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FINAL PERFORMANCE REPORT

FEDERAL AID GRANT NO. T-24-P-1

A HERPETOLOGICAL SURVEY OF THE BLACK MESA ECOREGIONAND SURROUNDING AREA

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

June 1, 2005 through May 31, 2008

FINAL PERFORMANCE REPORT

State: OKLAHOMA **Grant Number:** T-24-P-1

Grant Program: State Wildlife Grants

Grant Title: A Herpetological Survey of the Black Mesa Ecoregion and Surrounding Area

Grant Period: 1 June 2005–31 May 2008

Principal Investigator: Stanley F. Fox

Objective:
To conduct a 3-year survey of the herpetofauna in the Black Mesa ecoregion and surrounding area with a particularly focus efforts on Oklahoma's horned lizards, *Phrynosoma modestum* (if encountered) and *P. cornutum*.

Summary of Progress:
Attached Master's Thesis serves as the final report.

Significant Deviations: None

Principal Investigator: Dr. Stanley F. Fox,
Regents Professor and Curator of Herpetology
Oklahoma State University

Prepared by: Timothy S. Pariard

Date: 15 July 2008

Approved by:

Wildlife Division Administration
Oklahoma Department of Wildlife Conservation

John D. Stafford
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HERPETOLOGICAL SURVEY OF THE BLACK MESA ECOREGION, OKLAHOMA, WITH AN EMPHASIS ON THE ECOLOGY OF THE TEXAS HORNED LIZARD (*PHRYNOSOMA CORNUTUM*)

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MESA ECOREGION, OKLAHOMA, WITH

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THE TEXAS HORNED LIZARD

(*PHRYNOSOMA CORNUTUM*)

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CHAPTER I

HERPETOLOGICAL SURVEY OF THE BLACK MESA ECOREGION, OKLAHOMA

ABSTRACT

I conducted a herpetological survey of the Black Mesa ecoregion, which is located in the extreme northwestern corner of Oklahoma's Panhandle. The Black Mesa ecoregion is the coolest, driest, and highest region in the State and is characterized by flat-topped sandstone mesas capped with black basaltic lava. I surveyed reptiles and amphibians in this unique ecoregion of Oklahoma using a variety of sampling methods from June to August 2005 and May to August, 2006–2007. The various methods of capture included drift fence arrays with pitfall and double-ended funnel traps, cover boards, visual surveys, road cruising along specific routes, nocturnal call surveys at amphibian breeding sites, and opportunistic encounters. I collected data on the location of capture with a GPS unit, habitat and microhabitat at time of capture, and a variety of morphological measurements. A total of 26 reptile species (16 snake, 7 lizard, and 3 turtle species) and 9 amphibian species (8 frog and 1 salamander species) was captured or heard. A total of 1,920 individual animals was captured or observed, including 1,248 amphibians (1,246 frogs and 2 salamanders) and 672 reptiles (167 snakes, 470 lizards, and 35 turtles). My results indicated the importance of heterogeneous habitat and microhabitat for maximal reptile and amphibian diversity.

Rainfall (> 1 mm) significantly increased capture and observation of frog and turtle species within 2 days, whereas lizard captures were significantly decreased.

INTRODUCTION

Biological monitoring and animal surveys provide baseline data by documenting presence and relative abundance of different species. These data also are often useful in demographic analyses and comparisons and contribute to the understanding of ecological traits such as habitat preferences and species-specific seasonal activity patterns (Dickman 1987; Ford & Hampton 2005). Importantly, such information provides insight into establishing proper management and conservation practices for species of special concern (Ford & Hampton 2005; Kopachena & Kollar 1999).

There are many different sampling techniques used in a herpetological survey, depending on the type of species that are being studied. To generate a complete species list for an area, a combination of sampling methods usually is needed to sample all amphibians and reptiles (Jones 1986). Because of different ecological characteristics across species, no single method is best for detecting all species in a particular area (Heyer et al. 1994). For example, Crosswhite et al. (1999) found that pitfall traps were an effective method in capturing anurans and lizards but were not effective in capturing large squamates, such as large snakes. Instead, large squamates were captured most effectively using funnel traps. That study and others (Andreone et al. 2003; Greenburg et al. 1994) showed significant differences in capture success for various herpetological taxa among different sampling methods. Greenburg et al. (1994) compared effectiveness of pitfall and funnel traps and found that each technique had bias against some taxonomic

groups and species. They attributed that bias to differences in behavior and morphology among species.

Ford and Hampton (2005) surveyed amphibians and reptiles at an Army National Guard Training Site in Lamar County, Texas. They used visual encounter surveys, turtle traps, cover items, anuran call surveys, and road cruising. Their most effective technique in capturing species was visual encounter surveys, but other techniques, such as call surveys, recorded amphibians not found using any other method. While use of all possible methods is best, financial resources can limit researchers to select among sampling methods based on the type of habitat and species found in an area (Donnelly et al. 2005).

It is important to sample in different habitats when conducting surveys for reptiles and amphibians. Lewis et al. (2000) conducted a herpetological survey in four different forest habitats and found different herpetofaunal assemblages in each forest type. Crosswhite et al. (2004) found that four habitat parameters (canopy coverage, litter depth, woody plant cover, and large, woody debris) used in their study explained much of the variation in species composition among three sample sites.

Saenz et al. (2006) found that abiotic factors should be considered in a herpetological inventory. Some frogs are known to be more active due to breeding during and after rainfall (Blair 1960, Obert 1975). However, other researchers (Brown and Shine 2002) found that weather variables are relatively poor at predicting numbers of individuals and species encountered during herpetological surveys.

The extreme northwestern corner of the Oklahoma Panhandle is a unique ecosystem called the Black Mesa ecoregion (Oklahoma Biodiversity Task Force, 1996).

Herpetofauna of the Black Mesa ecoregion and surrounding area is not well known (Webb, 1970; Carpenter and Krupa, 1989). Eleven species of reptiles and amphibians found at Black Mesa are either recognized by the Oklahoma Department of Wildlife Conservation (ODWC) as species of special concern (a designation that identifies a species as a conservation priority for the State's nongame wildlife program) and/or listed by the Oklahoma Natural Heritage Inventory (ONHI) as Rare Oklahoma Vertebrates. A main priority from Oklahoma's Comprehensive Wildlife Conservation Strategy (2005) was the scientific survey of Oklahoma's natural biodiversity. My objectives were to conduct a complete species inventory of reptiles and amphibians at Black Mesa and describe the herpetofauna in terms of relative abundance and habitat and rainfall associations.

STUDY AREA

The Black Mesa ecoregion is located in the northwestern corner of Cimarron County, Oklahoma (Figure 1). It is bordered by New Mexico to the west and Colorado to the north. It is the coolest, driest, and highest (1516 m above mean sea level) region of the state and is characterized by flat-topped sandstone mesas (Figure 2) capped with black basaltic lava (Oklahoma Biodiversity Task Force, 1996). Most of the land is either privately owned or public that is leased out to ranchers. The only land for public use is located in Black Mesa State Park or close by in the Black Mesa Nature Preserve. The region has windy springs, cold winters, and hot dry summers. Black Mesa ecoregion is a complex integration of arid grasslands, shrublands (*Yucca* sp., *Opuntia* sp.), and cedar (*Juniper virginiana*)/rocky woodlands (McPherson 2003). Areas of pinyon pine (*Pinus edulis*) woodlands and riparian trees (e.g., *Populus deltoids*) are limited in the area but

still add to Black Mesa's biological diversity. Because of drought conditions in this region for several years, the man-made Lake Carl Etling in the state park contained very little water over the 3-year survey. The reservoir became very shallow over the last several years, which led to the decision of the State of Oklahoma to drain it in 2004.

METHODS

Survey

I used a variety of field survey methods at Black Mesa during June to August 2005 and May to August, 2006–2007. Reptiles and amphibians were captured using arrays of drift fences with pitfall and double-ended funnel traps (Campbell and Christman 1982, Jones 1986, Corn 1994), time-constrained visual searches (Jones 1986, Crump and Scott 1994), nocturnal aural surveys of breeding anurans (Vogt and Hine 1982), road cruising along specific routes (Campbell and Christman 1982, Jones 1986, Shaffer and Juterbock 1994), cover board searches (Fellers and Drost 1994), and opportunistic captures (Campbell and Christman 1982, Jones 1986).

I placed combinations of drift fence arrays and cover boards in different habitats throughout the region. The habitats included grassland (Figure 3), riparian (Figure 4), shrubland (Figure 5), and cedar/rocky (Figure 6) habitats. I used arrays as the main method of sampling. They consisted of drift fences, pitfall traps, and double-ended funnel traps (Campbell and Christman 1982, Jones 1986). Each array consisted of three 15- x 0.5-m sections of drift fence (galvanized tin roof flashing), originating from a central pitfall trap and radiating outward at 120° (Figure 7). All but one trench used to bury the fencing was dug with a gas-powered trenching machine. I dug the one trench by hand. After each trench was dug, I buried the flashing ≤ 17 cm into the ground, leaving ≥

33 cm above ground to discourage snakes from attempting to crawl over it or adult frogs from jumping over it (Vogt and Hine 1982). I thought that the depth of the buried drift fence would help against the strong winds and roaming cattle razing the fencing over the 3-year study. I stabilized each drift fence section by driving 4 posts of 91.4-cm rebar into the ground next to the fencing. Two posts were secured at the ends of each fence, and the other two were spaced equally in the middle. I drilled holes into the drift fence with a cordless drill so that the rebar could be secured to the drift fence with wire. A 30-cm path was cleared on each side of the drift fencing to make it easier for the herpetofauna to travel along it (Fair & Henke 1997).

Four pitfall traps were used with each array (Campbell and Christman 1982, Jones 1986, Corn 1994). Pitfall traps consisted of two 19-L buckets buried in the ground. I placed one bucket on top of the other inverted bucket to make a deeper pitfall in order to try to capture larger snakes. To accomplish this, I cut the bottoms out of each bucket with a jig-saw, drilled holes in the sides of each bucket near the bottom using a cordless drill, placed the buckets together with their bottoms touching, and then tied together the bottoms of the buckets with wire. I then dug a hole deep and wide enough to sink the two 19-L buckets so that the top bucket was flush with the ground. Each array contained four double-bucket pitfall traps: in the center and at the ends of each wing of the array (Figure 7). I cut the fencing so that it hung over the top of the buckets, as shown in Figure 7. Wooden lids supported by wooden pegs were placed 4 cm above each bucket to furnish shade for trapped animals (Campbell and Christman 1982). Wooden lids were 33- x 33-cm squares of 1.91-cm plywood. I made the pegs with four 4- x 4-cm pieces of wood.

Funnel traps were made of aluminum window screening (Campbell and Christman 1982). I placed double-ended funnel traps (6/array) on each side of each section of the drift fence approximately 7.5 m from the central pitfall trap. Funnel traps were molded and positioned to fit as close to the drift fence as possible to prevent animals from moving between traps and the fence. I made a more natural entry into the trap by placing soil and detritus in a ramp-like fashion up to the openings of the double-ended funnel traps (Campbell and Christman 1982, Crosswhite et al. 1999). I also placed an asphalt shingle over each funnel trap to provide shade for trapped animals. Shingles and the wooden lids over the pitfall traps helped minimize animal mortality due to overheating and desiccation (Campbell and Christman 1982).

I set up 12 drift fence arrays during June 2005 and checked the traps once a day during July and August 2005. Every other week, 6 of the 12 arrays were open, while the other 6 were closed. I opened all 12 arrays during the last 2 weeks of sampling during August 2005. Beginning May 2006, I established 2 additional arrays for a total of 14 drift fence arrays (Figure 8). Every other week during the 2006 field season, 7 of the 14 arrays were open at any one time. In alternate weeks, I opened the other 7 arrays and closed the previous 7 that had been open. This cycle of opening and closing occurred until mid-August when the field season ended. I used the same type of array cycling during the 2007 field season during May–August except that the number of drift fence arrays used in 2007 decreased by 2. One array was run over by a tractor and the other was on land that was leased by a different rancher who put up a fence, which stopped access to that array. During the 2006 and 2007 field seasons, I checked the open arrays at least every other day. I closed pitfall traps when they were not in use with tight-fitting

snap lids (Crosswhite et al. 1999), and I placed large rocks on top of the lids wherever cattle were present to ensure that they did not step through the lids. When funnel traps were not in use, they were removed.

Visual searching involved intensive scrutiny of specific habitat (Jones 1986, Crump and Scott 1994). Diurnal species that were difficult to capture via drift fences, such as *P. cornutum* (Fair and Henke 1997), were surveyed using this method, and nocturnal species also were found by lifting rocks and vegetative debris (Jones 1986). I selected areas to visually search that would sample the variety of habitats and geographic regions within Black Mesa, with particular attention given to areas not sampled by other methods.

Nocturnal aural surveys of breeding anurans involved listening for male frog calls at amphibian breeding sites (Vogt and Hine 1982, Scott and Woodward 1994). I identified species by call and estimated the number of calling frogs of each species during 10 minutes in the following categories: 1) no calls; 2) individuals can be counted, space between calls; 3) calls of individuals can be distinguished, but some overlap; and 4) full chorus, calls constant and continuous, overlap between calls.

Road cruising is commonly used to collect amphibians and reptiles, especially nocturnal species (Campbell and Christman 1982, Jones 1986, Shaffer and Juterbock 1994). Road cruising consisted of driving on one of four specified routes (17.6, 11.1, 10.7, and 7.2 km) between dusk and 2–4 hours after dusk at 35–55 km/hr using low headlight beams. Snakes, lizards, and frogs not usually found during daytime searches were found with this method (Jones 1986).

The cover board (artificial cover) method involved placing four 121.9- x 121.9- x 1.27-cm sheets of plywood in the proximity of each drift fence array (Fellers and Drost 1994). I placed a rock on top of each cover board to keep them from blowing away. Cover boards were not used during the 2005 field season. I installed them in December 2005 and they were used in the 2006 and 2007 field seasons. Due to property owners removing boards and boards blowing away, the number of boards varied between 2006 and 2007, with 44 used in 2006 and 42 used in 2007. I checked the cover boards whenever I checked the nearby drift fence arrays.

The opportunistic captures method involved capturing a reptile or amphibian during general field activities when not using any of the other methods (Campbell and Christman 1982, Jones 1986). Opportunistic captures included captures on the road on the way to check drift fence arrays, buy groceries and gas, and any other time a reptile or amphibian was found on the road while not road cruising.

For each specimen captured, sex, species, and time and date of capture were recorded. I fixed each observed herpetofauna location using a GPS unit (Garmin eTrex Vista® C, Olathe, Kansas) as degrees latitude and longitude. I recorded habitat data for all methods except road cruising. Habitats were grassland (Figure 3), riparian (Figure 4), shrubland (Figure 5), cedar/rocky (Figure 6), and human habitation. Microhabitat data were recorded for all methods except drift fence arrays. Microhabitats included sand, soil, rock, paved road, or gravel road. I collected rainfall data from an Oklahoma Mesonet station 8 km SE of Kenton, Oklahoma.

I implanted all horned lizards and snakes ≥ 5.0 g with a passive integrated transponder (PIT; Electronic ID, Inc., Cleburne, Texas), and all lizards were individually

marked with a unique toe clip for future identification (Donnelly et al. 1994). All turtles were individually marked with a number, in the order of capture, engraved on their plastrons using a Dremel® tool (Jones 1986). I marked all frogs except very young ones, with a toe clip unique for each of the 3 years of study (Donnelly et al. 1994).

I collected voucher specimens, which were preserved and deposited in the Oklahoma State University Collection of Vertebrates. I had a valid Oklahoma Scientific Collector's Permit and approval from Oklahoma State University's Animal Care and Use Committee (AS0513).

Niche Breadth

I calculated niche breadth (Pianka 1986) for each species based on habitat and microhabitat data. The equation was:

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

where p_i is the proportion of resources in the ith class. A niche breadth of 0 meant that a certain species used only one habitat and/or microhabitat, whereas species with the greatest niche breadths had the most even distribution of individuals over the biggest range of habitat and/or microhabitat categories.

Habitat and Microhabitat Associations

Chi-square analyses were used to test for homogeneity of habitat and microhabitat use within each major herpetofauna taxon (snakes, lizards, turtles, and frogs) except salamanders. Only species with ≥ 5 recorded individuals were used in these analyses. Certain habitat and microhabitat categories were discarded from the analysis when no individuals within a taxon occupied a category.

Habitat analyses throughout this study did not include road cruising data, and microhabitat analyses did not include frog call or drift fence array data. During road cruising, it was dark and I was unable to discern the habitat type. During frog call surveys, I could not see the specific microhabitat where the frogs were calling. I did not use herpetofauna caught in arrays in the microhabitat analyses because animals moved along the drift fence to be captured, thus traversing more than one microhabitat.

Rainfall Associations

I analyzed each taxon, except salamanders, using Chi-square Goodness-of-Fit analysis to determine the effect of rainfall on activity using data from the drift fence array, cover board, road cruising, visual searching, and opportunistic encounter methods. Each individual was placed in one of two categories: 1) 0–2 days after rainfall (> 1 mm) and 2) during all other times. I analyzed frog call data separately using these same two categories.

RESULTS

Survey

There were 1,295 trap-days (1 drift fence array with 4 pitfall and 6 funnel traps opened on a single day = 1 trap-day) of drift fence arrays over all three field seasons combined. Total effort over all three years devoted to visual searching was 99.4 person-hours. I conducted a total of 35 surveys at anuran breeding sites and devoted a total effort of 851 km to road cruising over all three years. A total effort of 1,587 sampling-days (where 1 cover board checked on a single day = 1 sampling-day) was devoted to cover boards over all three years.

I heard or captured 26 reptile species (16 snake, 7 lizard, and 3 turtle species) and 9 amphibian species (8 frog and 1 salamander species; Table 1). A total of 1,920 individual animals were captured or observed (Figure 9), including 1,248 amphibians (1,246 frogs, and 2 salamanders) and 672 reptiles (167 snakes, 470 lizards, and 35 turtles; Table 1).

The opportunistic capture method worked best for capturing snakes (Table 2); 92 snakes were captured. Pitfall traps were the next best method for capturing snakes (34 individuals). Following pitfall traps, the best method for capturing snakes was road cruising, followed by funnel traps, cover boards, and visual searching. Funnel traps worked well for capturing larger snakes. A few species of snakes were captured with only pitfall and funnel traps. Only 2 individuals of *Rhinocheilus lecontei* were captured; one was found in a pitfall trap and the other was found in a funnel trap. The only *Thamnophis cyrtopsis* captured was found in a funnel trap.

The opportunistic capture method worked best for capturing lizards (215 individuals), while pitfall traps was the next best method (171 individuals; Table 2). Following pitfall traps, the best method for capturing lizards was funnel traps, followed by cover boards, visual searching, and road cruising. Only two *Aspidoscelis tesselatus* were captured, and they were both captured in pitfall traps.

Turtles were found only with the opportunistic capture method (Table 2). Because turtle traps were not used, aquatic turtles were not sampled well. However, I did use dipnets during the visual searching method in bodies of water but did not capture any turtles.

With respect to amphibians, the nocturnal call survey method detected the most frogs (964 frogs; Table 2). Following call surveys, the best method for sampling frogs was pitfall traps, followed by road cruising, opportunistic captures, funnel traps, and visual searching. Only two *Ambystoma tigrinum* were captured and both were captured in pitfall traps.

Niche Breadth

Records of capture and observation for reptiles and amphibians among 5 habitat and 6 microhabitat types revealed a broad range of variation in niche breadth among species (Tables 3 and 4). For example, *Thamnophis radix* had the greatest habitat niche breadth (1.199) among snakes, followed by *Pituophis catenifer* (0.998) and *Masticophis flagellum* (0.958). *Leptotyphlops dulcis* had a relatively narrow niche breadth (0.206). Microhabitat analysis indicated that *Sonora semiannulata* had the greatest niche breadth (1.154), followed by *T. radix* (1.089) and *P. catenifer* (1.041). Lizards, turtles, and frogs also showed variation in habitat and microhabitat niche breadth (Tables 3 and 4).

Habitat and Microhabitat Associations

Species within snake, lizard, and frog taxa differed significantly in habitat associations; however, turtles did not show a significant difference in habitat associations (Table 5). For snakes, *L. dulcis* was confined more to riparian habitat, *M. flagellum* more to grassland habitat, and *P. catenifer* more to shrubland habitat than other snake species. For lizards, *Plestiodon obsoletus* and *Aspidoscelis sexlineatus* were found more in riparian habitat, *Crotaphytus collaris* more in cedar/rocky habitat, and *Phrynosoma cornutum* more in grassland habitat than other lizard species. For frogs, *Spea multiplicata* contributed more to the Chi-square by its high frequency of capture or

observation in shrubland habitat, and *Bufo woodhousii* in grassland habitat than other frog species.

Snake and lizard species both differed significantly in association with the 6 microhabitats (Table 6). Neither turtle or frog species showed a significant difference in microhabitat associations. For snakes, *Crotalus viridis* contributed to the Chi-square by using paved road microhabitat more and *M. flagellum* contributed by using soil microhabitat more than other snake species. For lizards, *P. cornutum* was found more on paved road microhabitat, *P. obsoletus* more on soil microhabitat, and *C. collaris* more on rock microhabitat than other lizard species.

Rainfall Associations

Turtles and frogs were captured more often 0–2 days after rainfall (turtles: $\chi^2 = 7.62$, $df = 1$, $P = 0.006$; frogs: $\chi^2 = 32.62$, $df = 1$, $P < 0.001$). *Terrapene ornata* contributed more to this trend than other turtles, and *Gastrophryne olivacia* and *Spea bombifrons* contributed more to this trend than other frogs. Lizards were found more often during days other than 0–2 days after rainfall ($\chi^2 = 18.78$, $df = 1$, $P < 0.001$). *A. sexlineatus* contributed more to this trend than other lizards. Snakes were not found to be differentially active 0–2 days after rainfall vs. all other days; however, every species had a higher percentage of individuals in the all other days category ($\chi^2 = 2.11$, $df = 1$, $P = 0.146$).

Frog call surveys were analyzed separately using the same two categories. Frogs called more often 0–2 days after rainfall ($\chi^2 = 381.48$, $df = 1$, $P < 0.001$). Each frog species followed this trend, but *S. multiplicata* contributed more than other species of frogs.

DISCUSSION

Survey

The Black Mesa ecoregion lies in the extreme northwestern corner of Oklahoma's Panhandle. One species captured, *T. cyrtopsis*, is found only at Black Mesa in Oklahoma; *A. tesselatus* and *Bufo debilis*, two other species I caught, are found at Black Mesa and in only one other restricted locality in Oklahoma. Range maps in contemporary field guides indicate that an additional 7 species have been documented in the Black Mesa ecoregion (Conant and Collins 1998, Sievert and Sievert 2005) but were not found in this study (Table 1). *Thamnophis elegans* and *Phrynosoma modestum* have been found only at Black Mesa in Oklahoma (Sievert and Sievert 2005), but were not found in this study. The population of *P. modestum* previously documented was a disjunct population separated from the rest of its range in Texas and New Mexico by 250 km (Conant and Collins 1998). This disjunct population of *P. modestum* was known from only one museum record (Sam Noble Oklahoma Museum of Natural History) and an additional verified sight record (Oklahoma Natural Heritage Inventory, Norman, Oklahoma). The most recent record was from 1990. If this species occurs at Black Mesa, it is evidently rare and locally distributed. I conducted many of the visual encounter surveys in rocky open areas, where *P. modestum* is known to occur (Sherbrooke 2003), but I did not find this lizard.

Success of the different sampling methods was variable. Vogt and Hine (1982) associate such variation to the training of individuals involved, time of day and year of sampling, rareness or agility of a species to evade capture, and type of habitats sampled. Results from this study parallel previous work (Crosswhite et al. 1999, Andreone et al.

2003, Greenburg et al. 1994) with respect to the type of species captured using different methods. For example, funnel traps captured large squamates and pitfall traps worked well at capturing small elusive squamates and amphibians. The only salamander caught, *A. tigrinum*, was found using only pitfall traps. One species of snake, *L. dulcis*, which is a small (12.7–24 cm) elusive species, was captured almost exclusively in pitfall traps. In contrast, the visual search method produced the only *Hypsiglena torquata* of the study.

Although road cruising provides occurrence and abundance data on some nocturnal and secretive herpetofauna, Jones (1986) stated that it was time consuming, yielded relatively few records, verified only nocturnal species that migrated across roads, and biased samples because it was limited to areas with roads. However, Drost et al. (1999) found that road cruising resulted in nearly five times as many individuals as all of the other techniques they used (drift fence arrays, cover boards, visual searching) combined. I found *C. viridis* almost exclusively while road cruising. This species is known to be nocturnal during the hottest part of the year (Conant and Collins 1998), and it is thought that it either seeks out roads, which retain heat into the night, or pauses as it moves across them (Lillywhite 1987). Many frogs also were found with this method right after a rainfall when frogs tend to move (Blair 1960).

Niche Breadth

Niche-breadth analysis indicated that some species used a greater range of habitats and microhabitats than other species. Among snake species with ≥ 5 individuals included in the analysis, *L. dulcis* and *Diadophis punctatus* had the smallest habitat niche breadth; both were found mainly in the riparian habitat. Both species are relatively small and are known to be found in moist areas (Conant and Collins 1998, Sievert and Sievert

2005). The larger snakes, such as *P. catenifer* and *M. flagellum*, had relatively large habitat niche breadths. *M. flagellum* has a large home range (Johnson et al. 2007) and a closely related species to *P. catenifer* (*P. melanoleucus*) traverses large areas (Gerald et al. 2006). Large home ranges would therefore increase the likelihood that these species would be found in many different habitats and microhabitats than other species with smaller home ranges.

All but one *C. viridis* were found on the paved road microhabitat; thus, its microhabitat niche breadth was low. Diller and Wallace (1996) found that *C. viridis* primarily used rocky substrates in southwestern Idaho. This species is nocturnal during the hot summer months (Sievert and Sievert 2005), so most individuals were captured at night either by road cruising or opportunistic capture. Details of natural history may explain why *C. viridis* was not caught in funnel or pitfall traps. Duvall et al. (1985) found that *C. viridis* exhibited relatively little activity during warmer periods of mid-summer. Because it is very warm at Black Mesa during summer, *C. viridis* may have moved relatively little and therefore had a smaller chance of going into a funnel trap compared with snakes such as *P. melanoleucus* that move greater distances (Diller and Wallace 1996). Duvall et al. (1985) also found that *C. viridis* established a home range after active prey burrows were located. They stated that the snakes remained in a specific area for several weeks while occupying the burrows of their prey. Such restricted movement is not conducive to capture by drift fence arrays.

P. obsoletus were almost always found on soil. This species prefers fine-grained soil suitable for burrowing (Conant and Collins 1998). *B. woodhousii* possessed one of the largest habitat and microhabitat niche breadths out of all the frogs. This species is

commonly found around lights in the evening, lawns, and gardens (Sievert and Sievert 2005).

Habitat and Microhabitat Associations

Because the habitats and microhabitats used by most herpetofauna taxa in this study (except turtles, probably due to the small sample size) were found to be significantly heterogeneous, it can be concluded that a diverse habitat and microhabitat will maximize the number of amphibian and reptile species a certain region can contain. The statistical analysis of habitat and microhabitat within each major taxon must be interpreted with some caveats. The Chi-square analyses within each taxon contained some fractional expected values (Tables 5 and 6). Habitats or microhabitats that had these values were not pooled with adjacent habitats or microhabitats because this results in an undesirable loss of power (Cochran 1952). Lewontin and Felsenstein (1965) stated that even fractional expectations do not, in general, invalidate the Chi-square test. There also were small sample sizes for some taxa. For example, most frogs were found by the nocturnal call survey and drift fence array methods, but data from both of these methods were not included in the microhabitat analyses (see Methods). Habitats and microhabitats also may have overlapped in some situations. For example, although some areas were labeled as riparian and soil, at times there was shrubland habitat and sandy microhabitat in very close proximity to the site of capture.

Rainfall Associations

This study supports the claim that rainfall is a very important abiotic factor influencing calling activity of some anurans (Obert 1975, Saenz et al. 2006). Oseen and Wassersug (2002) stated that calling activity in response to rainfall corresponded to the

breeding strategies of anurans. Past studies have shown that some species of anurans may respond in their own way to the influence of rainfall (Bertoluci 1998, Moriera and Lima 1991). *G. olivacea* and *S. multiplicata* had the highest percentage of individuals calling 0–2 days after rainfall. Both of those species are known to breed in temporary pools and roadside ditches after a heavy rainfall (Sievert and Sievert 2005). Response to early spring rains may be the reason why *Bufo cognatus*, a species found at Black Mesa, was not heard during my call surveys. *B. cognatus* breeds very early in the year in some places, for example April (Conant and Collins 1998), and because field work did not begin at Black Mesa until mid-May at the earliest, this toad might have bred prior to my field work.

Frogs also were significantly more active 0–2 days after rainfall when all other methods were included besides frog calls. This finding is consistent with their avoidance of desiccating conditions (Shoemaker et al. 1992). Among the turtles, *T. ornata* was found significantly more often 0–2 days after rainfall, whereas *K. flavescens* was found a greater percentage of the time on other days. Plummer (2003) found that surface activity of *T. ornata* was greatly affected by rainfall and temperature in southeastern Arizona. He noted that precipitation increased the activity of *T. ornata* and they were more active in the early morning and late afternoon. A different study (Plummer 2004) found that the primary stimulus to end subterranean dormancy (estivation) in *T. ornata* was precipitation. However, mesic conditions do not last long after a rain event in arid environments like Black Mesa, so within a few days, *T. ornata* probably limited its activity to cool hours and a small home range near a known burrow. Ligon and Stone (2003) found that a population of *K. sonoriense* exhibited terrestrial estivation in

response to extended drought conditions. Because *K. flavescens* is also a terrestrial estivator (Seidel 1978), it probably behaved similarly during dry periods. As pools dried up during dry summer months, *K. flavescens* probably slowly moved onto land and moved into burrows or other estivation spots. Such behavior may explain why *K. flavescens* captures occurred more on days not associated with rain.

Although snakes did not show a greater amount of activity in either category of rainfall, a few patterns were noted. Of all the snakes, *T. radix* had the greatest percentage of individuals captured during 0–2 days after rainfall, and *C. viridis* and *P. catenifer* had the greatest percentage of individuals captured during other days. This dichotomy in activity among these species may be the result of their different diets. Brown and Shine (2002) found that predator activity was related to prey activity. Diet of *T. radix* consists chiefly of amphibians, fish, and earthworms (Conant and Collins 1998, Sievert and Sievert 2005), whereas diets of *C. viridis* and *P. catenifer* consist chiefly of rodents, lizards, and birds (Conant and Collins 1998, Sievert and Sievert 2005). As noted earlier, frogs at Black Mesa were found to be significantly more active right after rainfall, whereas lizards were found significantly more often during all other days.

The species of lizard that was most active on days not following a rain was *A. sexlineatus*. This species is usually found in dry, open, sunny areas (Sievert and Sievert 2005), so perhaps after a rain it would wait a few days for the substrate to dry out.

In addition to providing inventory data to those involved in biological diversity conservation, this study is important for its contribution to understanding distribution and ecology of amphibians and reptiles in the region. Because Black Mesa is a unique

ecoregion for Oklahoma and the whole nation, results of this study will hopefully help in conserving the unique combination of reptiles and amphibians that occupy it.

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Table 1. Number of individuals captured of each species for each year and the total for all three years combined in the Black Mesa ecoregion, Cimarron County, Oklahoma, 2005–2007. Seven species supposed to be in this region but undetected in my study are also included and indicated by an asterisk.

Species	2005	2006	2007	Total Captured
Snakes				
Crotalus viridis (Prairie Rattlesnake)	8	6	17	31
Pituophis catenifer (Bullsnake)	8	9	11	28
Masticophis flagellum (Western Coachwhip)	5	12	10	27
Thamnophis radix (Plains Garter Snake)	3	9	3	15
Leptotyphlops dulcis (Texas Blind Snake)	2	9	9	20
Heterodon nasicus (Western Hognose Snake)	2	6	4	12
Diadophis punctatus (Ringneck Snake)	1	4	3	8
Tropidoclonion lineatum (Lined Snake)	1	2	2	5
Pantherophis emoryi (Great Plains Rat Snake)	2	1	2	5
Lampropeltis getula (Speckled Kingsnake)	0	1	3	4
Sonora semiannulata (Ground Snake)	1	2	1	4
Tantilla nigriceps (Blackhead Snake)	0	2	1	3
Rhinocheilus lecontei (Texas Longnose Snake)	1	1	0	2
Thamnophis cyrtopsis (Blackneck Garter Snake)	0	1	0	1
Arizona elegans (Kansas Glossy Snake)	1	0	0	1
Hypsiglena torquata (Texas Night Snake)	0	0	1	1
**Thamnophis elegans* (Wandering Garter Snake)	0	0	0	0

Table 1. cont.

Species	2005	2006	2007	Total Captured
**Coluber constrictor* (Eastern Racer)	0	0	0	0
**Nerodia erythrogaster* (Plain-bellied Water Snake)	0	0	0	0
Total Snakes	35	65	67	167
Lizards				
Phrynosoma cornutum (Texas Horned Lizard)	44	68	72	184
Plestiodon obsoletus (Great Plains Skink)	35	49	40	124
Aspidoscelis sexlineatus (Prairie Racerunner)	15	33	21	69
Crotaphytus collaris (Eastern Collared Lizard)	12	20	7	39
Sceloporus undulatus (Prairie Lizard)	10	10	7	27
Holbrookia maculata (Earless Lizard)	6	10	9	25
Aspidoscelis tesselatus (Checkered Whiptail)	0	2	0	2
**Phrynosoma modestum* (Roundtail Horned Lizard)	0	0	0	0
Total Lizards	122	192	156	470
Turtles				
Terrapene ornata (Ornate Box Turtle)	3	14	11	28
Kinosternon flavescens (Yellow Mud Turtle)	2	2	1	5
Trachemys scripta (Red-eared Slider)	1	0	1	2
**Apalone spinifera* (Spiny Softshell Turtle)	0	0	0	0
**Chelydra serpentina* (Snapping Turtle)	0	0	0	0
Total Turtles	6	16	13	35

Table 1. cont.

Species	2005	2006	2007	Total Captured
Frogs				
Bufo debilis (Western Green Toad)	3	202	279	484
Spea multiplicata (New Mexico Spadefoot)	3	222	131	356
Bufo woodhousii (Woodhouse's Toad)	88	47	66	201
Gastrophryne olivacea (Great Plains Narrow-mouthed Toad)	0	16	77	93
Rana catesbeiana (Bullfrog)	7	25	17	49
Spea bombifrons (Plains Spadefoot)	0	17	26	43
Bufo punctatus (Red-spotted Toad)	4	9	1	14
Rana blairi (Plains Leopard Frog)	0	4	2	6
**Bufo cognatus* (Great Plains Toad)	0	0	0	0
Total Frogs	105	542	599	1246
Salamanders				
Ambystoma tigrinum (Tiger Salamander)	0	0	2	2
Total Salamanders	0	0	2	2
GRAND TOTAL	268	815	837	1920

Table 2. Total number of each species documented by sampling method during 2005–2007, where PF = Pitfall Traps, FT = Funnel Traps, CB = Cover Boards, VS = Visual Searches, RC = Road Cruising, OC = Opportunistic Captures, and CS = Call Surveys. The relative abundance (RA) of each species captured is categorized as rare (≤ 5), common (6–20) or abundant (≥ 20).

Species	PF	FT	CB	VS	RC	OC	CS	RA
Snakes								
Crotalus viridis	0	0	0	1	8	22	-	Abundant
Pituophis catenifer	1	1	0	1	2	23	-	Abundant
Masticophis flagellum	1	3	1	1	2	19	-	Abundant
Thamnophis radix	1	2	0	0	3	9	-	Common
Leptotyphlops dulcis	19	0	0	1	0	0	-	Common
Heterodon nasicus	0	0	0	0	0	12	-	Common
Diadophis punctatus	2	0	6	0	0	0	-	Common
Tropidoclonion lineatum	4	0	0	0	0	1	-	Rare
Pantherophis emoryi	1	1	0	0	1	2	-	Rare
Lampropeltis getula	1	0	0	0	0	3	-	Rare
Sonora semiannulata	0	0	0	2	0	2	-	Rare
Tantilla nigriceps	2	0	1	0	0	0	-	Rare
Rhinocheilus lecontei	1	1	0	0	0	0	-	Rare
Thamnophis cyrtopsis	0	1	0	0	0	0	-	Rare
Arizona elegans	1	0	0	0	0	0	-	Rare
Hypsiglena torquata	0	0	0	1	0	0	-	Rare
Total Snakes	34	9	8	7	16	93	-	

Table 2. cont.

Species	PF	FT	CB	VS	RC	OC	CS	RA
Lizards								
Phrynosoma cornutum	4	3	0	6	11	160	-	Abundant
Plestiodon obsoletus	87	12	19	0	0	6	-	Abundant
Aspidoscelis sexlineatus	57	10	1	1	0	0	-	Abundant
Crotaphytus collaris	8	2	5	6	0	18	-	Abundant
Sceloporus undulatus	11	0	2	5	0	9	-	Abundant
Holbrookia maculata	2	1	0	0	0	22	-	Abundant
Aspidoscelis tesselatus	2	0	0	0	0	0	-	Rare
Total Lizards	171	28	27	18	11	215	-	
Turtles								
Terrapene ornata	0	0	0	0	0	28	-	Abundant
Kinosternon flavescens	0	0	0	0	0	5	-	Rare
Trachemys scripta	0	0	0	0	0	2	-	Rare
Total Turtles	0	0	0	0	0	35	-	
Frogs								
Bufo debilis	20	0	0	0	5	5	454	Abundant
Spea multiplicata	13	0	0	0	11	12	320	Abundant
Bufo woodhousii	105	13	0	1	37	18	27	Abundant
Gastrophryne olivacea	10	0	0	0	0	2	81	Abundant
Rana catesbeiana	3	0	0	0	0	4	42	Abundant
Spea bombifrons	2	0	0	0	1	2	38	Abundant
Bufo punctatus	5	0	0	0	7	2	0	Common
Rana blairi	4	0	0	0	0	0	2	Common
Total Frogs	162	13	0	1	61	45	964	
Salamanders								
Ambystoma tigrinum	2	0	0	0	0	0	-	Rare
Total Salamanders	2	0	0	0	0	0	-	

Table 3. Number of individuals of each species documented in each habitat at the Black Mesa ecoregion from 2005–2007. Niche breadth is in bold for each species with ≥ 5 individuals. Road cruising captures are not included.

Species	Shrubland	Grassland	Cedar/ Rocky	Riparian	Human	Total	Niche Breadth
Snakes							
Pituophis catenifer	13	8	0	4	-	25	**0.998**
Masticophis flagellum	5	13	0	4	-	22	**0.958**
Leptotyphlops dulcis	0	0	1	18	-	19	**0.206**
Crotalus viridis	11	7	1	0	-	19	**0.839**
Thamnophis radix	2	3	1	6	-	12	**1.199**
Heterodon nasicus	3	8	0	1	-	12	**0.824**
Diadophis punctatus	1	0	0	7	-	8	**0.377**
Tropidoclonion lineatum	4	0	0	1	-	5	**0.500**
Pantherophis emoryi	1	1	0	2	-	4	1.040
Lampropeltis getula	2	1	0	1	-	4	1.040
Sonora semiannulata	3	1	0	0	-	4	0.562
Tantilla nigriceps	1	0	1	1	-	3	1.099
Rhinocheilus lecontei	1	0	0	1	-	2	0.693
Thamnophis cyrtopsis	1	0	0	0	-	1	0.000

Table 3. cont.

Species	Shrubland	Grassland	Cedar/ Rocky	Riparian	Human	Total	Niche Breadth
Arizona elegans	0	1	0	0	-	1	0.000
Hypsiglena torquata	0	0	1	0	-	1	0.000
Total Snakes	48	43	5	46	-	142	
Lizards							
Phrynosoma cornutum	38	84	2	2	3	129	**0.834**
Plestiodon obsoletus	31	3	0	90	1	125	**0.711**
Aspidoscelis sexlineatus	5	0	0	63	0	68	**0.263**
Crotaphytus collaris	14	6	22	0	0	42	**0.983**
Holbrookia maculata	7	17	0	2	0	26	**0.828**
Sceloporus undulatus	3	0	5	13	3	24	**1.179**
Aspidoscelis tesselatus	0	0	0	2	0	2	0.000
Total Lizards	98	110	29	172	7	416	
Turtles							
Terrapene ornata	10	13	0	1	-	24	**0.829**
Kinosternon flavescens	1	4	0	0	-	5	**0.500**
Trachemys scripta	1	0	0	1	-	2	0.693
Total Turtles	12	17	0	2	-	31	

Table 3. cont.

Species	Shrubland	Grassland	Cedar/ Rocky	Riparian	Human	Total	Niche Breadth
Frogs							
Bufo debilis	308	8	2	163	-	481	**0.743**
Spea multiplicata	342	0	0	102	-	444	**0.539**
Bufo woodhousii	48	12	1	85	-	146	**0.920**
Gastrophryne olivacea	78	0	0	12	-	90	**0.393**
Spea bombifrons	34	0	0	8	-	42	**0.487**
Rana catesbeiana	5	2	0	32	-	39	**0.578**
Rana blairi	0	0	4	6	-	10	**0.673**
Bufo punctatus	2	4	0	1	-	7	**0.956**
Total Frogs	817	26	7	409	-	1259	
Salamanders							
Ambystoma tigrinum	1	1	-	-	-	2	0.693

Table 4. Number of individuals of each species documented in each microhabitat at the Black Mesa ecoregion from 2005–2007. Niche breadth is in bold for each species with ≥ 5 individuals. Drift fence array captures and frog call surveys are not included.

Species	Sand	Soil	Rock	Paved Road	Woody Substrate	Gravel Road	Total	Niche Breadth
Snakes								
Crotalus viridis	0	0	0	26	0	1	27	**0.158**
Pituophis catenifer	1	4	1	16	0	2	24	**1.041**
Masticophis flagellum	0	9	0	9	0	1	19	**0.863**
Thamnophis radix	1	2	1	6	0	0	10	**1.089**
Heterodon nasicus	1	2	0	5	0	0	8	**0.900**
Sonora semiannulata	0	4	1	1	0	1	7	**1.154**
Diadophis punctatus	0	5	0	0	0	0	5	**0.000**
Leptotyphlops dulcis	0	2	1	1	0	0	4	1.040
Pantherophis emoryi	0	1	0	2	0	0	3	0.636
Lampropeltis getula	0	2	0	1	0	0	3	0.636
Tropidoclonion lineatum	0	1	0	0	0	0	1	0.000
Tantilla nigriceps	0	0	1	0	0	0	1	0.000
Hypsiglena torquata	0	0	1	0	0	0	1	0.000
Rhinocheilus lecontei	0	0	0	0	0	0	0	0.000
Thamnophis cyrtopsis	0	0	0	0	0	0	0	0.000

Table 4. cont.

Species	Sand	Soil	Rock	Paved Road	Woody Substrate	Gravel Road	Total	Niche Breadth
Arizona elegans	0	0	0	0	0	0	0	0.000
Total Snakes	3	32	6	67	0	5	113	
Lizards								
Phrynosoma cornutum	26	48	2	84	0	12	172	**1.229**
Crotaphytus collaris	3	6	10	2	1	6	28	**1.575**
Plestiodon obsoletus	1	22	0	1	0	0	24	**0.345**
Holbrookia maculata	3	9	0	8	0	0	20	**1.010**
Sceloporus undulatus	1	3	4	0	3	0	11	**1.294**
Aspidoscelis sexlineatus	0	1	0	0	0	0	1	0.000
Aspidoscelis tesselatus	0	0	0	0	0	0	0	0.000
Total Lizards	34	89	16	95	4	18	256	
Turtles								
Terrapene ornata	1	11	0	10	0	3	25	**1.110**
Kinosternon flavescens	0	2	0	3	0	0	5	**0.673**
Trachemys scripta	0	1	0	1	0	0	2	0.693
Total Turtles	1	14	0	14	0	3	32	

Table 4. cont.

Species	Sand	Soil	Rock	Paved Road	Woody Substrate	Gravel Road	Total	Niche Breadth
Frogs								
Bufo woodhousii	1	1	0	51	0	0	53	**0.187**
Spea multiplicata	0	0	0	26	0	0	26	**0.000**
Bufo debilis	0	0	0	10	0	0	10	**0.000**
Bufo punctatus	0	0	0	6	0	0	6	**0.000**
Rana catesbeiana	0	1	0	3	0	0	4	0.562
Spea bombifrons	0	0	0	3	0	0	3	0.000
Gastrophryne olivacea	0	0	0	2	0	0	2	0.000
Rana blairi	0	0	0	0	0	0	0	0.000
Total Frogs	1	2	0	101	0	0	104	
Salamanders								
Ambystoma tigrinum	0	0	0	0	0	0	0	0.000

Table 5. Frequency distribution of observed and expected (in parentheses) values of each species captured in the different habitats at the Black Mesa ecoregion from 2005–2007. Only species with ≥ 5 individuals captured are used in this analysis.

Species	Cedar/Rocky	Grassland	Riparian	Shrubland	Human	Total
Snakes[1]						
Pituophis catenifer	0 (0.56)	8 (7.78)	4 (8.33)	13 (8.33)	-	25
Masticophis flagellum	0 (0.49)	13 (6.84)	4 (7.33)	5 (7.33)	-	22
Crotalus viridis	1 (0.47)	7 (6.07)	0 (6.38)	11 (6.07)	-	19
Leptotyphlops dulcis	1 (0.42)	0 (5.91)	18 (6.33)	0 (6.33)	-	19
Thamnophis radix	1 (0.27)	3 (3.73)	6 (4.00)	2 (4.00)	-	12
Heterodon nasicus	0 (0.27)	8 (3.73)	1 (4.00)	3 (4.00)	-	12
Diadophis punctatus	0 (0.18)	0 (2.49)	7 (2.67)	1 (2.67)	-	8
Tropidoclonion lineatum	0 (0.11)	0 (1.56)	1 (1.67)	4 (1.67)	-	5
Total	3	39	41	39	-	122
Lizards[2]						
Phrynosoma cornutum	2 (9.04)	84 (34.27)	2 (52.97)	38 (30.54)	3 (2.18)	129
Plestiodon obsoletus	0 (8.76)	3 (33.21)	90 (51.33)	31 (29.59)	1 (2.11)	125
Aspidoscelis sexlineatus	0 (4.76)	0 (18.07)	63 (27.92)	5 (16.10)	0 (1.15)	68
Crotaphytus collaris	22 (2.94)	6 (11.16)	0 (17.25)	14 (9.94)	0 (0.71)	42
Holbrookia maculata	0 (1.82)	17 (6.91)	2 (10.68)	7 (6.15)	0 (0.44)	26

Table 5. cont.

Species	Cedar/Rocky	Grassland	Riparian	Shrubland	Human	Total
Sceloporus undulatus	5 (1.68)	0 (6.38)	13 (9.85)	3 (5.68)	3 (0.41)	24
Total	29	110	170	98	7	414
Turtles[3]						
Terrapene ornata	-	13 (14.07)	1 (0.83)	10 (9.10)	-	24
Kinosternon flavescens	-	4 (2.93)	0 (0.17)	1 (1.90)	-	5
Total	-	17	1	11	-	29
Frogs[4]						
Bufo debilis	2 (2.67)	8 (9.93)	163 (156.26)	308 (312.13)	-	481
Spea multiplicata	0 (2.47)	0 (9.17)	102 (144.24)	342 (288.12)	-	444
Bufo woodhousii	1 (0.81)	12 (3.01)	85 (47.43)	48 (94.74)	-	146
Gastrophryne olivacea	0 (0.50)	0 (1.86)	12 (29.24)	78 (58.40)	-	90
Spea bombifrons	0 (0.23)	0 (0.87)	8 (13.64)	34 (27.25)	-	42
Rana catesbeiana	0 (0.22)	2 (0.80)	32 (12.67)	5 (25.31)	-	39
Rana blairi	4 (0.06)	0 (0.21)	6 (3.25)	0 (6.49)	-	10
Bufo punctatus	0 (0.04)	4 (0.15)	1 (2.27)	2 (4.54)	-	7
Total	7	26	409	817	-	1259

[1] $\chi^2 = 86.02$, $df = 21$, $P < 0.001$
[2] $\chi^2 = 471.92$, $df = 20$, $P < 0.001$
[3] $\chi^2 = 1.19$, $df = 2$, $P = 0.551$
[4] $\chi^2 = 580.45$, $df = 21$, $P < 0.001$

Table 6. Frequency distribution of observed and expected (in parentheses) values of each species captured in the different microhabitats at the Black Mesa ecoregion from 2005–2007. Only species with ≥ 5 individuals captured are used in this analysis.

Species	Gravel Road	Paved Road	Rock	Sand	Soil	Woody	Total
Snakes[1]							
Crotalus viridis	1 (1.35)	26 (17.01)	0 (0.81)	0 (0.81)	0 (7.02)	-	27
Pituophis catenifer	2 (1.20)	16 (15.12)	1 (0.72)	1 (0.72)	4 (6.24)	-	24
Masticophis flagellum	1 (0.95)	9 (11.97)	0 (0.57)	0 (0.57)	9 (4.94)	-	19
Thamnophis radix	0 (0.50)	6 (6.30)	1 (0.30)	1 (0.30)	2 (2.60)	-	10
Heterodon nasicus	0 (0.40)	5 (5.04)	0 (0.24)	1 (0.24)	2 (2.08)	-	8
Diadophis punctatus	0 (0.25)	0 (3.15)	0 (0.15)	0 (0.15)	5 (1.30)	-	5
Sonora semiannulata	1 (0.35)	1 (4.41)	1 (0.21)	0 (0.21)	4 (1.82)	-	7
Total	5	63	3	3	26	-	100
Lizards[2]							
Phrynosoma cornutum	12 (12.14)	84 (64.08)	2 (10.79)	26 (22.93)	48 (59.36)	0 (1.64)	172
Crotaphytus collaris	6 (1.98)	2 (10.43)	10 (1.76)	3 (3.73)	6 (9.66)	1 (0.44)	28
Plestiodon obsoletus	0 (1.69)	1 (8.94)	0 (1.50)	1 (3.20)	22 (8.28)	0 (0.38)	24
Holbrookia maculata	0 (1.41)	8 (7.45)	0 (1.25)	3 (2.67)	9 (6.90)	0 (0.31)	20
Sceloporus undulatus	0 (0.78)	0 (4.10)	4 (0.69)	1 (1.47)	3 (3.80)	3 (0.17)	11
Total	18	95	16	34	88	4	255

Table 6. cont.

Species	Gravel Road	Paved Road	Rock	Sand	Soil	Woody	Total
Total	18	95	16	34	88	4	255
Turtles[3]							
Terrapene ornata	3 (2.5)	10 (10.83)	-	1 (0.83)	11 (10.83)	-	25
Kinosternon flavescens	0 (0.50)	3 (2.17)	-	0 (0.17)	2 (2.17)	-	5
Total	3	13	-	1	13	-	30
Frogs[4]							
Bufo woodhousii	-	51 (51.88)	-	1 (0.56)	1 (0.56)	-	53
Spea multiplicata	-	26 (25.45)	-	0 (0.27)	0 (0.27)	-	26
Bufo debilis	-	10 (9.79)	-	0 (0.10)	0 (0.10)	-	10
Bufo punctatus	-	6 (5.87)	-	0 (0.6)	0 (0.86)	-	6
Total	-	93	-	1	1	-	95

[1] $\chi^2 = 51.14$, $df = 24$, $P = 0.001$
[2] $\chi^2 = 180.52$, $df = 20$, $P < 0.001$
[3] $\chi^2 = 1.20$, $df = 3$, $P = 0.753$
[4] $\chi^2 = 1.62$, $df = 6$, $P = 0.951$

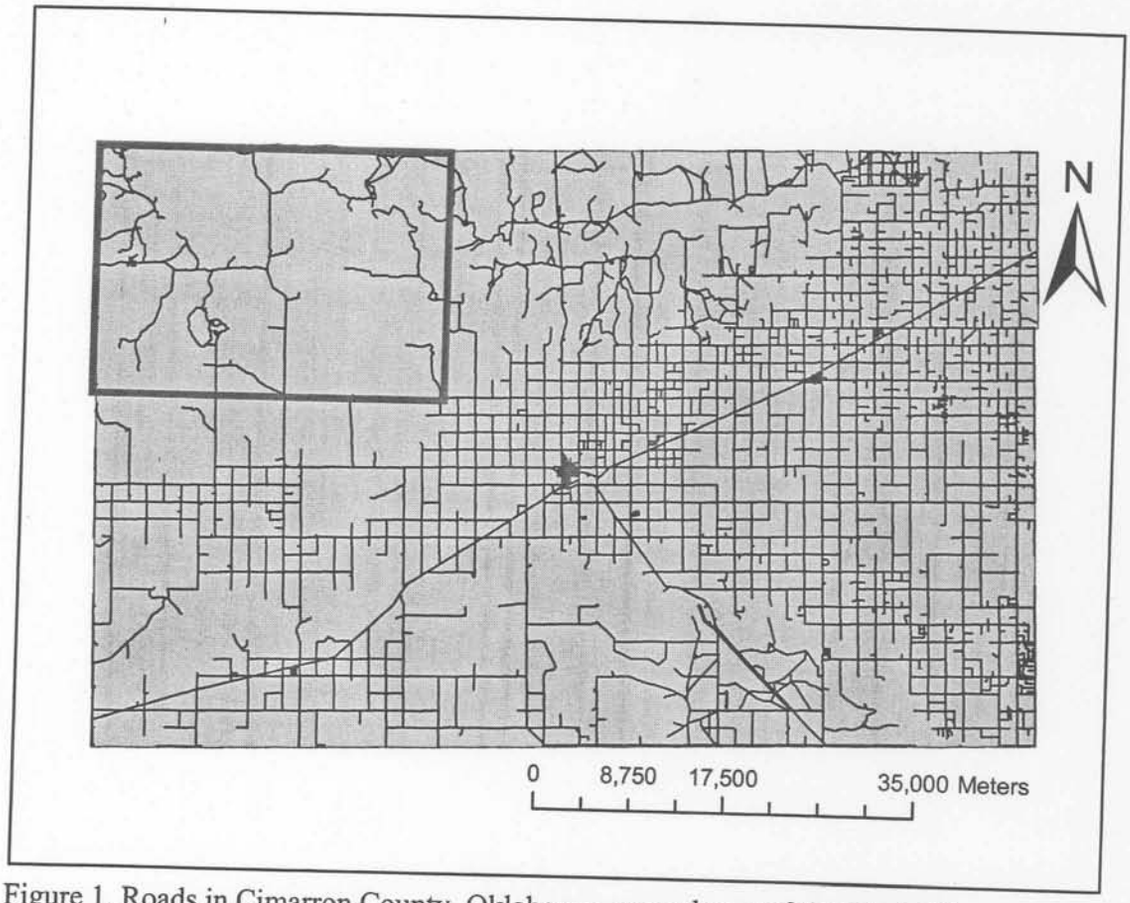

Figure 1. Roads in Cimarron County, Oklahoma; general area of the Black Mesa ecoregion outlined in red

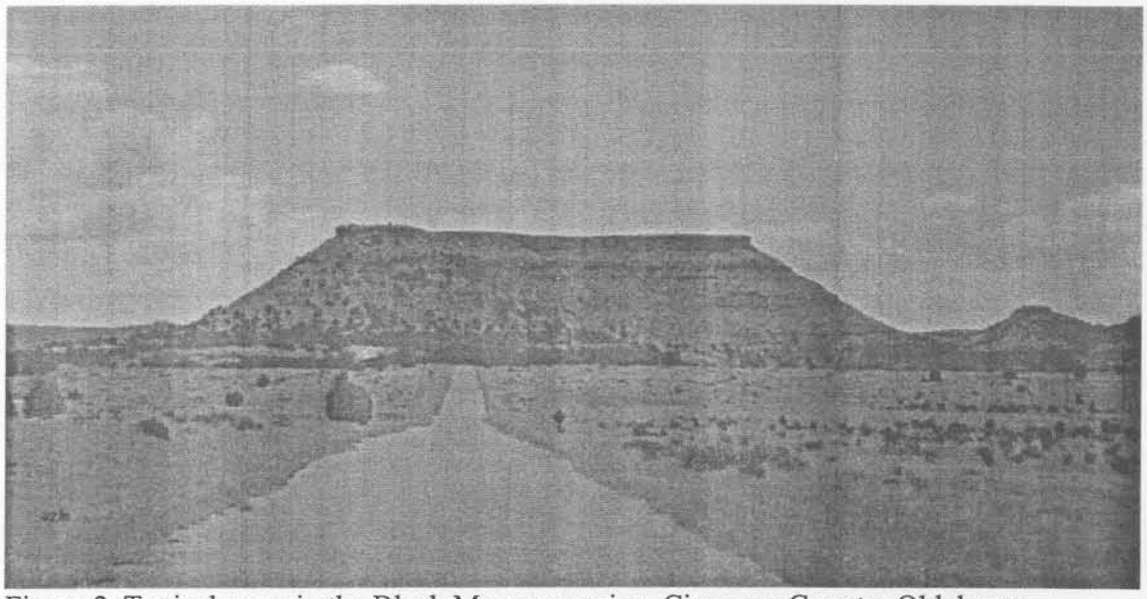

Figure 2. Typical mesa in the Black Mesa ecoregion, Cimarron County, Oklahoma.

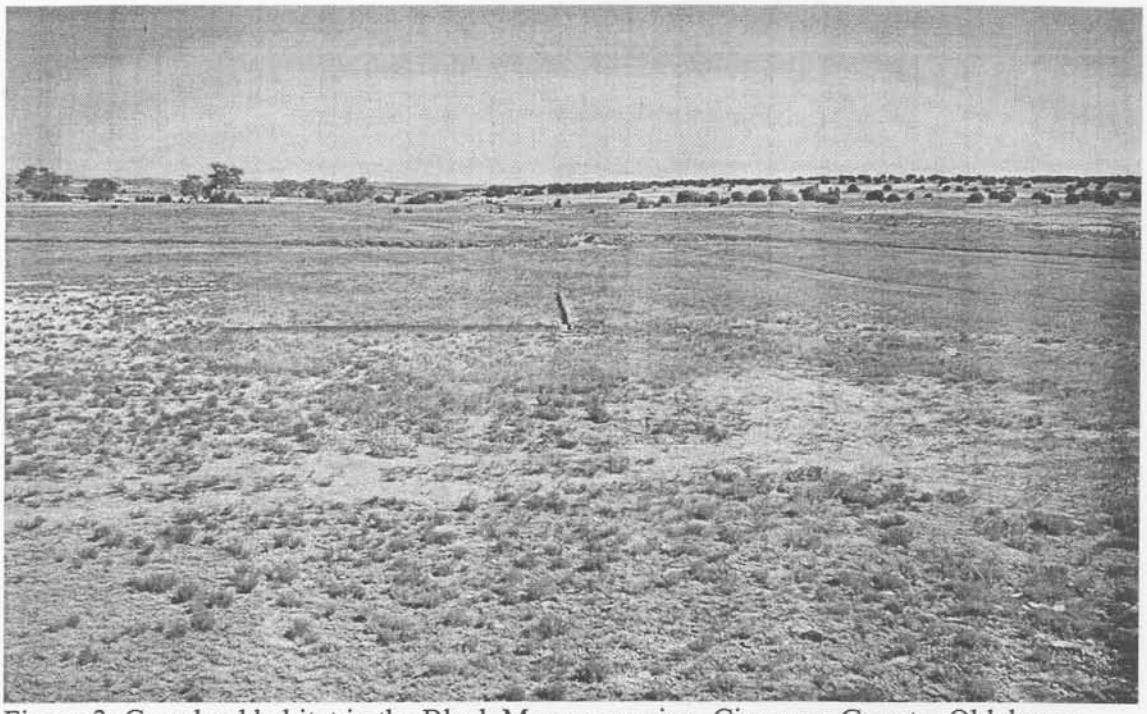

Figure 3. Grassland habitat in the Black Mesa ecoregion, Cimarron County, Oklahoma.

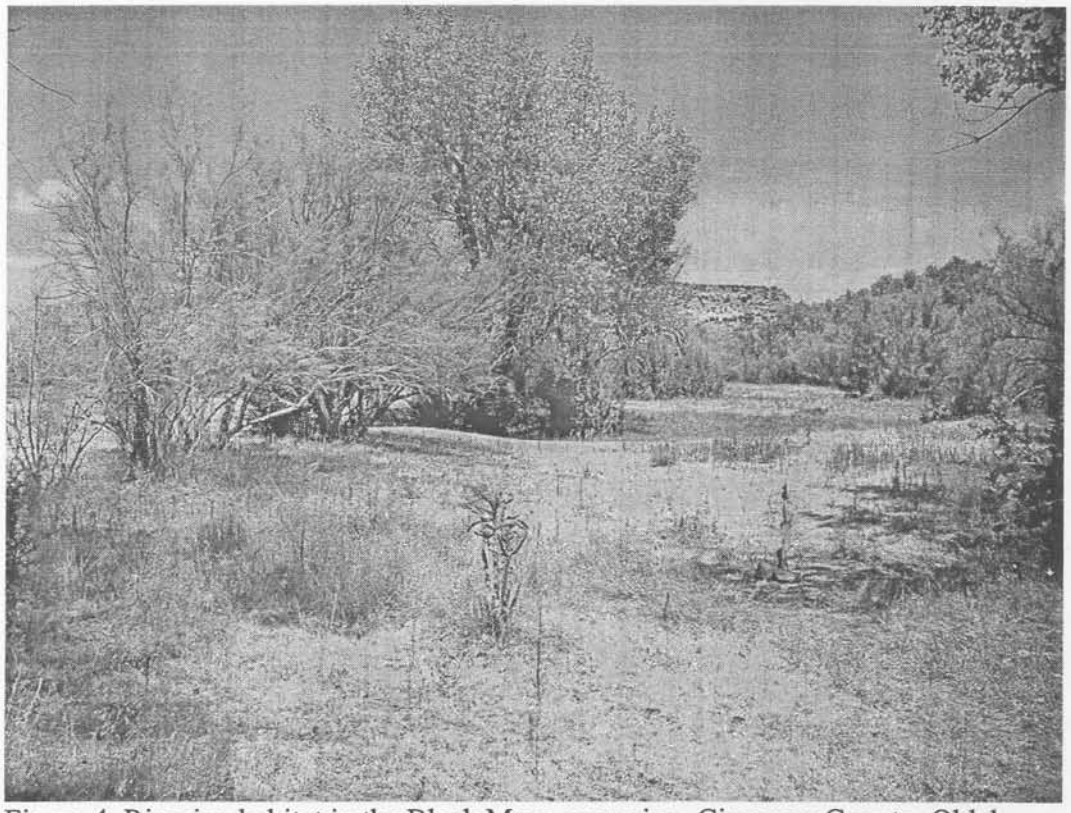

Figure 4. Riparian habitat in the Black Mesa ecoregion, Cimarron County, Oklahoma.

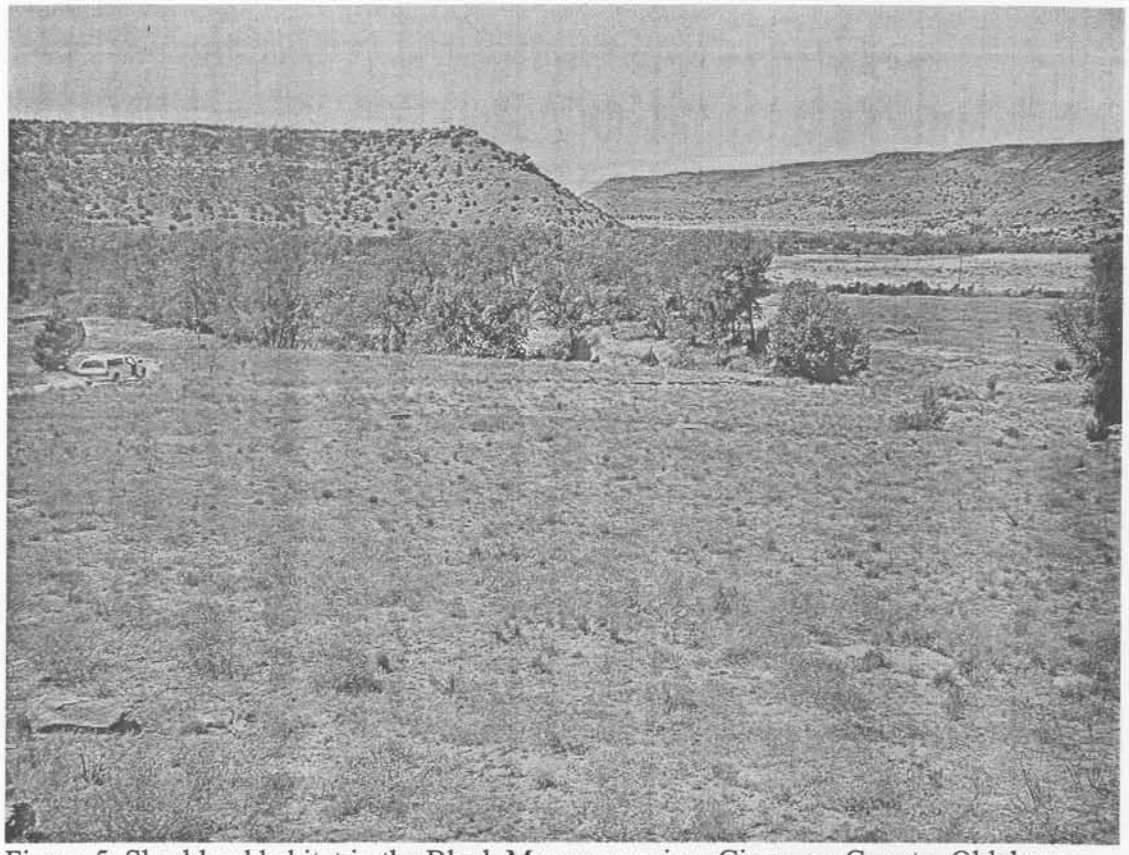

Figure 5. Shrubland habitat in the Black Mesa ecoregion, Cimarron County, Oklahoma.

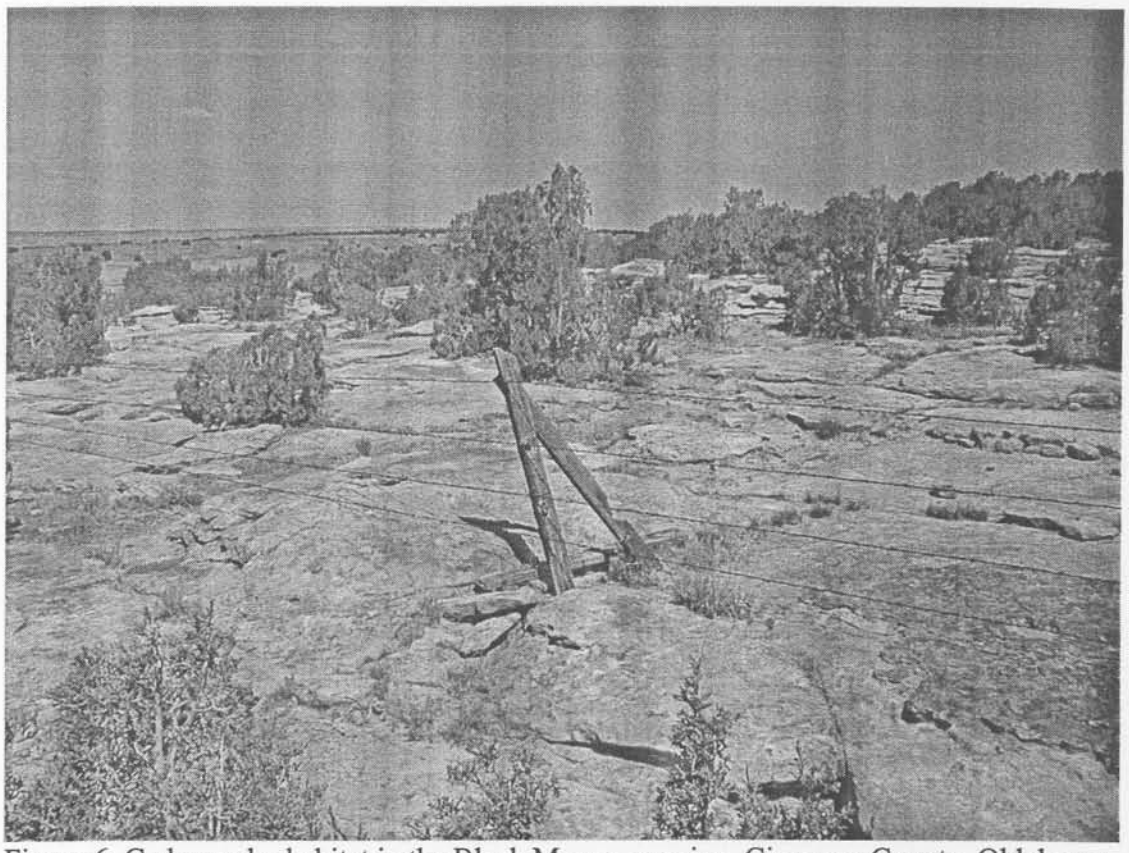

Figure 6. Cedar-rocky habitat in the Black Mesa ecoregion, Cimarron County, Oklahoma.

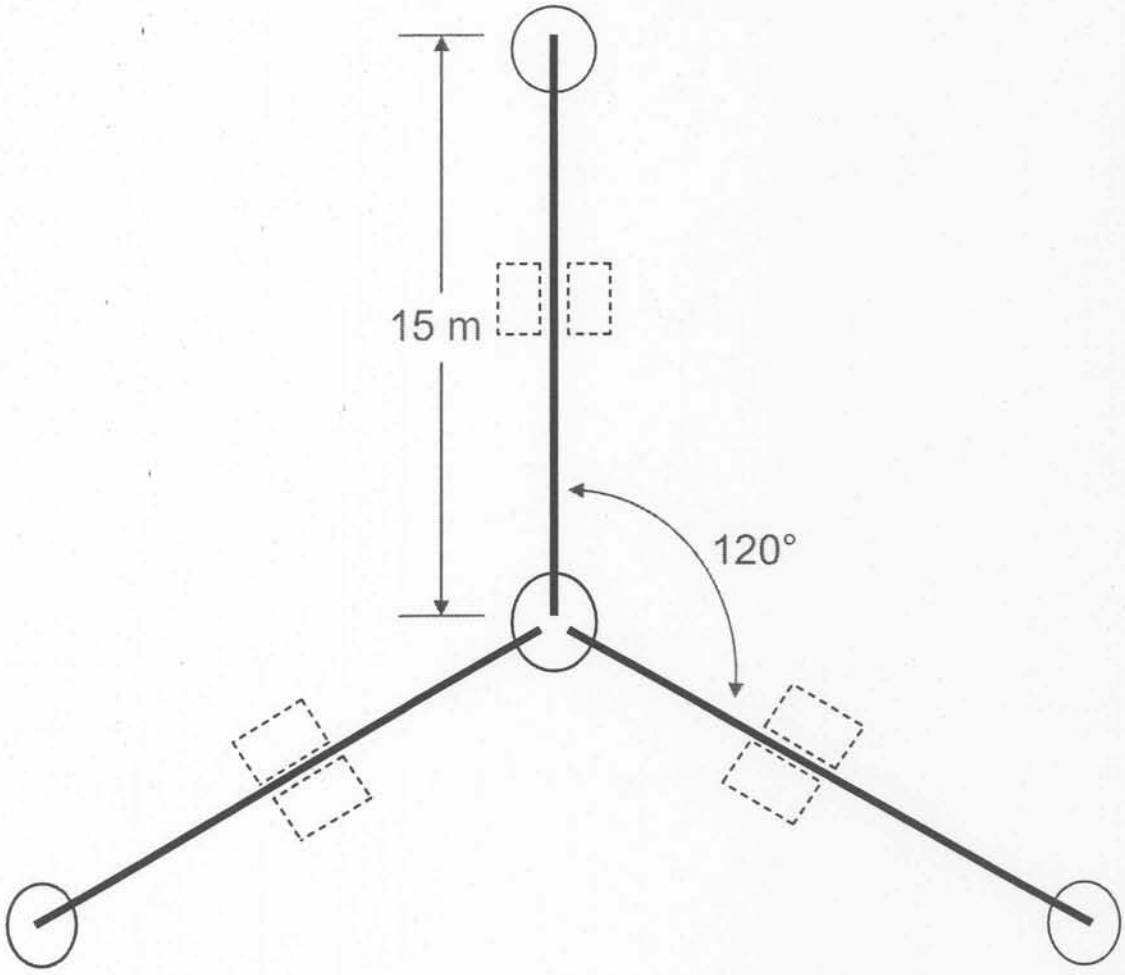

Figure 7. Drift fence array showing the 120° spacing between each drift fence, length of each drift fence, and placement of pitfall and funnel traps.

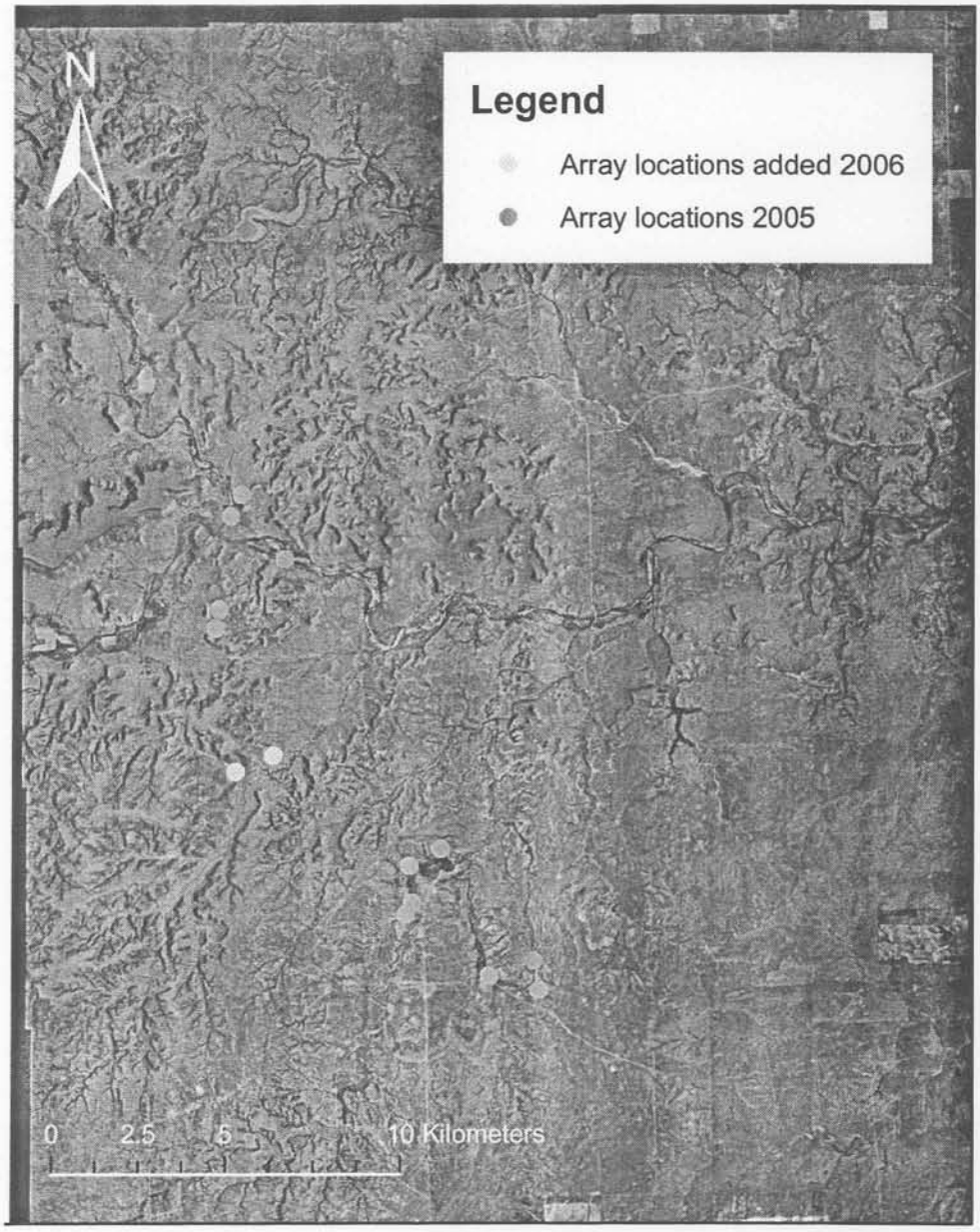

Figure 8. Locations of the 12 drift fence arrays built in 2005 and locations of the other 2 arrays built in 2006 in the Black Mesa ecoregion, Cimarron County, Oklahoma.

Figure 9. Distribution of all individuals captured at the Black Mesa ecoregion, Cimarron County, Oklahoma, 2005–2007. Each red dot is a different individual with considerable overlap.

CHAPTER II

ECOLOGY OF THE TEXAS HORNED LIZARD AT THE BLACK MESA ECOREGION, OKLAHOMA

ABSTRACT

The Texas horned lizard (*Phrynosoma cornutum*) has declined throughout much of its range. It is increasingly important to understand the ecology of this species to make proper conservation decisions. I studied ecology of the Texas horned lizard at the Black Mesa ecoregion, Oklahoma, from May to August, 2006–2007. Lizards were tracked with radiotelemetry, and morphometrics, survival, home range size, home range overlap, daily and monthly movements, and microhabitat use were evaluated. Mass and snout-vent length of adult females were larger than adult males. Males had longer tails than females. Summer survival was 0.41–0.48, comparable to other populations. Male lizards had larger home ranges than females by the 95% minimum convex polygon (MCP) method but not the 95% fixed kernel (FK) method. Mean home range size (± 1 SE) of males and females was 1.34 ± 1.30 ha by the 95% MCP method and 2.46 ± 2.85 ha by the 95% FK method. Body size was correlated positively with home range size for males and females. Percentage of home range overlap between and within sexes did not vary for the 95% MCP method. Although not significantly so, male:female pairs overlapped more than female:female pairs and male:male pairs. Daily movements of male lizards were greater in May than in July but not between May and June or June and July. There was

no difference in movements of female lizards between June and July. There also was no difference in daily movements between male and female lizards during June or July. Males moved more in May than June or July, probably to encounter females. Lizards selected areas of bare ground during morning, vegetative cover during afternoon, and a mixture of vegetation and bare ground during evening.

INTRODUCTION

The Texas horned lizard (*Phrynosoma cornutum*) is recognized by the Oklahoma Department of Wildlife Conservation (ODWC) as a species of special concern (a designation that identifies a species as a conservation priority for the State's nongame wildlife program; Oklahoma's Comprehensive Wildlife Conservation Strategy 2005). Populations of horned lizards are declining or have disappeared in parts of their range (Price 1990, Carpenter et al. 1993, Donaldson et al. 1994, Henke 2003). Suggested causes of this decline include invasion by imported red fire ants (*Solenopsis invicta*), habitat alteration (e.g., development), insecticides, agricultural irrigation or tilling, lawn mowing and watering, highway mortality, and commercial exploitation (Price 1990, Carpenter et al. 1993, Donaldson et al. 1994).

Texas horned lizards have a distinctive white line along their back that is bordered with black and several dark spots bordered posteriorly by cream- or yellow-colored crescents (Sherbrooke 2003). They are wide-bodied, dorso-ventrally flattened, and have prominent horns across the back of their head with the medial pair being longer than the others, spiny scales covering their dorsal surface, and two rows of pointed fringe scales along each side of the abdomen (Sherbrooke 2003).

Their preferred food source is ants, but they also eat a significant number of beetles (Pianka and Parker 1975). Horned lizards must eat large numbers of ants to compensate for the ants low nutritional value (Pianka et al. 1979). Therefore, the wide body and large stomach of horned lizards are believed to be adaptations to the poor nutritional characteristics of their dominant prey (Pianka and Parker 1975).

Knowledge of habitat selection by a species is a prerequisite for effective conservation. *P. cornutum* is found in arid and semiarid areas with a mixture of bare ground and vegetation (Ballinger 1974, Carpenter et al. 1993, Fair and Henke 1998, Sherbrooke 2003). Although past studies have documented microhabitat use in Texas horned lizards (Fair and Henke 1998, Stark 2000, Burrow et al. 2001, Endriss 2006), more studies are needed to compare different populations in different ecoregions. Studying different populations will add specific knowledge of this species and to the whole *Phrynosoma* genus.

All species of horned lizards are reluctant to run when approached by a predator, depending instead on their cryptic coloration to avoid detection (Pianka and Parker 1975). Due to their cryptic nature, horned lizards are difficult to track (Zug et al. 2001). However, techniques such as florescent powder tracking (Lemen and Freeman 1985, Stark and Fox 2000) and radiotelemetry (Fair and Henke 1999, Kernohan 2001, Wone and Beauchamp 2003) have made it possible to track and learn about these extremely cryptic lizards.

Space use and movements are related to the behavior and resource requirements of a species (Stamps 1977, Perry and Garland 2002). Texas horned lizards are known to have small daily activity areas (Carpenter et al. 1993), but their total home ranges are

reported to be 0.03–1.50 ha (Fair and Henke 1999) or 0.02–14.63 ha (Burrow 2000). It has been debated whether or not these lizards are territorial or if they show some form of mutual avoidance (Whitford and Whitford 1973, Stamps 1977, Fair and Henke 1999, Munger 1984).

I used radiotelemetry to monitor microhabitat and space use of Texas horned lizards at the Black Mesa ecoregion, Oklahoma. My objectives were to: 1) describe their morphometrics and summer survival; 2) determine the average home range sizes of adult males and females; 3) determine the percentage of home range overlap between and within sexes; 4) describe movements; 5) determine microhabitat selection; and 6) compare this Black Mesa population with other populations of *P. cornutum* in Oklahoma and other states.

STUDY AREA

The Black Mesa ecoregion is located in the northwestern corner of Cimarron County, Oklahoma (Figure 1). It is bordered by New Mexico to the west and Colorado to the north. It is the coolest, driest, and highest (1516 m above mean sea level) region of the state and is characterized by flat-topped sandstone mesas (Figure 2) capped with black basaltic lava (Oklahoma Biodiversity Task Force, 1996). Most of the land is either privately owned or public that is leased out to ranchers. The only land for public use is located in Black Mesa State Park or close by in the Black Mesa Nature Preserve. The region has windy springs, cold winters, and hot dry summers. Black Mesa ecoregion is a complex integration of arid grasslands, shrublands (*Yucca* sp., *Opuntia* sp.), and cedar (*Juniper virginiana*)/rocky woodlands (McPherson 2003). Areas of pinyon pine (*Pinus*

edulis) woodlands and riparian trees (e.g., *Populus deltoids*) are limited in the area but add to Black Mesa's biological diversity.

METHODS

Field Methods

Lizards were captured during visual searching and opportunistic encounter methods (see Chapter 1) from May to August 2006 and from May to August 2007. For each specimen, sex, mass, snout-vent length (SVL), and tail length were recorded. Lizards > 5.5 g were implanted with a passive integrated transponder (PIT; Electronic ID, Inc., Cleburne, Texas), and all lizards were individually marked with a unique toe clip for future identification (Heyer et al. 1994).

Adult lizards were monitored through radiotelemetry using three sizes of radio transmitters (Holohil Inc., Model: BD-2): 1.8 g, battery life 14 weeks; 1.4 g, battery life 9 weeks; or 0.9 g, battery life 6 weeks. As lizards were captured, they were released with transmitters if the mass of available transmitters was < 10% of the lizard's total body mass (Wone and Beauchamp 2003). Transmitters were adhered posterior to the lizard's head using a clear silicone adhesive or super glue gel and secured with a black elastic band around the neck (Endriss 2006). The elastic band ensured that lizards did not lose transmitters when they molted, and it allowed reattachment of transmitters as they came unattached. Three lizards' transmitters were replaced with new ones after the battery life ended on the old transmitters. Beginning 24 hours after release, lizards were relocated using a handheld, three-element, Yagi antenna 3–5 times/week until the end of each field season.

Each lizard location was recorded using a hand-held GPS unit (Garmin eTrex Vista® C, Olathe, Kansas). Latitude and longitude were recorded with an accuracy of ≤ 5 m. Those coordinates were imported into a PC using DNRGarmin downloading software and converted into Universal Transverse Mercator (UTM) coordinates using the North American Datum 1983 (NAD 1983). UTM coordinates were imported into geographic information systems software (ArcMap 9.1 and ArcView 3.3, ESRI 2005) for analysis.

Morphometrics

Mean mass, SVL, tail length, and total length measurements were calculated only for adult males and adult females. Following Endriss (2006), I considered the minimal adult SVL for both sexes to be 49 mm. [Lizards < 49 mm and found in May, June, or July were considered yearlings, while lizards < 20 mm found in August were considered hatchlings.] Although other authors have suggested minimum adult SVL measurements to be 70–75 mm (Ballinger 1974) and 75 mm (Henke and Montemayor 1997), those values were for lizards in southern Texas, and lizards in Oklahoma are known to mature at smaller sizes (Stark 2000). For example, Stark (2000) observed a male and female mating with SVL of 53.8 and 56.0 mm, respectively, and a female with SVL of 67.5 mm excavating a nest in north-central Oklahoma.

Home Ranges

Home Range Size

Two home range estimators were used, one of which was the minimum convex polygon method (Rose 1982) to permit comparison with other home range analyses (Kernohan et al. 2001). Therefore, lizard home range sizes were calculated using 95% minimum convex polygons (MCP; Rose 1982, Stone and Baird 2002) and 95% fixed

kernels (FK; Worton 1989, Larkin and Halkin 1994) using the Animal Movements Analysis Program in ArcView 3.3 (Hooge and Eichenlaub 2000). I used the 95% MCP method so as to exclude extreme outliers (Endriss 2006). The MCP method constructed home ranges by connecting outer locations to form a convex polygon (Kernohan et al. 2001). The FK method placed a probability density function over each point and gave a higher density value where points were concentrated; those density values were shown as contours (Kernohan et al. 2001, Moeller 2004). Thus, larger contours were produced from higher density values. The smoothing factors (h) for the 95% FK home ranges were determined using the least-squares cross validation method (LSCV; Worton 1989). The LSCV method varied h and identified the value of h that produced the minimum estimated error for each lizard (Row and Blouin-Demers 2006).

The minimum number of points used to accurately estimate home range size was determined by calculating cumulative 100% MCP home ranges (Rose 1982, Stone and Baird 2002). Home range size was calculated for the first 5 location points and again for each additional 5 points collected for a lizard. That analysis indicated that size for most home ranges leveled off at 10 and 15 location points; therefore, home range size for each additional location point from 10–15 also was calculated (Figure 3). That analysis indicated that home ranges leveled off before or by 12 points; therefore, I used only lizards with $\geq$ 12 location points in home range and microhabitat analysis. The home ranges of two lizards continued to increase substantially after 12 points (Figure 3). One was a female that moved to a suitable area to lay her eggs and then moved back to her original home range. The other was a male who gradually shifted his home range to the southeast. Generally though, home ranges leveled off before or by 12 location points.

Home Range Overlap

Home range overlap was calculated for male:male pairs, female:female pairs, and male:female pairs using the 95% MCP estimates and ArcMap 9.1 software. Overlap was calculated only for those lizards that were alive during the same time period. For all lizard pairs, percentage overlap of each lizard's home range was calculated. The percentage of home range that females overlapped with females, males overlapped with males, and males overlapped with females was transformed (arcsin of the square root of the proportion) and compared using analysis of variance (Sokal and Rohlf 1969).

Movements

I calculated the distance traveled between consecutive location points for each lizard using Hawth's analysis tools extension to ArcMap 9.1 (Beyer 2004). Average daily distance traveled in separate months for male and female lizards was calculated by summing straight line distances between consecutive points in a month divided by number of days. For each male lizard, I calculated an average distance traveled per day in May, June, and July and for female lizards in June and July because these were the only months when female lizards were located frequently enough to have an accurate estimate of their daily distance traveled.

Survival

I calculated summer survival using the Kaplan-Meier staggered entry design (Pollock et al. 1989) for all lizards from May to August in 2006–2007 that were tracked with telemetry for $\geq$ 14 days. Because the fate of several lizards was unknown, I measured two different survival rate estimates, termed categories, using different assumptions. The first (Category 1) assumed that lizards with unknown fates were alive;

the second (Category 2) assumed that lizards with unknown fates were dead. The only cause of unknown fates was finding a transmitter without a lizard, which could be due to either a predation event or a lizard losing the transmitter. The fate of the lizard was considered known if the lizard's carcass was found, a lizard's transmitter was found right next to its PIT tag, or the lizard was released upon finishing the field season.

Microhabitat

I collected microhabitat data in a 0.1-m^2 frame centered on each lizard location and at paired random locations 10 m from each lizard. The location of each random point was paced in the direction of the second hand of a watch. For example, when I was ready to collect microhabitat data for the random location, I looked down at my watch and whichever way the second hand of my watch was pointing was the direction in which I walked. I estimated the percent cover (in 5% increments) of grass, forb canopy, shrub or tree canopy, rock, litter, and bare ground by looking top-down onto the frame. I termed microhabitat data at the lizard location "used microhabitat" and microhabitat data at the paired random location "available microhabitat."

I used compositional analysis to compare microhabitat use to microhabitat availability (Aebischer et al. 1993). Compositional analysis used individual lizards, rather than points, as sample units and compared used and available microhabitat to determine if microhabitat use differed from the microhabitat's availability. Only lizards with ≥ 12 points were used in this analysis (see Home Ranges methods). If lizards selected microhabitats differently from their availability, compositional analysis ranked microhabitats in order of relative preference and avoidance. Compos Analysis 6.2 Plus (Smith 2005) was used to analyze microhabitat data. An assumption that can affect the

analysis is that microhabitat data from different lizards are equally accurate, which is incorrect if the number of location points per lizard varies. To compensate for this, I used the square root of the number of location points per lizard to weight the log-ratio differences as recommended by Aebischer et al. (1993).

Bingham and Brennan (2004) found that nonzero substitutions in used habitat created an increase in Type I error rates based on the substitution numbers used. Using simulated data based on known habitat use and availability parameters, they found that substitutions between 0.3 and 0.7 minimized the Type I error rate. Substitutions < 0.3 incorrectly identified habitats with small availabilities as significantly avoided, whereas substitutions > 0.7 incorrectly identified habitats with small availabilities as significantly preferred. Therefore, I ran each analysis with the substitution value of 0.3 for each zero value in the used microhabitat category.

Compositional analysis was used to test four different scenarios. I first used it to test the overall microhabitat use data against the overall available microhabitat data. I then separated data into time of day categories (morning, afternoon, and evening) and analyzed them separately. The morning category was 0700–1100 hr, afternoon was 1100–1800 hr, and evening was 1800–2130 hr.

RESULTS

Morphometrics

The Kolmogorov-Smirnov test for normality indicated that the morphometric distributions by sex were not different from normal ($Z < 1.12$, $P > 0.16$). Levene's test revealed that variances of morphometric measurements were homogeneous ($F_{1,111} < 3.61$, $P > 0.43$), except the variances for tail length ($F_{1,111} = 6.15$, $P = 0.015$). Thus, I

conducted two-sample t-tests to compare mass, SVL, and total length by sex, and an adjusted two-sample t-test for unequal variances to compare tail length by sex.

Adult female lizards ($n = 59$) were larger than adult males ($n = 54$) for mass ($t_{111} = 3.34$, $P = 0.001$) and SVL ($t_{111} = 4.66$, $P < 0.001$); however, there was no difference in total length ($t_{111} = 1.43$, $P = 0.156$). Adult male lizards had longer tails than adult females ($t_{99.9} = 3.96$, $P < 0.001$).

Home Ranges

Home Range Size

The Kolmogorov-Smirnov test for normality indicated that the distributions of the 95% MCP and 95% FK home ranges were not different from normal for females and males ($Z < 0.99$ and 1.12, $P > 0.210$ and 0.161, respectively). Levene's test revealed that variances for the 95% FK home ranges were homogeneous ($F_{1,21} = 2.86$, $P = 0.105$), but they were not homogeneous for the 95% MCP ($F_{1,21} = 9.11$, $P = 0.007$). Thus, the 95% MCP home range sizes were compared between males and females using an adjusted t-test for unequal variances and the 95% FK home range sizes were compared between males and females using a t-test for pooled variances.

Mean female home range sizes (± 1 SE) were 0.71 ± 0.67 ha (range: 0.03–2.01) by the 95% MCP method and 1.42 ± 1.27 ha (range: 0.11–3.43) by the 95% FK method (Table 1). Mean male home range sizes were 1.92 ± 1.47 ha (range: 0.16–4.56) by the 95% MCP method and 3.40 ± 3.57 ha (range: 0.36–12.67) by the 95% FK method. Mean home range sizes pooled for both sexes were 1.34 ± 1.30 ha by the 95% MCP method and 2.46 ± 2.85 ha by the 95% FK method. The 95% MCP home ranges of male lizards were larger than those of female lizards ($t_{15.7} = 2.57$, $P = 0.021$); however, they did not

differ with the 95% FK method ($t_{21} = 1.74$, $P = 0.097$). Body size (mass and SVL) was correlated positively with home range size for male ($n = 12$, $P < 0.017$) and female ($n = 11$, $P < 0.043$) lizards (Table 2).

Home Range Overlap

Percentage overlap of 95% MCP home ranges did not vary between and within sexes ($F_{2, 26} = 0.62$, $P = 0.546$; Table 3). Nevertheless, female home ranges were overlapped by male home ranges to a greater degree than male home ranges were overlapped by male home ranges or female home ranges were overlapped by female home ranges (Table 3).

Movements

The Kolmogorov-Smirnov test for normality indicated that the movement data did not differ from normal ($Z < 1.11$, $P > 0.172$). Levene's test revealed that variances between male and female lizards by month (June and July) were homogeneous (June: $F_{1,18} = 1.05$, $P = 0.318$; July: $F_{1,25} = 0.36$, $P = 0.851$); therefore, I used *t*-tests to test for differences between male and female lizards in the average daily distance traveled for each month. Levene's test also found that variances were homogeneous between different months for males ($F_{2,30} = 1.29$, $P = 0.289$), but not for females ($F_{1,18} = 11.21$, $P = 0.004$); therefore, I used a conventional one-way analysis of variance for males and an adjusted *t*-test for unequal variances for females to test for differences among the average daily distances traveled by month. If a significant difference was found using the ANOVA for males, Tukey's multiple comparison test was used to identify differences.

Within each month, daily movements did not vary between sexes (June: $t_{18} = 0.26$, $P = 0.796$; July: $t_{25} = 0.54$, $P = 0.594$). Daily movements varied across months for

males ($F_{2,30} = 6.401$, $P = 0.005$) but not for females ($t_7 = 1.28$, $P = 0.242$). Males moved more during May than during July ($F_{1,18} = 0.31$, $P = 0.004$). Although not significant, females moved more during June than July (Table 4). The average daily distance traveled over the entire study (± 1 SE) for both sexes was 21.61 ± 1.98 m (range = 4.43–74.28).

Survival

Survival was 0.48 for Category 1 (95% CI: 0.33–0.63) and 0.41 for Category 2 (95% CI: 0.28–0.54; $n = 32$). Nine lizards were depredated: 6 by a western coachwhip snake (*Masticophis flagellum*) based on tracking a lizard with a radio to a snake, 2 by ants (*Crematogaster punctulata*) based on finding an unmutilated lizard corpse near an ant mound and covered with ants, and 1 by a grasshopper mouse (*Onychomys leucogaster*) based on finding a lizard without its head or internal organs. Two lizards were run over, one on a paved road and one on a dirt road. Mortalities for lizards not tracked ≥ 14 days (which were excluded from the survival calculations) included 3 due to avian predators based on finding the transmitter and PIT tag in close proximity, 3 due to western coachwhip snakes based on tracking a lizard with a radio to a snake, 3 due to either being run over by a farm vehicle or being stepped on by cattle based on finding a lizard crushed off of a dirt road, and 1 being run over on a gravel road.

Microhabitat

Overall microhabitat use differed from overall microhabitat availability ($\lambda = 0.41$, $\chi^2_5 = 20.57$, $P = 0.001$, $n = 23$). Microhabitat categories were ranked: shrub/tree canopy > bareground > forb canopy > litter > grass > rock (Table 5). Shrub/tree canopy, bareground, forb canopy, litter, and grass were selected more than rock, and bareground

and litter also were selected more than grass (Table 5). During morning hours (0700–1100), microhabitat use differed from microhabitat availability ($\lambda = 0.61, \chi^2_5 = 11.15, P = 0.048, n = 23$). Microhabitat categories during morning hours were ranked: bareground > shrub/tree canopy > litter > forb canopy > grass > rock (Table 6). Bareground and litter were selected more than rock, and bareground also was selected more than grass (Table 6). During afternoon hours (1100–1800), microhabitat use differed from microhabitat availability ($\lambda = 0.34, \chi^2_5 = 23.94, P < 0.001, n = 22$). Microhabitat categories during afternoon hours were ranked: shrub/tree canopy > forb canopy > bareground > litter > grass > rock (Table 7). Shrub/tree canopy, bareground, and litter were selected more than grass, and shrub/tree canopy also was selected more than rock (Table 7). During evening hours (1800–2130), microhabitat use differed from microhabitat availability ($\lambda = 0.49, \chi^2_5 = 14.64, P = 0.012, n = 21$). Microhabitat categories during evening hours were ranked: shrub/tree canopy > bareground > litter > rock > grass > forb canopy (Table 8). Bareground was selected more than grass.

DISCUSSION

Morphometrics

Sizes of Texas horned lizards at Black Mesa further support the notion that *P. cornutum* is smaller in northern parts of its range. Montgomery et al. (2003) looked at the relationship of body size to latitude in *P. cornutum* from central Mexico to southeastern Colorado and found a trend of decreased size with increased latitude for several morphological characteristics of *P. cornutum*. Moeller et al. (2005) reported that mass and SVL measurements of *P. cornutum* in southern Texas averaged 45.2 g and 92.4 mm for adult females and 39 g and 85 mm for adult males, respectively. Stark and Fox

(2000) reported that mass and SVL measurements averaged 18 g and 60 mm for adult females and 13 g and 58 mm for adult males in central Oklahoma, respectively. Stark (2000) found that *P. cornutum* in southern Texas were significantly larger than populations in north-central Oklahoma.

This trend is contrary to Bergmann's rule (Ashton and Feldman 2003): animals from higher latitudes are larger than counterparts from lower latitudes. The explanation for this rule is that larger animals expend less energy for thermoregulation because of their smaller surface-to-volume ratio; thus, it is more economical for animals to be larger in colder climates. It has been debated if Bergmann's rule applies to ectotherms because they grow slowly at low temperatures (Mousseau 1997; Belk and Houston 2002; Angilletta et al. 2004). Ashton (2004) found that most species of amphibians, however, follow Bergmann's rule. Ashton and Feldman (2003) found that most species of lizards and snakes are larger at lower latitudes; however, turtles were smaller. Exceptions to Bergmann's rule, however, have been found within most groups of animals. For example, Angilletta et al. (2004) examined life-history traits of *Sceloporus undulatus* and found it to follow Bergmann's rule.

Cruz et al. (2005) suggested that latitudinal patterns in body size are easiest to detect among closely related species with similar habitat requirements because of less extensive life-history variation among clades occupying distinct environments. For example, Ashton (2001) found that different clades of *Crotalus viridis* follow different size-latitude trends. Bergmann's rule held for the eastern clade of rattlesnakes that inhabit relatively homogeneous environments throughout their range, but the western sister clade is distributed along a heterogeneous environmental gradient and exhibited a

reverse to Bergmann's rule. Cruz et al. (2005) found that the variation in the strength of Bergmann's rule in *Liolaemus* lizards depended on the phylogenetic scale of the analysis. They found that inclusion of all species in their analysis weakened the relationship between body size and latitude.

Although there seems to be a debate of whether or not some lizards follow Bergmann's rule or whether others reverse it, there is no debate that some factor or factors affect sizes of Texas horned lizards at varying latitudes. Montgomery et al. (2003) postulated that the decreased size in *P. cornutum* with increased latitude may be the result of shorter seasonal activity periods, effects of animal body surface area to volume ratios on heat loss and gain, a decline in the net primary productivity and available energy for growth, some other unrecognizable factor, or a combination of factors.

Factors involved in the evolution of longer tails in male lizards than female lizards are even less clear. In fact, there appear to be no published articles explaining this sexual difference. Alberts et al. (2004) found this same relationship in tail length in male San Diego coast horned lizards compared with female lizards but gave no explanation for their finding. Cooper and Vitt (1989) found that the difference in head size between male and female *Sceloporus undulatus* was due to a reduction in the rate of head growth relative to body-size growth in females rather than strictly by an increase in male head size. They stated that females presumably invest mainly in reproduction and body growth at the expense of an increase in head size. They used their findings to caution against attributing sexual differences in morphological characters to sexual selection unless morphological characters under investigation are implicated in determining

reproductive success. Thus, further research is needed to elucidate reasons why tail length is longer in male *P. cornutum* than females at the Black Mesa ecoregion. To determine if sexual selection is involved, male lizards need to be monitored to determine differential mating success. If males with longer tails gain more matings than those with shorter tails, then sexual selection might be responsible. On the other hand, the difference in tail length may be something as simple as males needing a longer tail to gain the proper copulatory position or longer tails to help protect the males' hemipenes.

The female-biased sexual size dimorphism (SSD) found in my study has been found for other populations of *P. cornutum* (Stark 2000, Endriss 2006) and for other *Phrynosoma* species (Zamudio 1998). Stark (2000) reported that *P. cornutum* females were significantly larger than males in southern Texas and central Oklahoma. This SSD is unusual among iguanid lizards because it is usually the male who is larger (Stamps 1977). Males of this family usually defend territories (Stamps 1983). To copulate successfully with a female, a male must either attract her to his territory or expand his territory to encompass her home range and court her there (Stamps 1977). Thus, to increase its mating success, a male iguanid lizard usually defends a territory that holds females, and the larger more dominant males usually win agnostic interactions with smaller subordinate males (Zamudio 1998). However, *Phrynosoma* lizards may not follow this same strategy.

It has been debated whether *Phrynosoma* defend a territory (Lynn 1965, Stamps 1977, Fair and Henke 1999). Munger (1984) reported that horned lizards are somewhat territorial, although home ranges of individuals overlap. Lynn (1965) concluded that horned lizards were not territorial. Other researchers (Munger 1984, Fair and Henke

1999) suggested that horned lizards may mutually avoid one another to limit competition for food instead of guarding a home range. Even so, display interactions have been observed between two male *P. cornutum* in the field, which indicates some form of agonism perhaps related to territoriality (Whitford and Whitford 1973).

To explain female-biased SSD in horned lizards, Zamudio (1998) used phylogenetic independent contrasts to estimate evolutionary correlations among female body size, male body size, and SSD. She found that there were selective pressures to produce small males and termed this the small-male advantage hypothesis: smaller males mature earlier than larger males and also increase their encounter rates with females more than larger males, thus, in this way they increase their reproductive success.

Home Ranges

Home Range Size

Home range size is an important indicator of the resource requirements and behavioral strategies of a species (Perry and Garland 2002). In recent years, more information about home range sizes of Texas horned lizards has become available. Fair and Henke (1999) estimated mean home range sizes of *P. cornutum* in southern Texas at 0.73 ha ($n = 9$), but their estimates were based on a limited sample size. Endriss (2006), who conducted a study with *P. cornutum* at an urban park in central Oklahoma, estimated mean home range sizes at 0.43 ha ($n = 13$) and 0.57 ha ($n = 11$) for female and male lizards, respectively. Burrow et al. (2002), who conducted their study at a wildlife refuge in southern Texas, found mean home range sizes to be 0.66 ha ($n = 6$) when there was no grazing or burning. The home range sizes of this study ($\bar{x} = 1.34$ ha, $n = 23$) were more similar to results of Burrow et al. (2002) when lizards were tracked on land moderately

grazed by cattle and unburned ($\bar{x}$ = 1.33 ha, n = 9). Burrow et al. (2002) found the average size of lizard home ranges to be 2.62 ha when the land was heavily grazed and unburned. The land used in this study also was heavily grazed and unburned, but lizards were smaller than the more southern population studied by Burrow et al. (2002). Munger (1984) reported mean home range sizes of *P. cornutum* in Arizona of 1.38 ha for females (n = 13) and 2.40 for males (n = 10); however, he utilized a different method of home range construction and recommended that his data not be used for comparative purposes.

Whiting et al. (1993) found that Texas horned lizards selected areas that contained less dense vegetative ground cover. They stated that a low prey abundance and a partially vegetated habitat that facilitates locomotion, foraging, and thermoregulation was related to increased space use of Texas horned lizards. Land that is grazed by cattle may allow *P. cornutum* to be more motile and thus use more space. Unlike the study by Endriss (2006), my study was conducted in a less disturbed area; lizards were not limited to a certain area within a preserve.

Even though home ranges did not differ between sexes for the 95% FK method, they did differ for the 95% MCP home ranges, indicating that males have a larger home range than females. Also, recent research (Row and Blouin-Demers 2006) indicated that the FK home range method may not be a good estimator of herpetofauna home range sizes. Additionally, the smallest 95% MCP among female lizards was substantially smaller than the smallest 95% MCP among males (0.03 and 0.16, respectively). These findings add further support to the hypothesis that males are more mobile because increased mobility makes them more likely to find females during the mating season (Zamudio 1998, Stark et al. 2005). Unlike my study, previous studies did not find a

significant difference between male and female *P. cornutum* 95% MCP home ranges (Moeller 2004, Endriss 2006), although they did show a trend in that direction.

Body size was correlated positively to home range size in both sexes. A larger size may require both sexes to use a larger area to find adequate food resources. Males would benefit from a larger home range because they would be able to encounter more females during the mating season (Stark et al. 2005). Endriss (2006) hypothesized that larger male horned lizards may be dominant over smaller males during encounters, and that male body size may be a tradeoff between small size for mobility (Zamudio 1998) and large size for dominance and energy reserves for movement. Females, on the other hand, are probably more likely to adjust their home ranges for nesting activities. Larger gravid females might increase their movements when they search for a suitable nesting location (Burrow 2000).

Home Range Overlap

It is difficult to identify factors that may affect home range overlap in Texas horned lizards. Only a few studies have addressed these factors. Like my study, Fair and Henke (1999) found that more male:female pairs overlapped than male:male or female:female pairs. They also found that weekly home ranges were fairly exclusive. They stated that the minimum overlap in home ranges found could be considered either territoriality or mutual avoidance. Similar to my study, Endriss (2006) did not find a statistically significant pattern in home range overlap. Data in my study and Endriss (2006) suggested that some form of territoriality or mutual avoidance might be taking place in this species (Table 3). Future research should develop a method that evaluates the mutual avoidance hypothesis to analyze home range overlap data. Another difficulty

is that these lizards are very cryptic and it is hard to determine if all individuals in a certain area are being tracked. Researchers must spend a great deal of time in the field to collect all lizards in a specific area.

Movements

Similar to Stark et al. (2005) and Endriss (2006), my results indicated that male *P. cornutum* moved more during the mating season than males after the mating season. Stark et al. (2005) proposed that male *P. cornutum* travel greater distances early in the season (April–May) to increase their chances of locating and mating with females. Stark et al. (2005) and Endriss (2006) also found that males moved significantly more during May than females, but not during any other month. Because I did not have data for females during May, I was not able to test this. However, my data did support the notion that males and females do not differ in daily distances moved in June–August.

Overall average daily distances moved by lizards in my study (21.61 ± 1.98 m) were shorter than those reported in previous studies with *P. cornutum* (Whitford and Bryant 1979, Fair and Henke 1999, Stark et al. 2005, Endriss 2006), where means were 25.0–46.8 m/day. Various methods of data collection may have caused this discrepancy. Stark et al. (2005) used fluorescent powder trails to calculate distance traveled, whereas Whitford and Bryant (1979) used intensive observation with binoculars. Both of those studies, along with Fair and Henke (1999) who used radiotelemetry and located lizards 10 times/day to calculate average distance traveled/day, had the largest estimates, of 36.5–46.8 m/day. All of those studies used more than just the straight line distance between consecutive location points, which were collected, at most, once a day. Endriss (2006) on the other hand, used florescent powder tracking and radiotelemetry. Unlike Fair and

Henke (1999), Endriss (2006) and I located lizards with radiotelemetry at most once a day. By doing so, our telemetry data represent lizards moving in a straight-line manner between consecutive points, whereas lizards most likely moved in a circuitous path between points. Therefore, I suggest that the higher estimates of 36.5–46.8 m/day for average individual daily movements by *P. cornutum* are more accurate.

Survival

In recent years, many researchers have calculated summer and annual survival of *P. cornutum* (Munger 1986, Fair and Henke 1999, Burrow 2002, Moeller 2004, Endriss 2006). It is difficult to make comparisons of survival between different populations of *P. cornutum*, however, because of different methods used to calculate survival, different time-frames used by researchers, and lack of a consistent conditioning period (minimal time tracked in order to estimate survival) across all studies. Even though a formal procedure has not been followed by every researcher, some patterns can be discussed.

Burrow et al. (2002) stated that estimates of survival of horned lizards were imprecise and debatable due to the large numbers of censored (unknown fates) lizards. However, only 2 of the 32 lizards in my study were censored. Estimates of summer survival calculated in this study, 0.48 for Category 1 and 0.41 for Category 2, were most similar to those calculated by Burrow et al. (2002) for moderately grazed and heavily grazed land. Burrow et al. (2002) calculated Category 1 summer survival of 0.60 at a wildlife refuge in southern Texas in moderately grazed land and 0.36 in heavily grazed land. They suggested that heavily grazed sites may increase vulnerability of horned lizards to mortality. The land on which *P. cornutum* at Black Mesa were tracked was moderately to heavily grazed by cattle and full of predators (see Chapter 1). Alberts et al.

(2004) found that the San Diego coast horned lizard (*Phrynosoma coronatum*) had higher rates of bird predation on grazed land than undisturbed land.

Munger (1986) estimated summer survival of *P. cornutum* in southeastern Arizona at 0.86 for Category 1 and 0.48 for Category 2 ($n = 25$). Fair and Henke (1999) calculated annual survival (March–October) for 9 lizards at 0.54 and 0.09 for Category 1 and 2, respectively. Fair and Henke (1999) reported that their low estimates of survival may have been due to the backpack style harnesses they used to house transmitters on the lizards' backs. Endriss (2006) estimated summer survival for 45 lizards at 0.77 and 0.70 for Category 1 and 2, respectively. She attributed her high estimates of survival to the possibility of low human-caused mortalities and the lack of typical predators of horned lizards at her study site, an urban park in Oklahoma City, Oklahoma. Many *M. flagellum*, a major predator of *P. cornutum*, were seen during my study, whereas none were seen by Endriss (2006; personal communication).

It would be interesting to track *P. cornutum* at Black Mesa in a non-grazed area to discern effects of grazing on the survival of this lizard in this region. Due to the remoteness and undeveloped nature of Black Mesa, and its many predators, summer survival may still be low, even in land that is not grazed. When new technologies become available, such as sub-dermal radio transmitters, they should be used with Texas horned lizards to determine if the radio transmitters used in this study biased survival estimates.

Microhabitat

My results support previous studies that found *P. cornutum* using a mixture of open and vegetated microhabitats (Fair and Henke 1998, Burrow et al. 2001, Stark 2000,

Endriss 2006). By using a variety of microhabitats, *P. cornutum* is able to regulate its body temperature (Prieto and Whitford 1971). The specific microhabitat used depended on the time of day. This is not surprising because previous researchers have found that Texas horned lizard activity varies by time of day and season (Burrow et al. 2001, Endriss 2006).

Stark (2000) found that *P. cornutum* principally selected bare ground, grass, herbaceous vegetation, leaf litter, and gravel at his study sites in north-central Oklahoma. He noted that Texas horned lizards often traveled through areas of dense vegetation for extended distances rather than just entering vegetation and taking refuge; he attributed this behavior to predator avoidance and foraging activities. He suggested microhabitat suitable for this species should include a patchwork of bare ground and dense vegetation.

Ambient temperature plays a large role in the variation in activity of *P. cornutum*. During hot summer months, *P. cornutum* is most active in the morning and evening hours (Pianka and Parker 1975). Areas of bare ground were used more during morning and evening hours at Black Mesa. Those areas probably provided basking habitat for thermoregulatory activities during cooler parts of the day.

Burrow et al. (2001) proposed another reason why horned lizards used bare ground; it concerned their supposed preferential prey, harvester ants (*Pogonomyrmex* spp.; Pianka and Parker 1975). Ecothermic ants in hot climates avoid midday activity and, like horned lizards, are more active in the morning and evening, especially when foraging on bare ground (Burrow et al. 2001). Thus, Burrow et al. (2001) proposed that due to harvester ants' increased activity in the morning and evening, horned lizards were more likely to forage during those same times. Although there were harvester ants at

Black Mesa, I did not come across a lizard eating them. All *P. cornutum* I found foraging were eating a different genus of ant, specifically *Crematogaster punctulata*. The 2 horned lizards that were overcome and killed by ants were killed by *C. punctulata*. However, this does not mean that *P. cornutum* does not eat harvester ants at Black Mesa. Even if it does not rely heavily on harvester ants there, the ants *P. cornutum* does forage for (*C. punctulata*) may possess similar behavior to harvester ants and also forage during cooler temperatures.

In my study, Texas horned lizard behavior in the afternoon differed from that during the morning and evening. Shrub/tree canopy and forb canopy were used the most during this hottest part of the day (1100–1800 hr). These areas probably provided cover from the extreme temperatures and from predators. *Masticophis flagellum*, the snake that ate 9 of the *P. cornutum* with radios, is a diurnal, active forager that relies heavily on vision to hunt (Secor and Nagy 1994), so refuging out of the open during parts of the day may be important for *P. cornutum* at Black Mesa.

It is unclear why shrub/tree canopy was selected more than bare ground during the evening (although not significantly so). One possible reason may be that it was still too warm to be out in the open during the time between 1800–2130 hr at Black Mesa. Another possibility is that lizards decreased their chances of being preyed on by staying under cover for a longer period of time. It may have been a combination of temperature and predator considerations. I also may not have had a large enough number of observations per lizard for this time period; this was the time period in which I had the fewest observations per lizard. Nevertheless, bareground was used significantly more than grass; shrub/tree canopy was used more than grass, but not significantly so.

Rock microhabitat was selected more than grass and forb canopy in the evening (although not significantly so). Texas horned lizards may use rock microhabitats for thermoregulatory activities (heat conduction) when temperatures begin to cool in the evening. *P. cornutum* was often found on the paved roads in the evening, and paved roads were considered a rock microhabitat.

These results support the idea that areas of bare ground and sparse vegetation are an important part of Texas horned lizard microhabitat. *P. cornutum* selects bare ground areas during cooler parts of the day and vegetated areas during the hottest portions. Rocky areas may also play an important role in the thermoregulatory behavior of this species at Black Mesa during the evening hours. The microhabitat recommendations presented here should be factored into land management decisions, particularly by governmental agencies overseeing large tracts of public lands, if we are to conserve *P. cornutum*.

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Table 1. The number of points, area of 95% minimum convex polygon (MCP), and area of 95% fixed kernel (FK) home ranges of lizards tracked at Black Mesa, Cimarron County, Oklahoma, 2006–2007.

Sex	Number of points	95% MCP (ha)	95% FK (ha)
Male	19	0.16	0.36
Male	31	0.44	0.75
Male	15	0.81	1.43
Male	26	0.85	1.97
Male	23	1.05	2.23
Male	15	1.27	2.87
Male	15	1.37	2.17
Male	34	2.26	3.25
Male	21	2.91	12.67
Male	39	3.16	3.49
Male	15	4.20	8.36
Male	26	4.56	1.30
Female	20	0.03	0.11
Female	12	0.11	0.28
Female	15	0.30	0.41
Female	32	0.35	1.00
Female	19	0.37	0.65
Female	13	0.38	1.08
Female	12	0.42	1.12
Female	16	0.78	1.02
Female	16	1.30	3.25
Female	30	1.75	3.43
Female	13	2.01	3.29

Table 2. Correlation between body size and home range size of adult male and female lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007.

Home-range method	Body measurement	Sex	P-value	Correlation coefficient (r)
95% MCP	Snout-vent length	Male	0.015	0.62
95% MCP	Mass	Male	0.017	0.61
95% FK	Snout-vent length	Male	0.012	0.64
95% FK	Mass	Male	0.002	0.77
95% MCP	Snout-vent length	Female	0.043	0.54
95% MCP	Mass	Female	0.032	0.58
95% FK	Snout-vent length	Female	0.035	0.57
95% FK	Mass	Female	0.036	0.56

Table 3. Mean (± 1 SE) percentage of lizard's 95% MCP home ranges that overlapped between and within sexes of Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007.

Comparison	*n*	Mean	(± 1 SE)
Male:male	12	21.40	5.70
Female:female	8	12.90	2.50
Male:female[1]	10	24.65	6.76

[1] Overlap of females' home ranges by males

Table 4. Mean (± 1 SE) daily distance (m) traveled in specific months by Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007.

Sex	Month	*n*	Mean	(± 1 SE)
Male	May	6	36.3	3.1
Male	June	13	24.6	4.9
Male	July	14	14.7	2.0
Female	June	7	26.9	7.9
Female	July	13	16.4	2.2

Table 5. Ranking matrix for microhabitat selection by Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007[a].

	Shrub/tree canopy	Bareground	Forb canopy	Litter	Grass	Rock	Rank
Shrub/tree canopy		+	+	+	+	+++	5
Bareground	−		+	+	+++	+++	4
Forb canopy	−	−		+	+	+++	3
Litter	−	−	−		+++	+++	2
Grass	−	−−−	−	−−−		+++	1
Rock	−−−	−−−	−−−	−−−	−−−		0

[a]Three +'s or three −'s indicate that a habitat category in that row was used significantly more or less, respectively, than a habitat category in the corresponding column. One + or one − indicates that a habitat category was used more or less, respectively, but the difference was not statistically significant.

Table 6. Ranking matrix for microhabitat selection from 0700–1100 hr by Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007[a].

	Bareground	Shrub/tree canopy	Litter	Forb canopy	Grass	Rock	Rank
Bareground		+	+	+	+++	+++	5
Shrub/tree canopy	−		+	+	+	+	4
Litter	−	−		+	+	+++	3
Forb canopy	−	−	−		+	+	2
Grass	−−−	−	−	−		+	1
Rock	−−−	−	−−−	−	−		0

[a]Three +'s or three −'s indicate that a habitat category in that row was used significantly more or less, respectively, than a habitat category in the corresponding column. One + or one − indicates that a habitat category was used more or less, respectively, but the difference was not statistically significant.

Table 7. Ranking matrix for microhabitat selection from 1100–1800 hr by Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007[a].

	Shrub/tree canopy	Forb canopy	Bareground	Litter	Grass	Rock	Rank
Shrub/tree canopy		+	+	+	+++	+++	5
Forb canopy	−		+	+	+	+	4
Bareground	−	−		+	+++	+	3
Litter	−	−	−		+++	+	2
Grass	−−−	−	−−−	−−−		+	1
Rock	−−−	−	−	−	−		0

[a]Three +'s or three −'s indicate that a habitat category in that row was used significantly more or less, respectively, than a habitat category in the corresponding column. One + or one − indicates that a habitat category was used more or less, respectively, but the difference was not statistically significant.

Table 8. Ranking matrix for microhabitat selection from 1800–2130 hr by Texas horned lizards at Black Mesa, Cimarron County, Oklahoma, 2006–2007[a].

	Shrub/tree canopy	Bareground	Litter	Rock	Grass	Forb canopy	Rank
Shrub/tree canopy		+	+	+	+	+	5
Bareground	–		+	+	+++	+	4
Litter	–	–		+	+	+	3
Rock	–	–	–		+	+	2
Grass	–	–––	–	–		+	1
Forb canopy	–	–	–	–	–		0

[a]Three +'s or three –'s indicate that a habitat category in that row was used significantly more or less, respectively, than a habitat category in the corresponding column. One + or one – indicates that a habitat category was used more or less, respectively, but the difference was not statistically significant.

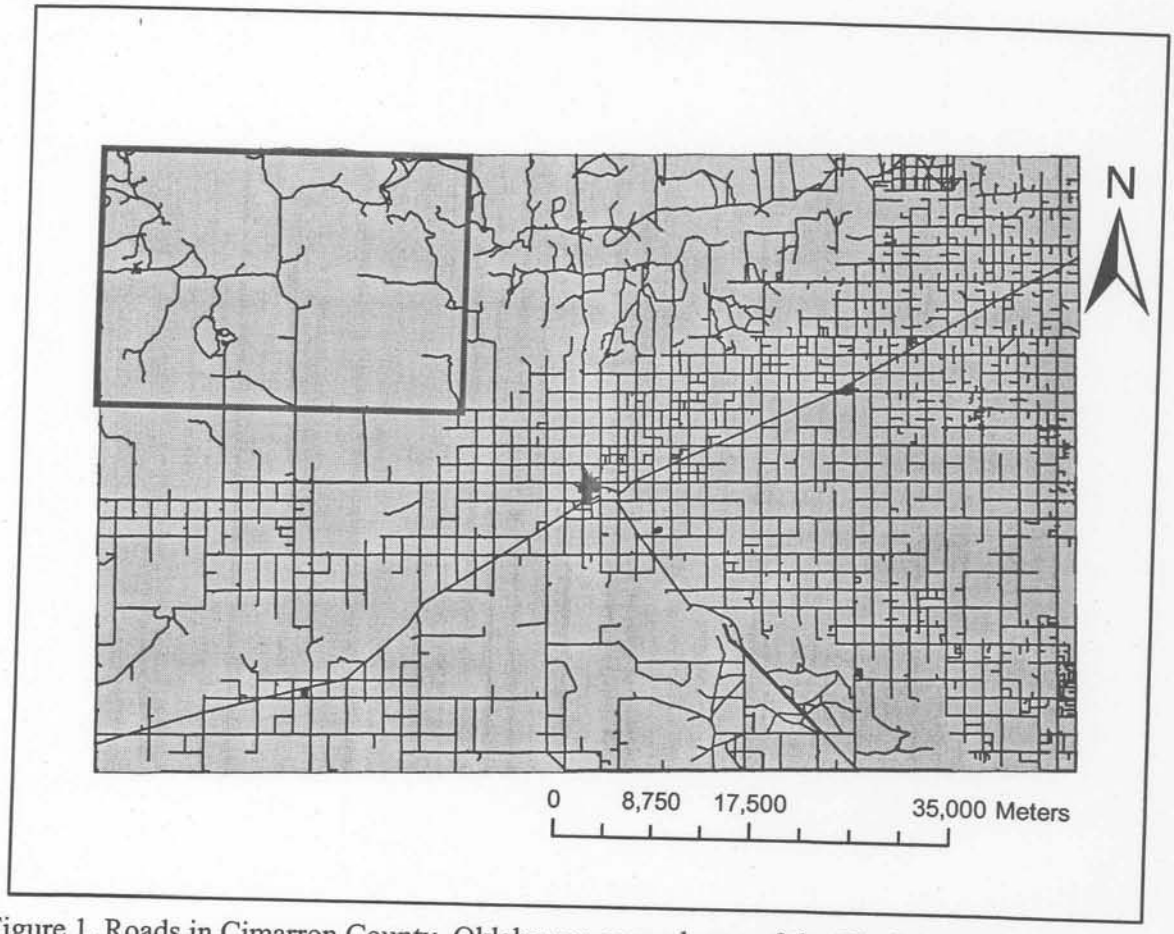

Figure 1. Roads in Cimarron County, Oklahoma; general area of the Black Mesa ecoregion outlined in red.

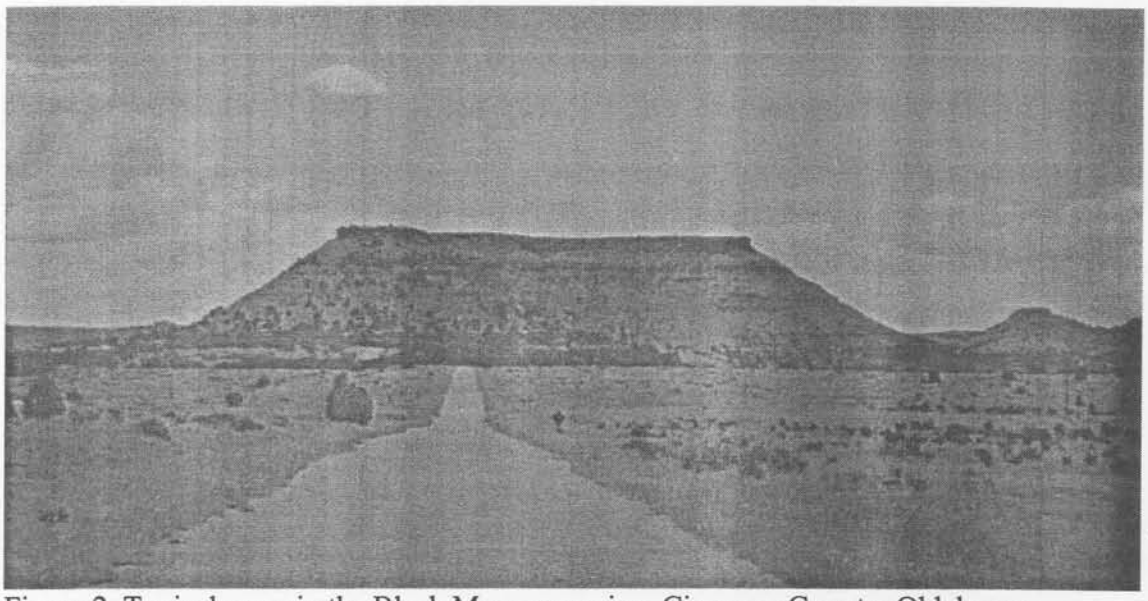

Figure 2. Typical mesa in the Black Mesa ecoregion, Cimarron County, Oklahoma.

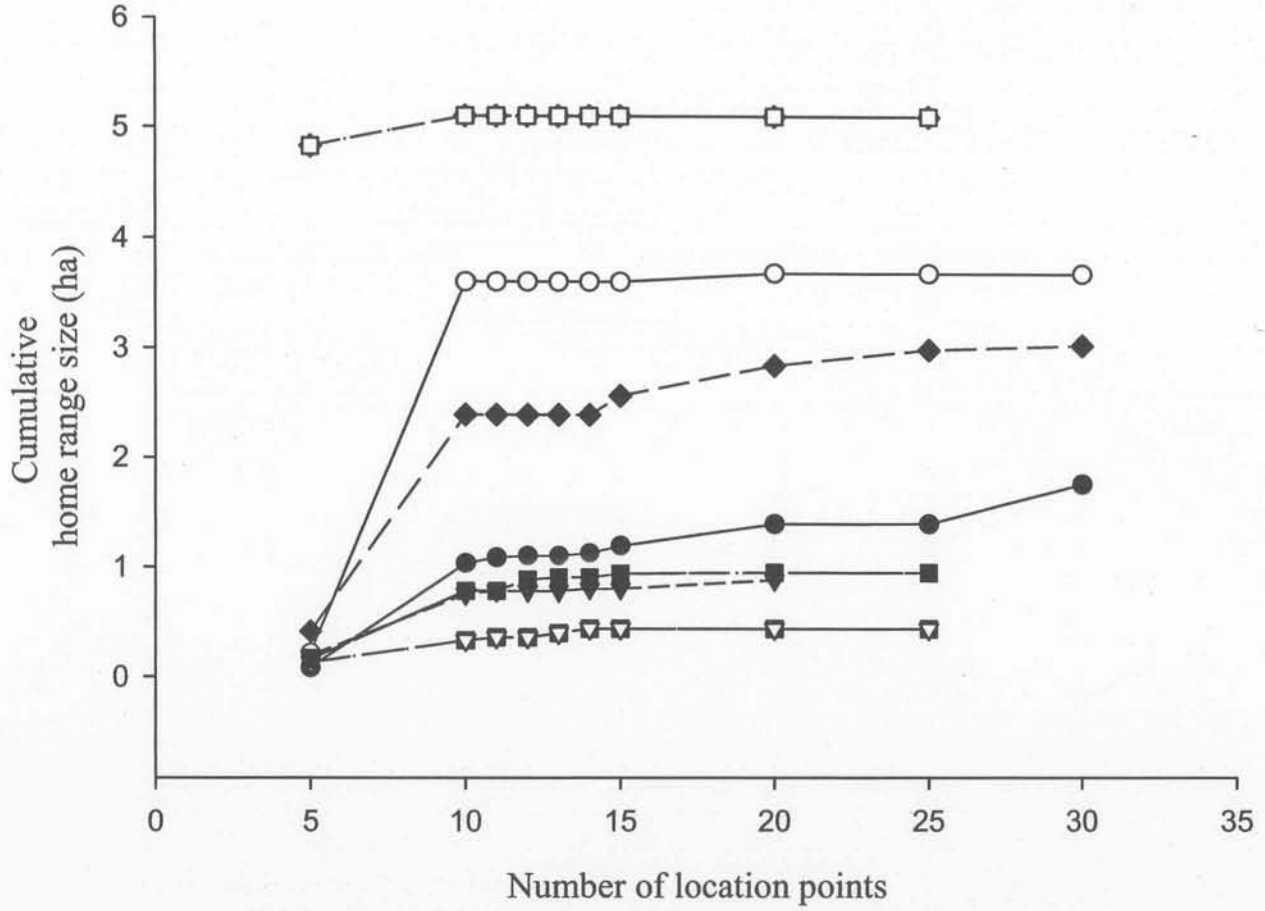

Figure 3. Cumulative home range size as calculated using MCP from radio location points collected for lizards at the Black Mesa ecoregion, Cimarron County, Oklahoma, 2006–2007. Each line represents a different lizard.

VITA

Timothy S. Periard

Candidate for the Degree of

Master of Science

Thesis: HERPETOLOGICAL SURVEY OF THE BLACK MESA ECOREGION, OKLAHOMA, WITH AN EMPHASIS ON THE ECOLOGY OF THE TEXAS HORNED LIZARD, *PHRYNOSOMA CORNUTUM*

Major Field: Zoology

Biographical:

Personal Data: Born in Bay City, Michigan, on June, 30, 1980, the son of Guy and Kathleen Periard.

Education: Received Bachelor of Science degree in Biology from Central Michigan University, Mount Pleasant, Michigan, in August 2003. Completed the requirements for the Master of Science degree with a major in Zoology at Oklahoma State University, Stillwater, Oklahoma, in December 2007.

Experience: Supplemental Physiology Instructor at Central Michigan University, September to May 2003; Employed by City Year Boston, August to June 2004; Substitute Teacher at Bay Arenac Intermediate School District in Bay City, Michigan, September to May 2005; Graduate Teaching Assistant at Oklahoma State University, Department of Zoology, from August to May of 2006 and August 2007 to present; National Science Foundation Graduate Fellow at Oklahoma State University, Rural Alliance for Improving Science Education, from July 2006 to May 2007; Graduate Research Assistant at Oklahoma State University, Department of Zoology, during the summers of 2005, 2006, and 2007.

Professional Memberships: Southwestern Association of Naturalists, Oklahoma Academy of Sciences, American Society of Ichthyologists and Herpetologists, American Association for the Advancement of Science.

Name: Timothy S. Periard | Date of Degree: December, 2007

Institution: Oklahoma State University | Location: Stillwater, Oklahoma

Title of Study: HERPETOLOGICAL SURVEY OF THE BLACK MESA ECOREGION, OKLAHOMA, WITH AN EMPHASIS ON THE ECOLOGY OF THE TEXAS HORNED LIZARD, *PHRYNOSOMA CORNUTUM*

Pages in Study: 93 | Candidate for the Degree of Master of Science

Major Field: Zoology

Scope and Methods of Study: My objectives were to: 1) conduct a complete species inventory of reptiles and amphibians at the Black Mesa ecoregion utilizing drift fence arrays with pitfall and funnel traps, cover boards, road cruising, nocturnal call surveys at amphibian breeding sites, visual searching, and opportunistic encounters in June to August in 2005 and May to August in 2006 and 2007, 2) describe the herpetofauna in terms of relative abundance and rainfall and habitat associations, and 3) examine the ecology of the Texas horned lizard at Black Mesa utilizing radiotelemetry from May to August in 2006 and 2007. Data were collected on morphometrics, home range size, home range overlap, movements, survival, and microhabitat use.

Findings and Conclusions: A total of 1,920 individual animals were captured or observed, including 1,248 amphibians (1,246 frogs and 2 salamanders) and 672 reptiles (167 snakes, 470 lizards, and 35 turtles). A total of 26 reptile species (16 snake, 7 lizard, and 3 turtle species) and 9 amphibian species (8 frog and 1 salamander species) were captured or heard. My results indicate the importance of heterogeneous habitat and microhabitat for maximal reptile and amphibian diversity. Rainfall (> 1 mm) significantly increased capture and observation success of frog and turtle species within 2 days, whereas lizard captures were significantly decreased. For the ecology of the Texas horned lizard, adult females were larger than adult males. Home range size (± 1 SE) pooled between both sexes averaged 1.34 ± 1.30 ha by the 95% MCP method and 2.46 ± 2.85 ha by the 95% FK method. Body size was positively correlated to home range size for both males and females. Daily movements of male lizards were larger in May than July. Survival estimates were between the estimates of other populations. Microhabitat analyses indicated that lizards selected areas of bare ground in the morning, vegetated areas with cover in the afternoon, and a mixture of vegetated areas and bare ground in the evening.

Advisor's Approval: Dr. Stanley F. Fox

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