summer-burned ($p=0.011$) or winter-burned ($p=0.002$) plots. In June 2009, humidity did not differ between summer-burned and unburned ($p=0.873$) plots; however, humidity was lower in winter-burned than summer-burned ($p=0.018$) or unburned ($p=0.028$) plots. In July 2009, humidity did not differ between summer-burned and unburned ($p=0.540$) plots; however, humidity was lower in winter-burned than summer-burned (p<0.001) or unburned (p=0.012) plots (Table I.34).

I detected a treatment*period interaction for percentage of bare ground (F=4.39; p<0.001; Table I.35). Percentage of bare ground was highest in May 2009 (p≤0.027) and lowest in July 2008 (p≤0.025, Table I.35).

Percentage of bare ground did not differ by treatment in July 2008 (p≥0.562, Table I.35). In August 2008, percent bare ground did not differ between winter-burned and summer-burned (p=0.272) or unburned (p=0.443); however, percent bare ground was higher in summer-burned than unburned (p=0.041) plots. In September 2008, percent bare ground did not differ between unburned and winter-burned (p=0.712) plots; however, summer-burned plots had a higher percentage of bare ground than unburned (p<0.001) and winter-burned (p<0.001) plots. In May 2009, percent bare ground did not differ between summer-burned and winter-burned (p=0.354) plots; however, unburned plots had a lower percentage of bare ground than summer-burned (p<0.001) or winter-burned (p=0.003) plots. In June 2009, percent bare ground did not differ between summer-burned and winter-burned (p=0.114) plots; however, unburned plots had a lower percentage of bare ground than summer-burned (p<0.001) or winter-burned (p<0.001) plots. In July 2009, percent bare ground did not differ between summer-burned and winter-burned (p=0.151) plots; however, unburned plots had a lower percentage of bare ground than summer-burned (p<0.001) or winter-burned (p<0.001) plots. In August

2009, unburned plots had a lower percentage of bare ground than summer-burned ($p<0.001$) and winter-burned ($p<0.001$) plots and summer-burned plots had a lower percentage of bare ground than winter-burned ($p<0.001$) plots. In September 2009, percent bare ground did not differ between summer-burned and winter-burned ($p=0.246$) plots; however, unburned plots had a lower percentage of bare ground than summer-burned ($p<0.001$) or winter-burned ($p=0.012$) plots (Table I.35).

I detected a treatment*period interaction for percent grass cover ($F=2.36$; $p=0.003$; Table I.36). In summer-burned plots, percent grass cover was highest in July 2008 ($p\leq0.044$) and lowest in September 2008 ($p\leq0.026$). In winter-burned plots, percent grass cover was highest in June 2009 ($p\leq0.031$) and lowest in September 2008 ($p\leq0.026$). In unburned plots, percent grass cover was highest in August 2008 ($p\leq0.043$) and lowest in August 2009 ($p\leq0.052$, Table I.36).

Percent grass cover did not differ by treatment in August 2008, May 2009, June 2009, and September 2009 ($p\geq0.110$, Table I.36). In July 2008, percent grass cover did not differ between unburned and winter-burned ($p=0.672$) plots; however, summer-burned plots had a higher percentage of grass cover than unburned ($p=0.014$) or winter-burned ($p=0.030$) plots. In September 2008, percent grass cover did not differ between summer-burned and winter-burned ($p=0.382$) or unburned and winter-burned ($p=0.208$) plots; however, summer-burned plots had a lower percentage of grass cover than unburned ($p=0.026$) plots. In July 2009, percent grass cover did not differ between summer-burned and winter-burned (p=0.291) plots; however, unburned plots had a lower percentage of grass cover than summer-burned (p=0.010) or winter-burned (p<0.001) plots. In August 2009, percent grass cover did not differ between winter-burned and summer-burned (p=0.120) or between winter-burned and unburned (p=0.111) plots; however, unburned plots had a lower percentage of grass cover than did summer-burned (p=0.002) plots (Table I.36).

I detected a treatment*period interaction for percent forb cover (F=2.91; p<0.001; Table I.37). In summer-burned and unburned plots, percent forb cover was highest in June 2009 (p≤0.027) and May 2009 (p≤0.038) and lowest in September 2008 (p≤0.040). In winter-burned plots, percent forb cover was highest in May 2009 (p≤0.013) and lowest in August 2009 (p≤0.011, Table I.37).

Percent forb cover did not differ by treatment in July 2008 and 2009, August 2008, May 2009, and September 2009 (p≥0.087, Table I.37). In September 2008, percent forb cover did not differ between summer-burned and unburned (p=0.700) or unburned and winter-burned (p=0.186); however, winter-burned plots had a higher percentage of forb cover than summer-burned (p=0.037). In June 2009, unburned plots had a higher percentage of forb cover than summer-burned (p=0.006) or winter-burned (p<0.001) plots and summer-burned plots had a higher percentage of forb cover than winter-burned (p=0.011) plots. In August 2009, percent forb cover did not differ between summer-burned and winter-burned (p=0.477) plots; however, unburned plots had a higher percentage of forb cover than summer-burned ($p=0.039$) or winter-burned ($p=0.005$) plots (Table I.37).

I detected a treatment*period interaction for percent litter cover ($F=3.69$; $p<0.001$; Table I.38). Percent litter cover was highest in July 2008 ($p\leq0.043$) and lowest in June 2009 ($p\leq0.021$). Percent litter cover was higher in unburned than in summer-burned or winter-burned plots ($p\leq0.053$, Table I.38).

Percent litter cover did not differ by treatment in August 2008 and September 2008 ($p\geq0.133$, Table I.38). In July 2008, percent litter cover did not differ between winter-burned and summer-burned ($p=0.114$) or unburned ($p=0.144$); however, unburned plots had a higher percentage of litter cover than summer-burned ($p=0.005$) plots. In May 2009, percent litter cover did not differ between winter-burned and summer-burned ($p=0.099$) or unburned ($p=0.086$) plots; however, unburned plots had a higher percentage of litter cover than summer-burned ($p=0.003$) plots. In June 2009, percent litter cover did not differ between summer-burned and winter-burned ($p=0.157$) plots; however, unburned plots had a higher percentage of litter cover than summer-burned ($p<0.001$) or winter-burned ($p=0.017$) plots. In July 2009, percent litter cover did not differ between summer-burned and winter-burned ($p=0.152$) plots; however, unburned plots had a higher percentage of litter cover than summer-burned ($p<0.001$) or winter-burned ($p<0.001$) plots. In August 2009, percent litter cover did not differ between summer-burned and winter-burned ($p=0.143$) plots; however, unburned plots had a higher percentage of litter cover than summer-burned ($p<0.001$) or winter-burned ($p<0.001$) plots. In September 2009, percent litter cover did not differ between summer-burned and winter-burned ($p=0.600$) plots; however, unburned plots had a higher percentage of litter cover than summer-burned ($p<0.001$) or winter-burned ($p=0.001$) plots (Table I.38).

I did not detect a treatment*period interaction for air temperature ($F=1.50$; $p=0.104$), percentage of rock ($F=1.14$; $p=0.316$), percentage of woody cover ($F=0.70$; $p=0.780$), or vegetation height ($F=1.24$; $p=0.275$).

Microhabitat Use

Between species-- During 2008 and 2009, I collected microhabitat data from 194 captures of *Centruroides vittatus* and 1147 captures of *Vaejovis coahuilae*. When comparing the 2 species using only data from the actual locations (excluding random points), 4 differences in habitat use were significant. *Centruroides vittatus* tended to use areas with cooler substrate temperatures ($p=0.006$; Table I.4), cooler air temperatures ($p=0.017$), and a lower percentage of bare ground ($p=0.001$). *Vaejovis coahuilae* used areas with a lower percentage of humidity ($p=0.022$; Table I.4).

Within species--Centruroides vittatus--Age effects-- Juvenile *C. vittatus* tended to use areas with a higher percentage of bare ground ($p=0.083$) than adults of the same species and areas with a lower humidity ($p=0.072$) than subadults of the same species (Table I.9).

Treatment effects-- Use of substrate temperature (p=0.524), air temperature (p=0.853), humidity (p=0.713), percentage of rock (p=1.000), percentage of grass (p=0.280), percentage of forb (p=0.593), percentage of woody (p=0.997), and vegetation height (p=0.467, Table I.11) by *Centruroides vittatus* did not differ by treatment. *Centruroides vittatus* in summer-burned and winter-burned plots used areas with a higher percentage of bare ground (p<0.001) and a lower percentage of litter (p<0.001, Table I.11) than did those in unburned plots. *Centruroides vittatus* in winter-burned plots used areas with higher wind speed (p=0.001) than did those in unburned and summer-burned plots (Table I.11).

Period effects-- *Centruroides vittatus* used the coolest substrate temperatures in September 2009 and used progressively warmer substrate temperatures in May 2009, September 2008, July 2008, June 2009, July 2009, August 2008, and August 2009, respectively (Table I.13). Use of substrate temperature differed significantly (p<0.001) among all periods with few exceptions. Use of substrate temperature did not differ between August 2008 and July 2009 (p=0.677) and between July 2008 and May 2009 (p=0.455). *Centruroides vittatus* used areas with warmer substrate temperatures in August 2009 than in August 2008 (p=0.031), in August 2008 than in June 2009 (p=0.0004) in August 2009 than in July 2009 (p=0.023), and in July 2009 than in June 2009 (p=0.005; Table I.13).

Centruroides vittatus used areas with significantly warmer air temperatures in August 2008, August 2009, July 2008, and July 2009 than in June 2009, May 2009, September 2008, and September 2009 (Table I.13). Air temperatures used in August 2008 were warmer those used in June 2009 ($p<0.001$), May 2009 ($p<0.001$), September 2008 ($p<0.001$), and September 2009 ($p<0.001$). Air temperatures used in August 2009 were warmer than those used in June 2009 ($p=0.001$), May 2009 ($p<0.001$), September 2008 ($p<0.001$), and September 2009 ($p<0.001$). Air temperatures used in July 2008 were warmer than those used in June 2009 ($p<0.001$), May 2009 ($p<0.001$), September 2008 ($p<0.001$), and September 2009 ($p<0.001$). Air temperatures used in July 2009 were warmer than those used in June 2009 ($p<0.001$), May 2009 ($p<0.001$), September 2008 ($p=0.0005$), and September 2009 ($p<0.001$). Air temperatures in September 2009 were cooler than those used in June 2009 ($p=0.005$) and September 2008 ($p=0.001$, Table I.13).

Centruroides vittatus used areas with higher wind speed in August 2009 than in any other period except July 2009 ($p=0.343$, Table I.13). *Centruroides vittatus* also used areas with lower wind speed in August 2008 than in July 2009 ($p<0.001$) and September 2009 ($p=0.005$). *Centruroides vittatus* used areas with lower wind speed in September 2008 than in any other period except September 2009 ($p=0.877$). *Centruroides vittatus* used areas with higher wind speed in July 2009 than in June 2009 ($p=0.034$), May 2009 ($p=0.027$), and September 2009 ($p<0.001$). Areas with higher wind speed were used in

July 2009 than in July 2008 (p=0.001) and in June 2009 than in September 2009 (p=0.028, Table I.13).

Centruroides vittatus used areas with higher humidity in September 2008 than in all other periods except June 2009 (p=0.109, Table I.13) and September 2009 (p=0.463). Scorpions used areas with higher humidity in September 2009 than in all other periods except June 2009 (p=0.074) and September 2008 (p=0.463). Scorpions used areas with lower humidity in August 2008 than in July 2008 (p=0.020) and June 2009 (p=0.001). Scorpions used areas with higher humidity in June 2009 than in August 2009 (p=0.039), in July 2008 than in May 2009 (p=0.013), in June 2009 than in July 2009 (p=0.004), and in June 2009 than in May 2009 (p=0.001, Table I.13).

Centruroides vittatus used areas with a significantly lower percentage of grass cover in September 2008 than in August 2009 (p=0.032), July 2008 (p=0.003), July 2009 (p=0.001), and June 2009 (p=0.002, Table I.13). *Centruroides vittatus* used areas with a significantly lower percentage of grass cover in August 2008 than in July 2008 (p=0.042), July 2009 (p=0.017), and June 2009 (p=0.025, Table I.13).

Centruroides vittatus used areas with a higher percentage of forb cover in May 2009 than in any other period (p≤0.001, Table I.13). *Centruroides vittatus* used areas with a higher percentage of forb cover in July 2008 than in September 2008 (p=0.048) or June 2009 (p=0.036, Table I. 13). *Centruroides vittatus* used areas with a higher percentage of litter cover in August 2008 than in July 2009 (p=0.005) and June 2009 (p=0.006, Table I.13).

Centruroides vittatus used a higher percentage of bare ground in July 2008 than in August 2009 (p=0.022), July 2009 (p<0.001), June 2009 (p<0.001), and May 2009 (p=0.017). *Centruroides vittatus* used areas with a higher percentage of bare ground in September 2008 than in July 2009 (p=0.011) and June 2009 (p=0.012, Table I.13). *Centruroides vittatus* used areas with a significantly higher percentage of bare ground in September 2009 than in August 2008 (p=0.010), July 2008 (p=0.001), May 2009 (p=0.033), and September 2008 (p=0.009, Table I.13). *Centruroides vittatus* used areas with a significantly lower percentage of bare ground in July 2008 than in July 2009 (p=0.006) and June 2009 (p=0.002, Table I.13).

Use of percentage of rock by *Centruroides vittatus* was excluded from analysis because no rock was documented at *C. vittatus* locations (Table I.13). Use of vegetation height (p=0.296) by *Centruroides vittatus* did not differ by period (Table I.13). Use of percentage of woody canopy (p=0.697) by *Centruroides vittatus* did not differ by period (Table I.13).

Interactions-- I detected a treatment*period interaction for use of substrate temperature by *Centruroides vittatus* (F=4.71, p<0.001; Table I.15). *Centruroides vittatus* used areas with the warmest substrate temperatures in winter-burned (p≤0.054) and unburned (p≤0.049) plots in August 2009 and summer-burned plots in August 2008

($p \leq 0.053$). *Centruroides vittatus* used areas with the coolest substrate temperatures in winter-burned, summer-burned, and unburned plots in September 2008 ($p \leq 0.032$), May 2009 ($p \leq 0.020$), and September 2009 ($p \leq 0.045$, Table I.15).

Use of substrate temperature by *Centruroides vittatus* did not differ by treatment in July 2008, May 2009, June 2009, August 2009, and September 2009 ($p \geq 0.065$, Table I.15). In August 2008, use of substrate temperature did not differ between summer-burned plots and unburned plots ($p=0.955$) or between summer-burned plots and winter-burned plots ($p=0.058$); however, *C. vittatus* used areas with warmer substrate temperatures in unburned plots than winter-burned plots ($p=0.050$). In September 2008, use of substrate temperature did not differ between summer-burned plots and unburned plots ($p=0.293$); however, *C. vittatus* used areas with cooler temperatures in winter-burned plots than summer-burned plots ($p=0.006$) and unburned plots ($p<0.001$). In July 2009, use of substrate temperature did not differ between summer-burned plots and unburned plots ($p=0.145$); however, *C. vittatus* used areas with warmer temperatures in winter-burned plots than summer-burned plots ($p=0.007$) and unburned plots ($p<0.001$; Table I.15).

I detected a treatment*period interaction for use of air temperature by *Centruroides vittatus* ($F=3.23$, $p<0.001$, Table I.17). In summer-burned plots, *C. vittatus* used areas with the warmest air temperatures in August 2008 ($p \leq 0.011$) and areas with the coolest air temperatures in September 2009 ($p \leq 0.021$). In unburned plots, *C. vittatus* used areas with the warmest air temperatures in July 2008 (p≤0.033) and areas with the coolest air temperatures in June 2009 (p≤0.022). In winter-burned plots, *C. vittatus* used areas with the warmest air temperatures in August 2009 (p≤0.023) and areas with the coolest air temperatures in September 2009 (p≤0.014, Table I.17).

Use of air temperature by *Centruroides vittatus* did not differ by treatment in August 2008 and 2009, September 2008 and 2009, May 2009, and July 2009 (p≥0.158, Table I.17). In July 2008, use of air temperature did not differ between summer-burned and unburned (p=0.060) plots or between summer-burned and winter-burned (p=0.783); however, *C. vittatus* used areas with warmer air temperatures in unburned plots than in winter-burned plots (p=0.020). In June 2009, use of air temperature did not differ between summer-burned plots and winter-burned plots (p=0.192); however, *C. vittatus* used areas with cooler air temperatures in unburned plots (p<0.001) than in summer-burned plots or winter-burned plots (Table I.17).

I detected a treatment*period interaction for use of wind speed by *Centruroides vittatus* (F=2.22, p=0.009; Table I.19). In summer-burned plots, *C. vittatus* used areas with the highest wind speed in July 2009 (p≤0.017) and areas with the lowest wind speed in September 2009 (p≤0.015). In winter-burned plots, *C. vittatus* used areas with the highest wind speed in August 2009 (p≤0.054) and areas with the lowest wind speed in September 2008 (p≤0.025). In unburned plots, *C. vittatus* used areas with the highest wind speed in August 2009 ($p \leq 0.015$) and areas with the lowest wind speed in September 2008 ($p \leq 0.003$, Table I. 19).

Use of wind speed by *Centruroides vittatus* did not differ by treatment in July 2008, August 2008 and 2009, September 2008 and 2009, and May 2009 ($p \geq 0.121$, Table I.19). In May 2009, use of wind speed did not differ between summer-burned plots and unburned plots ($p=0.461$) or summer-burned plots and winter-burned plots ($p=0.068$); however, *C. vittatus* used areas with lower wind speed in unburned plots than in winter-burned plots ($p=0.020$). In June 2009, use of wind speed did not differ between summer-burned plots and unburned plots ($p=0.762$); however, *C. vittatus* used areas with higher wind speed in winter-burned plots than in summer-burned ($p=0.009$) and unburned ($p<0.001$) plots. In July 2009, use of wind speed did not differ between summer-burned and unburned ($p=0.086$) or unburned and winter-burned ($p=0.182$) plots; however, *C. vittatus* used areas with higher wind speed in summer-burned than unburned ($p=0.005$) plots (Table I.19).

I detected a treatment*period interaction for use of humidity by *Centruroides vittatus* ($F=1.82$, $p=0.039$; Table I.21). In summer-burned plots, *C. vittatus* used areas with the highest humidity in September 2009 ($p \leq 0.039$) and areas with the lowest humidity in May 2009 ($p \leq 0.035$). In winter-burned plots, *C. vittatus* used areas with the highest humidity in September 2008 ($p \leq 0.037$) and areas with the lowest humidity in August 2009 ($p \leq 0.040$). In unburned plots, *C. vittatus* used areas with the highest humidity in September 2008 (p≤0.055) and areas with the lowest humidity in May 2009 (p≤0.018, Table I.21).

Use of humidity by *Centruroides vittatus* did not differ by treatment in August 2008 and 2009 and September 2008 and 2009 (p≥0.084, Table I.21). In July 2008, use of humidity did not differ between summer-burned and unburned plots (p=0.476) or between summer-burned and winter-burned plots (p=0.293); however, *C. vittatus* used areas with higher humidity in winter-burned plots than in unburned plots (p=0.047). In May 2009, use of humidity did not differ between summer-burned and unburned plots (p=0.164) or between unburned plots and winter-burned plots (p=0.101); however, *C. vittatus* used areas with lower humidity in summer-burned plots than in winter-burned plots (p=0.030). In June 2009, use of humidity did not differ between summer-burned plots and unburned plots (p=0.355) or between summer-burned plots and winter-burned plots (p=0.553); however, *C. vittatus* used areas with lower humidity in unburned plots than in winter-burned plots (p=0.034). In July 2009, use of humidity did not differ between summer-burned plots and unburned plots (p=0.443) or between summer-burned plots and winter-burned plots (p=0.216); however, *C. vittatus* used areas with higher humidity in unburned plots than in winter-burned plots (p=0.011; Table I.21).

I detected a treatment*period interaction for use of percentage of litter cover by *Centruroides vittatus* (F=1.89, p=0.030; Table I.27). In summer-burned plots, *C. vittatus* used areas with a lower percentage of litter cover in August 2009 (p≤0.045), July 2009

($p \leq 0.048$), and June 2009 ($p \leq 0.028$). In unburned plots, use of percentage of litter cover did not differ significantly by in any period ($p \geq 0.193$). In winter-burned plots, *C. vittatus* used areas with a lower percentage of litter cover in July 2009 ($p \leq 0.043$), June 2009 ($p \leq 0.047$), and May 2009 ($p \leq 0.041$, Table I.27).

Use of percentage of litter cover by *Centruroides vittatus* did not differ by treatment in July 2008 and September 2008 and 2009 ($p \geq 0.077$, Table I.27). In August 2008, use of percentage of litter cover did not differ between summer-burned plots and unburned plots ($p=0.667$) or unburned plots and winter-burned plots ($p=0.129$); however, *C. vittatus* used areas with a lower percentage of litter cover ($p=0.051$) in summer-burned plots than in winter-burned plots. In May 2009, use of percentage of litter cover did not differ between summer-burned and unburned ($p=0.066$) or winter-burned ($p=0.772$); however, *C. vittatus* used areas with a higher percentage of litter cover in unburned than in winter-burned plots ($p<0.001$). In June 2009, use of percentage of litter cover did not differ between summer-burned and winter-burned plots ($p=0.668$); however, *C. vittatus* used areas with a higher percentage of litter cover in unburned plots than in summer-burned ($p=0.052$) and winter-burned ($p=0.027$) plots. In July 2009, use of percentage of litter cover did not differ between summer-burned and unburned ($p=0.166$) plots or summer-burned and winter-burned ($p=0.820$) plots; however, *C. vittatus* used areas with a higher percentage of litter cover in unburned than in winter-burned ($p=0.043$) plots. In August 2009, use of percentage of litter did not differ between summer-burned and winter-burned (p=0.995) plots or unburned and winter-burned (p=0.098) plots; however, *C. vittatus* used a higher percentage of litter cover in unburned plots than in summer-burned (p=0.039) plots (Table I.27).

I did not detect a treatment*period interaction for use of percent of bare ground (F=1.40, p=0.156), percent grass cover (F=1.27, p=0.234), percent forb cover (F=1.33, p=0.193), percent woody cover (F=0.42, p=0.967), or vegetation height (F=0.52, p=0.837) by *Centruroides vittatus*.

Vaejovis coahuilae--Sex effects--Two differences in habitat use were significant between the sexes of *Vaejovis coahuilae*. Relative to females, males tended to used areas with warmer substrate temperatures (p=0.008), warmer air temperatures (p=0.007) and a higher percentage of litter (p=0.065; Table I.8).

Age effects-- Juvenile *V. coahuilae* tended to use areas with cooler substrate temperatures than adults (p<0.001) and subadults (p<0.001) of the same species; adults and subadults did not differ significantly in their use of substrate temperature. Juvenile *V. coahuilae* tended to use areas with cooler air temperatures than adults (p<0.001) and subadults (p<0.001); adults and subadults did not differ significantly in their use of air temperature. Juvenile *V. coahuilae* also tended to use areas with a higher percentage of bare ground than subadults of the same species (p=0.076). Subadult *V. coahuilae* tended to use areas with lower wind speed than juveniles (p=0.040) and adults (p<0.001); juveniles and adults did not differ significantly in their use of wind speed. Subadults also tended to use areas with lower humidity than adults of the same species (p=0.072; Table I.10).

Treatment effects-- Use of air temperature (p=0.610), wind speed (p=0.068), humidity (p=0.215), percentage of rock (p=0.199), percentage of forb (p=0.235), percentage of woody (p=0.902), and vegetation height (p=0.520, Table I.12) by *Vaejovis coahuilae* did not differ by treatment. *Vaejovis coahuilae* in winter-burned and summer-burned plots used areas with a higher percentage of bare ground (p<0.001), a higher percentage of grass (p<0.001), and a lower percentage of litter (p<0.001) than did those in unburned plots. *Vaejovis coahuilae* in winter-burned plots used areas with warmer substrate temperatures (p=0.042, Table I.12) than those in unburned and summer-burned plots.

Period effects-- Use of substrate temperature (p<0.001) by *Vaejovis coahuilae* differed by period (Table I.14). Use of substrate temperature differed significantly (p<0.001) among all periods with few exceptions. *Vaejovis coahuilae* used areas with warmer temperatures in August 2008 than in July 2009 (p=0.007) and used areas with warmer temperatures in July 2009 than in June 2009 (p=0.028, Table I.14).

Use of substrate temperature by *Vaejovis coahuilae* differed significantly (p<0.001) among all periods with few exceptions (Table I.14). *Vajeovis coahuilae* used areas with higher air temperatures in August 2008 than in July 2008 (p<0.001), in June 2009 than in May 2009 (p=0.036), and in September 2008 than in May 2009 (p=0.034).

Use of air temperature did not differ between July 2008 and July 2009 (p=0.670) or between June 2009 and September 2008 (p=0.837, Table I.14).

Vaejovis coahuilae used areas with higher wind speed in August 2009 than in any other period (p<0.001, Table I.14). *Vaejovis coahuilae* used areas with significantly lower wind speed in September 2008 than in any other period (p<0.001) except August 2008 (p=0.070). *Vaejovis coahuilae* used areas with lower wind speed in August 2008 than in July 2008 (p=0.001), July 2009 (p<0.001), June 2009 (p<0.001), and September 2009 (p<0.001). *Vaejovis coahuilae* used areas with higher wind speed in June 2009 than in July 2008 (p<0.001) and July 2009 (p<0.001). *Vaejovis coahuilae* used areas with higher wind speed in June 2009 than in May 2009 (p=0.008). Use of wind speed did not differ between July 2008 and July 2009 (p=0.764) or May 2009 (p=0.729). Use of wind speed did not differ between September 2009 and July 2008 (p=0.065), July 2009 (p=0.095), June 2009 (p=0.195), or May 2009 (p=0.213). Use of wind speed did not differ between July 2009 and May 2009 (p=0.894, Table I.14).

Vaejovis coahuilae used areas with higher humidity in July 2009 than in August 2008 (p=0.007), in August 2009 than in May 2009 (p=0.041), in June 2009 than in July 2009 (p=0.014), and in September 2009 than in September 2008 (p=0.019, Table I.14). Use of humidity did not differ between July 2008 and July 2009 (p=0.183) or between July 2008 and June 2009 (p=0.182, Table I.14).

Vajeovis coahuilae used areas with a lower percentage of bare ground in August 2008 than in August 2009 (p<0.001), July 2009 (p<0.001), June 2009 (p<0.001), May 2009 (p<0.001), and September 2009 (p=0.005) and areas with a higher percentage of bare ground in August 2008 than in July 2008 (p<0.001, Table I.14). *Vaejovis coahuilae* used areas with a lower percentage of bare ground in July 2008 than in any other period: August 2008 (p<0.001), August 2009 (p<0.001), July 2009 (p<0.001), June 2009 (p<0.001), May 2009 (p<0.001), September 2008 (p=0.001), and September 2009 (p<0.001). *Vaejovis coahuilae* used areas with a lower percentage of bare ground in September 2008 than in August 2009 (p<0.001), July 2009 (p<0.001), June 2009 (p<0.001), May 2009 (p<0.001), and September 2009 (p=0.006). Use of percentage of bare ground did not differ between August 2008 and September 2008 (p=0.979); August 2009 and July 2009, (p=0.270), June 2009 (p=0.513), May 2009 (p=0.108), or September 2009 (p=0.814); July 2009 and June 2009 (p=0.834), May 2009 (p=0.407), or September 2009 (p=0.616); June 2009 and May 2009 (p=0.367) or September 2009 (p=0.778); and May 2009 and September 2009 (p=0.278, Table I.14).

Vaejovis coahuilae used areas with a significantly higher percentage of forb cover (p<0.001) in May 2009 than any other period except June 2009 (p=0.028, Table I.14). *Vaejovis coahuilae* used areas with a higher percentage of forb cover in June 2009 than in August 2008 (p<0.001), August 2009 (p<0.001), July 2008 (p=0.008), July 2009 (p<0.001), September 2008 (p=0.032), and September 2009 (p=0.003). *Vaejovis* *coahuilae* used areas with a higher percentage of forb cover in September 2008 than in August 2008 (p=0.040) or July 2009 (p=0.028, Table I.14).

Vaejovis coahuilae used areas with a higher percentage of litter cover in July 2008 than in August 2008 (p=0.003), in August 2009 than in June 2009 (p=0.006), in August 2009 than in May 2009 (p=0.018), and in September 2008 than in September 2009 (p<0.001, Table I.14). Use of percentage of litter cover did not differ between August 2008 and September 2008 (p=0.251); August 2009 and July 2009 (p=0.288) or September 2009 (p=0.262); July 2009 and June 2009 (p=0.065), May 2009 (p=0.113), or September 2009 (p=0.697); June 2009 and May 2009 (p=0.990) or September 2009 (0.278); and May 2009 and September 2009 (p=0.327, Table I.14).

Vaejovis coahuilae used areas with higher vegetation in June 2009 than August 2009 (p<0.001), July 2009 (p=0.003), and September 2009 (p=0.028, Table I.14). Use of vegetation height did not differ between August 2009 and July 2009 (p=0.233), May 2009 (p=0.081), or September 2009 (p=0.338); July 2009 and May 2009 (p=0.366) or September 2009 (p=0.880); June 2009 and May 2009 (p=0.126); and May 2009 and September 2009 (p=0.540, Table I.14).

Use of percentage of rock (p=0.084) by *Vaejovis coahuilae* did not differ by period (Table I.14). Use of percentage of grass cover (p=0.451) by *Vaejovis coahuilae* did not differ by period (Table I.14). Use of percentage of woody cover (p=0.255) by *Vaejovis coahuilae* did not differ by period (Table I.14).

Interactions--I detected a treatment*period interaction for use of substrate temperature by *Vaejovis coahuilae* (F=5.17, p<0.001; Table I.16). *Vaejovis coahuilae* used areas with the warmest substrate temperatures in August 2009 (p≤0.019) and areas with the coolest substrate temperatures in September 2008 (p≤0.010), May 2009 (p≤0.051), and September 2009 (p≤0.051, Table I.15).

Use of substrate temperature by *Vaejovis coahuilae* did not differ by treatment in July 2008 and May 2009 (p≥0.157, Table I.16). In August 2008, use of substrate did not differ between unburned and winter-burned plots (p=0.935); however, *V. coahuilae* used areas with warmer substrate temperatures in summer-burned plots than unburned (p=0.002) plots and winter-burned (p=0.007) plots. In September 2008, *V. coahuilae* used areas with warmer substrate temperatures in unburned than in summer-burned (p=0.008) plots, areas with warmer substrate temperatures in summer-burned than in winter-burned (p=0.005), and areas with warmer substrate temperatures in unburned than in winter-burned (p<0.001) plots. In June 2009, use of substrate temperature did not differ between summer-burned and unburned plots (p=0.326); however, *V. coahuilae* used areas with warmer substrate temperatures in winter-burned than summer-burned (p=0.003) and unburned (p=0.001) plots. In July 2009, use of substrate temperature did not differ between summer-burned and unburned (p=0.154); however, *V. coahuilae* used areas with warmer substrate temperatures in winter-burned than summer-burned (p<0.001) and unburned (p=0.050) plots. In August 2009, use of substrate temperature did not differ between summer-burned and unburned (p=0.450) or unburned and winter-burned (p=0.109) plots; however, *V. coahuilae* used areas with warmer substrate temperatures in winter-burned than summer-burned (p=0.019) plots. In September 2009, use of substrate temperature did not differ between summer-burned and winter-burned (p=0.672) plots; however, *V. coahuilae* used areas with cooler substrate temperatures in unburned plots than in summer-burned (p=0.030) and winter-burned (p=0.006) plots (Table I.16).

I detected a treatment*period interaction for use of air temperature by *Vaejovis coahuilae* (F=2.25, p=0.005; Table I.18). *Vaejovis coahuilae* used areas with the warmest air temperatures in August 2008 (p≤0.024) and August 2009 (p≤0.002). *Vaejovis coahuilae* used areas with the coolest air temperatures in September 2009 (p≤0.040, Table I.18).

Use of air temperature by *Vaejovis coahuilae* did not differ by treatment in July 2008, May 2009, August 2009, and September 2009 (p≥0.156, Table I.18). In August 2008, use of air temperature did not differ between summer-burned and winter-burned plots (p=0.337) or unburned and winter-burned plots (p=0.318); however, *V. coahuilae* used areas with warmer air temperatures in summer-burned than unburned plots (p=0.024). In September 2008, use of air temperature did not differ between summer-burned and unburned plots (p=0.127) or between summer-burned and winter-burned plots (p=0.410); however, *V. coahuilae* used areas with warmer air temperatures in unburned than winter-burned plots (p=0.051). In June 2009, use of air temperature did not differ between summer-burned and winter-burned plots (p=0.115); however, *V. coahuilae* used areas with warmer air temperatures in unburned than summer-burned (p=0.020) or winter-burned (p<0.001) plots. In July 2009, use of air temperature did not differ between unburned and summer-burned (p=0.227) or unburned and winter-burned (p=0.531) plots; however, *V. coahuilae* used areas with warmer air temperatures in winter-burned than summer-burned (p=0.045) plots (Table I.18).

I detected a treatment*period interaction for use of wind speed by *Vaejovis coahuilae* (F=3.73, p<0.001; Table I.20). *Vaejovis coahuilae* used areas with the highest wind speeds in August 2009 (p≤0.012) and areas with the lowest wind speeds in September 2008 (p≤0.051, Table I.20).

Use of wind speed by *Vaejovis coahuilae* did not differ by treatment in August 2008, September 2008 and 2009, May 2009, and June 2009 (p≥0.128, Table I.20). In July 2008, use of wind speed did not differ between unburned and winter-burned (p=0.771) plots; however, *V. coahuilae* used areas with higher wind speed in summer-burned than unburned (p=0.002) or winter-burned (p<0.001) plots. In July 2009, use of wind speed did not differ between unburned and winter-burned (p=0.447) plots; however, *V. coahuilae* used areas with lower wind speed in summer-burned than unburned (p<0.001) or winter-burned (p<0.001) plots. In August 2009, use of wind speed did not differ between unburned and winter-burned (p=0.876) plots; however, *V. coahuilae* used areas with higher wind speed in summer-burned than in unburned (p=0.004) or winter-burned (p=0.002) plots (Table I.20).

I detected a treatment*period interaction for use of humidity by *Vaejovis coahuilae* (F=3.97, p<0.001; Table I.22). In summer-burned and unburned plots, *V. coahuilae* used areas with the highest humidity in September 2009 (p≤0.005). In winter-burned plots, *V. coahuilae* used areas with the highest humidity in September 2008 (p<0.001). *Vaejovis coahuilae* used areas with the lowest humidity in August 2009 (p≤0.009) and May 2009 (p≤0.030, Table I.22).

Use of humidity by *Vaejovis coahuilae* did not differ by treatment in July 2008, May 2009, August 2009, and September 2009 (p≥0.206, Table I.22). In August 2008, use of percentage of humidity did not differ between unburned and winter-burned (p=0.380) plots; however, *V. coahuilae* used areas with a lower percentage of humidity in summer-burned than in unburned (p=0.004) or winter-burned (p<0.001) plots. In September 2008, use of percentage of humidity did not differ between summer-burned and winter-burned (p=0.180) plots; however, *V. coahuilae* used areas with a lower percentage of humidity in unburned than summer-burned (p=0.003) or winter-burned (p<0.001) plots. In June 2009, use of percentage of humidity did not differ between summer-burned and unburned (p=0.264) plots; however, *V. coahuilae* used areas with a lower percentage of humidity in winter-burned than in summer-burned (p=0.002) or unburned (p<0.001) plots. In July 2009, use of percentage of humidity did not differ between summer-burned and unburned

($p=0.512$) or unburned and winter-burned ($p=0.078$) plots; however, *V. coahuilae* used areas with a higher percentage of humidity in summer-burned than in winter-burned ($p=0.007$) plots (Table I.22).

I detected a treatment*period interaction for use of percentage of bare ground by *Vaejovis coahuilae* ($F=2.11$, $p=0.010$; Table I.23). In summer-burned plots, *V. coahuilae* used areas with the largest percentage of bare ground in September 2009 ($p \leq 0.021$). In winter-burned plots, *V. coahuilae* used areas with the largest percentage of bare ground in June 2009 ($p<0.001$). In unburned plots, *V. coahuilae* used areas with the largest percentage of bare ground in May 2009 ($p \leq 0.044$). *Vaejovis coahuilae* used areas with the smallest percentage of bare ground in July 2008 ($p \leq 0.001$, Table I.23).

Use of percentage of bare ground by *Vaejovis coahuilae* did not differ by treatment in July 2008 and May 2009 ($p \geq 0.064$, Table I.23). In August 2008, use of percentage of bare ground did not differ between unburned and winter-burned ($p=0.298$) or summer-burned and winter-burned ($p=0.080$) plots; however, *V. coahuilae* used areas with a higher percentage of bare ground in summer-burned than unburned ($p=0.001$). In September 2008, use of percentage of bare ground did not differ between winter-burned and unburned ($p=0.782$) or summer-burned ($p=0.076$); however, *V. coahuilae* used areas with a higher percentage of bare ground in summer-burned than unburned ($p=0.052$) plots. In June 2009, use did not differ between summer-burned and unburned ($p=0.197$) or winter-burned (0.055); however, *V. coahuilae* used areas with a higher percentage of bare ground in winter-burned than unburned (p=0.005) plots. In July 2009, use did not differ between summer-burned and winter-burned (p=0.588) plots; however, *V. coahuilae* used areas with a lower percentage in unburned plots than in summer-burned (p<0.001) or winter-burned (p<0.001) plots. In August 2009, use did not differ between summer-burned and winter-burned (p=0.119) plots; however, *V. coahuilae* used areas with a lower percentage of bare ground in unburned plots than in summer-burned (p<0.001) or winter-burned (p<0.001) burned plots. In September 2009, use did not differ between summer-burned and winter-burned (p=0.239) plots; however, *V. coahuilae* used areas with a lower percentage of bare ground in unburned than in summer-burned (p=0.002) or winter-burned (p=0.045) plots (Table I.23).

I detected a treatment*period interaction for use of percentage of rock by *Vaejovis coahuilae* (F=2.15, p=0.008; Table I.24). *Vaejovis coahuilae* used areas with a higher percentage of rock in winter-burned plots in July 2008 than in any treatment in any period (p≤0.004). However, use did not differ between any other treatments in any other periods (p≥0.555, Table I.24).

Use of percentage of rock by *Vaejovis coahuilae* did not differ by treatment in May 2009, June 2009, July 2009, August 2008 and 2009, and September 2008 and 2009 (p≥0.591, Table I.24). In July 2008, use did not differ between summer-burned and unburned (p=0.997) plots; however, *V. coahuilae* used areas with a higher percentage in winter-burned than summer-burned (p<0.001) or unburned (p<0.001) plots (Table I.24).

I detected a treatment*period interaction for use of percentage of grass cover by *Vaejovis coahuilae* (F=2.58, p=0.001; Table I.25). In summer-burned plots, *V. coahuilae* used areas with the highest percentage of grass cover in June 2009 ($p \leq 0.021$) and areas with the lowest percentage of grass cover in September 2008 ($p \leq 0.021$). In winter-burned plots, *V. coahuilae* used areas with the highest percentage of grass cover in September 2009 ($p \leq 0.004$) and areas with the lowest percentage of grass cover in May 2009 ($p \leq 0.046$). In unburned plots, *V. coahuilae* used areas with the highest percentage of grass cover in July 2008 ($p \leq 0.001$) and areas with the lowest percentage of grass cover in August 2009 ($p \leq 0.053$). *Vaejovis coahuilae* used areas with the highest percentage of grass cover in winter-burned plots in September 2009 ($p \leq 0.047$) and areas with the lowest percentage of grass cover in winter-burned plots in August 2009 ($p \leq 0.022$, Table I.25).

Use of percentage of grass cover by *Vaejovis coahuilae* did not differ by treatment in July 2008, August 2008, May 2009, and June 2009 ($p \geq 0.068$, Table I.25). In September 2008, use of percentage of grass cover did not differ between summer-burned and unburned (p=0.899) plots; however, *V. coahuilae* used areas with a higher percentage of grass cover in winter-burned than summer-burned (p=0.017) or unburned (p=0.013) plots. In July 2009, use of percentage of grass cover did not differ between summer-burned and unburned (p=0.575) or summer-burned and winter-burned (p=0.068) plots; however, *V. coahuilae* used areas with a higher percentage of grass cover in winter-burned than in unburned (p=0.033) plots. In August 2009, use did not differ between summer-burned and winter-burned (p=0.798) plots; however, *V. coahuilae* used areas with a higher percentage of grass cover in winter-burned than in summer-burned or unburned plots (p<0.001). In September 2009, use of percentage of grass cover did not differ between summer-burned and unburned (p=0.188) or summer-burned and winter-burned (p=0.211) plots; however, *V. coahuilae* used areas with a higher percentage of grass cover in winter-burned than unburned (p=0.006) plots (Table I.25).

I detected a treatment*period interaction for use of percentage of forb cover by *Vaejovis coahuilae* (F=2.91, p<0.001; Table I.26). In summer-burned and unburned plots, *V. coahuilae* used areas with the highest percentage of forb cover in June 2009 (p≤0.018) and May 2009 (p≤0.021). In winter-burned plots, *V. coahuilae* used areas with the highest percentage of forb cover in May 2009 (p≤0.053) and September 2008 (p≤0.020). *Vaejovis coahuilae* used areas with the lowest percentage of forb cover in summer-burned plots in September 2009 (p≤0.003), in winter-burned plots in August 2008 (p≤0.018), and in unburned plots in July 2009 (p≤0.004, Table I.26).

Use of percentage of forb cover by *Vaejovis coahuilae* did not differ by treatment in July 2008 and 2009 and September 2009 (p≥0.120, Table I.26). In August 2008, use of percentage of forb cover did not differ between summer-burned and unburned (p=0.249) or unburned and winter-burned (p=0.290) plots; however, *V. coahuilae* used areas with a higher percentage of forb cover in summer-burned than in winter-burned (p=0.032) plots.

In September 2008, use of percentage of forb cover did not differ between summer-burned and unburned (p=0.148) or summer and winter-burned (p=0.125) plots; however, *V. coahuilae* used areas with a higher percentage of forb cover in winter-burned than in summer-burned (p<0.001) plots. In May 2009, use of percentage of forb cover did not differ between summer-burned and unburned (p=0.294) or summer-burned and winter-burned (p=0.457) plots; however, *V. coahuilae* used areas with a higher percentage of forb cover in summer-burned than in winter-burned (p=0.021) plots. In June 2009, use did not differ between summer-burned and unburned (p=0.940) plots; however, *V. coahuilae* used areas with a lower percentage of forb cover in winter-burned than in summer-burned (p<0.001) or unburned (p=0.008) plots. In August 2009, use did not differ between summer-burned and unburned (p=0.120) and summer-burned and winter-burned (p=0.700) plots; however, *V. coahuilae* used areas with a higher percentage of forb cover in unburned than in winter-burned (p=0.048) plots (Table I.26).

I detected a treatment*period interaction for use of percentage of litter cover by *Vaejovis coahuilae* (F=3.80, p<0.001; Table I.28). In summer-burned plots, winter-burned plots, and unburned plots, *V. coahuilae* used areas with the highest percentage of litter cover in July 2008 (p≤0.023). In summer-burned plots and unburned plots, *V. coahuilae* used areas with the lowest percentage of litter cover in May 2009 (p≤0.039). In winter-burned plots, *V. coahuilae* used areas with the lowest percentage of litter cover in September 2009 (p≤0.008, Table I.28).

Use of percentage of litter cover by *Vaejovis coahuilae* did not differ by treatment in July 2008 (p≥0.595, Table I.28). In August 2008, use did not differ between summer-burned and winter-burned (p=0.289) plots; however, *V. coahuilae* used areas with a higher percentage of litter cover in unburned than summer-burned (p<0.001) or winter-burned (p=0.050) plots. In September 2008, *V. coahuilae* used areas with a higher percentage of litter cover in unburned than in summer-burned (p=0.034) plots, a higher percentage of litter cover in summer-burned than in winter -urned (p=0.028) plots, and a higher percentage of litter cover in unburned than in winter-burned (p<0.001) plots. In May 2009, use did not differ between winter-burned and summer-burned (p=0.055) or unburned (p=0.532) plots; however, *V. coahuilae* used areas with a higher percentage of litter cover in unburned than in summer-burned (p=0.039) plots. In June 2009, use did not differ between summer-burned and winter-burned (p=0.407) plots; however, *V. coahuilae* used areas with a higher percentage of litter cover in unburned plots than in summer-burned (p=0.002) or winter-burned (p=0.011) plots. In July 2009, use did not differ between summer-burned and winter-burned (p=0.449) plots; however, *V. coahuilae* used areas with a lower percentage of litter cover in winter-burned plots than in summer-burned (p<0.001) or unburned (p<0.001) plots. In August 2009, use did not differ between summer-burned and winter-burned (p=0.394) plots; however, *V. coahuilae* used areas with a higher percentage of litter cover in unburned plots than in summer-burned (p<0.001) or winter-burned (p<0.001) plots. In September 2009, use did not differ between summer-burned and winter-burned (p=0.596) plots; however, *V. coahuilae* used areas with a higher percentage of litter cover in unburned plots than in summer-burned (p<0.001) or winter-burned (p<0.001) plots (Table I.28).

I detected a treatment*period interaction for use of vegetation height by *Vaejovis coahuilae* (F=1.99, p=0.046; Table I.29). *Vaejovis coahuilae* used areas with the highest vegetation height in summer-burned plots in June 2009 (p≤0.037) and areas with the lowest vegetation height in unburned plots in August 2009 (p≤0.049). Use of vegetation height did not differ by period in winter-burned plots (p≥0.095, Table I.29).

Vegetation height used by *Vaejovis coahuilae* did not differ by treatment in May 2009, July 2009, and September 2009 (p≥0.068, Table I.29). In August 2009, use of vegetation height did not differ between summer-burned and unburned (p=0.340) or summer-burned and winter-burned (p=0.106) plots; however, *V. coahuilae* used areas with taller vegetation in winter-burned than summer-burned (p=0.009) plots. In June 2009, use of vegetation height did not differ between summer-burned and unburned (p=0.203) or summer-burned and winter-burned (p=0.650); however, *V. coahuilae* used areas with taller vegetation in summer-burned than in winter-burned (p=0.020) plots (Table I.29).

I did not detect a treatment*period interaction for use of percent woody cover (F=0.77, p=0.703) by *Vaejovis coahuilae*.

Microhabitat Selection

Between species--During 2008 and 2009, I collected microhabitat data from 194 captures of *Centruroides vittatus*, 1147 captures of *Vaejovis coahuilae*, and 35 captures of *Vaejovis russelli*. When comparing the actual scorpion locations with the random locations within a species, *Centruroides vittatus* did not display selection for any aspects of its microhabitat (Table I.1). *Vaejovis coahuilae* only displayed selection for 1 aspect of its microhabitat: a higher percentage of bare ground (p=0.010; Table I.2). *Vaejovis russelli* marginally displayed selection for only 1 aspect of its microhabitat: a higher percentage of bare ground (p=0.067; Table I.3). Because of the small number of captures, the microhabitat data collected from *V. russelli* was excluded from further analyses.

Within species--Sex effects-- Males and females generally selected similar habitats. *Centruroides vittatus* displayed no differences in microhabitat selection between the sexes (Table I.5). While female *Vaejovis coahuilae* did not display selection for any aspects of its microhabitat (Table I.6), male *V. coahuilae* selected for areas with a higher percentage of bare ground (p=0.008) and a lower percentage of grass (p=0.068; Table I.7).

Age effects-- Within a species, adults, subadults, and juveniles generally selected similar habitats. *Centruroides vittatus* displayed no differences in microhabitat selection among age groups. *Vaejovis coahuilae* subadults and juveniles also displayed no differences in microhabitat selection while adults selected for a higher percentage of bare ground (p=0.004).

Scorpion Abundance and Diversity

Treatment effects--Fewer *C. vittatus* were captured in summer-burned plots than in unburned (p=0.024) and winter-burned (p=0.044) plots (Table I.39). Captures of *C. vittatus* did not differ between unburned and winter-burned plots (p=0.799). *Vaejovis coahuilae* captures varied among treatments (p=0.002). More *V. coahuilae* were captured in summer-burned plots than in unburned (p<0.001) or winter-burned (p=0.085). More *V. coahuilae* were captured in winter-burned plots than in unburned plots (p=0.067). More total scorpions were captured in summer-burned plots than in unburned plots (p=0.006) and in winter-burned plots than in unburned plots (p=0.071). Total captures did not differ between summer-burned and winter-burned plots (p=0.311, Table I.39).

Both modified Simpson's (Mod D) and Shannon-Weinter (H') were greater for unburned plots relative to summer-burned plots (Mod D, p=0.004; H', p=0.004, Table I.39) and greater for winter-burned plots relative to summer-burned plots (Mod D, p=0.073; H', p=0.057). Both diversity indices did not differ between unburned and winter-burned plots (Mod D, p=0.244; H', p=0.323). Evenness was higher in unburned plots than in summer-burned plots (p=0.004). Evenness did not differ between winter-burned plots and summer-burned (p=0.122) or unburned (p=0.153) plots. *Vaejovis* *russelli* captures (p=0.972) and species richness (p=0.159) did not differ among treatments (Table I.39).

Period effects--All abundance and diversity categories decreased in all periods from 2008 to 2009 with the exception of *Vaejovis coahuilae* captures; *V. coahuilae* captures increased from 2008 to 2009 in July and August (Table I.40). *Centruroides vittatus* (p<0.001) were captured more frequently in August 2008 than in August 2009 (p=0.003), June 2009 (p=0.051), May 2009 (p=0.024), and September 2009 (p<0.001). More *C. vittatus* were captured in July 2008 relative to August 2009 (p<0.001), July 2009 (p=0.011), June 2009 (p=0.006), May 2009 (p=0.002), September 2008 (p=0.031), and September 2009 (p<0.001). More *C. vittatus* were captured in September 2008 than in September 2009 (p=0.031; Table I.40).

Vaejovis coahuilae captures were higher in August 2009 than in July 2008 (p=0.039). Fewer *V. coahuilae* were captured in June 2009 and May 2009 relative to August 2008 (p≤0.001) and 2009 (p<0.001), July 2008 (p≤0.025) and 2009 (p≤0.008), and September 2008 (p≤0.001). The fewest *V. coahuilae* were captured in September 2009 relative to August 2008 and 2009 (p<0.001), July 2008 (p<0.001) and 2009 (p<0.001), and September 2008 (p<0.001; Table I.40).

Vaejovis russelli captures were highest in August 2008 and September 2008 relative to all other periods (p≤0.009, Table I.40). Total scorpion captures were lowest in June 2009, May 2009, and September 2008 in relation to August 2008 and 2009

($p<0.001$), July 2008 ($p\leq0.001$) and 2009 ($p\leq0.005$), and September 2009 ($p<0.001$). Total scorpion captures were lowest in September 2009 relative to June 2009 ($p=0.039$) and highest in August 2008 relative to July 2009 ($p=0.033$).

Species richness was higher in all periods in 2008 than in all periods in 2009. Shannon-Weiner diversity ($p<0.001$) was highest in August 2008 relative to August 2009 ($p<0.001$), July 2009 ($p=0.036$), June 2009 ($p=0.042$), May 2009 ($p<0.001$), and September 2009 ($p<0.001$). Shannon-Weiner diversity was higher in July 2008 and September 2008 than in August 2009 ($p=0.003$), May 2009 ($p\leq0.003$), and September 2009 ($p\leq0.004$). Evenness was lower in August 2009 than in August 2008 ($p=0.005$), July 2008 ($p=0.006$) and 2009 ($p=0.051$), June 2009 ($p=0.042$), and September 2008 ($p=0.011$). Evenness was lower in May 2009 and September 2009 than in August 2008 ($p\leq0.009$), July 2008 ($p\leq0.010$), and September 2008 ($p\leq0.018$). Evenness was also lower in September 2009 than in June 2009 ($p=0.050$). Modified Simpson's diversity ($p=0.002$) was lower in August 2008, May 2009, and September 2009 than in August 2009 ($p\leq0.002$), July 2008 ($p\leq0.008$), and September 2008 ($p\leq0.014$; Table I.40).

Interactions--I detected a treatment*period interaction for *Vaejovis coahuilae* captures ($F=3.08$, $p<0.001$, Table I.41). In summer-burned plots, *V. coahuilae* captures were highest in September 2008 ($p\leq0.041$) and lowest in September 2009 ($p\leq0.001$). In winter-burned and unburned plots, *V. coahuilae* captures were highest in August 2009 ($p\leq0.047$) and lowest in May 2009 ($p\leq0.030$, Table I.41).

Captures of *V. coahuilae* did not differ by treatment in July 2008, May 2009, August 2009, and September 2009 ($p \geq 0.073$, Table I.41). In August 2008, captures did not differ between unburned and summer-burned ($p=0.123$) or winter-burned ($p=0.246$) plots; however, captures were higher in summer-burned than unburned ($p=0.008$) plots. In September 2008, captures did not differ between unburned and winter-burned plots ($p=0.561$); however, captures were higher in summer-burned ($p<0.001$) than unburned or winter-burned plots. In June 2009, captures did not differ between summer-burned and unburned ($p=0.246$) or winter-burned ($p=0.333$); however, captures were higher in winter-burned than unburned ($p=0.035$) plots. In July 2009, captures did not differ between winter-burned and summer-burned ($p=0.221$) or unburned ($p=0.438$) plots; however, captures were higher in summer-burned than unburned plots ($p=0.047$; Table I.41).

I detected a treatment*period interaction for total scorpion captures ($F=3.43$, $p<0.001$, Table I.42). In summer-burned plots, total scorpion captures were highest in September 2008 ($p \leq 0.001$) and lowest in September 2009 ($p \leq 0.009$). In winter-burned plots, total scorpion captures were highest in July 2008 ($p \leq 0.025$) and lowest in September 2009 ($p \leq 0.006$). In unburned plots, total scorpion captures were highest in August 2008 ($p \leq 0.025$) and lowest in May 2009 ($p \leq 0.015$, Table I.42).

Total captures did not differ by treatment in July 2008 and 2009, May 2009, August 2009, and September 2009 ($p \geq 0.055$, Table I.42). In August 2009, total captures did not differ between unburned and summer-burned (p=0.111) or winter-burned (p=0.385) plots; however, total captures were higher in summer-burned than in winter-burned (p=0.015) plots. In September 2008, total captures did not differ between unburned and winter-burned (p=0.462) plots; however, total captures were higher in summer-burned (p<0.001) than unburned or winter burned plots. In June 2009, total captures did not differ between summer-burned and unburned (p=0.385) or winter-burned (p=0.143) plots; however, total captures were higher in winter-burned than unburned plots (p=0.021; Table I.42).

I did not detect a treatment*period interaction for *Centruroides vittatus* captures (F=0.69, p=0.776) or *Vaejovis russelli* captures (F=0.22, p=0.999). I did not detect a treatment*period interaction for species richness (F=0.32, p=0.990), Shannon-Weiner diversity (F=0.48, p=0.937), modified Simpson's diversity (F=0.56, p=0.887), or evenness (F=0.50, p=0.928).

DISCUSSION

Microhabitat Selection and Use

Prescribed fire may indirectly affect invertebrates by modifying both the microclimate and habitat structure of an area (Gillette et al. 2008). Prescribed fires can cause a decrease in relative humidity close to the ground, an increase in soil surface temperature, altered plant species composition and foliar characteristics, reduced litter, and modified soil moisture (Majer 1984, Mitchell 1990, Brennan et al. 2006).

On my study site summer and winter burning were effective at reducing litter and increasing bare ground. Despite documenting much variation in microhabitat use, microhabitat selection rarely occurred in the scorpion species and variables I examined. In my study, while *Centruroides vittatus* did not select for any of the microhabitat variables by species, sex, or age, *Vaejovis coahuilae* and *Vaejovis russelli* both selected for a higher percentage of bare ground, *V. coahuilae* males selected for a higher percentage of bare ground, and adult *V. coahuilae* selected for a higher percentage of bare ground.

Scorpion capture sites in plots that had been burned in the summer and winter also had significantly higher substrate temperatures, higher wind speed, higher percentage of grass cover, and a lower percentage of forb cover than unburned plots. However, *Centruroides vittatus* tended to use areas with lower substrate temperature, lower air temperature, and a lower percentage of bare ground. Juveniles tended to use a higher percentage of bare ground than adults and a lower percentage of humidity than subadults. *Vaejovis coahuilae* used areas with a lower percentage of humidity. Males used areas with higher substrate temperatures, higher air temperatures, and a higher percentage of litter. Juveniles used areas with lower substrate temperatures, lower air temperatures, and higher percentage of bare ground. Subadults used areas with lower wind speed and lower humidity.

The differences between availability, selection, and use suggest that some partitioning may be occurring among these species. Bradley and Brody (1984) found that *Vaejovis coahuilae*, *Vaejovis russelli*, and *Paruroctonus utahensis* occupied different areas within similar habitat near Albuquerque, New Mexico, and reasoned that they may compete exploitatively. Williams (1970) stated 2 main factors, habitat specialization and prey preference, permitted coexistence among scorpions at South Mountain in Phoenix, Arizona. Because *V. coahuilae* and *V. russelli* are burrowing species and selected for areas with a higher percentage of bare ground, the competition for resources may be causing *C. vittatus* to utilize vegetation for foraging. By climbing vegetation, *C. vittatus* is able to use vertical space rather than horizontal and to take advantage of the higher prey abundance available there (Brown and O’Connell 2000). Also, scorpions of all 3 species may be using microhabitat differently by age to avoid competition for prey and predation by larger scorpions.

Centruroides vittatus tended to use areas with a higher percentage of bare ground in September while *V. coahuilae* tended to use areas with a lower percentage of bare ground in the same period. This suggests the species are also partitioning microhabitat temporally. As mating and courtship usually occur in July and August, scorpion surface activity drops off in September. *C. vittatus* may be able to take advantage of more ideal microhabitat as the surface activity of *V. coahuilae* slows.

Both *C. vittatus* and *V. coahuilae* used microhabitat differently by period and use was influenced by a treatment*period interaction. However, this may be because of the effects of activity patterns of the scorpions rather than the effects of the burning treatments. Microhabitat use can shift as scorpions use environmental cues such as temperature, precipitation, illumination, humidity, etc. to evaluate the level of predation risk and/or food availability (McReynolds 2008, Skutelsky 1996). Also, scorpion activity and thus, microhabitat use, may also be affected by patterns of foraging or reproductive behaviors so these effects of burning should be interpreted with caution (Smith and Morton 1990).

Scorpion Abundance and Diversity

In my study, *V. coahuilae* and total scorpion captures were highest in summer burned plots and lowest in unburned plots while *C. vittatus* captures, diversity, and evenness were lowest in summer burned plots and highest in unburned plots. This may be because of competition (Bradley and Brody 1984, Williams 1970) or niche partitioning. *V. coahuilae* selects for a higher percentage of bare ground in summer burned plots and uses the increased bare ground to build burrows and forage by waiting inside burrow entrances or on exposed substrates to encounter prey (Williams 1987). *Centruroides vittatus* will sometimes actively search for prey by traversing exposed substrates

(Williams 1987) and may be more successful foraging in areas with more cover and less bare ground as in unburned plots.

Both species may be partitioning microhabitat. Ideally, scorpions should use habitat that maximizes prey abundance and minimizes the risk of predation (Brown and O'Connell 2000). However, Polis et al. (1986) stated that scorpions may reach densities of 5000/ha and biomasses of 5-20 kg/ha in grassland ecosystems. In large densities, competition for resources may cause some species to trade off predator avoidance and optimal foraging (Brown and O'Connell 2000). Past competition for resources may have caused *V. coahuilae* to become more successful exploiting the surface area by using burrows for shelter and foraging using a sit-and-wait strategy (Williams 1987). As a result, *C. vittatus* has adapted to areas with harsher habitat conditions by using available plant material for shelter (Shelley and Sissom 1995), exploiting vegetation and areas above the surface for foraging (Brown and O'Connell 2000), and adopting a mobile rather than stationary foraging strategy (Williams 1987).

Abundance and diversity differed by period. Captures of *C. vittatus* and *V. coahuilae* peaked in July and August whereas captures of *V. russelli* were highest in August and September. *Vaejovis russelli* may be active later in the summer to avoid competition for resources with *C. vittatus* and especially with *V. coahuilae* as I found that both species of *Vaejovis* selected for a higher percentage of bare ground. In addition, captures of *C. vittatus*, richness, diversity, and evenness decreased from 2008 to 2009 while captures of *V. coahuilae* increased. These drops may be a result of recent burning as the second burn of my study site took place in August 2008 and February 2009. Eastwood (1978) suggested that burrowing scorpions in South Africa were abundant after fire and that non-burrowing species were less likely to persist through frequent fires. As *V. coahuilae* is a burrowing species and *C. vittatus* is not, *V. coahuilae* may have been more likely to persist through the second burn and become active sooner after the burn occurred.

My results are for a landscape for which fire has only recently been reintroduced. As fire is repeatedly applied to these sites, vegetation and microhabitat differences based upon treatment are likely to become more pronounced. Thus, I suspect more dramatic effects of burning on abundance and microhabitat selection of these scorpions in this ecosystem. Based on current trends, burning would seem to favor the burrowing species (*Vaejovis coahuilae*) at the expense of the climbing species (*Centruroides vittatus*).

Literature Cited

Bradley, R. A., and A. J. Brody. 1984. Relative abundance of three vaejovid scorpions across a habitat gradient. Journal of Arachnology 11:437-440.

Brennan, K. E. C., L. Ashby, J. D. Majer, M. L. Moir, J. M. Koch. 2006. Simplifying assessment of forest management practices for invertebrates: how effective are higher taxon and habitat surrogates for spiders following prescribed burning. Forest Ecology and Management 231:138-154.

Brockway, D. G., R. G. Gatewood, and R. B. Paris. 2002. Restoring fire as an ecological process in shortgrass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons. Journal of Environmental Management 65:135-152.

Brown, C. A., and D. J. O'Connell. 2000. Plant climbing behavior in the scorpion *Centruroides vittatus*. American Midland Naturalist 144:406-418.

Carlson, D. H., T. L. Thurow, R. W. Knight, and R. K. Heitschmidt. 1990. Effect of honey mesquite on the water balance of Texas Rolling Plains rangeland. Journal of Range Management 43:491-496.

Churchill, T. B. 1997. Spiders as ecological indicators: an overview for Australia. Memorial Museum of Victoria. 56:331-337.

Eastwood, E. B. 1978. Notes on the scorpion fauna of the Cape. Part 3. Some observations on the distribution and biology of scorpions on Table Mountain. Annals of the South African Museum 74: 229-248.

Farley, R. D. 2005. Developmental changes in the embryo, pronymph, and first molt of the scorpion *Centruroides vittatus* (Scorpiones: Buthidae). Journal of Morphology 265:1-27.

Fet, V., W. D. Sissom, G. Lowe, and M. E. Braunwalder. 2000. Catalog of the scorpions of the world (1758-1998). The New York Entomological Society, New York.

Francke, O. F., and W. D. Sissom. 1984. Comparative review of the methods used to determine the number of molts to maturity in scorpions (Arachnida), with analysis of the post-birth development of *Vaejovis coahuilae* Williams (Vaejovidae). Journal of Arachnology 12:1-20.

Freckman, D. W. 1994. Life in the soil: soil biodiversity: its importance to ecosystem processes. Report of a workshop held at the Natural History Museum, London, England, 30 August – 1 September 1994. 1-24.

Gillette, N. E., R. S. Vetter, S. R. Mori, C. R. Rudolph, and D. R. Welty. 2008. Response of ground-dwelling spider assemblages to prescribed fire following stand structure manipulation in the southern Cascade Range. Canadian Journal of Forest Research 38:969-980.

Hall, G. I. 2005. Relationships between cattle grazing and Rio Grande wild turkeys in the southern Great Plains. Thesis, Texas Tech University, Lubbock, Texas, USA.

Hall, G. I., M. C. Wallace, W. B. Ballard, D. C. Ruthven, III, R. L. Houchin, R. T. Huffman, R. S. Phillips, and R. Applegate. 2007. Rio Grande wild turkey habitat selection in the southern Great Plains. Journal of Wildlife Management 71:2583-2591.

Koponen, S. 2005. Early succession of a boreal spider community after forest fire. Journal of Arachnology 33:230-235.

Lawrence, K. L. and D. H. Wise. 2000. Spider predation on forest-floor Collembola and evidence for indirect effects on decomposition. Pedobiologia 48:33-39.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University

Press, Princeton, New Jersey.

Majer, J. D. 1984. Short-term responses of soil and litter invertebrates to a cool autumn burn in jarrah (*Eucalyptus marginata*) forest in western Australia. Pedobiologia 26:229-247.

McClaran, M. P. and T. R. Van Devender, editors. 1995. The desert grassland. University of Arizona Press, Tucson, Arizona.

McReynolds, C. N. 2008. Microhabitat preferences for the errant scorpion, *Centruroides vittatus* (Scorpiones, Buthidae). Journal of Arachnology 36:557-564.

Mitchell, R. G. 1990. Effects of prescribed fire on insect pests. In: Walstad, J. D., S. R. Radosevich, D. V. Sandberg (Eds.). Natural and prescribed fires in Pacific northwest forests. Oregon State University Press. Corvallis.

Moldenke, A. R., M. Pajutee, and E. Ingham. 1999. The functional role of forest soil arthropods: the soil is a living place. Proceedings of the California Forest Soils Council Conference on Forest Soils Biology and Forest Management, 23-24 Februrary 1996. Edited by R. F. Powers, D. L. Hauxwell, and G. M. Nakamura. U.S. Forest Service General Technical Report. PSW-GTR-138. 7-22.

Nobile, C. J., and P. M. Johns. 2005. Prelude to a kiss: evidence for mate discrimination in the striped bark scorpion, *Centruroides vittatus*. Journal of Insect Behavior 18:405-413.

Polis, G. A. 1988. Foraging and evolutionary responses of desert scorpions to harsh environmental periods of food stress. Journal of Arid Environments 14:123-134.

Polis, G. A., C. A. Myers, and M. Quinlan. 1986. Burrowing biology and spatial distribution of desert scorpions. Journal of Arid Environments 10:137-146.

Richardson, W. E., J. Hajek, E. Blakley, and C. Neitsch. 1974. Soil survey of Cottle County, Texas. United States Department of Agriculture, Soil Conservation Service, in cooperation with the Texas Agricultural Experiment Station. Washington, D. C., USA.

Schaffer, L. R., and D. R. Formanowicz, Jr. 1996. A cost of vivparity and parental care in scorpions: reduced sprint speed and behavioural compensation. Animal Behavior 51:1017-1024.

Shelley, R.M., and W.D. Sissom. 1995.Distributions of the scorpions *Centruroides vittatus* (Say) and *Centruroides hentzi* (Banks) in the United States and Mexico (Scorpiones, Buthidae). Journal of Arachnology 23:100-110.

Sissom, W. D. and B. E. Hendrixson. 2005. A new species of Vaejovis (Scorpiones: Vaejovidae) from Coahuila and Nuevo Leon and a key to the vaejovid species from northeastern and north-central Mexico. Zootaxa 1088:33-43.

Skutelsky, O. 1996. Predation risk and state-dependent foraging in scorpions: effects of moonlight on foraging in the scorpion *Buthus occitanus*. Animal Behaviour 52:49-57.

Smith, G. T., and S. R. Morton. 1990. Responses by scorpions to fire-initiated succession in arid Australian spinifex grasslands. Journal of Arachnology 18:241-244.

Spears, B. L., W. B. Ballard, M. C. Wallace, R. S. Phillips, D. C. Holdstock, J. H.

Brunjes, R. Applegate, P. S. Gipson, M. S. Miller, and T. Barnett. 2002. Retention times of miniature radiotransmitters glued to wild turkey poults. Wildlife Society Bulletin 30:861-867.

Stahnke, H. L. 1972. UV light, a useful field tool. BioScience 22:604-607.

Teague, W. R., W. E. Grant, U. P. Kreuter, H. Diaz-Solis, S. Dube, M. M. Kothmann, W. E. Pinchak, and R. J. Ansley. 2008. An ecological economic simulation model for assessing fire and grazing management effects on mesquite rangelands in Texas. Ecological Economics 64:611-624.

Williams, S. C. 1970. Coexistence of desert scorpions by differential habitat preferences. Pan-Pacific Entomology 46:254-267.

Williams, S. C. 1987. Scorpion bionomics. Annual Review of Entomology 32:275-295.

Table I.1. Influence of treatment on use of microhabitat variables (mean±SE) across all scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Unburned (n=374)	Summer (n=486)	Winter (n=453)	P
Substrate temp (°C)	24.36±0.20a	24.01±0.16b	24.11±0.17b	0.049
Air temp (°C)	23.94±0.24a	23.21±0.21a	23.11±0.27a	0.901
Wind (KPH)	0.78±0.07a	0.76±0.06b	0.86±0.06b	0.017
Humidity	65.35±0.62a	67.77±0.59a	65.99±0.55a	0.579
Bare (%)	14.35±1.29a	35.60±1.54b	32.72±1.65c	<0.001
Rock (%)	0.00±0.00a	0.19±0.12a	0.44±0.31a	0.611
Grass (%)	18.54±1.63a	23.18±1.51b	24.20±1.61b	0.032
Forb (%)	9.23±1.22a	6.28±0.79b	6.23±0.86b	0.003
Woody (%)	2.45±0.75a	1.06±0.43a	1.73±0.57a	0.163
Litter (%)	64.32±2.01a	41.26±1.72b	42.22±1.91c	<0.001
Vegetation height (cm)	6.84±0.74a	6.68±0.58a	6.78±0.65a	0.440

Table I.2. Influence of period on use of microhabitat variables (mean±SE) based upon actual locations from all scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

		2008		
	P value	July (n=205)	August (n=236)	September (n=198)
Substrate Temperature (°C)	<0.001	23.83±0.11 a	26.24±0.14 b	21.17±0.18 c
Air Temperature (°C)	<0.001	24.44±0.08 a	25.52±0.12 d	20.63±0.16 c
Wind (KPH)	<0.001	0.58±0.07 a	0.30±0.05 c	0.06±0.02 d
Humidity	<0.001	67.68±0.39 b	63.58±0.82 c	79.33±0.36 d
Bare (%)	<0.001	7.73±1.38 e	24.98±1.91 a	23.09±1.96 a
Rock (%)	0.546	0.98±0.69	0.00±0.00	0.41±0.25
Grass (%)	<0.001	28.61±2.38 a	25.53±2.04 ab	12.74±1.69 d
Forb (%)	<0.001	5.59±0.86 ab	3.86±0.73 a	4.30±1.03 ad
Woody (%)	0.774	1.46±0.69	1.29±0.64	2.13±0.91
Litter (%)	<0.001	71.85±2.67 e	58.39±2.53 a	62.37±2.38 a
Vegetation height (cm)	<0.001	.	.	.

Table I.2 con't. Influence of period on use of microhabitat variables (mean±SE) based upon actual locations from all scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

	2009				
	May (n=80)	June (n=119)	July (n=189)	August (n=224)	September (n=62)
Substrate Temperature (°C)	18.31±0.14 d	25.19±0.21 e	25.46±0.23 f	27.53±0.13 g	17.44±0.32 h
Air Temperature (°C)	18.63±0.16 b	19.43±1.05 bc	24.40±0.20 a	27.32±0.13 e	17.03±0.30 f
Wind (KPH)	0.79±0.10 a	1.29±0.16 b	0.66±0.07 a	1.98±0.10 e	1.05±0.18 b
Humidity	55.37±0.60 a	67.96±1.37 b	65.41±0.80 e	57.55±0.67 a	79.29±0.93 f
Bare (%)	46.50±4.13 c	39.83±3.34 b	36.43±2.49 b	37.95±2.47 bcd	28.79±4.40 bd
Rock (%)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Grass (%)	16.19±3.15 bcd	30.17±3.61 a	23.97±2.68 ac	18.50±2.28 cd	24.03±4.82 ac
Forb (%)	18.50±3.08 c	15.34±2.81 c	6.56±1.36 ab	5.78±1.49 ab	10.81±3.47 bd
Woody (%)	1.56±1.28	2.52±1.44	2.12±1.05	1.56±0.80	0.00±0.00
Litter (%)	27.75±3.78 cd	19.29±2.87 c	34.05±2.68 b	37.83±2.62 b	40.16±5.21 bd
Vegetation height (cm)	6.65±0.76 ab	10.12±1.04 c	7.50±0.76 b	4.61±0.62 a	6.06±0.96 ab

Table I.3. Influence of burning treatment on substrate temperature used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=503)	Winter-Burned (n=459)	Unburned (n=383)
July 2008	24.07±0.30 a	23.60±0.11 a	23.94±0.20 a
August 2008	26.94±0.21 b	25.36±0.26 a	26.02±0.25 a
September 2008	21.18±0.27 a	20.29±0.29 b	22.31±0.33 c
May 2009	18.46±0.27 a	18.15±0.21 a	18.47±0.24 a
June 2009	24.91±0.28 a	25.76±0.32 a	24.16±0.47 b
July 2009	24.63±0.21 a	26.55±0.35 b	25.37±0.61 a
August 2009	26.97±0.23 a	27.89±0.17 b	27.70±0.27 a
September 2009	17.61±0.82 ab	18.45±0.57 b	16.55±0.33 a

Table I.4. Influence of burning treatment on wind speed used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=486)	Winter-Burned (n=453)	Unburned (n=374)
July 2008	1.00±0.17 b	0.30±0.07 a	0.57±0.14 a
August 2008	0.30±0.07 a	0.40±0.11 a	0.21±0.07 a
September 2008	0.06±0.03 a	0.00±0.00 a	0.15±0.09 a
May 2009	0.74±0.16 a	0.95±0.15 a	0.53±0.21 a
June 2009	1.12±0.17 ab	1.61±0.29 a	0.77±0.24 b
July 2009	0.30±0.10 b	0.92±0.13 a	0.87±0.14 a
August 2009	2.39±0.20 b	1.72±0.14 a	1.84±0.18 a
September 2009	1.56±0.43 a	1.04±0.15 ab	0.75±0.33 b

Table I.5. Influence of burning treatment on humidity used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=486)	Winter-Burned (n=453)	Unburned (n=374)
July 2008	67.33±0.89 a	68.73±0.49 a	66.65±0.68 a
August 2008	60.49±1.30 b	67.43±1.29 a	64.50±1.50 a
September 2008	80.13±0.36 a	80.83±0.44 a	74.69±1.25 b
May 2009	54.81±0.92 a	55.64±1.04 a	55.51±0.93 a
June 2009	70.11±2.69 a	66.20±1.98 b	69.04±2.43 a
July 2009	68.10±1.15 a	62.34±1.38 b	65.20±1.65 a
August 2009	59.26±1.22 a	56.79±0.98 a	56.68±1.25 a
September 2009	80.23±2.67 a	76.65±1.02 a	80.74±1.20 a

Table I.6. Influence of burning treatment on percent bare ground used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=503)	Winter-Burned (n=459)	Unburned (n=383)
July 2008	7.09±2.43 a	9.88±2.53 a	5.60±2.02 a
August 2008	29.34±2.96 a	23.85±3.61 ab	20.20±3.41 b
September 2008	30.91±2.86 b	14.66±3.38 a	12.22±2.93 a
May 2009	57.61±5.82 a	50.38±6.35 a	23.89±7.77 b
June 2009	52.84±6.12 a	41.78±4.53 a	13.91±5.43 b
July 2009	41.27±4.06 a	47.02±4.22 a	16.83±3.54 b
August 2009	49.79±4.23 a	50.72±4.15 b	13.95±2.93 c
September 2009	47.19±9.95 a	34.00±7.64 a	13.46±4.85 b

Table I.7. Influence of burning treatment on percent grass used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=503)	Winter-Burned (n=459)	Unburned (n=383)
July 2008	38.73±5.00 a	26.57±3.83 b	22.84±3.54 b
August 2008	24.90±2.97 a	25.16±3.99 a	26.64±3.88 a
September 2008	9.25±1.86 a	13.81±3.78 ab	21.11±4.61 b
May 2009	20.65±6.79 a	12.82±4.03 a	17.78±6.84 a
June 2009	26.76±6.18 a	35.34±5.23 a	22.39±8.28 a
July 2009	26.73±4.58 a	32.26±4.73 a	10.10±3.85 b
August 2009	27.01±4.51 a	18.68±3.73 ab	10.26±3.40 b
September 2009	30.31±9.63 a	27.50±8.87 a	17.50±7.19 a

Table I.8. Influence of burning treatment on percent forb cover used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=503)	Winter-Burned (n=459)	Unburned (n=383)
July 2008	7.45±2.05 a	3.98±1.04 a	6.04±1.58 a
August 2008	4.95±1.31 a	5.41±1.63 a	1.18±0.64 a
September 2008	2.30±0.69 a	8.81±3.28 b	4.00±2.19 ab
May 2009	21.09±4.92 a	14.49±4.62 a	23.89±6.95 a
June 2009	17.16±5.05 a	7.71±2.88 b	31.96±8.72 c
July 2009	5.93±2.21 a	4.11±1.33 a	10.38±3.39 a
August 2009	3.96±2.19 a	2.04±1.40 a	11.25±3.55 b
September 2009	7.50±6.22 a	12.50±6.91 a	11.54±5.23 a

Table I.9. Influence of burning treatment on percent litter used by scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned (n=503)	Winter-Burned (n=459)	Unburned (n=383)
July 2008	62.55±5.56 a	70.24±4.33 ab	81.49±3.93 b
August 2008	55.61±3.76 a	57.30±5.23 a	62.89±4.52 a
September 2008	59.56±3.12 a	65.42±5.08 a	66.22±5.30 a
May 2009	12.39±4.72 a	28.08±5.60 ab	46.67±8.25 b
June 2009	6.89±2.50 a	18.90±3.67 a	40.22±9.50 b
July 2009	26.93±3.76 a	20.16±3.66 a	60.87±5.25 b
August 2009	19.44±3.05 a	28.22±3.83 a	64.87±4.68 b
September 2009	21.56±6.63 a	29.50±8.55 a	59.81±8.44 b

Table I.10. Measurements of microhabitat variables (mean±SE) from actual locations between *Centruroides vittatus* (n=190) and *Vaejovis coahuilae* (n=1123) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Centruroides vittatus	*Vaejovis coahuilae*	P
Substrate temp (°C)	23.84±0.26	24.37±0.11	0.006
Air temp (°C)	23.05±0.37	23.55±0.15	0.017
Wind (KPH)	0.70±0.08	0.79±0.04	0.507
Humidity	67.06±0.82	65.98±0.37	0.022
Bare (%)	24.03±2.28	33.24±0.99	0.001
Rock (%)	0.00±0.00	0.38±0.18	0.480
Grass (%)	24.69±2.36	21.60±0.90	0.108
Forb (%)	7.21±1.31	6.57±0.53	0.907
Woody (%)	2.95±1.05	1.87±0.37	0.231
Litter (%)	51.36±2.98	45.03±1.16	0.149
Vegetation height (cm)	6.95±1.13	6.39±0.35	0.636

Table I.11. Measurements for microhabitat variables (mean±SE) from capture locations of *Centruroides vittattus* scorpions during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Adult	Subadult	Juvenile
Substrate temp (°C)	23.72±0.28 a	23.10±1.30 a	24.99±0.88 a
Air temp (°C)	22.84±0.41 a	23.05±0.22 a	24.69±0.81 a
Wind (KPH)	0.68±0.08 a	0.80±0.80 a	0.84±0.21 a
Humidity	67.23±0.83 ab	82.75±3.05 b	63.01±3.22 a
Bare (%)	22.03±2.34 a	65.00±35.00 ab	34.25±7.85 b
Rock (%)	0.00±0.00 a	0.00±0.00 a	0.00±0.00 a
Grass (%)	24.53±2.53 a	0.00±0.00 a	28.75±7.37 a
Forb (%)	7.41±1.43 a	0.00±0.00 a	6.50±3.65 a
Woody (%)	2.76±1.05 a	0.00±0.00 a	5.00±5.00 a
Litter (%)	53.34±3.17 a	35.00±35.00 a	37.50±9.41 a
Vegetation height (cm)	6.74±1.29 a	0.00±0.00 a	9.20±2.19 a

Table I.12. Influences of treatment on microhabitat variables (mean±SE) using actual locations from *Centruroides vittattus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Unburned	Summer-Burned	Winter-Burned	P
Substrate temp (°C)	24.12±0.40a	24.99±0.46a	22.91±0.45a	0.524
Air temp (°C)	22.82±0.75a	24.32±0.44a	22.57±0.53a	0.853
Wind (KPH)	0.60±0.10a	0.88±0.21b	0.71±0.12b	0.001
Humidity	64.92±1.19a	66.93±2.04a	69.24±1.29a	0.713
Bare (%)	14.81±2.65a	30.24±5.42b	30.13±4.09b	<0.001
Rock (%)	0.00±0.00a	0.00±0.00a	0.00±0.00a	1.000
Grass (%)	21.86±3.61a	26.67±5.32a	26.53±3.84a	0.280
Forb (%)	9.29±2.19a	4.05±2.07a	6.80±2.25a	0.593
Woody (%)	3.14±1.74a	4.76±2.71a	1.73±1.39a	0.997
Litter (%)	62.88±4.46a	44.52±6.43b	43.20±4.81b	<0.001
Vegetation height (cm)	4.97±1.20a	6.62±1.40a	9.00±2.30a	0.469

Table I.13. Influence of period on use of microhabitat variables (mean±SE) based on actual locations from *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

		2008		
Variable	P value	July	August	September
Substrate Temperature (°C)	<0.001	24.39±0.19 a	26.34±0.32 b	21.24±0.55 c
Air Temperature (°C)	<0.001	24.91±0.13 a	25.63±0.29 a	20.59±0.47 b
Wind (KPH)	<0.001	0.58±0.13 ac	0.65±0.16 a	0.07±0.07 e
Humidity	<0.001	65.80±0.69 bcg	63.93±2.28 a	78.98±0.46 ef
Bare (%)	0.005	11.04±3.30abc	21.88±4.83abc	22.78±6.75abc
Rock (%)	.	0.00±0.00	0.00±0.00	0.00±0.00
Grass (%)	0.005	29.79±4.90bc	18.50±4.31abc	11.85±5.04a
Forb (%)	<0.001	12.29±3.12ac	4.38±2.89ac	1.67±1.22a
Woody (%)	0.697	3.75±1.97	4.75±2.91	7.41±5.14
Litter (%)	<0.001	67.19±5.75ad	60.75±6.41acd	52.22±8.07acd
Vegetation height (cm)	.	.	.	.

Table I.13 con't. Influence of period on use of microhabitat variables (mean±SE) based on actual locations from *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

	2009				
Variable	May	June	July	August	September
Substrate Temperature (°C)	18.11±0.31 a	23.92±0.43 d	26.07±0.73 b	27.42±0.67 e	16.27±1.25 f
Air Temperature (°C)	18.53±0.29 bc	18.73±2.35 b	25.04±0.61 a	26.28±0.65 a	15.74±1.01 c
Wind (KPH)	0.66±0.17 acd	0.88±0.27 ac	1.31±0.28 b	1.32±0.33 b	0.43±0.27 ade
Humidity	59.44±0.96 abd	71.69±3.00 ce	63.93±2.44 abd	62.84±3.02 ab	79.80±2.34ef
Bare (%)	23.61±7.48abc	40.00±7.52ab	34.13±6.76ab	25.91±9.34abc	48.33±16.16bd
Rock (%)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Grass (%)	16.67±7.51abc	37.05±8.07bc	38.04±7.86bc	25.00±10.66abc	10.00±5.00abc
Forb (%)	24.44±7.60bc	0.00±0.00a	2.39±2.17ac	9.09±6.10ac	0.00±0.00ac
Woody (%)	0.00±0.00	0.00±0.00	0.22±0.22	0.00±0.00	0.00±0.00
Litter (%)	44.72±10.36ac	29.55±8.16bc	31.09±7.24bc	46.36±13.01ac	45.00±15.28acd
Vegetation height (cm)	13.44±4.36	4.54±0.82	6.30±1.07	4.54±1.40	3.67±1.96

Table I.14. Influence of burning treatment on substrate temperature based upon random locations for *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	24.58±0.47 a	10	23.31±0.22 a	13	24.87±0.22 a	25
August 2008	27.18±0.50 ab	12	25.25±0.52 b	16	26.95±0.46 a	12
September 2008	21.91±1.02 a	7	19.11±0.62 b	12	23.83±0.26 a	8
May 2009	20.60 a	1	18.00±0.43 a	10	17.90±0.39 a	7
June 2009	24.53±1.83 a	3	23.67±0.42 a	11	24.03±0.87 a	8
July 2009	25.85±0.46 a	4	28.07±0.75 b	9	24.36±1.33 a	10
August 2009	27.45±0.55 a	4	28.20±1.60 a	2	27.08±1.40 a	5
September 2009	17.00 a	1	16.20±3.60 a	2	16.07±1.83 a	3

Table I.15. Influence of burning treatment on air temperature based upon random locations for *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	24.83±0.43 ab	10	26.62±0.16 b	13	25.20±0.14 a	25
August 2008	26.24±0.43 a	12	24.83±0.47 a	16	26.08±0.53 a	12
September 2008	20.75±0.98 a	6	19.60±0.48 a	12	23.31±0.24 a	4
May 2009	20.94 a	1	18.29±0.38 a	10	18.52±0.38 a	7
June 2009	24.43±1.45 a	3	21.28±2.45 a	11	13.09±5.09 b	8
July 2009	24.64±0.57 a	4	26.57±0.87 a	9	23.82±1.04 a	10
August 2009	24.49±0.55 a	4	27.61±1.72 a	2	26.39±1.21 a	5
September 2009	14.94 a	1	15.83±3.56 a	2	15.94±1.31 a	3

Table I.16. Influence of burning treatment on wind speed based upon random locations for *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	1.01±0.32 a	10	0.28±0.19 a	13	0.56±0.18 a	25
August 2008	0.68±0.30 a	12	0.56±0.28 a	16	0.72±0.26 a	12
September 2008	0.00±0.00 a	6	0.00±0.00 a	12	0.40±0.40 a	4
May 2009	0.97 ab	1	0.98±0.22 ab	10	0.16±0.16 a	7
June 2009	0.59±0.59 a	3	1.48±0.45 b	11	0.16±0.16 a	8
July 2009	2.45±1.35 a	4	1.07±0.22 ab	9	1.06±0.32 b	10
August 2009	1.29±0.84 a	4	1.69±0.24 a	2	1.19±0.39 a	5
September 2009	0.00 a	1	0.56±0.56 a	2	0.48±0.48 a	3

Table I.17. Influence of burning treatment on humidity based upon random locations for *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	66.33±1.51 ab	10	69.87±1.17 b	13	63.48±0.70 a	25
August 2008	60.30±4.71 a	12	67.23±2.80 a	16	63.17±4.76 a	12
September 2008	78.97±0.67 a	6	79.74±0.56 a	12	76.73±1.13 a	4
May 2009	52.10 ab	1	61.59±0.57 b	10	57.43±1.72 a	7
June 2009	76.13±12.17 ab	3	76.56±4.16 b	11	63.33±2.96 a	8
July 2009	60.08±4.89 ab	4	58.12±4.05 b	9	68.69±3.36 a	10
August 2009	63.18±1.17 a	4	60.25±7.05 a	2	63.60±6.59 a	5
September 2009	90.10 a	1	75.15±1.85 a	2	79.47±1.11 a	3

Table I.18. Influence of burning treatment on percent litter based upon random locations for *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	62.00±13.23 a	10	73.46±10.73 a	13	66.00±8.16 a	25
August 2008	51.67±13.19 a	12	72.50±9.11 b	16	54.17±11.51 ab	12
September 2008	57.86±14.01 a	7	44.17±13.79 a	12	12.50±12.50 a	8
May 2009	0.00 ab	1	24.50±10.12 a	10	80.00±14.47 b	7
June 2009	3.33±3.33 a	3	14.55±6.69 a	11	60.00±15.73 b	8
July 2009	22.50±8.64 ab	4	13.89±5.64 b	9	50.00±13.66 a	10
August 2009	31.25±23.66 a	4	10.00±10.00 ab	2	73.00±15.13 b	5
September 2009	0.00 a	1	22.50±2.50 a	2	75.00±14.43 a	3

Table I.19. Measurements of microhabitat variables (mean±SE) from actual locations for male (n=564) and female (n=440) *Vaejovis coahuilae* scorpions (n=440) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Males	Females	P
Substrate temp (°C)	24.99±0.14	24.30±0.18	0.008
Air temp (°C)	24.24±0.19	23.31±0.26	0.007
Wind (KPH)	0.79±0.05	0.80±0.06	0.707
Humidity	65.95±0.50	66.01±0.61	0.695
Bare (%)	32.53±1.43	33.49±1.52	0.711
Rock (%)	0.42±0.25	0.22±0.22	0.505
Grass (%)	20.36±1.21	23.46±1.50	0.147
Forb (%)	5.74±0.74	7.77±0.92	0.072
Woody (%)	2.34±0.57	1.65±0.56	0.402
Litter (%)	47.36±1.65	42.36±1.82	0.065
Vegetation height (cm)	6.61±0.54	6.36±0.55	0.842

Table I.20. Measurements for microhabitat variables (mean±SE) from capture locations of *Vaejovis coahuilae* scorpions during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Adult	Subadult	Juvenile
Substrate temp (°C)	24.75±0.12 a	23.74±0.51 a	21.72±0.35 b
Air temp (°C)	23.83±0.16 a	23.78±0.45 a	21.25±0.45 b
Wind (KPH)	0.83±0.04 a	0.22±0.07 b	0.72±0.13 a
Humidity	66.08±0.40 a	64.32±1.35 b	66.30±1.22 ab
Bare (%)	33.27±1.07 ab	27.71±4.45 a	35.60±3.30 b
Rock (%)	0.35±0.18 a	0.00±0.00 a	0.86±0.86 a
Grass (%)	21.74±0.97 a	21.36±4.31 a	20.39±2.94 a
Forb (%)	6.67±0.60 a	6.02±2.20 a	4.91±1.09 a
Woody (%)	2.02±0.42 a	2.37±1.81 a	0.43±0.43 a
Litter (%)	44.87±1.26 a	50.00±5.32 a	44.61±3.70 a
Vegetation height (cm)	6.54±0.40 a	4.95±1.04 a	5.22±0.74 a

Table I.21. The influence of treatment on microhabitat variables (mean±SE) using actual locations from *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Unburned	Summer-Burned	Winter-Burned	P
Substrate temp (°C)	24.66±0.23a	24.03±0.17ab	24.54±0.19b	0.042
Air temp (°C)	24.33±0.24a	23.23±0.22a	23.31±0.30a	0.610
Wind (KPH)	0.80±0.07a	0.72±0.06a	0.85±0.06a	0.068
Humidity	65.09±0.72a	67.39±0.61a	65.03±0.60a	0.215
Bare (%)	20.10±1.61a	39.27±1.56b	36.43±1.78b	<0.001
Rock (%)	0.00±0.00a	0.09±0.09a	1.04±0.52a	0.199
Grass (%)	15.89±1.57a	22.26±1.39b	25.34±1.67b	<0.001
Forb (%)	6.84±1.01a	6.74±0.87a	6.17±0.90a	0.235
Woody (%)	1.00±0.48a	2.09±0.62a	2.28±0.71a	0.902
Litter (%)	64.48±2.10a	38.52±1.75b	37.40±1.95b	<0.001
Vegetation height (cm)	5.21±0.70a	6.34±0.54a	7.29±0.60a	0.520

Table I.22. Influence of period on use of microhabitat variables (mean±SE) based on actual locations from *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

		2008		
Variable	P value	July	August	September
Substrate Temperature (°C)	<0.001	23.76±0.14 a	26.37±0.15 b	21.18±0.19 c
Air Temperature (°C)	<0.001	24.47±0.10 a	25.81±0.13 c	20.74±0.18 b
Wind (KPH)	<0.001	0.59±0.09 b	0.23±0.05 a	0.07±0.03 a
Humidity	<0.001	67.81±0.44 a	62.74±0.87 b	78.62±0.41 c
Bare (%)	<0.001	14.87±2.20 c	27.19±2.12 a	28.05±2.17 a
Rock (%)	0.084	2.55±1.26	0.00±0.00	0.20±0.20
Grass (%)	0.451	22.13±2.38	24.52±2.03	11.77±1.97
Forb (%)	<0.001	6.37±1.22 ae	5.00±1.08 a	6.21±1.30 be
Woody (%)	0.255	1.53±0.72	2.83±1.09	2.07±0.91
Litter (%)	<0.001	66.91±3.03 b	55.84±2.74 a	52.46±2.75 a
Vegetation height (cm)	.	.	.	.

Table I.22 con't. Influence of period on use of microhabitat variables (mean±SE) based on actual locations from *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05. A (.) signifies no data was available for that period.

	2009				
Variable	May	June	July	August	September
Substrate Temperature (°C)	18.62±0.18 d	25.67±0.23 e	25.87±0.23 f	27.70±0.14 g	17.58±0.32 h
Air Temperature (°C)	18.70±0.19 d	19.61±1.17 b	24.35±0.21 a	27.37±0.13 e	17.19±0.31 f
Wind (KPH)	0.85±0.11 b	1.28±0.15 c	0.59±0.07 b	1.90±0.10 d	0.92±0.20 bc
Humidity	54.17±0.64 d	66.86±1.54 ae	65.31±0.85 a	57.26±0.68 f	79.15±1.00 g
Bare (%)	48.87±4.50 b	45.05±3.50 b	44.37±2.52 b	38.05±2.46 b	35.63±4.25 b
Rock (%)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Grass (%)	17.26±3.57	25.57±3.38	20.96±2.38	20.35±2.23	24.64±4.60
Forb (%)	20.24±3.14 c	11.24±2.19 d	4.04±1.10 a	5.07±1.33 ab	4.02±2.09 ae
Woody (%)	0.00±0.00	4.33±2.04	1.27±0.73	1.41±0.81	0.00±0.00
Litter (%)	25.32±4.36 ce	22.06±2.97 cf	32.98±2.60	38.73±2.65 dh	40.18±4.98 cdi
Vegetation height (cm)	7.02±0.74 a	9.57±1.05 b	5.98±0.62 a	5.10±0.59 a	6.29±1.13 a

Table I.23. Influence of burning treatment on substrate temperature based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	23.90±0.34 a	45	23.77±0.14 a	70	23.57±0.27 a	42
August 2008	26.97±0.20 b	87	25.82±0.29 a	45	25.93±0.28 a	64
September 2008	21.08±0.27 a	119	20.57±0.30 b	47	22.27±0.38 c	37
May 2009	18.77±0.34 a	22	18.37±0.25 a	29	18.97±0.29 a	11
June 2009	25.02±0.29 a	34	26.43±0.36 b	48	24.71±0.45 a	15
July 2009	24.96±0.22 a	71	26.75±0.37 b	53	26.30±0.66 a	42
August 2009	27.07±0.24 a	68	28.04±0.19 b	74	27.95±0.28 ab	71
September 2009	17.87±0.85 a	15	18.70±0.46 a	18	16.52±0.29 b	23

Table I.24. Influence of burning treatment on air temperature based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	24.62±0.25 a	45	24.41±0.11 a	70	24.40±0.16 a	42
August 2008	26.44±0.18 a	87	25.23±0.20 ab	45	25.35±0.24 b	64
September 2008	20.47±0.24 ab	103	20.50±0.30 b	41	21.93±0.38 a	32
May 2009	18.59±0.37 a	22	18.60±0.25 a	29	19.17±0.32 a	11
June 2009	19.79±1.92 a	34	18.44±1.83 a	48	22.93±2.00 b	15
July 2009	23.37±0.20 a	71	25.16±0.36 b	53	24.99±0.57 ab	42
August 2009	26.78±0.25 a	68	27.59±0.16 a	74	27.72±0.27 a	71
September 2009	17.17±0.79 a	15	18.20±0.43 a	18	16.42±0.37 a	23

Table I.25. Influence of burning treatment on wind speed based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	1.12±0.21 a	45	0.35±0.09 b	70	0.42±0.16 b	42
August 2008	0.23±0.08 a	87	0.30±0.11 a	45	0.19±0.07 a	64
September 2008	0.45±0.04 a	103	0.00±0.00 a	41	0.14±0.10 a	32
May 2009	0.95±0.21 a	22	0.94±0.17 a	29	0.40±0.20 a	11
June 2009	1.15±0.18 a	34	1.46±0.26 a	48	1.01±0.27 a	15
July 2009	0.16±0.06 a	71	0.86±0.13 b	53	0.97±0.19 b	42
August 2009	2.22±0.20 a	68	1.71±0.14 b	74	1.80±0.16 b	71
September 2009	1.24±0.35 a	15	0.85±0.20 a	18	0.77±0.42 a	23

Table I.26. Influence of burning treatment on humidity based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	66.83±1.02 a	45	68.43±0.54 a	70	67.81±0.86 a	42
August 2008	59.71±1.34 a	87	66.45±1.44 b	45	64.26±1.56 b	64
September 2008	79.58±0.39 a	103	80.30±0.56 a	41	73.40±1.39 b	32
May 2009	54.88±0.95 a	22	53.54±1.14 a	29	54.40±0.87 a	11
June 2009	69.32±2.78 a	34	63.59±2.11 b	48	71.73±3.24 a	15
July 2009	67.89±1.19 a	71	62.73±1.54 b	53	64.22±1.88 ab	42
August 2009	59.02±1.28 a	68	56.71±0.99 a	74	56.16±1.25 a	71
September 2009	79.52±2.77 a	15	76.73±1.12 a	18	80.80±1.34 a	23

Table I.27. Influence of burning treatment on percent bare ground based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	12.22±3.59 a	45	18.64±3.68 a	70	11.43±3.89 a	42
August 2008	35.11±3.14 a	87	24.33±4.19 b	45	18.44±3.58 b	64
September 2008	32.31±3.01 a	119	22.55±4.06 ab	47	21.35±4.38 b	37
May 2009	52.27±6.98 a	22	53.10±6.90 a	29	30.91±10.04 a	11
June 2009	41.18±5.76 ab	34	52.92±4.82 b	48	28.67±9.04 a	15
July 2009	52.96±3.77 a	71	48.11±4.17 a	53	25.12±4.46 b	42
August 2009	51.99±4.07 a	68	43.18±4.37 a	74	19.37±3.33 b	71
September 2009	54.00±7.37 a	15	39.17±8.19 a	18	20.87±5.14 b	23

Table I.28. Influence of burning treatment on percent rock based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	0.00±0.00 a	45	5.71±2.79 b	70	0.00±0.00 a	42
August 2008	0.00±0.00 a	87	0.00±0.00 a	45	0.00±0.00 a	64
September 2008	0.34±0.34 a	119	0.00±0.00 a	47	0.00±0.00 a	37
May 2009	0.00±0.00 a	22	0.00±0.00 a	29	0.00±0.00 a	11
June 2009	0.00±0.00 a	34	0.00±0.00 a	48	0.00±0.00 a	15
July 2009	0.00±0.00 a	71	0.00±0.00 a	53	0.00±0.00 a	42
August 2009	0.00±0.00 a	68	0.00±0.00 a	74	0.00±0.00 a	71
September 2009	0.00±0.00 a	15	0.00±0.00 a	18	0.00±0.00 a	23

Table I.29. Influence of burning treatment on percent grass cover based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	25.11±4.52 a	45	17.86±3.43 a	70	26.07±4.79 a	42
August 2008	23.33±2.93 a	87	26.44±4.60 a	45	24.77±3.56 a	64
September 2008	16.68±2.25 a	119	28.30±5.21 b	47	13.38±4.21 a	37
May 2009	21.14±6.87 a	22	14.48±4.43 a	29	16.82±9.49 a	11
June 2009	29.85±6.34 a	34	26.15±4.57 a	48	14.00±7.42 a	15
July 2009	19.51±3.44 ab	71	28.40±4.60 b	53	14.05±4.40 a	42
August 2009	27.43±4.29 a	68	28.38±4.11 a	74	5.21±2.24 b	71
September 2009	25.67±7.99 ab	15	37.78±9.81 b	18	13.70±5.72 a	23

Table I.30. Influence of burning treatment on percent forb cover based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	6.89±2.66 a	45	5.36±1.68 a	70	7.50±2.26 a	42
August 2008	7.59±2.12 a	87	1.44±0.70 b	45	3.98±1.47 ab	64
September 2008	2.90±0.90 a	119	13.62±4.30 b	47	7.43±3.25 ab	37
May 2009	26.59±6.79 a	22	15.34±3.25 b	29	20.45±7.34 ab	11
June 2009	17.50±4.87 a	34	4.90±1.95 b	48	17.33±5.18 a	15
July 2009	4.44±1.93 a	71	4.62±2.12 a	53	2.62±1.12 a	42
August 2009	3.97±2.11 ab	68	2.91±1.72 b	74	8.38±2.91 a	71
September 2009	1.67±1.67 a	15	8.33±6.06 a	18	2.17±1.50 a	23

Table I.31. Influence of burning treatment on percent litter based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	n	Mean±SD	n	Mean±SD	n
July 2008	69.11±5.44 a	45	64.21±4.70 a	70	69.05±5.85 a	42
August 2008	47.59±3.94 a	87	55.89±5.99 a	45	67.03±4.62 b	64
September 2008	52.82±3.65 a	119	41.06±5.59 b	47	65.81±5.69 c	37
May 2009	12.05±4.66 a	22	29.48±7.11 a	29	40.91±11.24 b	11
June 2009	12.94±3.71 a	34	21.46±3.96 a	48	44.67±9.96 b	15
July 2009	25.35±3.43 a	71	23.40±3.73 a	53	57.98±5.56 b	42
August 2009	20.15±3.17 a	68	26.15±3.91 a	74	69.65±4.17 b	71
September 2009	23.33±6.03 a	15	20.00±6.26 a	18	66.96±7.54 b	23

Table I.32. Influence of burning treatment on vegetation height based upon random locations for *Vaejovis coahuilae* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned		Winter-Burned		Unburned	
Period	Mean±SD	N	Mean±SD	N	Mean±SD	N
May 2009	7.41±1.18 a	22	6.24±0.96 a	29	8.27±2.38 a	11
June 2009	12.35±2.12 a	34	7.77±1.18 b	48	9.00±2.74 ab	15
July 2009	4.75±0.75 a	71	7.11±0.99 a	53	6.62±1.70 a	42
August 2009	4.75±0.69 ab	68	7.05±1.28 b	74	3.39±0.91 a	71
September 2009	5.87±1.31 a	15	9.17±2.74 a	18	4.30±1.43 a	23

Table I.33. Measurements of microhabitat variables (mean±SE) from actual and random locations for *Centruroides vittatus* captured (n=190) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Actual	Random	P
Substrate temp (°C)	23.84±0.26	23.78±0.25	0.874
Air temp (°C)	23.05±0.37	22.95±0.37	0.845
Wind (KPH)	0.70±0.08	0.70±0.08	0.960
Humidity	67.06±0.82	67.38±0.82	0.747
Bare (%)	24.03±2.28	22.15±2.16	0.550
Rock (%)	0.00±0.00	0.00±0.00	1.000
Grass (%)	24.69±2.36	22.23±2.36	0.455
Forb (%)	7.21±1.31	7.25±1.43	0.979
Woody (%)	2.95±1.05	2.44±0.99	0.724
Litter (%)	51.36±2.98	55.33±2.97	0.340
Vegetation height (cm)	6.95±1.13	8.66±1.14	0.290

Table I.34. Measurements of microhabitat variables (mean±SE) from actual and random locations for *Vaejovis coahuilae* captured (n=1123) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Actual	Random	P
Substrate temp (°C)	24.37±0.11	24.20±0.11	0.290
Air temp (°C)	23.55±0.15	23.46±0.06	0.651
Wind (KPH)	0.79±0.04	0.82±0.04	0.572
Humidity	65.98±0.37	66.31±0.37	0.514
Bare (%)	33.24±0.99	29.65±1.00	0.011
Rock (%)	0.38±0.18	0.25±0.13	0.568
Grass (%)	21.60±0.90	22.20±0.99	0.647
Forb (%)	6.57±0.53	7.08±0.59	0.523
Woody (%)	1.87±0.37	1.56±0.35	0.547
Litter (%)	45.03±1.16	46.94±1.20	0.250
Vegetation height (cm)	6.39±0.35	6.51±0.40	0.819

Table I.35. Measurements of microhabitat variables (mean±SE) from actual and random locations for *Vaejovis russelli* captured (n=34) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Actual	Random	P
Substrate temp (°C)	24.46±0.66	24.25±0.67	0.807
Air temp (°C)	23.90±0.62	23.78±0.63	0.888
Wind (KPH)	0.31±0.11	0.44±0.16	0.445
Humidity	67.79±2.19	68.35±2.20	0.858
Bare (%)	38.71±5.66	24.71±5.00	0.067
Rock (%)	0.00±0.00	0.00±0.00	1.000
Grass (%)	21.86±4.62	30.71±6.23	0.270
Forb (%)	3.71±1.79	2.86±1.81	0.741
Woody (%)	0.29±0.29	0.43±0.43	0.781
Litter (%)	44.14±6.56	53.43±6.31	0.299
Vegetation height (cm)	2.75±2.75	2.50±2.50	0.391

Table I.36. Measurements of microhabitat variables (mean±SE) from actual locations between male (n=100) and female (n=69) *Centruroides vittatus* scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Males	Females	P
Substrate temp (°C)	23.89±0.37	23.43±0.41	0.445
Air temp (°C)	22.49±0.64	23.37±0.36	0.364
Wind (KPH)	0.58±0.09	0.84±0.14	0.253
Humidity	66.82±1.12	68.28±1.24	0.764
Bare (%)	22.02±2.97	23.29±3.89	0.722
Rock (%)	0.00±0.00	0.00±0.00	0.929
Grass (%)	25.53±3.34	22.36±3.78	0.378
Forb (%)	5.67±1.59	9.79±2.59	0.141
Woody (%)	3.41±1.60	1.71±1.00	0.391
Litter (%)	50.72±3.99	56.71±5.10	0.299
Vegetation height (cm)	5.54±0.84	9.14±3.72	0.171

Table I.41. Influence of treatment on abundance of *Centruroides vittatus* (CEVI), *Vaejovis coahuilae* (VACO), and *Vaejovis russelli* (VARU), as well as total captures, species richness, diversity [Modified Simpson's (Mod D) and Shannon-Weiner (H')], and evenness from scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. All values are mean±SE across the 5 plots within each treatment. Within a row, means followed by the same letter are not different at α=0.05.

	Unburned	Summer-Burned	Winter-Burned	P Value
CEVI	1.95±0.34a	1.05±0.24b	1.85±0.34a	0.046
VACO	7.58±0.90a	11.50±1.36b	9.60±0.97ab	0.002
VARU	0.30±0.09a	0.28±0.10a	0.30±0.10a	0.972
Total Captures	9.83±0.94a	12.83±1.44b	11.75±0.98ab	0.019
Species Richness	1.90±0.11a	1.65±0.11a	1.85±0.13a	0.159
H'	0.43±0.05a	0.25±0.04b	0.37±0.05ab	0.015
Evenness	0.54±0.06a	0.32±0.06b	0.44±0.06ab	0.014
Mod D	0.27±0.03a	0.15±0.03b	0.22±0.03ab	0.013

Table I.42. Influence of period on abundance of *Centruroides vittatus* (CEVI), *Vaejovis coahuilae* (VACO), and *Vaejovis russelli* (VARU), as well as total captures, species richness, diversity [Modified Simpson's (Mod D) and Shannon-Weiner (H')], and evenness from scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. All values are mean±SE across the 5 plots within each treatment. Within a row, means followed by the same letter are not different at α=0.05.

		2008		
	P value	July	August	September
CEVI	<0.001	3.20±0.69 a	2.67±0.56 a	1.80±0.47 c
VACO	<0.001	10.47±1.75 b	13.00±1.79 a	13.47±2.36 a
VARU	<0.001	0.33±0.13 b	0.87±0.27 a	0.87±0.19 a
Total Captures	<0.001	14.00±1.65 ad	16.53±1.55 a	16.13±2.39 ad
Species Richness	<0.001	2.20±0.17 a	2.33±0.19 a	2.33±0.16 a
H'	<0.001	0.49±0.07 ab	0.54±0.08 ab	0.49±0.07 ab
Evenness	0.004	0.58±0.08 c	0.59±0.08 c	0.56±0.07 c
Mod D	0.002	0.30±0.05 b	0.33±0.05 b	0.29±0.05 b

Table I.42 con’t. Influence of period on abundance of *Centruroides vittatus* (CEVI), *Vaejovis coahuilae* (VACO), and *Vaejovis russelli* (VARU), as well as total captures, species richness, diversity [Modified Simpson’s (Mod D) and Shannon-Weiner (H’)], and evenness from scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. All values are mean±SE across the 5 plots within each treatment. Within a row, means followed by the same letter are not different at α=0.05.

	2009				
	May	June	July	August	September
CEVI	1.20±0.62 b	1.40±0.41 c	1.53±0.33 c	0.73±0.30 b	0.40±0.16 b
VACO	3.93±0.85 c	6.40±1.15 c	11.27±1.60 a	14.20±1.44 a	3.73±0.79 c
VARU	0.00±0.00 b	0.00±0.00 b	0.00±0.00 b	0.20±0.11 b	0.07±0.07 b
Total Captures	5.13±0.77 b	7.80±1.13 bc	12.80±1.48 d	15.13±1.36 ad	4.20±0.83 c
Species Richness	1.33±0.13 b	1.60±0.13 b	1.73±0.12 b	1.60±0.19 b	1.27±0.21 c
H’	0.19±0.07 c	0.34±0.08 bc	0.33±0.06 bc	0.20±0.06 c	0.20±0.09 c
Evenness	0.27±0.10 ab	0.49±0.11 bc	0.48±0.09 bc	0.25±0.08 ab	0.25±0.10 ab
Mod D	0.13±0.05 a	0.23±0.06 ab	0.21±0.05 ab	0.11±0.04 a	0.13±0.05 a

Table I.43. Influence of period and burning treatment on the abundance of *Vaejovis coahuilae* during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. All values are mean±SE across the 5 plots within each treatment. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned	Winter-Burned	Unburned
July 2008	9.00±1.64 a	14.00±4.67 a	8.40±1.75 a
August 2008	17.40±3.33 a	9.00±2.37 b	12.60±2.82 ab
September 2008	23.80±3.57 a	9.20±1.02 b	7.40±2.01 b
May 2009	4.00±0.84 a	5.80±2.08 a	2.00±0.89 a
June 2009	6.60±1.29 ab	9.60±2.36 b	3.00±1.05 a
July 2009	14.60±4.06 a	10.80±1.28 ab	8.40±1.96 b
August 2009	13.60±3.11 a	14.80±2.24 a	14.20±2.63 a
September 2009	3.00±0.77 a	3.60±1.83 a	4.60±1.50 a

Table I.44. Influence of period and burning treatment on the abundance of total scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. All values are mean±SE across the 5 plots within each treatment. Within a row, means followed by the same letter are not different α=0.05.

	Summer-Burned	Winter-Burned	Unburned
July 2008	11.20±1.71 a	17.00±4.55 a	13.80±0.80 a
August 2008	20.60±2.50 a	13.20±2.18 b	15.80±2.69 ab
September 2008	26.20±3.89 a	12.20±1.56 b	10.00±1.97 b
May 2009	4.20±0.97 a	7.80±1.36 a	3.40±0.81 a
June 2009	7.20±1.36 ab	11.60±2.09 b	4.60±1.03 a
July 2009	15.40±3.76 a	12.60±1.33 a	10.40±1.96 a
August 2009	14.60±2.62 a	15.40±2.48 a	15.40±2.50 a
September 2009	3.20±0.80 a	4.20±1.83 a	5.20±1.66 a

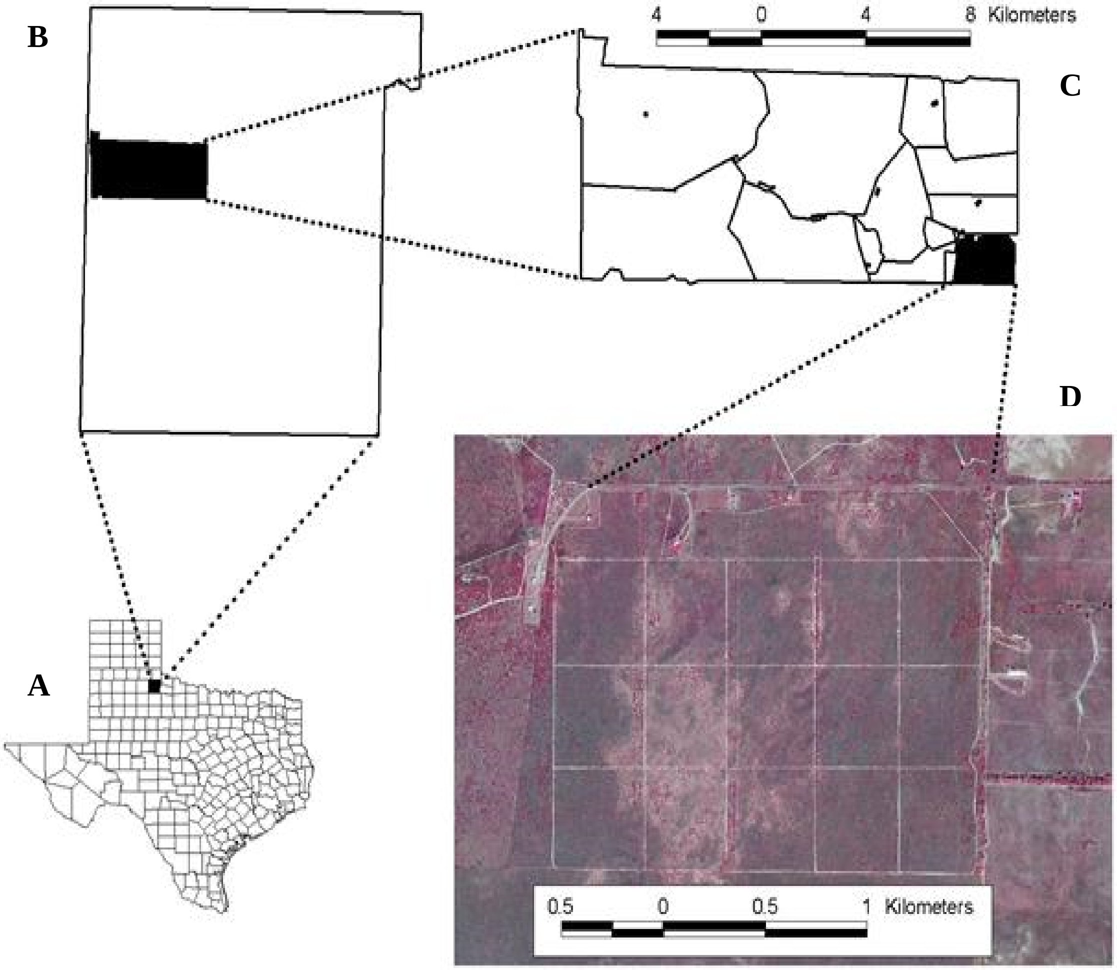

Figure I.1: Blowout map of my specific study indicating the location of Cottle County within Texas (A), Matador Wildlife Management Area within Cottle County (B), Headquarters Pasture within Matador Wildlife Management Area (C), and my specific study plots within Headquarters Pasture (D).

Blocks

1	2	3	4	5
U	W	W	U	S
S	U	S	W	U
W	S	U	S	W

Figure I.2: Diagrammatic representation of my specific study plots within Headquarters Pasture at Matador WMA in Cottle County, Texas. Headquarters Pasture was divided into 5 blocks, each consisting of 3 18-ha plots. Each of the 3 plots within a block was randomly assigned one of 3 treatments: unburned (U), winter burning (W), summer burning (S).

Chapter 2

NATURAL HISTORY OF 3 SCORPIONS IN A PRESCRIBED FIRE MATRIX

INTRODUCTION

Scorpions comprise a diverse and highly successful order of Arachnids. Scorpions are successful predators and occupy intermediate trophic positions and may effect invertebrate guilds (Churchill 1997, Lawrence and Wise 2000). Scorpions are xeric adapted and, as such, use water and food efficiently. The body is protected by a sclerotized exoskeleton that retards water loss. They further minimize water loss by excreting guanine, uric acid, or xanthine (Williams 1987). They are adapted for surviving long periods between feedings by gorging on prey and storing the excess energy in specialized glands (Williams 1987, Polis 1988).

As xeric-adapted organisms, scorpions are most abundant and diverse in arid and semi-arid environments such as the southeastern Great Plains (Williams 1987). The families Vaejovidae and Buthidae are widespread in North America (Sissom and Hendrixson 2005). The family Vaejovidae includes species distributed from central Mexico through the United States and into southern Canada and is the largest scorpion family in North America and 146 species have been described on the continent (Brown 1997, Sissom and Hendrixson 2005). The family Buthidae is the largest scorpion family overall and contains >90 genera and >900 species (Fet et al. 2000). Two species of Vaejovidae, *Vaejovis coahuilae* and *Vaejovis russelli*, and one species of Buthidae, *Centruroides vittatus*, are prominent in the southeastern Great Plains (Sissom and Hendrixson 2005, Shelley and Sissom 1995).

Scorpion life history is difficult to evaluate and most studies provide only a partial life history (Williams 1987). Thus, the life history information available for these 3 species is highly variable. While many studies have focused on *C. vittatus*, few studies have considered *V. coahuilae*, and, at this time, no studies have been conducted on the life history of *V. russelli*. *Vaejovis coahuilae*, a burrowing species, is found in much of New Mexico, southeastern Arizona, western Texas, and northern Mexico (Sissom unpublished data). As mentioned previously, little is known of the life history of *V. coahuilae* and the information currently available is mostly the result of captive studies (Francke and Sissom 1984). Furthermore, only partial life history has been obtained from these captive studies because the scorpions frequently die before reaching sexual maturity (Francke and Sissom 1984).

Centruroides vittatus, a non-burrowing species, occurs in a variety of microhabitats in grasslands, deserts, and deciduous and pine forests, and inhabits rock crevices, canyon walls, and volcanic hills. They commonly enter houses and seek refuge under *Yucca* spp. and other available plant material. They occur from sea level to over 1800 m in the Guadalupe and Chisos Mountains of Texas as well as up to 2340 m among the mountains of Coahuila, Mexico (Shelley and Sissom 1995). *Centruroides vittatus* occurs throughout the south central plains of the US and extends south from Thayer County, Nebraska to over half the lengths of the states Tamaulipas, Nuevo Leon, and Coahuila, Mexico. *Centruroides vittatus* also occurs along the northern edge of Chihuahua and encompasses all of Oklahoma, Arkansas, and Missouri, south to the Mississippi River and extends as far westward as the Rio Grande in southern New Mexico, the Sangre de Cristo Mountains in northern New Mexico, and south central Colorado. Further expansion into the Arkansas River Valley in Colorado may have occurred (Shelley and Sissom 1995).

Centruroides vittatus is known to climb vegetation. Brown and O'Connell (2000) found that 20-25% of the scorpions they encountered were on vegetation and occurred at a height ranging from 2 cm to >75 cm. However, whether this is a predator avoidance behavior, a foraging response to higher prey abundance, a reaction to a climatic gradient, or a result of random movements is not known (Brown and O'Connell 2000).

In general, all 3 species share a similar life history. After fertilization, young develop viviparously within the ovarian tube of the female (Francke 1982). At birth, the larvae do not feed and are incapable of significant independent locomotion. They are also incapable of stinging because they lack a fully formed telson. The larvae position themselves on the mother's dorsum and remain there for 1 to 2 weeks when they molt to the second (first nymphal) instar stage and begin to disperse (Francke 1982). Nymphs molt several times before reaching sexual maturity within the first year of life. Females appear to mature as sixth instars and males mature in more than one instar (Francke and Sissom 1984). Scorpions are generally long-lived and, in many taxa, females tend to live longer than males (Williams 1987). This higher mortality in males may be because of increased exposure to predators and harsh habitat conditions during mating season.

Mating is preceded by an elaborate courtship called the "promenade a deux" that normally occurs at night on exposed surfaces (Williams 1987). Once mates locate each other, they grip each other by the pedipalps and walk forward and backward in coordinated movements until the male determines a suitable substrate for spermatophore deposition. After deposition, the male guides the female over the spermatophore and insemination takes place (Williams 1987).

Gestation is variable. Temperate taxa such as members of *Vaejovis* have 1 litter per year while tropical taxa such as members of *Centruroides* may have more than 1 litter per year. The gestation period for *Centruroides vittatus* is 8 months (Baerg 1961). Litter size is also variable. Reported litters contain 6 to 105 young per litter while *Centruroides vittatus* averages a litter of 20 to 47 young (Baerg 1961). After young are born, *Vaejovis* mothers remain inactive in their protective shelters until young disperse while *Centruroides* females may be seen during nocturnal hours in exposed areas with young on their dorsum (Williams 1987).

Scorpions are obligate predators. They feed primarily on insects, arachnids, and other arthropods and are capable of capturing almost any prey that they can physically immobilize and ingest (Williams 1987). Scorpions use 3 strategies to encounter prey: waiting on exposed substrates, active stalking, and waiting inside their burrow entrances. Most species of *Vaejovis* wait on exposed substrates to encounter prey while members of *Centruroides* sometimes actively search for prey by traversing exposed substrates (Williams 1987).

Scorpions spend most of their time in an inactive state and only periodically become active to engage in predation, burrowing, and courtship (Williams 1987). Scorpions are active on the surface from March through October with the highest densities occurring from May through September (Williams 1987). Surface activity increases significantly during courtship season, especially among mature males as they become nomadic to actively search for mates (Williams 1987).

Scorpion activity is influenced by environmental cues such as air and soil temperature, rainfall, humidity, moonlight, and courtship season (Williams 1987, Skutelsky 1996, Kaltsas et al. 2008). Increased scorpion activity has been correlated with increased humidity and wind speed (Skutelsky 1996) and decreased moonlight (Hadley and Williams 1968, Polis 1980, Skutelsky 1996). Skutelsky (1996) found that adult *Buthus occitanus israelis* scorpions were significantly less active on full moon nights than on dark nights, while juveniles were often foraging during twilight and early morning. Polis (1980) found that moonlight did not significantly affect surface density of the desert scorpion *Paruroctonus mesaensis,* but that mating and feeding activity occurred more frequently on moonless nights.

Scorpion activity may also be influenced by prescribed fire. Smith and Morton (1990) found that at least 1 species of grassland scorpion, *Lychus alexandrinus*, persisted readily through fires in Australian grasslands and hypothesized that, because of several aspects of their ecology, scorpions have the capacity to withstand the direct effect of fire disturbance as well as to take advantage of altered conditions that follow such disturbances (Smith and Morton 1990). Scorpions are well established and adapted to grassland ecosystems and thus, may reach densities of 5000/ha and biomasses of 5-20 kg/ha (Polis et. al 1986). Most live in burrows or beneath persistent shelters (Polis 1988). They are long-lived and have extremely low metabolic rates and are able to eat large amounts of food and store excess energy from that food in the hepatopancreatic glands, making it possible for them to survive many months without food (Williams 1987, Polis 1988). However, the responses of scorpions to burning are largely unknown.

To better understand the relationship between scorpions and their habitat, I examined age and sex ratios, sexual dimorphism, and the effect of weather variables on abundance and diversity of all 3 species at a site in the southeastern Great Plains. My specific objectives were to determine the effects of prescribed fire on age structure and sex ratios, the effects of weather variables on abundance and diversity, and document sexual dimorphism of *C. vittatus, V. coahuilae,* and *V. russelli*.

STUDY AREA

Matador Wildlife Management Area

My study site is located within the 11,370-ha Matador Wildlife Management Area in the central Rolling Plains of Cottle County, Texas (Hall et al. 2007; Figure I.1). Topography ranges from riparian plains to gently rolling hills and steep-walled canyons (Richardson et al. 1974). The area is traversed by the confluence of the Middle and South Pease Rivers (Spears et al. 2002, Hall et al. 2007). The dominant soil association on the area is Miles (fine-loamy, mixed, thermic, alfisols) and Springer (coarse-loamy, mixed, thermic, alfisols) with nearly level to strongly sloping, deep, coarse textured to moderately coarse textured soils on outwash plains (Richardson et al. 1974).

The primary woody vegetation found on the Matador WMA includes honey mesquite (*Prosopis glandulosa*), sand sagebrush (*Artemisia filifolia*), shinnery oak (*Quercus havardii*), sand plum (*Prunus angustifolia*), acacia (*Acacia angustissima*), redberry juniper (*Juniperus pinchoti*), cottonwood (*Populus deltoids*), western soapberry (*Sapindus drummondii*), and netleaf hackberry (*Celtiss occidentalis*, Spears et al. 2002). Dominant grasses on the area include sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), purple three-awn (*Aristida purpurea*), little bluestem (*Andropogon scoparius*), Japanese brome (*Bromus japonicus*), and plains bristlegrass (*Setaria leucopila*). Dominant forb species include western ragweed (*Ambrosia psilostachya*), plantain (*Plantago* spp.), common sunflower (*Helianthus annuus*), and lamb's quarters (*Chenopodium album*, Hall 2005).

METHODS

Burning and Experimental Design

My specific study site was located in Headquarters Pasture (Figure I.1) and consisted of 273 ha of sand sagebrush–honey mesquite shrubland. The site is divided into 15 plots, each approximately 400 m^2 in size, for a replicated burning project. Treatments include unburned, summer-burned, and winter-burned (Figure I.2). There are 5 replicates of the treatment; each replicate consists of 3 plots. Each of these 3 plots within a block was randomly assigned 1 of 3 treatments.

The winter-burned and summer-burned plots had been burned once prior to this study. The previous winter and summer burns were conducted in February 2005 and August

2005, respectively. The most recent winter and summer burns were conducted in February 2009 and August 2008, respectively.

Data Collection

All sampling took place within a 2-week period from July-September 2008 and May-September 2009. Sampling started 1 week before the new moon and ended 1 week after the new moon. Scorpions were encountered by intensive searches using blacklights (Stahnke 1972**)**. An intensive search was defined as 1 person-hour of search time per plot. Before searching began in each plot, the level of ambient light was determined using a photometer. A portable weather station (Kestrel Meters, Sylvin Lake, Michigan, USA) was used to record air temperature, wind speed, and humidity at ground level of each scorpion capture. Substrate temperature was recorded using an infrared thermometer (Raynger ST, Raytek, Santa Cruz, California, USA).

After recording microhabitat data for the actual scorpion location, I acquired a random location. To acquire a random point, I threw the frame over my shoulder for a distance of approximately 2 to 3 m. At this point, I recorded the same parameters as I did for the actual scorpion locations.

The location of each scorpion was recorded with a global positioning system (GPS; E-trex, Garmin Limited, Olathe, Kansas, USA) to an accuracy of $\leq$4 m. Sex, age (juvenile, subadult, or adult), and species were recorded for each scorpion. Prosoma/Mesosoma length, metasoma length, total length, telson/aculus length, and pedipalp length were also recorded for each scorpion. Mating, feeding, and plant climbing behavior were noted. Scorpions were released at the site of capture following data collection.

Statistical Analysis

I used Analysis of Variance (ANOVA) in the Statistical Analysis System (SAS Institute, Cary, North Carolina, USA) to compare age structure and sexual dimorphism for *Centruroides vitattus*, *Vaejovis coahuilae*, and *Vaejovis russelli*. Age structure and sex ratio were analyzed with treatment and period (month/year) as main effects and treatment*period interaction. Because of the small number of captures, *Vaejovis russelli* was excluded from age structure analysis. Differences in sexual dimorphism of measurements was based upon a species*sex interaction.

I used Chi-square tests to determine if sex ratio differed from 1:1. Because of the small number of captures, *V. russelli* was excluded from all sex ratio analysis except the Chi-square tests.

I used regressions to determine if weather variables had an effect on abundance and diversity. Scorpion species diversity was calculated using both modified Simpson's and Shannon-Wiener diversity indices (Magurran 1988). Shannon's diversity index was calculated as:

$$- \Sigma\, p_i \ln p_i$$

where p_i is the proportion of individuals found in the *i*th species and modified Simpson's diversity index was calculated as:

$$1 - \Sigma p_i^2$$

All statistical comparisons were considered significant at $\alpha=0.05$.

RESULTS

Age Structure

The proportion of adult *C. vittatus* was higher in unburned than in summer-burned plots (p=0.024) but did not differ significantly between winter-burned and summer-burned (p=0.246) or unburned (p=0.260) plots (Table II.1). The proportion of subadult *C. vittatus* did not differ by treatment (p=0.609). The proportion of juvenile *C. vittatus* differed by treatment (p=0.061). The proportion of juveniles was higher in winter-burned than in summer-burned (p=0.019) plots but did not differ significantly between unburned and summer-burned (p=0.377) or winter-burned (p=0.139) plots (Table II.1).

The proportion of adult (p=0.984) and subadult (p=0.274) *V. coahuilae* did not differ by treatment (Table II.2). The proportion of juvenile *V. coahuilae* was higher in summer-burned than in unburned plots (p=0.008) but did not differ significantly between winter-burned and summer-burned (p=0.190) or unburned (p=0.170) plots (Table II.2).

The proportion of adult *C. vittatus* was lowest in August 2009 and significantly lower in that period than in August 2008 (p=0.002), September 2008 (p=0.037), July 2008 (p<0.001), June 2009 (p=0.033), July 2009 (p=0.003, Table II.3). The proportion of adults was highest in July 2008 and significantly higher than in September 2008 (p=0.042), May

2009 (p=0.010), June 2009 (p=0.046), and September 2009 (p=0.001). The proportion of adults was lower in September 2009 than in July 2008 (p=0.001), August 2008 (p=0.025), and July 2009 (p=0.031). The proportion of subadult (p=0.550) and juvenile (p=0.205) *C. vittatus* did not differ by period (Table II.3).

The proportion of adult *V. coahilae* was lowest in May 2009 (p<0.001) and highest in August 2009 (Table II.4). The proportion of adults was significantly higher in August 2009 than in July 2008 (p=0.008) and September 2009 (p=0.007). The proportion of subadult *V. coahuilae* was lower in August 2009 than in July 2008 (p=0.011), August 2008 (p=0.002), and July 2009 (p=0.026). The proportion of subadult *V. coahuilae* was lower in June 2009 than in July 2008 (p<0.001), August 2008 (p=0.001), May 2009 (p=0.044), and July 2009 (p=0.010). The proportion of subadult *V. coahuilae* was lower in September 2008 and 2009 than in August 2008 (p≤0.003), July 2008 (p≤0.002) and July 2009 (p≤0.042). The proportion of juvenile *V. coahuilae* was highest in May 2009 and significantly higher in that period than in July 2008 (p=0.006), August 2008 (p<0.001), September 2008 (p=0.052), June 2009 (p=0.028), July 2009 (p=0.012), August 2009 (p<0.001), and September 2009 (p=0.002). The proportion of juvenile *V. coahuilae* was lowest in August 2009 and significantly lower in that period than in June 2009 (p=0.044) and September 2008 (p=0.023, Table II.4).

I did not detect a treatment*period interaction for the proportions of adult (p=0.923), subadult (p=0.410), or juvenile (p=0.812, Table II.5) *C. vittatus*. I did not detect a treatment*period interaction for the proportions of adult (p=0.735), subadult (p=0.740), or juvenile (p=0.899, Table II.6) *V. coahuilae*.

Sex Ratio

The overall sex ratio of *C. vittatus* was 35:52 (females:males), which differed marginally from 1:1 (X_1^2=2.97, p=0.085). The overall sex ratio of *V. coahuilae* was 451:577, which differed from a 1:1 ratio ((X_1^2=7.85, p=0.005). The overall sex ratio of *V. russelli* was 12:19, which did not differ from a 1:1 ratio (X_1^2=0.067, p=0.796).

The proportion of female *C. vittatus* did not differ by treatment (p=0.356, Table II.7). The proportion of female *V. coahuilae* was higher in summer-burned than in unburned (p=0.043) or winter-burned (p=0.030) plots, but did not differ between unburned and winter-burned plots (p=0.873, Table II.7).

The proportion of female *C. vittatus* was higher in August 2008 than in June 2009 (p=0.029), August 2009 (p=0.009), and September 2009 (p=0.013, Table II.8). The proportion of females was higher in July 2008 than in any other period ($p \leq 0.014$, Table II.8).

The proportion of female *V. coahuilae* was lower in July 2008 than in June 2009 (p=0.010) and August 2009 (p=0.012, Table II.8). The proportion of females was higher in May 2009 than in July 2008 ($p<0.001$), August 2008 (p=0.006), September 2008 (p=0.016), and July 2009 (p=0.006). The proportion of females was higher in September 2009 than in July 2008 ($p<0.001$), August 2008 (p=0.005), September 2008 (p=0.013), and July 2009 (p=0.005, Table II.8).

I did not detect a treatment*period interaction for the proportion of female *C. vittatus* (p=0.396) or the proportion of female *V. coahuilae* (p=0.154, Table II.9).

Weather and Scorpion Abundance and Diversity

There was a slight tendency for *V. coahuilae* captures to increase with increasing light level (y= 0.963x + 7.794, F_{117}=3.11, p=0.080, r^2=0.026, Figure II.3). There was a slight tendency for *V. russelli* captures to decrease with increasing light level (y= -0.086x + 0.470, F_{117}=3.23, p=0.075, r^2=0.027, Figure II.4). Total captures of scorpions was not influenced by light level (y= 0.833x + 9.994, F_{117}=2.21, p=0.140, r^2=0.019, Figure II.3). *Centruroides vittatus* captures was not influenced by light level (y= -0.043x + 1.731, F_{117}=0.08, p=0.783, r^2<0.001, Figure II.4). Species richness was not influenced by light level (y= -0.062x + 1.954, F_{117}=1.23, p=0.269, r^2=0.011, Figure II.5). Evenness not was influenced by light level (y= -0.003x + 0.447, F_{117}=0.01, p=0.926, r^2<0.001, Figure II.5). Shannon-Weiner (H') diversity was not influenced by light level (y= -0.020x + 0.394, F_{117}=0.67, p=0.414, r^2=0.006, Figure II.6). Modified Simpson's (Mod D) diversity was influenced by light level (y= -0.010x + 0.239, F_{117}=0.37, p=0.545, r^2=0.003, Figure II.6).

There was a tendency for *Vaejovis coahuilae* captures to increase with increasing substrate temperature (y= 0.576x - 3.603, F_{117}=16.08, p<0.001, r^2=0.122, Figure II.7). There was a tendency for total captures to increase with increasing substrate temperature (y= 0.655x - 3.495, F_{117}=20.51, p<0.001, r^2=0.150, Figure II.7). *Centruroides vittatus* captures were not influenced by substrate temperature (y= 0.064x + 0.158, F_{117}=2.23, p=0.138, r^2=0.019, Figure II.8). *Vaejovis russelli* captures were not influenced by substrate temperature ($y= 0.015x - 0.050$, $F_{117}=1.25$, $p=0.266$, $r^2=0.011$, Figure II.8). There was a slight tendency for species richness to increase with increasing substrate temperature ($y= 0.026x + 1.224$, $F_{117}=2.94$, $p=0.089$, $r^2=0.025$, Figure II.9). Evenness was not influenced by substrate temperature ($y= 0.010x + 0.206$, $F_{117}=1.60$, $p=0.209$, $r^2=0.014$, Figure II.9). Shannon-Weiner (H') diversity ($y= 0.009x + 0.151$, $F_{117}=1.70$, $p=0.194$, $r^2=0.015$, Figure II.10) was not influenced by substrate temperature. Modified Simpson's (Mod D) diversity was not influenced by substrate temperature ($y= 0.005x + 0.099$, $F_{117}=1.43$, $p=0.235$, $r^2=0.012$, Figure II.10).

There was a tendency for *Vaejovis coahuilae* captures ($y= 0.207x - 5.085$, $F_{117}=12.21$, $p<0.001$, $r^2=0.097$) and total captures ($y= 0.237x - 5.287$, $F_{117}=15.66$, $p<0.001$, $r^2=0.121$, Figure II.11) to increase with increasing air temperature. *Centruroides vittatus* captures were not influenced by air temperature ($y= 0.022x + 0.048$, $F_{117}=1.61$, $p=0.207$, $r^2=0.014$, Figure II.12). *Vaejovis russelli* captures were not influenced by air temperature ($y= 0.008x - 0.250$, $F_{117}=1.98$, $p=0.162$, $r^2=0.017$, Figure II.12). Species richness was not influenced by air temperature ($y= 0.010x + 1.142$, $F_{117}=2.42$, $p=0.122$, $r^2=0.021$, Figure II.13). Evenness was not influenced by air temperature ($y= 0.003x + 0.209$, $F_{117}=0.99$, $p=0.322$, $r^2=0.009$, Figure II.13). Shannon-Weiner (H') diversity was not influenced by air temperature ($y= 0.003x + 0.122$, $F_{117}=1.40$, $p=0.239$, $r^2=0.012$, Figure II.14). Modified Simpson's (Mod D) diversity was not influenced by air temperature ($y= 0.002x + 0.083$, $F_{117}=1.16$, $p=0.283$, $r^2=0.010$, Figure II.14).

There was a tendency for *Vaejovis russelli* captures (y= -0.195x + 0.409, F_{117}=4.87, p=0.029, r^2=0.041, Figure II.16) and species richness (y= -0.219x + 1.956, F_{117}=4.69, p=0.032, r^2=0.040, Figure II.17) to decrease with increasing wind speed. *Centruroides vittatus* captures were not influenced by wind speed (y= -0.431x + 1.874, F_{117}=2.29, p=0.133, r^2=0.020, Figure II.16). *Vaejovis coahuilae* captures were not influenced by wind speed (y= -1.140x + 10.418, F_{117}=1.26, p=0.264, r^2=0.011, Figure II.15). There was a slight tendency for total captures to decrease with increasing wind speed (y= -1.765x + 1.731, F_{117}=2.92, p=0.090, r^2=0.025, Figure II.15). Shannon-Weiner (H') diversity was not influenced by wind speed (y= -0.066x + 0.390, F_{117}=2.23, p=0.139, r^2=0.019, Figure II.18). Modified Simpson's (Mod D) diversity was not influenced by wind speed (y= -0.035x + 0.238, F_{117}=1.52, p=0.220, r^2=0.013, Figure II.18). Evenness was not influenced by wind speed (y= -0.076x + 0.482, F_{117}=2.06, p=0.154, r^2=0.018, Figure II.17).

Vaejovis coahuilae captures were not influenced by humidity (y= -0.019x + 11.055, F_{117}=0.14, p=0.711, r^2=0.001, Figure II.19). Total captures were not influenced by humidity (y= -0.012x + 12.541, F_{117}=0.05, p=0.817, r^2<0.001, Figure II.19). *Centruroides vittatus* captures were not influenced by humidity (y= 0.004x + 1.355, F_{117}=0.09, p=0.768, r^2<0.001, Figure II.20). *Vaejovis russelli* captures were not influenced by humidity (y= 0.003x + 0.130, F_{117}=0.33, p=0.568, r^2=0.003, Figure II.20). Species richness was not influenced by humidity (y= 0.005x + 1.479, F_{117}=1.10, p=0.297, r^2=0.010, Figure II.21). Evenness was not influenced by humidity (y= 0.001x + 0.371, F_{117}=0.16, p=0.694, r^2=0.001, Figure II.21). Shannon-Weiner (H') diversity was not influenced by humidity (y= 0.002x + 0.254,

F_{117}=0.45, p=0.505, r^2=0.004, Figure II.22). Modified Simpson’s (Mod D) diversity was not influenced by humidity (y= 0.001x + 0.173, F_{117}=0.23, p=0.634, r^2=0.002, Figure II.22).

Sexual Dimorphism

Centruroides vittatus had the largest prosoma/mesosoma, metasoma, total length and pedipalp measurements (p<0.001), while *V. coahuilae* had the smallest measuremtns for these variables (p<0.010, Table II.10).

The telson measurements differed by species (p<0.001). *Vaejovis russelli* had a larger telson than both *C. vittatus* (p=0.082) and *V. coahuilae* (p=0.0002). *Centruroides vittatus* had a larger telson than *V. coahuilae* (p<0.001, Table II.10).

Centruroides vittatus had the largest metasoma to total length ratio (p<0.001). The metasoma to total length ratio for *V. russelli* was larger than that of *V. coahuilae* (p=0.035, Table II.10). *Centruroides vittatus* had the smallest telson to prosoma/mesosoma ratio (p<0.001). *Vaejovis russelli* had the largest telson to prosoma/mesosoma ratio but did not differ from that of *V. coahuilae* (p=0.199, Table II.10). *Centruroides vittatus* had the smallest right pedipalp to prosoma/mesosoma ratio and *V. russelli* had the largest (p<0.0001, Table II.10).

I detected a species*sex interaction for the combined prosoma and mesosoma measurement (p=0.003, Table II.11). Females of each species had larger prosoma/mesosoma than males of the same species (p<0.001), but female *V. russelli* did not differ significantly from males of the same species (p=0.203). Female *C. vittatus* had the largest prosoma/mesosoma of the 3 species (p<0.0001) and male *V. coahuilae* had the smallest (p<0.0001). The prosoma/mesosoma of female *V. coahuilae* did not differ significantly from that of male (p=0.206) or female (p=0.598) *V. russelli* (Table II.11).

I detected a species*sex interaction for the metasoma measurement (p<0.0001). Female and male *C. vittatus* had larger metasoma than either sex of *V. coahuilae* and *V. russelli* (p<0.0001) and male *C. vittatus* had larger metasoma than females of the same species (p<0.0001). Female *V. coahuilae* had larger metasoma than males of the same species (p<0.0001) and smaller metasoma than male *V. russelli* (p=0.0008) but did not differ significantly from female *V. russelli* (p=0.234). Male *V. coahuilae* had smaller metasoma than either sex of *V. russelli* (female, p=0.021; male, p<0.0001). The metasoma of female and male *V. russelli* did not differ significantly (p=0.203, Table II.11).

I detected a species*sex interaction for the total length measurement (p<0.0001). Female and male *C. vittatus* had larger total lengths than either sex of *V. coahuilae* and *V. russelli* (p<0.0001) and male *C. vittatus* had larger total lengths than females of the same species (p=0.014). Female *V. coahuilae* had larger total lengths than males of the same species (p<0.0001) but did not differ significantly from female (p=0.623) or male (p=0.138) *V. russelli*. Male *V. coahuilae* had smaller total lengths than either sex of *V. russelli* (female, p=0.0004; male, p<0.0001). The total lengths of female and male *V. russelli* did not differ significantly (p=0.553, Table II.11).

I detected a species*sex interaction for the left and right pedipalp measurements (p<0.0001). Female and male *C. vittatus* had larger pedipalps than either sex of *V. coahuilae* and *V. russelli* (p<0.0001) but the pedipalps of female and male *C. vittatus* did not differ significantly (p=0.346). Female *V. coahuilae* had larger pedipalps than males of the same species (p<0.0001) and had smaller pedipalps than female (p=0.003) and male (p<0.0001) *V. russelli*. Male *V. coahuilae* had smaller pedipalps than either sex of *V. russelli* (p<0.0001). The pedipalp measurements of female and male *V. russelli* did not differ significantly (left, p=0.211; right, p=0.201, Table II.11).

I detected a species*sex interaction for the telson measurement (p=0.006). The telson measurements of female and male *C. vittatus* did not differ significantly from each other (p=0.255), that of female *V. coahuilae* (female, p=0.382; male, p=0.562), or that of male *V. russelli* (female, p=0.333; male, p=0.745). The telson measurements of female *V. coahuilae* did not differ significantly from that of male *V. russelli* (p=0.547). Male *V. coahuilae* had the smallest telson (p<0.0001; male *V. russelli*, p=0.034). Female *V. russelli* had larger telsons than male *V. russelli* (p=0.005) as well as either sex of *C. vittatus* (female, p=0.011; male, p=0.002) and *V. coahuilae* (female, p=0.002; male, p<0.0001, Table II.11).

I detected a species*sex interaction for the metasoma to total length measurements ratio (p<0.0001). Male *C. vittatus* had the largest metasoma to total length ratio (p<0.0001). Female *C. vittatus* had a smaller metasoma to total length ratio than that of male *V. coahuilae* (p<0.0001) and male *V. russelli* (p=0.004), a larger ratio than that of female *V. coahuilae* (p<0.0001), and did not differ from that of female *V. russelli* (p=0.774). Female *V. coahuilae* had the smallest ratio (p<0.0001; female *V. russelli*, p=0.021). Male *V. coahuilae* had a larger ratio than that of female *V. russelli* (p=0.011) and did not differ significantly from that of male *V. russelli* (p=0.590). Male *V. russelli* had a larger ratio than that of females of the same species (p=0.020, Table II.11).

I detected a species*sex interaction for the telson to prosoma/mesosoma measurements ratio (p<0.0001). Female and male *C. vittatus* had the smallest telson to prosoma/mesosoma ratios (p<0.0001) but male *C. vittatus* had a larger ratio than that of females of the same species (p<0.0001). Female *V. coahuilae* had a smaller ratio than that of males of the same species (p<0.0001) and female *V. russelli* (p<0.0001) but did not differ significantly from that of male *V. russelli* (p=0.500). The telson to prosoma/mesosoma ratio of male *V. coahuilae* did not differ significantly from that of female *V. russelli* (p=0.266). Male *V. russelli* had a larger telson to prosoma/mesosoma ratio than that of females of the same species (p=0.009) and that of male *V. coahuilae* (p=0.007, Table II.11).

I did not detect a species*sex interaction for the right pedipalp to prosoma/mesosoma measurements ratio (p=0.090, Table II.11).

Notes on Behavior

Plant climbing behavior was observed in both *V. coahuilae* and *C. vittatus*. Both species were found in forbs, grasses, and woody vegetation as well as aluminum flashing of drift fences installed in the plots. Only *C. vittatus* were observed feeding in vegetation and observed prey items included grasshoppers, Lycosids, cockroaches, and other scorpions.

Sixteen *C. vittatus* and 16 *V. coahuilae* were found in vegetation at a mean height of 18.875cm (3-110cm). Of the *C. vittatus* found in vegetation, 8 were male, 6 were female, and

2 were juvenile. Of the total number of *V. coahuilae*, 7 were male, 8 were female, and 1 was juvenile.

Mating behavior was observed once in both *V. coahuilae* and *C. vittatus* during the 15-24 July 2009 sampling period.

DISCUSSION

Age Structure

Polis and McCormick (1986) found that each age class of *Paruroctonus mesaensis* differed in predators, prey size and taxa, habitat use, and temporal patterns. Young and intermediately aged scorpions tended to be active during colder parts of the year when adults were relatively inactive. By being active when environmental conditions were more stressful, younger scorpions of several species are able to minimize co-occurrence on the surface and thus, the risk of cannibalism by larger scorpions, as well as minimize resource competition. This decrease in competition among age classes not only stabilizes the population, but also allows coexistence between age groups and species (Polis 1980, Polis 1984, Kaltsas et al. 2008).

In my study, juvenile, subadult, and adult *V. coahuilae* and *C. vittatus* were active during different periods. *Vaejovis coahuilae* adults were most active in August 2009 and least active in May 2009 while juveniles were most active in May 2009 and least active in August 2009. Since surface activity increases significantly during courtship season (Williams 1987), increased activity by adults in August was probably because of mating season and the decreased activity by juveniles during that time would minimize competition with and risk of predation by larger scorpions. *Centruroides vittatus* adults, however, were most active in July 2008 and least active in August 2009 while juveniles were most active in August 2008 and least active in September 2009. Thus, *C. vittatus* activity may be influenced by environmental factors other than mating season.

Sex Ratio

Williams (1987) summarized that surface activity increases significantly during courtship season, especially among mature males. Mature males will abandon burrows and become nomadic to actively search for mates (Williams 1987). During courtship season, this results in observed sex ratios that strongly favor males in several species including several species of *Vaejovis* including *V. confuses* (Williams 1968), *V. gertschi* (Toren 1973), and *V. spingerus* (Williams 1968).

Polis (1980) found that the proportion of mature male *Paruroctonus mesaensis* was highest in July and August and males conspicuously absent in early spring and late summer. The proportion of adult females, however, peaked twice: first, in spring during increased insect abundance and embryonic growth, and second, in the middle of August during increased adult male activity (Polis 1980). Polis (1980) suggested that inactivity of adult females in July and early August, during peak adult male activity, is because of birth and maternal brooding of the young through their first molt.

In my study, the proportion of female *C. vittatus* was highest in July 2008 and 2009 and lowest in September 2008 and 2009. The proportion of female *V. coahuilae* was highest in May 2009 and September 2008 and 2009 and lowest in July 2008 and 2009. The differences in peak activity between species may be the result of different courtship seasons. Competition for space for courtship or resources needed for embryonic growth as well as risk of predation by other active scorpions may have influenced the temporal courtship patterns among species.

The proportion of female *C. vittatus* was higher in 2008 than 2009 while the proportion of female *V. coahuilae* was higher in 2009 than 2008. This may be because of habitat changes or variable mortality because of burning in August 2008 and February 2009. In addition to increasing soil surface temperature, modifying soil moisture, and decreasing humidity close to the ground, prescribed fire also reduces litter and removes vegetation (Majer 1984, Mitchell 1990). *Centruroides vittatus* is known to seek refuge under available plant material and litter and prescribed fire may have removed available refuges or may have caused direct mortality while *Vaejovis coahuilae*, as a burrowing species, may have been able to avoid direct mortality by seeking refuge below ground. *Centruroides vittatus* is also known to climb vegetation to avoid predators or to forage and the removal of vegetation could make them susceptible to increased predation or decreased foraging opportunities.

Weather and Scorpion Abundance and Diversity

At least 124 vertebrates and 26 invertebrates prey on scorpions (Polis et al. 1981) and scorpions may use environmental cues such as moonlight, air and soil temperature, wind speed, and humidity to evaluate the level of predation risk and food availability (Skutelsky 1996, Kaltsas et al. 2008). Kaltsas et al. (2008) found that the foraging behavior of *Mesobuthus gibbosus* was influenced by moonlight, air and soil temperature, and humidity;

females would forage at burrow entrances where wind speed and moonlight were low and air temperature and humidity were high, males foraged in the open when moonlight and humidity were low and wind speed was high, and juveniles foraged in the open when air temperature was low and humidity high. Skutelsky (1996) found that adult *Buthus occitanus israelis* were less active on full moon nights than dark nights while moonlight did not affect the activity of juveniles. Skutelsky (1996) also found that scorpions foraging on moonlit nights were estimated to be 2 weeks further into a nutritional stress period than those foraging on dark nights; scorpions take more risks in foraging during periods of food stress and are more likely to forage on moonlit nights (Polis 1988, Skutelsky 1996).

In my study, moonlight and humidity did not influence scorpion abundance or diversity. However, as sampling was done one week immediately before and one week immediately following the new moon, this may not be an accurate interpretation of the influence of moonlight on scorpion abundance or diversity. *Vaejovis coahuilae* and total scorpion abundance tended to increase with increasing air and substrate temperatures while *V. russelli* abundance and species richness tended to decrease with increasing wind speed. Both *V. coahuilae* and *V. russelli* use a sit-and-wait foraging strategy and may be active under different weather conditions in order to optimize foraging and minimize the risk of predation by larger scorpions. Because of disproportionately large captures, the total scorpion abundance may tend to exhibit the same trends as *V. coahuilae*.

Sexual Dimorphism

Among species, *Centruroides vittatus* was consistently the largest scorpion and *V. coahuilae* the smallest scorpion in most measurements except for that of the telson and the telson to prosoma/mesosoma and right pedipalp to prosoma/mesosoma ratios. *Vaejovis russelli* had the largest telson and the largest telson to prosoma/mesosoma ration but did not differ significantly from similar measurements of *C. vittatus*. *Vaejovis russelli* had the largest right pedipalp to prosoma/mesosoma ratio while *C. vittatus* had the smallest.

Carlson and Rowe (2009) hypothesized that female *C. vittatus* were not as capable of escaping predators by running because they were larger and heavier than males. As a result, females have compensated for slow sprint speed with more accurate stinging ability. In my study, within a species, females had larger prosoma/mesosomas and larger telsons than males. Larger telsons and more accurate stinging ability may enable females to deter a variety of predators from which they would be unable to escape by sprinting.

The thinner, longer tails of male scorpions might prove useful in courtship or male-male combat (Carlson and Rowe 2009). Polis and Farley (1979) found that 17.1 percent of all cannibalisms by *Paruroctonus mesaensis* consisted of females preying on males during the breeding season and males defended themselves by attempting to sting the attacker. In my study, males of all 3 species had larger metasomas than females of the same species. Longer metasomas in males may be the result of selection because of cannibalism by females as males with a longer metasoma would enable males to defend themselves and maximize the distance between them and the attacker.

The larger total length of male scorpions might influence mating success (Nobile and Johns 2005, Carlson and Rowe 2009). Larger males are better equipped to push and pull females and may be able to complete courtship more quickly (Nobile and Johns 2005). Benton (1991) found that larger male *Euscorpius flavicaudis* acquire more mates and Carlson and Rowe (2009) suggested that, because they are capable of escaping males during courtship, *C. vittatus* females may discriminate among potential mates by using the pushing and pulling of the promenade a deux to assess male size.

In my study, male *C. vittatus* and *V. russelli* had larger total lengths than females of the same species but female *V. coahuilae* had larger total lengths than males of the same species. *Centruroides vittatus* and *V. russelli* males may be larger because of sexual selection and mate discrimination. Male *V. coahuilae*, however, may be smaller than females of the same species because of sexual selection pressures or niche partitioning. Female *V. coahuilae* may be less likely to cannibalize mates or males may be constrained by space or prey availability. As a result, male *V. coahuilae* have selectively compensated with smaller body size.

Female *C. vittatus* and *V. coahuilae* had larger pedipalps than males but male *V. russelli* had larger pedipalps than females of the same species. This may be the result of niche partitioning as pedipalp size may influence the size of prey each species is able to capture. Each species and the sexes within each species may be able to prey on different sizes of prey and, as a result, optimize foraging and avoid predation by larger scorpions while foraging.

Males of all 3 species had larger metasoma to total length ratios than females. Males may have much longer metasomas in relation to body size for defense against cannibalism during mating season (Carlson and Rowe 2005).

Male *C. vittatus* and *V. coahuilae* had larger telson to prosoma/mesosoma ratios than females of the same species with the exception of female *V. russelli*. Female *V. russelli* had the largest telsons in the study and small body size, giving them the largest telson to prosoma/mesosoma ratio. Females may have larger telsons in relation to body size to aid in defense. Because they are slower sprinters than males, they may have selectively compensated with more accurate stinging ability (Carlson and Rowe 1995).

Ideally, scorpions should be active during times and under conditions that maximize food abundance and minimize predation risk. However, scorpions may reach densities of 5000/ha and biomasses of 5-20 kg/ha in grassland ecosystems (Polis et al. 1986) and, in large densities, competition for resources may cause some species to trade off predator avoidance and optimal foraging (Brown and O'Connell 2000) and results in niche partitioning. In my study, scorpions appeared to exhibit niche partitioning both within (i.e., sex and age classes) and among species temporally, spatially, and morphologically to coexist in this landscape.

Literature Cited

Baerg, W. J. 1961. Scorpions: Biology and effect of their venom. Agriculture Experiment Station Bulletin 647. University of Arkansas, Fayetteville.

Brockway, D. G., R. G. Gatewood, and R. B. Paris. 2002. Restoring fire as an ecological process in shortgrass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons. Journal of Environmental Management 65:135-152.

Brown, C. A. 1997. Growth rates in the scorpion *Pseudouroctonus reddelli* (Scorpionida, Vaejovidae). Journal of Arachnology 25:288-294.

Brown, C. A., and D. J. O'Connell. 2000. Plant climbing behavior in the scorpion *Centruroides vittatus*. American Midland Naturalist 144:406-418.

Carlson, B. E. and M. P. Rowe. 2009. Temperature and desiccation effects on the antipredator behavior of *Centruroides vittatus* (Scorpiones: Buthidae). Journal of Arachnology 37:321-330.

Carlson, D. H., T. L. Thurow, R. W. Knight, and R. K. Heitschmidt. 1990. Effect of honey mesquite on the water balance of Texas Rolling Plains rangeland. Journal of Range Management 43(6):491-496.

Churchill, T. B. 1997. Spiders as ecological indicators: an overview for Australia. Memorial Museum of Victoria. 56:331-337.

Francke, O. F. 1982. Parturition in scorpions (Arachnida, Scorpiones): a review of the ideas. Review of Arachnology 4:27-37.

Francke, O. F., and W. D. Sissom. 1984. Comparative review of the methods used to determine the number of molts to maturity in scorpions (Arachnida), with analysis of the post-birth development of *Vaejovis coahuilae* Williams (Vaejovidae). Journal of Arachnology 12:1-20.

Hadley, N. F. and S. C. Williams. 1968. Surface activities of some North American scorpions in relation to feeding. Ecology 49:726-734.

Hall, G. I. 2005. Relationships between cattle grazing and Rio Grande wild turkeys in the southern Great Plains. Thesis, Texas Tech University, Lubbock, Texas, USA.

Hall, G. I., M. C. Wallace, W. B. Ballard, D. C. Ruthven, III, R. L. Houchin, R. T. Huffman, R. S. Phillips, and R. Applegate. 2007. Rio Grande wild turkey habitat selection in the southern Great Plains. Journal of Wildlife Management 71:2583-2591.

Kaltsas, D., I. Stathi, M. Mylonas. 2008. The foraging activity of *Mesobuthus gibbosus* (Scorpiones: Buthidae) in central and south Aegean archipelago. Journal of Natural History 42:513-527.

Lawrence, K. L. and D. H. Wise. 2000. Spider predation on forest-floor Collembola and evidence for indirect effects on decomposition. Pedobiologia 48:33-39.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey.

Majer, J. D. 1984. Short-term responses of soil and litter invertebrates to a cool autumn burn in jarrah (*Eucalyptus marginata*) forest in western Australia. Pedobiologia 26:229-247.

Mitchell, R. G. 1990. Effects of prescribed fire on insect pests. In: Walstad, J. D., S. R. Radosevich, D. V. Sandberg (Eds.). Natural and prescribed fires in Pacific northwest forests. Oregon State University Press. Corvallis.

Nobile, C. J. and P. M. Johns. 2005. Prelude to a kiss: evidence for mate discrimination in the striped bark scorpion, *Centruroides vittatus*. Journal of Insect Behavior 18:405-413.

Polis, G. A. and R. D. Farley. 1979. Behavior and ecology of mating in the cannibalistic scorpion, *Paruroctonus mesaensis* Stahnke (Scorpionida: Vaejovidae). Journal of Arachnology 7:33-46.

Polis, G. A. 1980. Seasonal patterns and age-specific variation in the surface activity of a population of desert scorpions in relation to environmental factors. Journal of Animal Ecology 49(1):1-18.

Polis, G. A., W. D. Sissom, and S. J. McCormick. 1981. Predators of scorpions: field data and a review. Journal of Arid Environments 4:309-327.

Polis, G. A., C. A. Myers, and M. Quinlan. 1986. Burrowing biology and spatial distribution of desert scorpions. Journal of Arid Environments 10:137-146.

Polis, G. A. 1988. Foraging and evolutionary responses of desert scorpions to harsh environmental periods of food stress. Journal of Arid Environments 14:123-134.

Richardson, W. E., J. Hajek, E. Blakley, and C. Neitsch. 1974. Soil survey of Cottle

County, Texas. United States Department of Agriculture, Soil Conservation Service, in cooperation with the Texas Agricultural Experiment Station. Washington, D. C., USA.

Shelley, R.M., and W.D. Sissom. 1995.Distributions of the scorpions *Centruroides vittatus* (Say) and *Centruroides hentzi* (Banks) in the United States and Mexico (Scorpiones, Buthidae). Journal of Arachnology 23:100-110.

Sissom, W. D. and B. E. Hendrixson. 2005. A new species of Vaejovis (Scorpiones: Vaejovidae) from Coahuila and Nuevo Leon and a key to the vaejovid species from northeastern and north-central Mexico. Zootaxa 1088:33-43.

Skutelsky, O. 1996. Predation risk and state-dependent foraging in scorpions: effects of moonlight on foraging in the scorpion *Buthus occitanus*. Animal Behaviour 52:49-57.

Smith, G. T., and S. R. Morton. 1990. Responses by scorpions to fire-initiated succession in arid Australian spinifex grasslands. Journal of Arachnology 18:241-244.

Spears, B. L., W. B. Ballard, M. C. Wallace, R. S. Phillips, D. C. Holdstock, J. H. Brunjes, R. Applegate, P. S. Gipson, M. S. Miller, and T. Barnett. 2002. Retention times of miniature radiotransmitters glued to wild turkey poults. Wildlife Society Bulletin 30:861-867.

Stahnke, H. L. 1972. UV light, a useful field tool. BioScience 22:604-607.

Teague, W. R., W. E. Grant, U. P. Kreuter, H. Diaz-Solis, S. Dube, M. M. Kothmann, W.

E. Pinchak, and R. J. Ansley. 2008. An ecological economic simulation model for assessing fire and grazing management effects on mesquite rangelands in Texas. Ecological Economics 64:611-624.

Toren, T. J. 1973. Biology of the California coast range scorpion *Vaejovis gertschi striatus* Hjelle (Scorpionida: Vaejovidae). MA thesis. San Fransisco State University, San Fransisco.

Williams, S. C. 1968. Habitat preferences and surface activities of the scorpions *Hadrurus arizonensis*, *Vejovis confuses* and *Vejovis spinigerus*. Dissertation. Arizona State University, Tempe.

Williams, S. C. 1970. Coexistence of desert scorpions by differential habitat preferences. Pan-Pacific Entomology 46:254-267.

Williams, S. C. 1987. Scorpion bionomics. Annual Review of Entomology 32:275-295.

Table II.1. The influence of burning treatment on the proportion of adults, subadults, and juveniles (mean±SE) for *Centruroides vittatus* captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned	Unburned	Winter-Burned
Adults	0.423±0.077 a	0.645±0.073 b	0.536±0.074 ab
Subadults	0.008±0.008 a	0.000±0.000 a	0.005±0.005 a
Juveniles	0.018±0.010 a	0.055±0.029 ab	0.134±0.046 b

Table II.2. The influence of burning treatment on the proportion of adults, subadults, and juveniles (mean±SE) for *Vaejovis coahuilae* captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned	Unburned	Winter-Burned
Adults	0.80±0.04 a	0.81±0.05 a	0.81±0.04 a
Subadults	0.18±0.05 a	0.10±0.04 a	0.17±0.05 a
Juveniles	0.34±0.06 a	0.17±0.05 b	0.26±0.05 ab

Table II.3. Proportions (mean±SE) of adults, subadults, and juveniles for *Centruroides vittatus* based upon capture period at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	2008			2009				
	July	August	September	May	June	July	August	September
Adults	0.86±0.09 a	0.69±0.10 a	0.53±0.13 ac	0.44±0.13abc	0.54±0.12 ac	0.68±0.12 a	0.20±0.11 b	0.33±0.13 bc
Subadults	0.00±0.00 a	0.00±0.00 a	0.04±0.04 a	0.00±0.00 a	0.03±0.03 a	0.00±0.00 a	0.00±0.00 a	0.00±0.00 a
Juveniles	0.04±0.04 a	0.21±0.08 a	0.14±0.08 a	0.05±0.05 a	0.07±0.05 a	0.08±0.06 a	0.20±0.11 a	0.00±0.00 a

Table II.4. Proportions (mean±SE) of adults, subadults, and juveniles for *Vaejovis coahuilae* based upon capture period at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	2008			2009				
	July	August	September	May	June	July	August	September
Adults	0.76±0.06 c	0.90±0.03 b	0.91±0.03 b	0.37±0.10 a	0.90±0.04 b	0.88±0.03 b	0.98±0.01 b	0.75±0.09 c
Subadults	0.34±0.10 ac	0.33±0.09 ac	0.04±0.04 bc	0.18±0.07 c	0.00±0.00 b	0.24±0.08 ac	0.03±0.03bc	0.05±0.05 bc
Juveniles	0.23±0.08 b	0.12±0.05 b	0.33±0.10 c	0.54±0.11 a	0.30±0.09 c	0.26±0.07 b	0.08±0.06 b	0.19±0.07 b

Table II.5. Proportions (mean±SE) of adults, subadults, and juveniles for *Centruroides vittatus* based upon capture period and burning treatment [summer-burned (S), winter-burned (W), and unburned (U)] at Matador Wildlife Management Area, Cottle County, Texas, USA.

		2008			2009				
Age	Treatment	July	August	September	May	June	July	August	September
Adults	S	0.80±0.20	0.52±0.22	0.47±0.23	0.20±0.20	0.40±0.24	0.60±0.24	0.20±0.20	0.20±0.20
	W	0.80±0.20	0.90±0.10	0.60±0.24	0.33±0.21	0.62±0.19	0.63±0.19	0.00±0.00	0.40±0.24
	U	0.98±0.03	0.65±0.18	0.53±0.23	0.80±0.20	0.60±0.24	0.80±0.20	0.40±0.24	0.40±0.24
Subadults	S	0.00±0.00	0.00±0.00	0.11±0.11	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	W	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.10	0.00±0.00	0.00±0.00	0.00±0.00
	U	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Juveniles	S	0.00±0.00	0.22±0.14	0.09±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	W	0.00±0.00	0.13±0.13	0.20±0.20	0.16±0.16	0.21±0.14	0.25±0.16	0.40±0.24	0.00±0.00
	U	0.11±0.11	0.27±0.17	0.12±0.12	0.00±0.00	0.00±0.00	0.00±0.00	0.20±0.20	0.00±0.00

Table II.6. Proportions (mean±SE) of adults, subadults, and juveniles for *Vaejovis coahuilae* based upon capture period and burning treatment at Matador Wildlife Management Area, Cottle County, Texas, USA.

		2008			2009				
Age	Treatment	July	August	September	May	June	July	August	September
Adults	S	0.70±0.20	0.90±0.03	0.78±0.05	0.47±0.16	0.80±0.08	0.90±0.03	0.99±0.01	0.87±0.10
	W	0.77±0.07	0.89±0.05	0.98±0.02	0.35±0.17	0.91±0.04	0.82±0.08	0.96±0.03	0.78±0.20
	U	0.81±0.12	0.89±0.08	0.96±0.04	0.28±0.20	1.00±0.00	0.92±0.06	1.00±0.00	0.62±0.17
Subadults	S	0.36±0.22	0.46±0.12	0.12±0.12	0.10±0.10	0.00±0.00	0.32±0.13	0.10±0.10	0.00±0.00
	W	0.50±0.14	0.25±0.15	0.00±0.00	0.33±0.14	0.00±0.00	0.30±0.18	0.00±0.00	0.00±0.00
	U	0.17±0.17	0.27±0.18	0.00±0.00	0.12±0.12	0.00±0.00	0.10±0.10	0.00±0.00	0.15±0.15
Juveniles	S	0.21±0.16	0.12±0.08	0.76±0.07	0.64±0.19	0.49±0.13	0.29±0.13	0.00±0.00	0.24±0.15
	W	0.27±0.16	0.16±0.10	0.10±0.10	0.46±0.19	0.40±0.17	0.32±0.14	0.24±0.15	0.11±0.11
	U	0.22±0.16	0.10±0.07	0.11±0.11	0.51±0.21	0.00±0.00	0.18±0.11	0.00±0.00	0.23±0.14

Table II.7. Proportions of female scorpions captured (mean±SE) during 2008 and 2009 in 3 burning treatments at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Summer-Burned	Unburned	Winter-Burned
Centruroides vittatus	0.16±0.05 a	0.20±0.05 a	0.26±0.06 a
Vaejovis coahuilae	0.54±0.05 a	0.42±0.05 b	0.41±0.04 b

Table II.8. Proportions (mean±SE) of female *Centruroides vittatus* (CEVI) and *Vaejovis coahuilae* (VACO) scorpions captured during July-September 2008 and May-September 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	2008			2009				
	July	August	September	May	June	July	August	September
CEVI	0.61±0.10 b	0.34±0.09 a	0.19±0.09 ac	0.14±0.08 ac	0.10±0.06 c	0.16±0.08 ac	0.05±0.04 c	0.07±0.07 c
VACO	0.25±0.04 ac	0.37±0.04 ac	0.40±0.04 ac	0.63±0.12 b	0.49±0.07 bc	0.37±0.04 ac	0.49±0.04 bc	0.64±0.10 b

Table II.9. Proportions (mean±SE) of female scorpions based upon capture period and burn treatment at Matador Wildlife Management Area, Cottle County, Texas, USA.

	Centruroides vittatus			*Vaejovis coahuilae*		
	Summer-Burned	Winter-Burned	Unburned	Summer-Burned	Winter-Burned	Unburned
July 2008	0.55±0.20	0.63±0.19	0.66±0.18	0.36±0.06	0.23±0.06	0.16±0.05
August 2008	0.15±0.10	0.64±0.19	0.23±0.10	0.38±0.07	0.27±0.01	0.47±0.08
September 2008	0.33±0.21	0.23±0.15	0.00±0.00	0.51±0.07	0.40±0.05	0.30±0.06
May 2009	0.00±0.00	0.13±0.13	0.30±0.20	0.80±0.20	0.69±0.18	0.40±0.24
June 2009	0.10±0.10	0.15±0.15	0.05±0.05	0.39±0.13	0.41±0.10	0.68±0.14
July 2009	0.10±0.10	0.27±0.19	0.10±0.10	0.34±0.09	0.37±0.07	0.40±0.05
August 2009	0.05±0.05	0.00±0.00	0.10±0.10	0.62±0.05	0.36±0.09	0.48±0.02
September 2009	0.00±0.00	0.00±0.00	0.20±0.20	0.89±0.07	0.55±0.21	0.47±0.16

Table II.10. Body size measurements including metasoma to total length (M-TL), telson to prosoma/mesosoma (T-PM), and right pedipalp to prosoma/mesosoma (RP-PM) ratios for scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

Variable	*Centruroides vittatus*	*Vaejovis coahuilae*	*Vaejovis russelli*
Prosoma/ Mesosoma	17.58±0.19 a	12.56±0.05 b	13.36±0.19 c
Metasoma	23.38±0.31 a	14.29±0.04 b	15.81±0.29 c
Total Length	40.95±0.42 a	26.84±0.09 b	29.17±0.42 c
Telson	4.61±0.05 a	4.41±0.02 b	4.76±0.15 a
Right Pedipalp	7.39±0.07 a	5.49±0.02 b	6.48±0.14 c
Left Pedipalp	7.39±0.07 a	5.49±0.02 b	6.48±0.14 c
M-TL Ratio	0.57±0.00 a	0.53±0.00 b	0.54±0.00 c
T-PM Ratio	0.27±0.00 a	0.35±0.00 b	0.36±0.01 bc
RP-PM Ratio	0.42±0.00 a	0.44±0.00 b	0.48±0.01 c

Table II.11. Body size measurements including metasoma to total length (M-TL), telson to prosoma/mesosoma (T-PM), and right pedipalp to prosoma/mesosoma (RP-PM) ratios for male and female scorpions captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA. Within a row, means followed by the same letter are not different at α=0.05.

	Centruroides vittatus		*Vaejovis coahuilae*		*Vaejovis russelli*	
Variable	Male	Female	Male	Female	Male	Female
Prosoma/Mesosom	16.72±0.23 a	18.83±0.28 b	11.64±0.04 c	13.71±0.07 d	13.27±0.28 c	13.49±0.24 c
Metasoma	24.71±0.43 a	21.44±0.29 b	14.02±0.05 c	14.63±0.07 d	16.18±0.40 e	15.28±0.39 ce
Total Length	41.42±0.62 a	40.27±0.50 b	25.66±0.09 c	28.34±0.13 d	29.44±0.66 c	28.77±0.41 c
Telson	4.58±0.07 a	4.67±0.08 a	4.26±0.02 b	4.61±0.03 a	4.53±0.23 a	5.09±0.10 c
Right Pedipalp	7.36±0.10 a	7.45±0.11 b	5.28±0.02 c	5.77±0.03 d	6.60±0.23 e	6.31±0.11 e
Left Pedipalp	7.36±0.09 a	7.45±0.11 b	5.28±0.02 c	5.77±0.03 d	6.60±0.22 e	6.31±0.11 e
M-TL Ratio	0.59±0.00 a	0.53±0.00 b	0.55±0.00 ad	0.52±0.00 c	0.55±0.00 d	0.53±0.01 e
T-PM Ratio	0.28±0.00 a	0.25±0.00 b	0.37±0.00 c	0.34±0.00 d	0.34±0.02 c	0.38±0.01 d
RP-PM Ratio	0.44±0.01 a	0.40±0.01 a	0.45±0.00 a	0.43±0.00 a	0.50±0.01 a	0.47±0.01 a

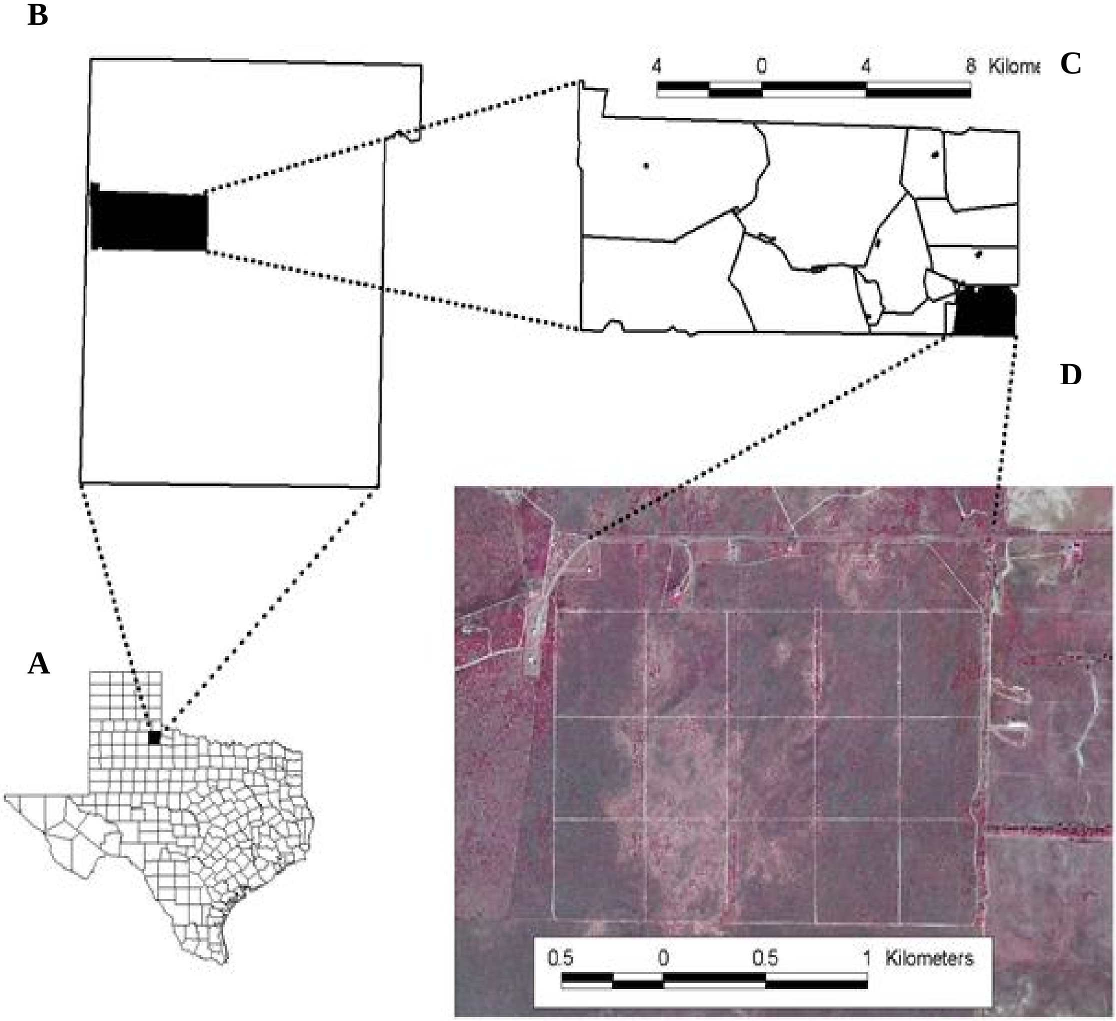

Figure II.1: Blowout map of my specific study indicating the location of Cottle County within Texas (A), Matador Wildlife Management Area within Cottle County (B), Headquarters Pasture within Matador Wildlife Management Area (C), and my specific study plots within Headquarters Pasture (D).

Blocks

1	2	3	4	5
U	W	W	U	S
S	U	S	W	U
W	S	U	S	W

Figure II.2: Diagrammatic representation of my specific study plots within Headquarters Pasture at Matador WMA in Cottle County, Texas. Headquarters Pasture was divided into 5 blocks, each consisting of 3 18-ha plots. Each of the 3 plots within a block was randomly assigned one of 3 treatments: unburned (U), winter burning (W), summer burning (S).

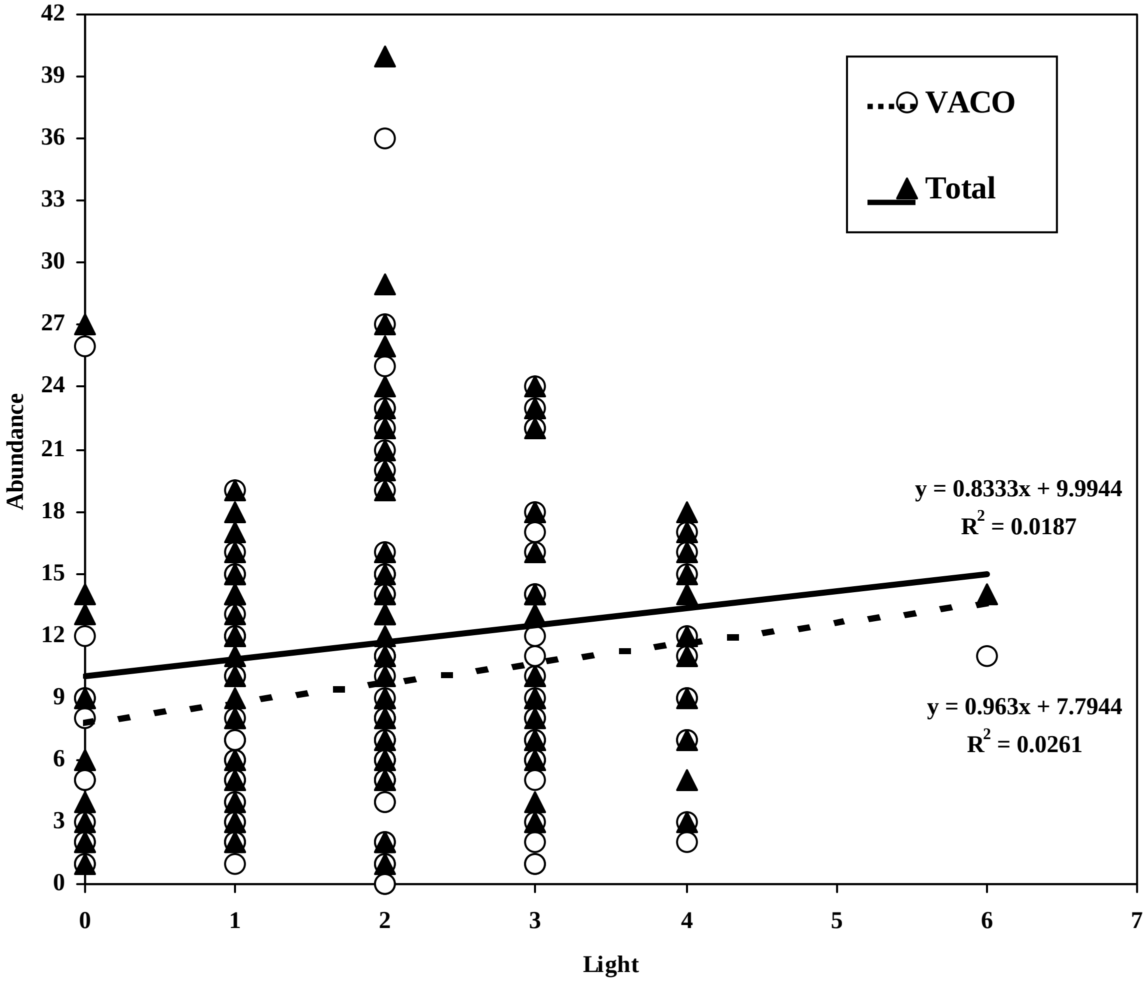

Figure II.3. Relationship between light level and abundance of *Vaejovis coahuilae* (p=0.080) and total scorpions (p=0.140) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

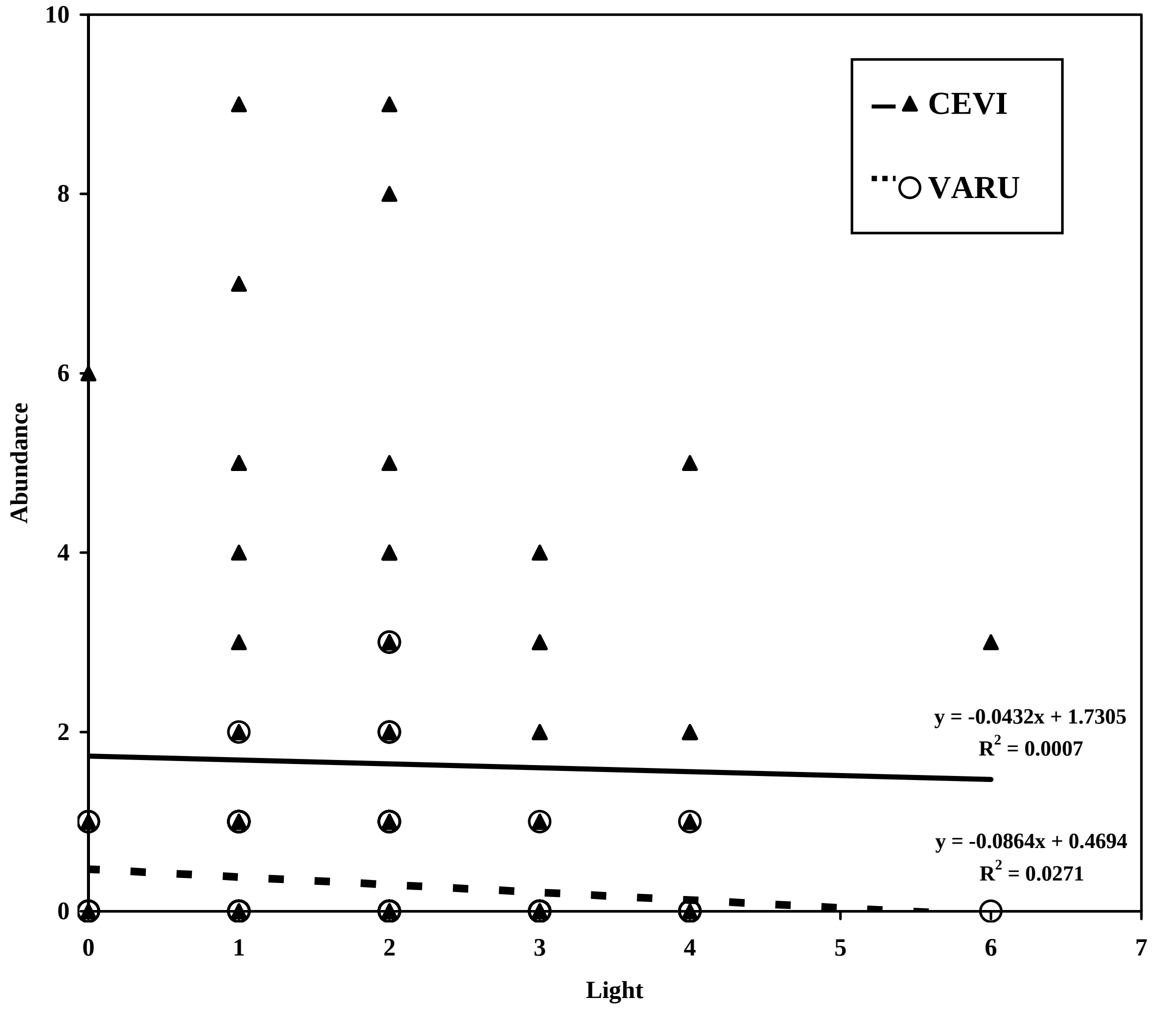

Figure II.4. Relationship between light level and abundance of *Centruroides vittatus* (p=0.783) and *Vaejovis russelli* (p=0.075) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

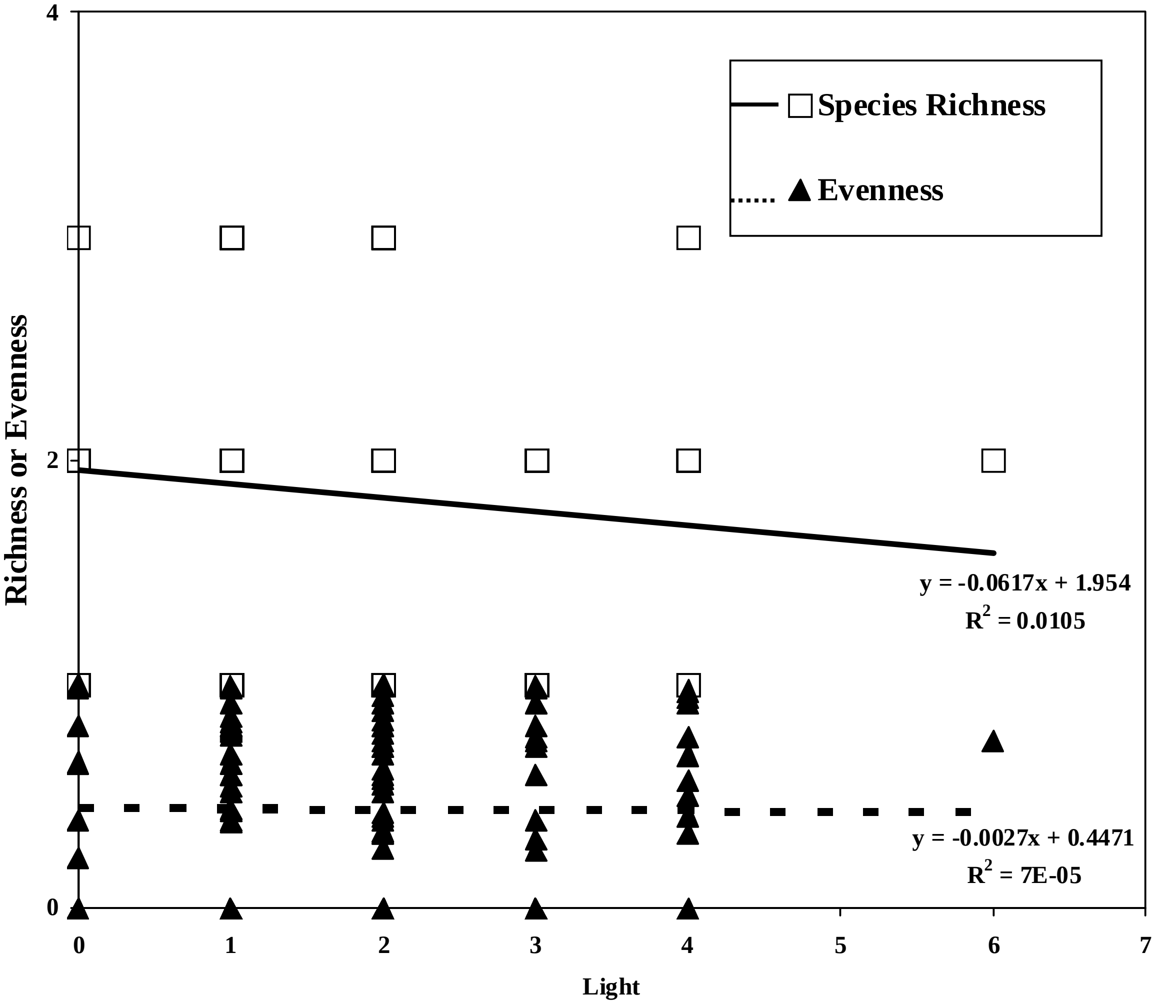

Figure II.5. Relationship between light level and scorpion species richness (p=0.269) and evenness (p=0.926) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

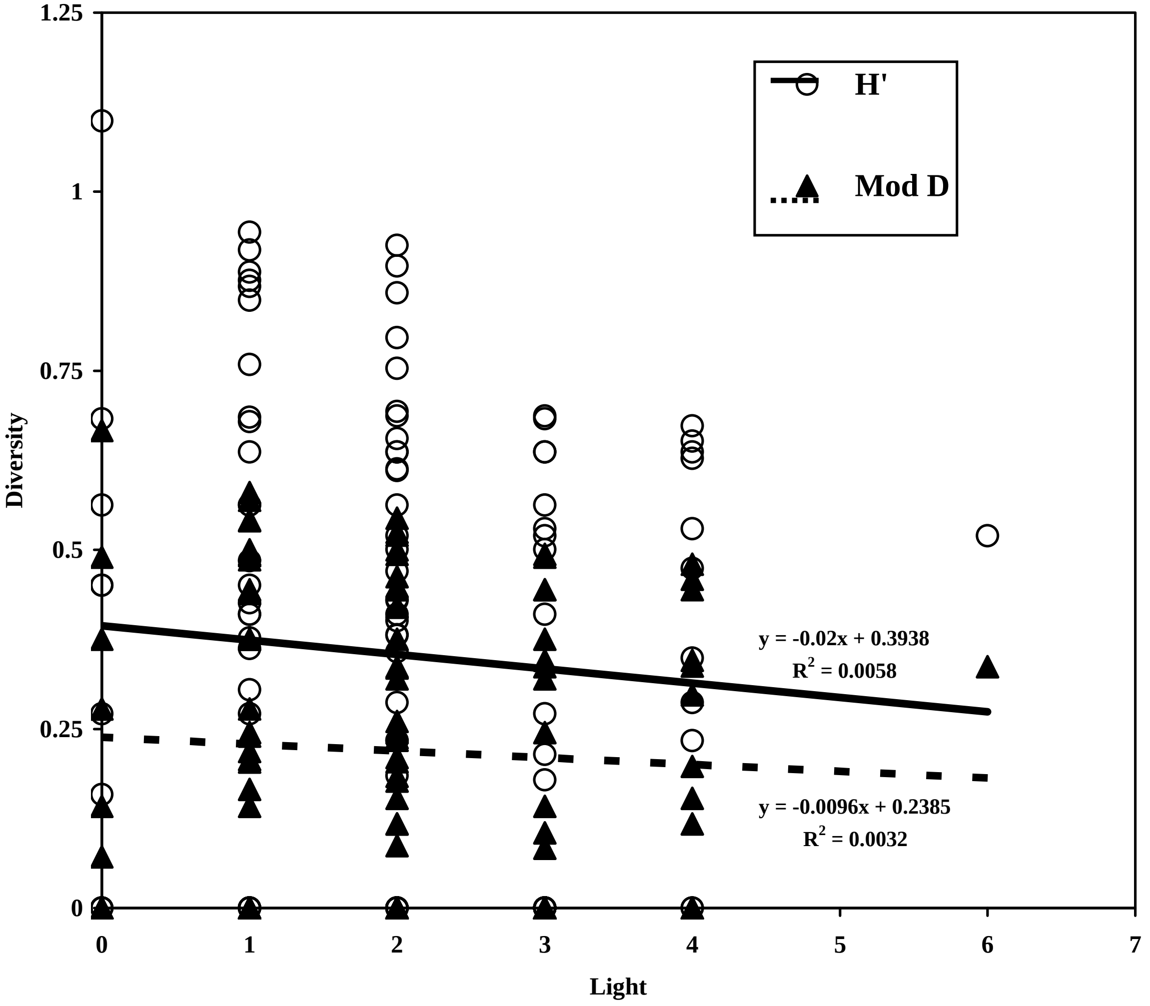

Figure II.6. Relationship between light level and Shannon-Weiner (H’, p=0.414) and modified Simpson’s (Mod D, p=0.545) diversity indices during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

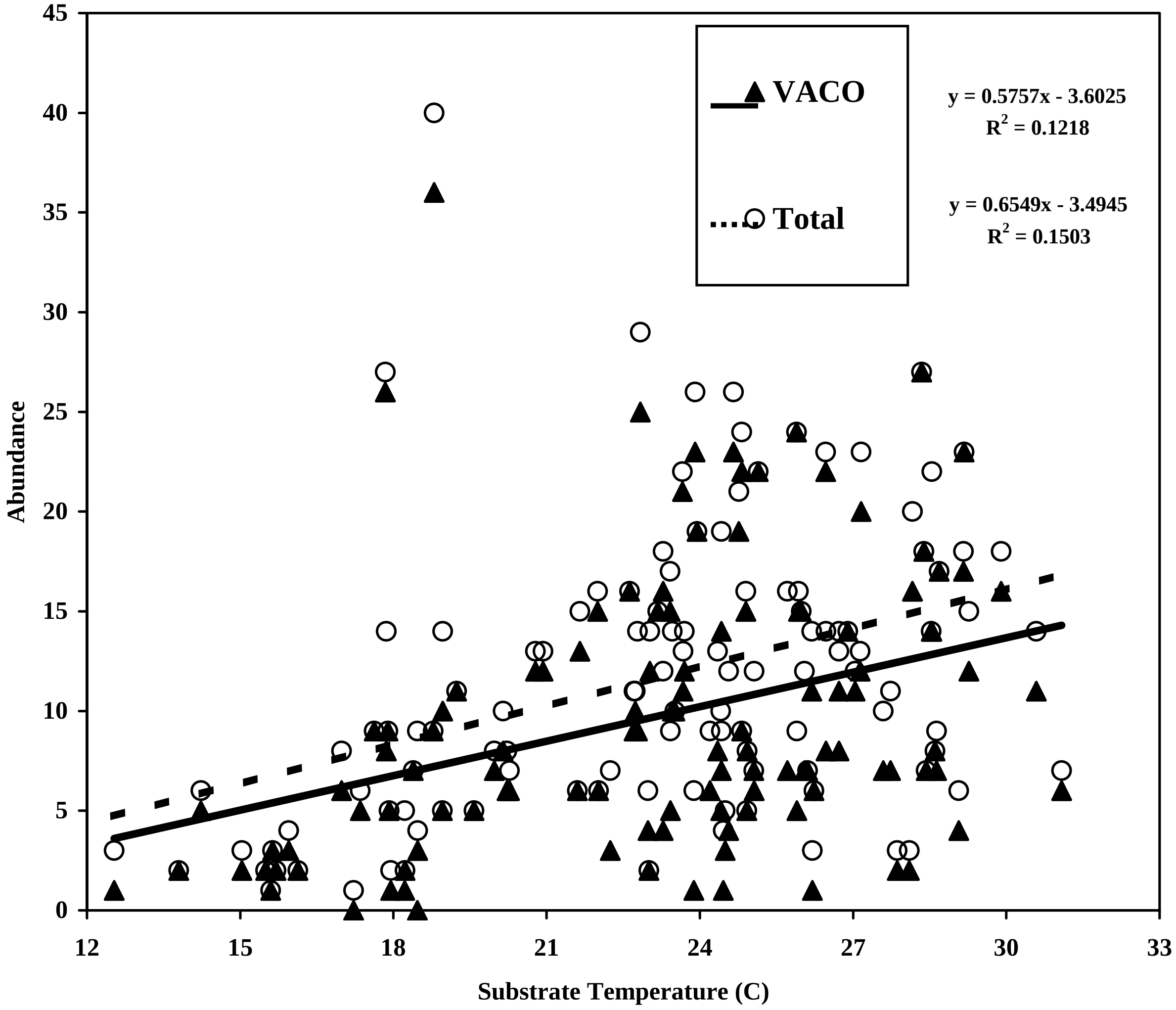

Figure II.7. Relationship between substrate temperature and abundance of *Vaejovis coahuilae* ($p<0.001$) and total scorpions ($p<0.001$) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

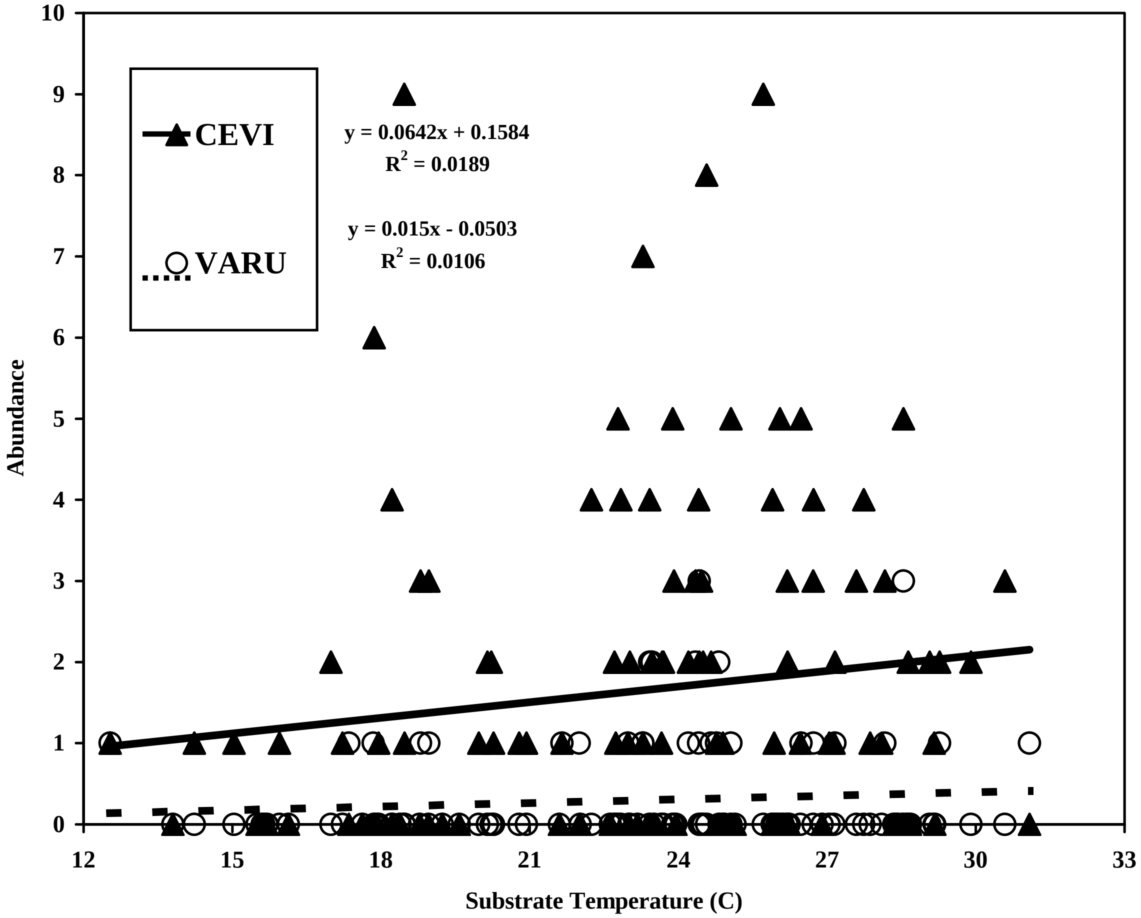

Figure II.8. Relationship between substrate temperature and abundance of *Centruroides vittatus* (p=0.138) and *Vaejovis russelli* (p=0.266) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

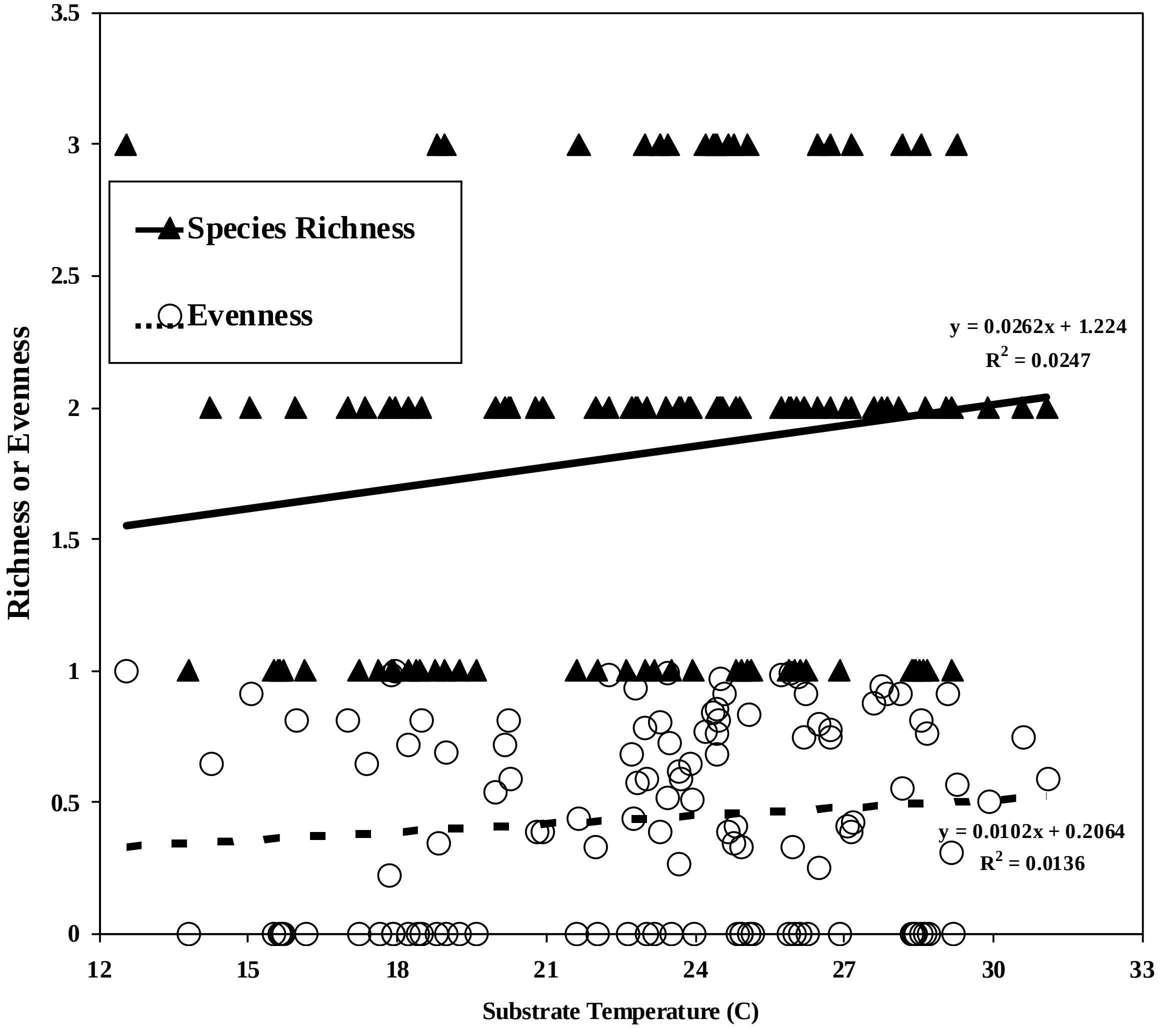

Figure II.9. Relationship between substrate temperature and scorpion species richness (p=0.089) and evenness (p=0.209) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

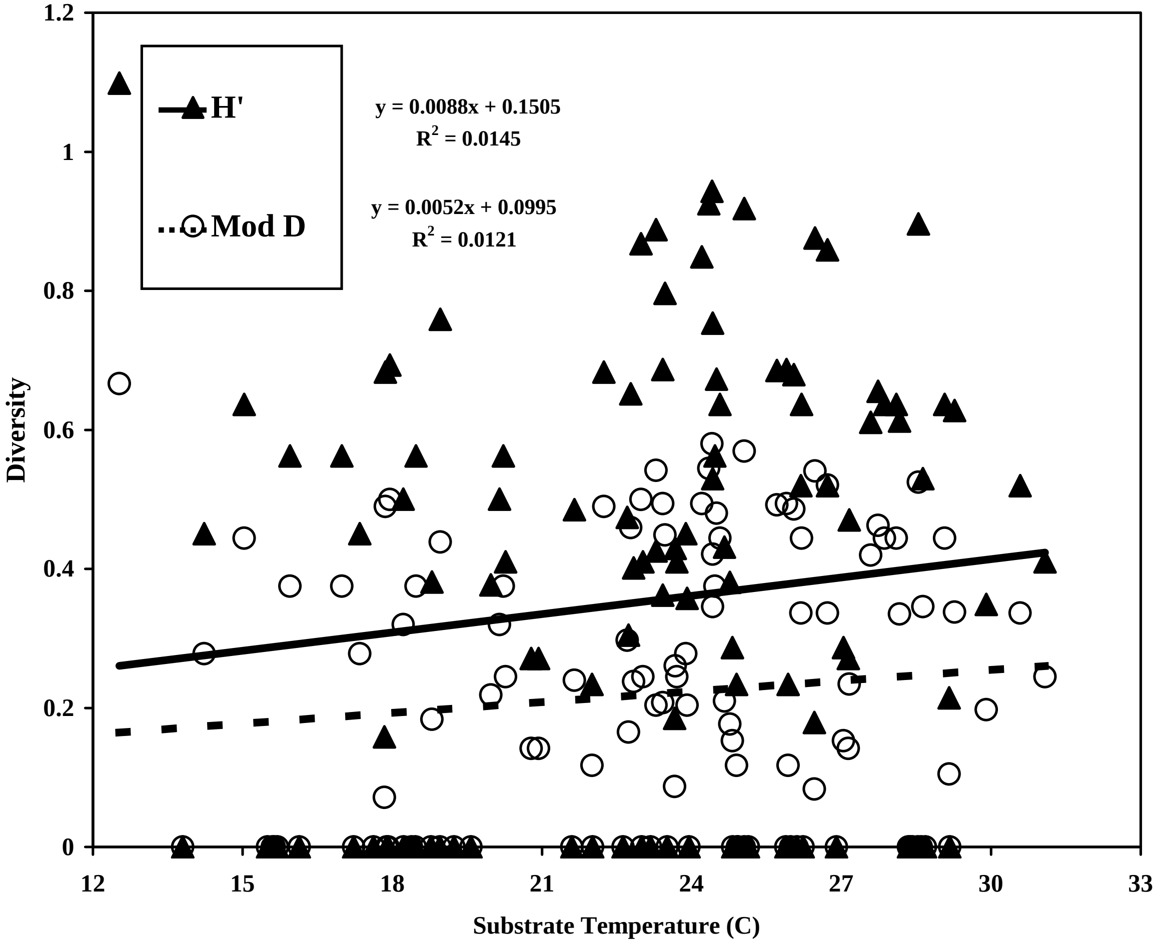

Figure II.10. Relationship between substrate temperature and Shannon-Weiner (H’, p=0.194) and modified Simpson’s (Mod D, p=0.235) diversity indices during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

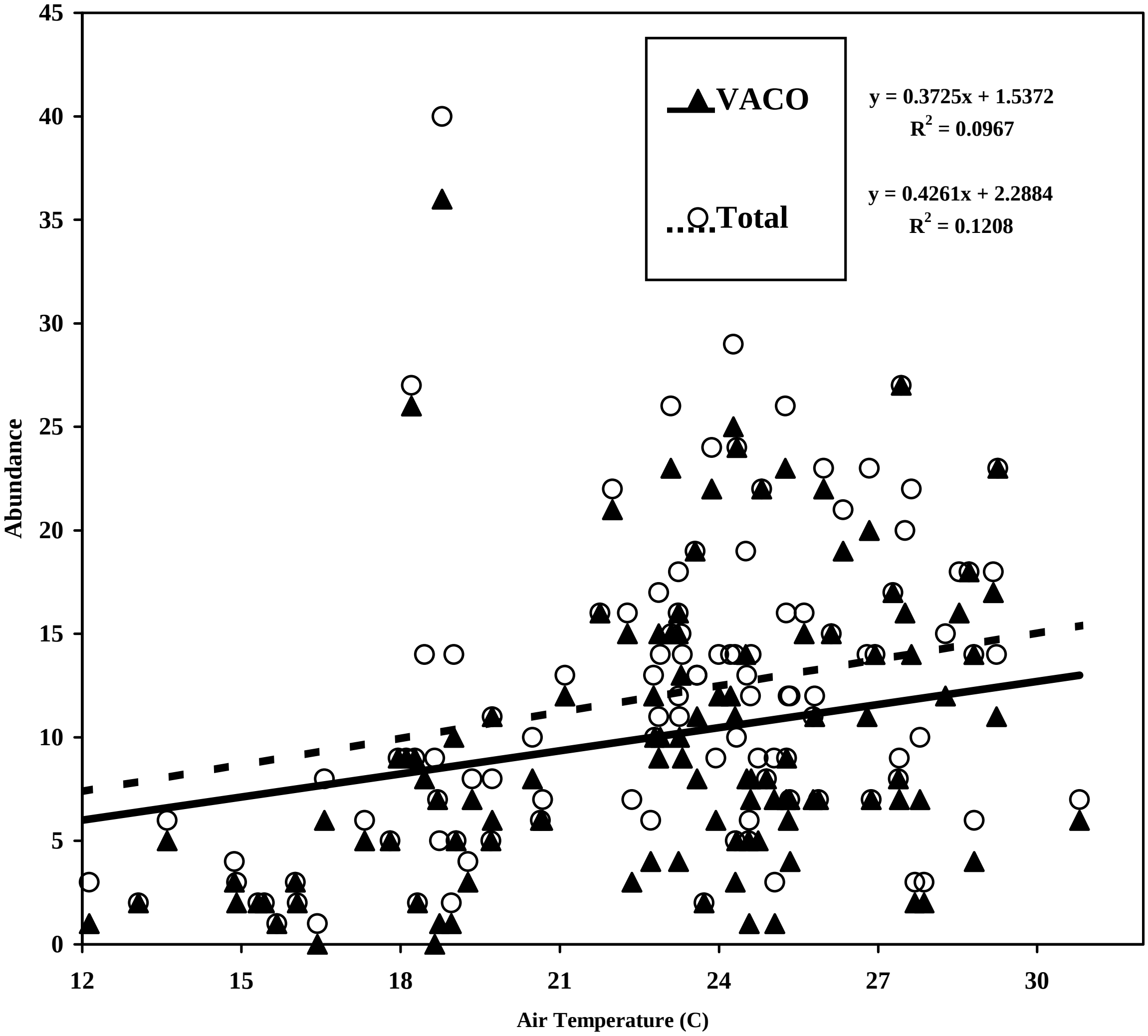

Figure II.11. Relationship between air temperature and abundance of *Vaejovis coahuilae* (p<0.001) and total scorpions (p<0.001) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

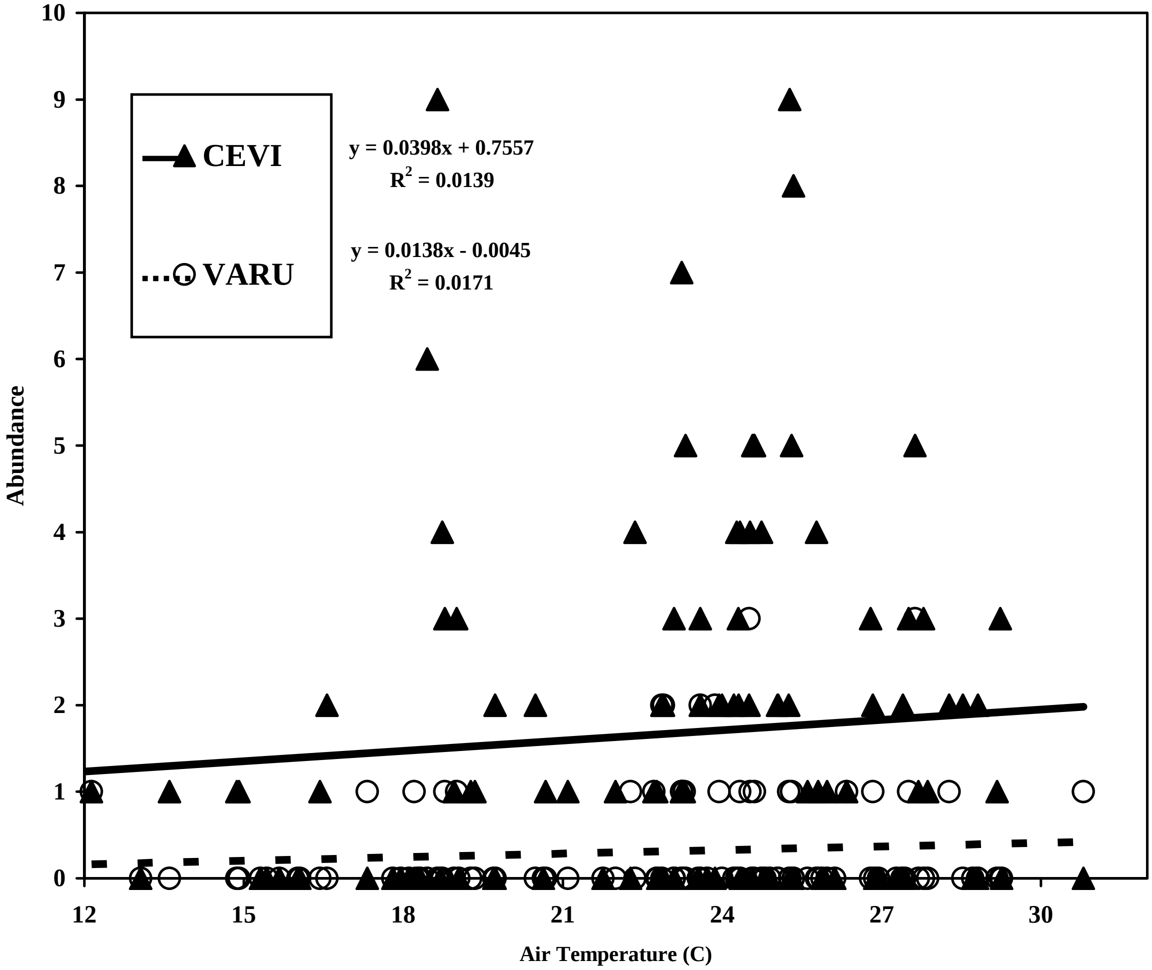

Figure II.12. Relationship between air temperature and abundance of *Centruroides vittatus* (p=0.207) and *Vaejovis russelli* (p=0.162) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

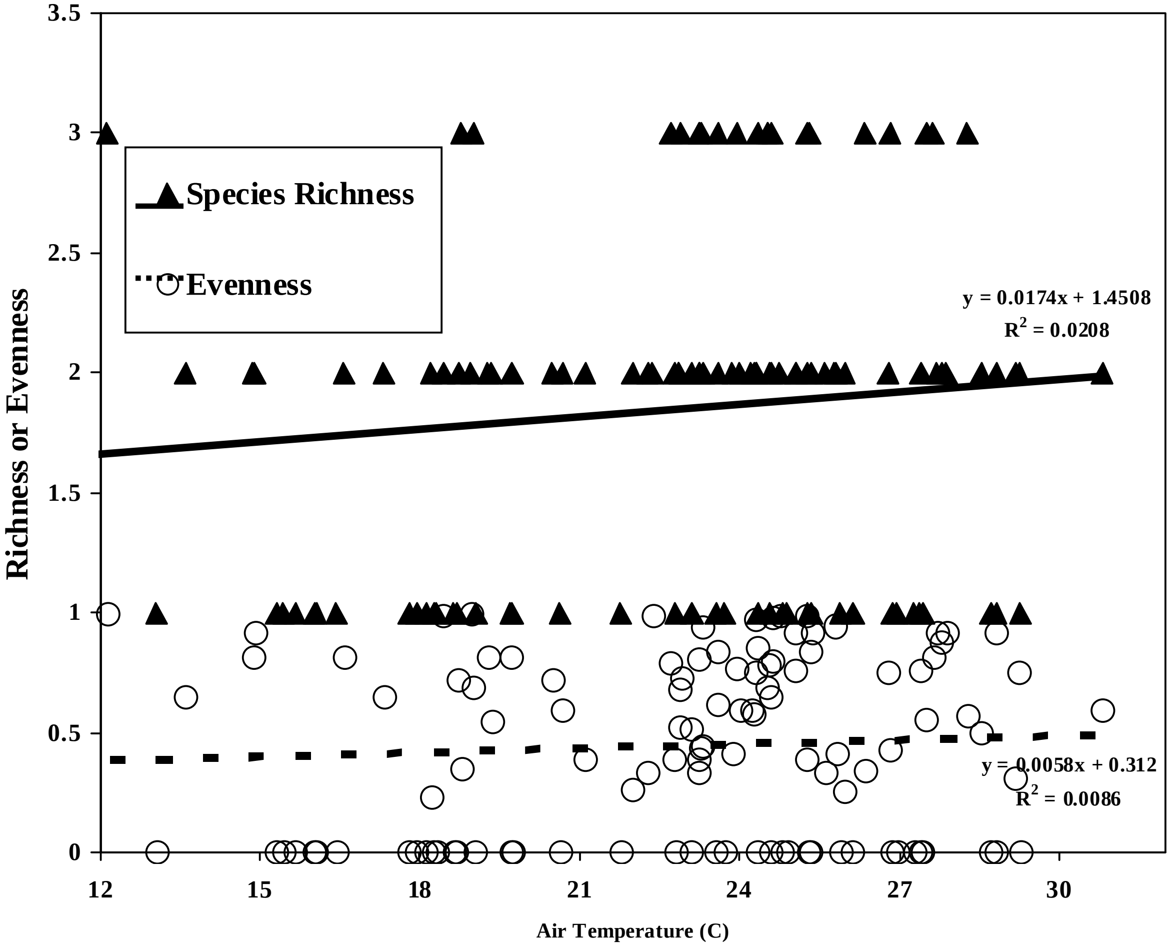

Figure II.13. Relationship between air temperature and scorpion species richness (p=0.122) and evenness (p=0.322) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

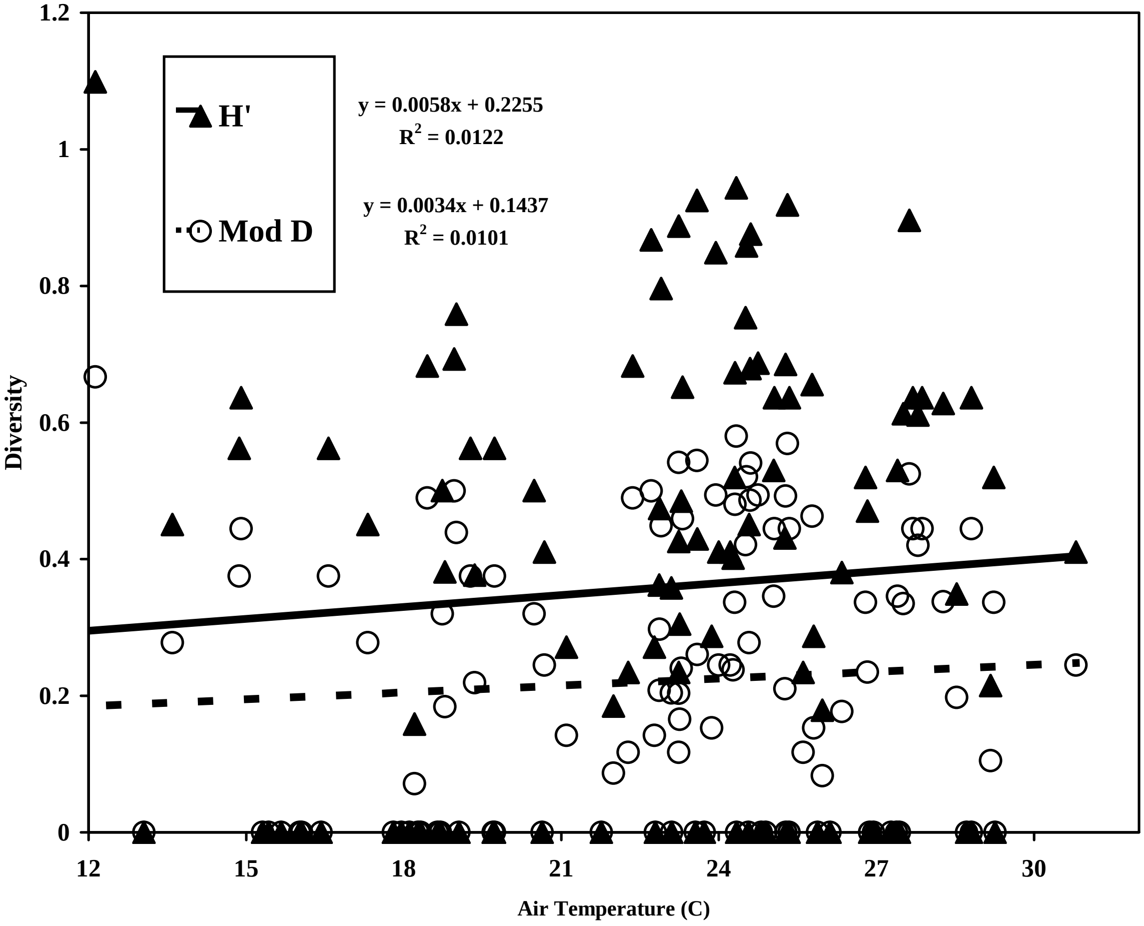

Figure II.14. Relationship between air temperature and Shannon-Weiner (H’, p=0.239) and modified Simpson’s (Mod D, p=0.283) diversity indices during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

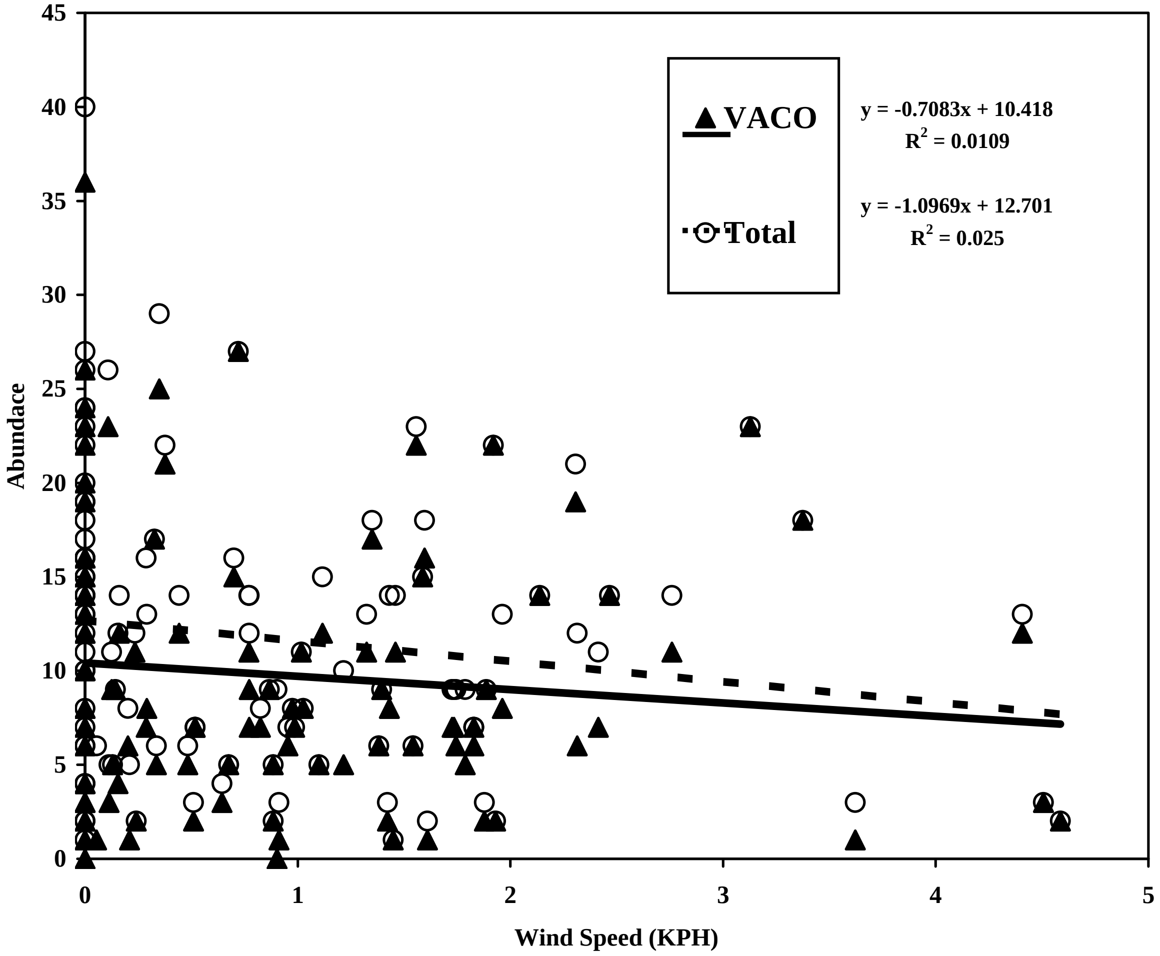

Figure II.15. Relationship between wind speed and abundance of *Vaejovis coahuilae* (p=0.264) and total scorpions (p=0.090) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

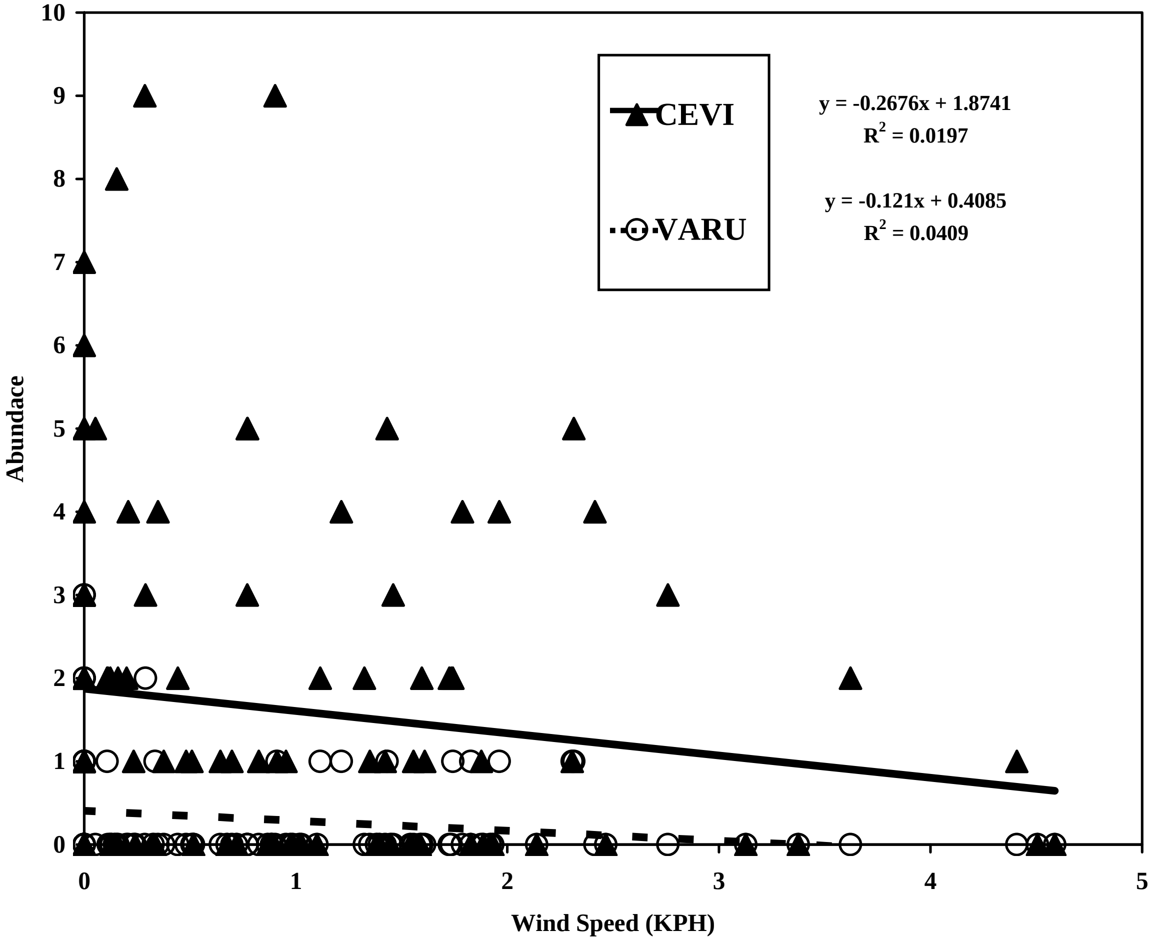

Figure II.16. Relationship between wind speed and abundance of *Centruroides vittatus* (p=0.133) and *Vaejovis russelli* (p=0.029) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

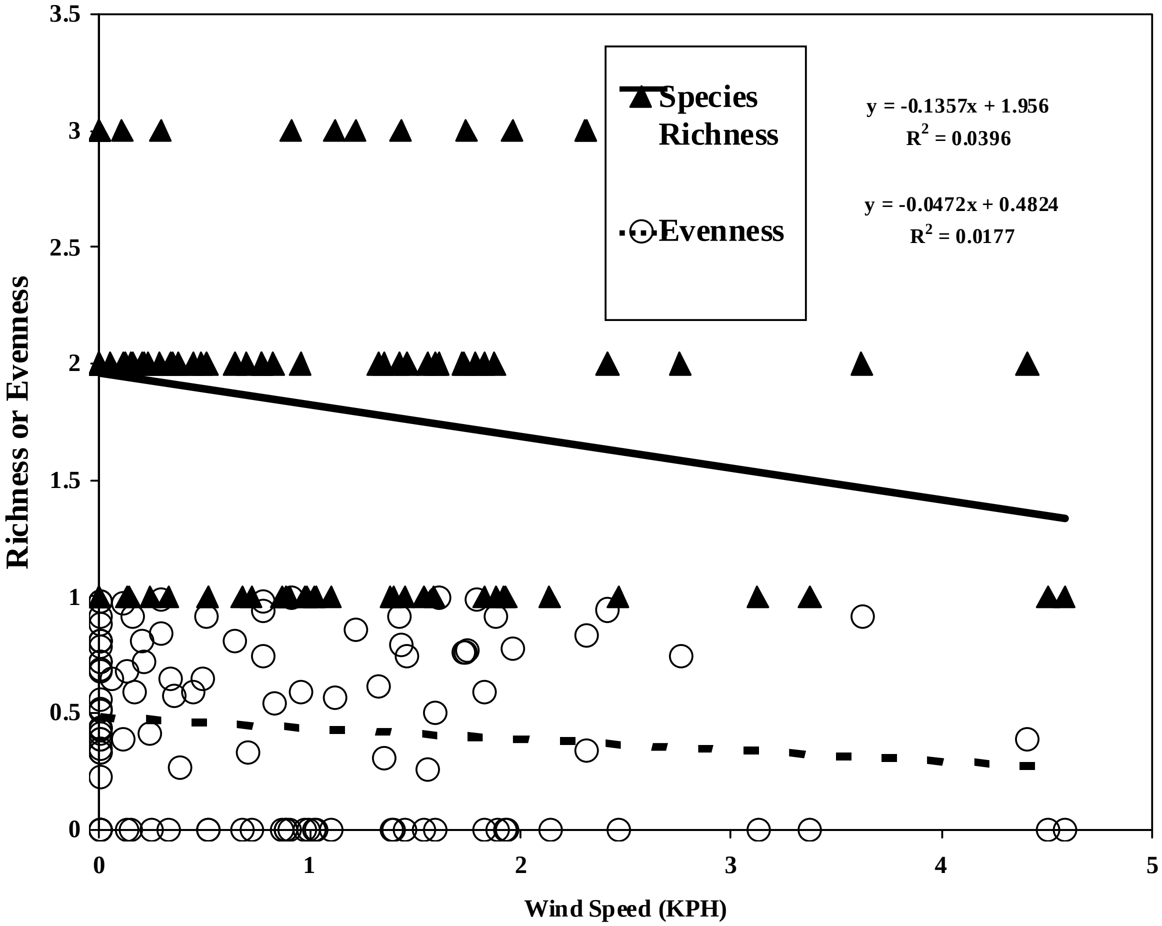

Figure II.17. Relationship between wind speed and scorpion species richness (p=0.032) and evenness (p=0.154) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

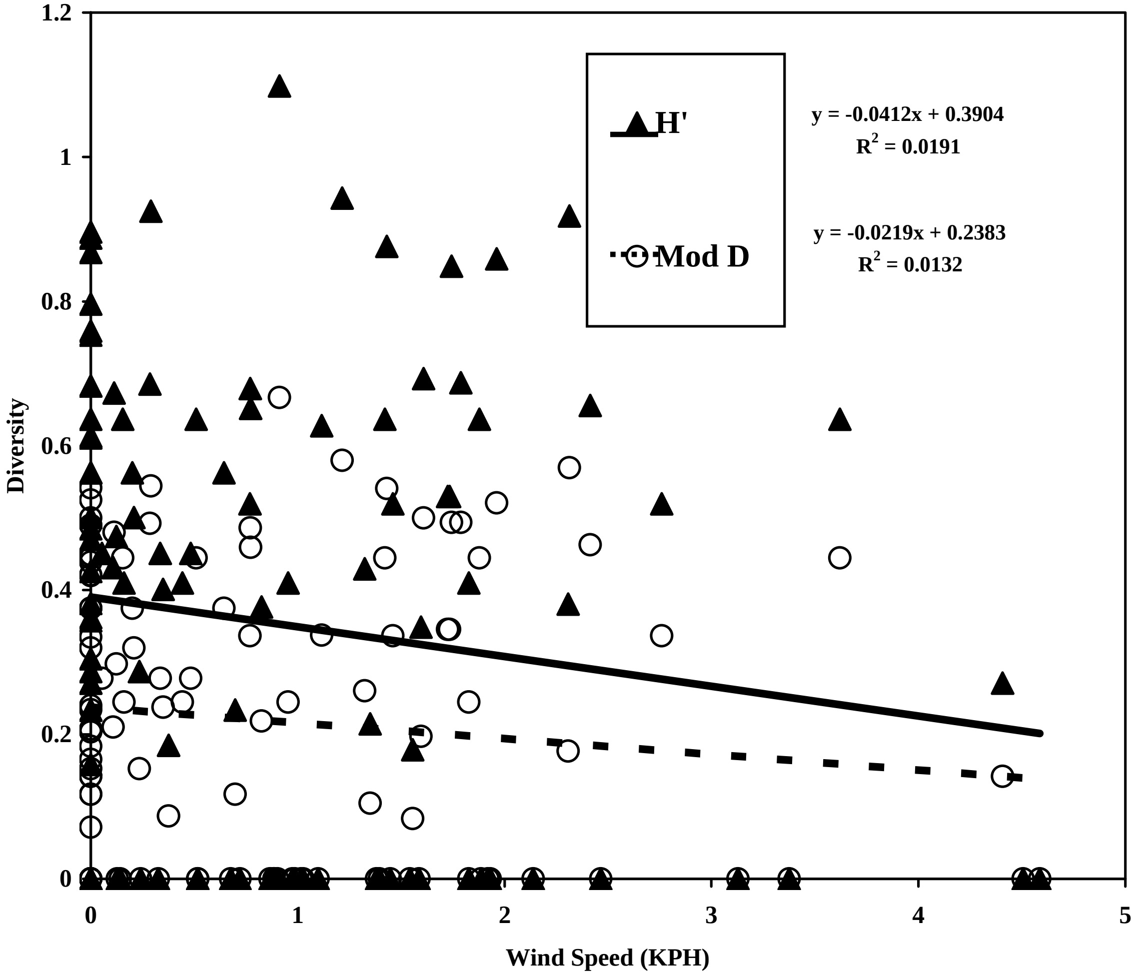

Figure II.18. Relationship between wind speed and Shannon-Weiner (H’, p=0.139) and modified Simpson’s (Mod D, p=0.220) diversity indices during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

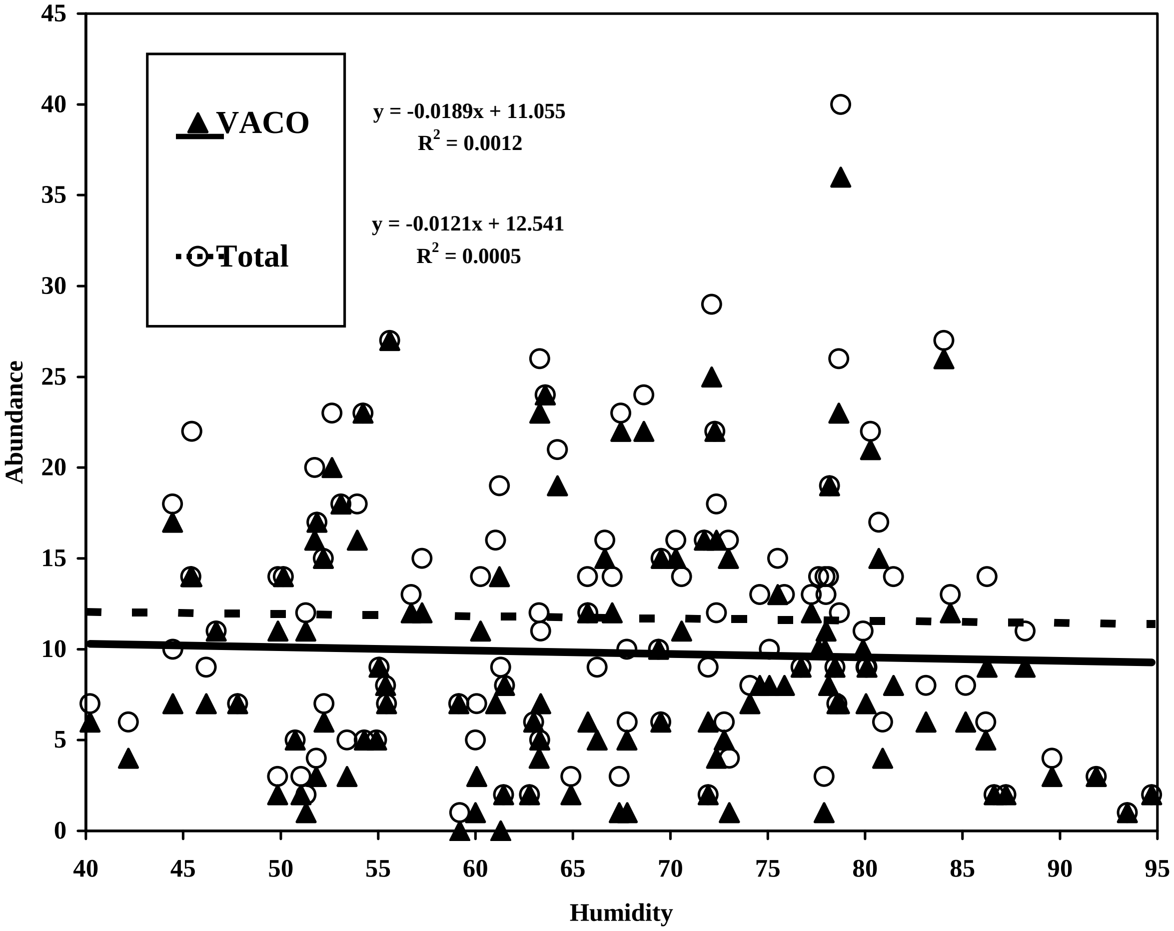

Figure II.19. Relationship between humidity and abundance of *Vaejovis coahuilae* (p=0.711) and total scorpions (p=0.817) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

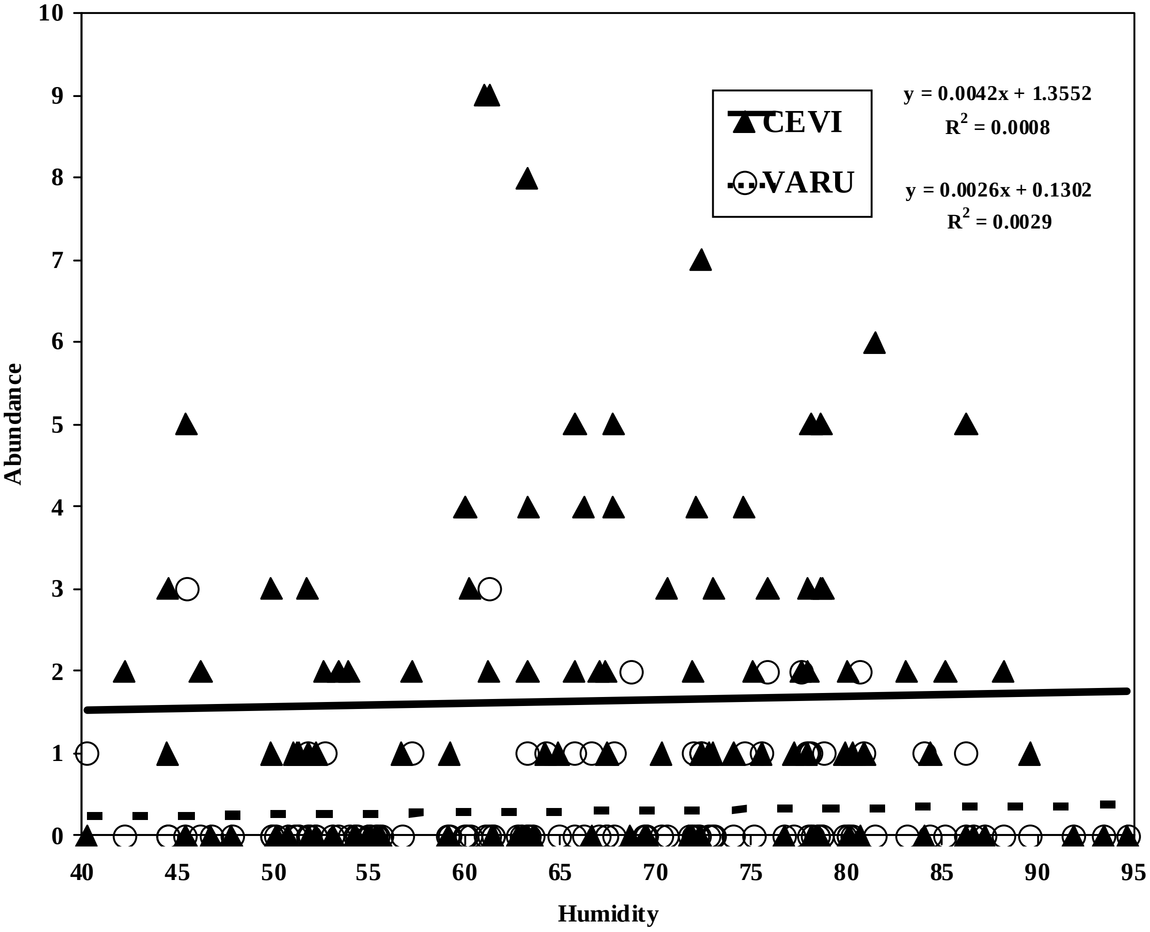

Figure II.20. Relationship between humidity and abundance of *Centruroides vittatus* (p=0.768) and *Vaejovis russelli* (p=0.568) captured during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

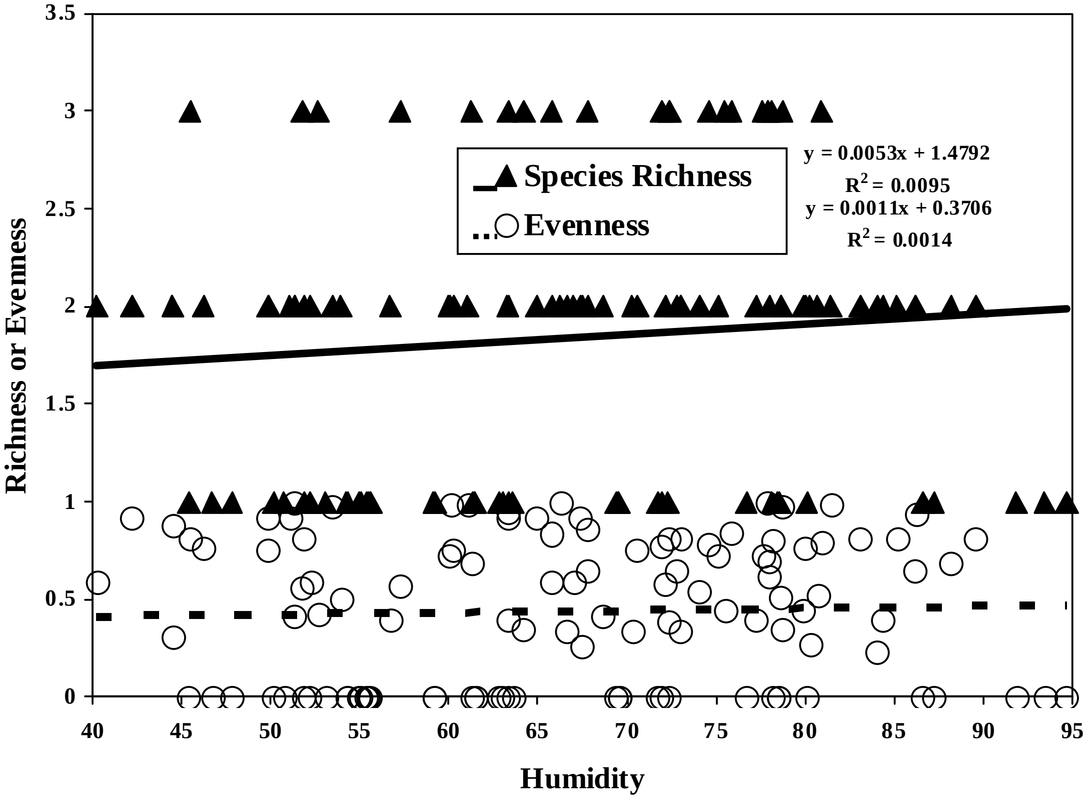

Figure II.21. Relationship between humidity and scorpion species richness (p=0.297) and evenness (p=0.694) during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.

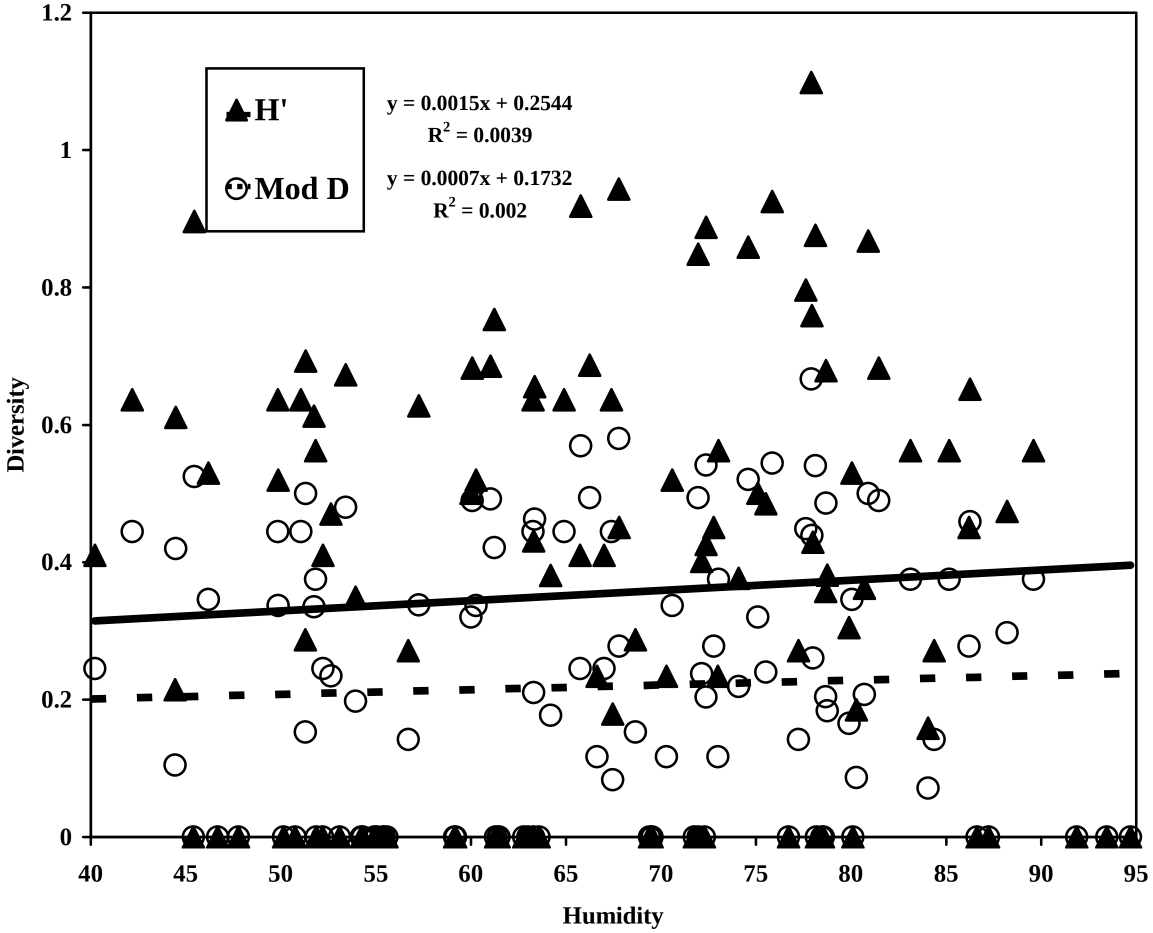

Figure II.22. Relationship between humidity and Shannon-Weiner (H’, p=0.505) and modified Simpson’s (Mod D, p=0.634) diversity indices during 2008 and 2009 at Matador Wildlife Management Area, Cottle County, Texas, USA.