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A Reexamination of the Eastern Collared Lizard (Crotaphytus collaris collaris) in Arkansas

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A REEXAMINATION OF THE EASTERN COLLARED LIZARD *(CROTAPHYTUS COLLARIS COLLARIS*) IN ARKANSAS

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ABSTRACT

Loss of suitable habitat is a threat to species worldwide. Habitat destruction, including loss, change, and fragmentation of habitat, is the leading cause of species extinction. Eastern collared lizards *(Crotaphytus collaris collaris*) are habitat specialists on glades. Both *C. c. collaris* and glade habitats are rare and of special concern in the state of Arkansas. Many glade populations have already been extirpated in the Ozarks of Arkansas and Missouri. Increasing knowledge of the distribution, habitat structure, and population dynamics of *C. c. collaris* is important to ensure the survival of this species in Arkansas.

A literature review of the *C. c. collaris* is presented in Chapter 1. Lizard characteristics, glade habitat characteristics, and information on habitat change, loss, and fragmentation of glades are described. The main goal of my thesis, presented in Chapter 2, was to determine differences across sites in environmental variables, habitat variables, tree community structure, and lizard body condition. I sought to establish differences in these factors in 17 historical *C. c. collaris* sites (7 with lizard presence and 8 with lizard absence) and determine if the differences were correlated with the presence or absence of *C. c. collaris* populations. Significant differences in some factors were found between present sites and absent sites. Environmental variables were not related to the presence or absence of *C. c. collaris*, indicating a habitat phenomenon rather than environmental. Lizard presence was correlated with habitat structure, as indicated in the ground and canopy cover surveys. Present sites had a positive correlation with rock and soil cover and a negative correlation with CWD, vegetation, and canopy cover; whereas absent sites had a positive correlation with CWD, vegetation, and canopy cover and a negative correlation with rock and soil cover. Present and absent sites had a significant difference in tree community structure. Absent sites had significantly larger trees and a higher frequency of trees compared to present sites. Lizard body condition was associated with the quality and openness of the glade. These data will prove useful in conservation efforts aimed at *C. c. collaris* recovery in Arkansas and other glade locations in the Ozarks.

This thesis is approved for recommendation
to the Graduate Council.

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CHAPTER 1. REVIEW OF THE EASTERN COLLARED LIZARD *(CROTAPHYTUS COLLARIS COLLARIS*)

INTRODUCTION

Crotaphytus collaris collaris, the eastern collared lizard, is a reptile of special concern in the states of Arkansas and Missouri. According to the 2011 Arkansas Natural Heritage Commission (ANHC) Annual Report, *C. c. collaris* has a state ranking of S3 (vulnerable in the state due to restricted range, few populations, or other factors making it vulnerable to extirpation) and a state status of INV (species of conservation concern that are under inventory by ANHC) (ANHC, 2011). *Crotaphytus collaris collaris* inhabit rocky, dry, fragmented glades found in the oak-hickory forests of the Ozark Highlands of both Arkansas and Missouri but there are also a few remaining isolated populations in the Arkansas River Valley (Trauth, 1989; Templeton et al., 1990). Glade habitats are also of special concern in Arkansas and have a state status of INV (habitat of conservation concern under inventory by ANHC), but this habitat does not yet have a state rank (ANHC, 2011). The distribution, abundance and presence or absence of *C. c. collaris* has not been thoroughly studied in Arkansas since the early 1970s in the Ozarks, and since 1989 in the River Valley by Stanley Trauth; however McAllister did studies on a few populations in 1985 and Trauth recently published a manuscript on historic populations along flooded lake shorelines (Trauth, 1970; 1989; 2011; McAllister et al., 1985).

The loss and fragmentation of favorable habitat due to the prevention of wildfires (from early European settlers) and human expansion is thought to have resulted in local extirpation or significant population reduction of *C. c. collaris* (Hutchison and Templeton, 1999; Templeton et al., 2001). Isolation of populations and reduced dispersal, due to habitat fragmentation, has caused the loss of genetic variation and high rates of local population extirpation in some parts of *C. c. collaris'* range, leading to higher probability of global extinction (Templeton et al., 1990). Due to habitat reduction and isolation, I undertook the study of *C. c. collaris* populations in Arkansas that were identified in earlier studies (Trauth, 1970; 1989; Trauth et al., 2004). Before examining the results of my study, in the following chapter I will more thoroughly explain the characteristics and habitat requirements of *C. c. collaris* that are relevant to their population dynamics.

COLLARD LIZARD CHARACTERISTICS

Crotaphytus collaris (Say, 1823), the common collared lizard, is in the order Squamata, the suborder Sauria, the family Crotaphytidae, and was recently placed in the subfamily Crotaphytinae. *Crotaphytus collaris* are terrestrial ectotherms that thermo-regulate through basking (heliothermism) (Trauth, 2004). They live in xeric habitats throughout central and western North America and northern Mexico (Pianka and Vitt, 2003). *Crotaphytus collaris* are sexually dimorphic and adult males are larger and have different coloration than females (Pianka and Vitt, 2003; Trauth et al., 2004).

Crotaphytus collaris consists of five subspecies throughout its range including the Eastern, *C. c. collaris* (Say, 1823), Western, *C. c. baileyi* (Stejneger, 1890), Chihuahuan, *C. fuscus* (Ingram and Tanner, 1971), Yellow-headed, *C. c. auriceps* (Fitch and Tanner, 1951), and Black Spotted, *C. c. melanomaculatus* (Axtell and Webb, 1995) collared lizard (McGuire, 1996). Lizards in the genus *Crotaphytus* range from Missouri, Arkansas, and Texas, all the way over to the Snake River of Oregon and Idaho, and into certain areas of California (Fitch and Tanner, 1951).

The Eastern collared lizard subspecies, *Crotaphytus collaris collaris*, the focus of this thesis, has a restricted range including southwestern United States and Northern Mexico (Davis, 1934; Conant and Collins, 1998) to more peripheral locations in the Ozarks (Hutchison, 2003). *Crotaphytus collaris collaris* specifically has a geographic range including Oklahoma, Missouri, Kansas, and Arkansas, south to midwestern and northwest Texas and west to eastern New Mexico (Burt, 1929; Stejneger and Barbour, 1933). More recently, the range also has been found to extend to the interior highlands of Arkansas and northern Coahuila, Mexico (Dellinger and Black, 1938; Dowling, 1957).

Crotaphytus collaris collaris have large heads with very strong jaws, and their long, large hind legs give them the strength to run on two feet around their habitat. Individuals of *C. c. collaris* are very sensitive to light and noise (Vance et al., 1965); because of this sensitivity they are skillful foragers. These reptiles are highly territorial, 'sit and wait' carnivores (Angert et al., 2002). Their main diet consists of large insects (insectivorous) such as grasshoppers, locusts, and beetles, jumping spiders, other lizards (saurophagous), and sometimes berries (Milstead, 1965; McAllister and Trauth, 1982; Macedonia et al., 2002; Pianka and Vitt, 2003). Gut content analysis of *C. c. collaris* from 5 Arkansas and 3 Missouri counties showed about 75% of prey were Orthopterans for developing lizards. The study found 93.2% of total *C. c. collaris* prey mass was from 5 orders: Orthoptera, Coleoptera, Araneida, Hymenoptera, and Lepidoptera (McAllister, 1985). They have also been known to eat smaller members of their own kind (Davis, 1934) and in one instance, a small cotton rat was found in the stomach of a collared lizard (McAllister and Trauth, 1982). Prior studies have suggested that they will eat almost anything within reasonable size regardless of classification (Davis, 1934; Milstead, 1965; McAllister and Trauth, 1982; Macedonia et al., 2002).

Crotaphytus collaris collaris, or 'Mountain Boomers' as called by locals, have bright and vivid coloration and are easy to spot, when in their open glade habitat. *Crotaphytus collaris collaris* have large, stout bodies, with maximum tail lengths of 223 mm and maximum snout vent lengths of 110 mm (Trauth et al., 2004). *Crotaphytus collaris collaris* are covered externally with horny scales (Davis, 1934), which are both granular and smooth (Trauth et al., 2004). The general body color is olive with white spots in transverse rows at edges of dark body bands (Fitch and Tanner, 1951). Adult males have the most vivid coloration. There is a pronounced dimorphism in males and females; as adults, body size, coloration, and pattern of males differ from females (Fitch and Tanner, 1951; Baird et al., 1997). Males are generally larger, have a basally swollen tail, and tend to have vivid shades of blue and green on their tail, belly and legs. They have an orange throat with the orange usually on part of the upper back as well. Eastern collared lizards have a noticeable double black collar on their shoulders (Trauth et al., 2004), hence the common name. Coloration is maximally developed when males have reached their adult body size at the beginning of their second year (Baird et al., 1997). Females are usually brown or tan; however, they do produce orange, yellow, or red spots during the reproductive season, either just before ovulation or just after mating (Pianka and Vitt, 2003; Trauth et al., 2004). Males and females do have similar coloration as hatchlings (Trauth et al., 2004); though there is a striking but gradual color change as the lizard grows from a juvenile to an adult. It is also noted that individual juvenile lizards can have a wide range of color variation or different hues due to temperature, activity and other factors (Fitch and Tanner, 1951). For example, juveniles can become more dark and dull when cold, and sharp and vivid when warm and active (Fitch and Tanner, 1951). The intense, bright colors become fainter shortly following death (Davis, 1934), so preserved specimens differ in coloration from living specimens.

The evolution of morphological differences between the sexes has probably occurred as a result of sexual selection (McCoy et al., 1994). Social behavior of *C. c. collaris* is one of many aspects of this animal that is greatly affected by this morphological variation. Sexual selection influences the evolution of both social behavior and mating systems (Baird et al., 1997); therefore it affects the population dynamics of these lizards. Even though there may be a female preference of brightness in male *C. c. collaris* (Baird et al., 1997), other factors are important in mate selection. The male must first impress the female in order for her to mate with him. A ritualized dance is performed between male and female *C. c. collaris* during courtship (Trauth et al., 2004). Males begin this dance by bobbing their head, doing pushups, puffing up their bodies as though to enlarge, and circling the female (Baird et al., 2003; 2007; Baird, 2004; Trauth et al., 2004). Although the male dance is much more obvious and extreme, the female does respond to the male by also performing a comparable dance (Trauth et al., 2004). If the female decides to mate with the male courting her, she lets the male bite her neck, beginning the mating behavior (Trauth et al., 2004). Gravid females develop spots before and after mating (Cooper et al., 1983; Pianka and Vitt, 2003). Several theories have been proposed, including that color changes may act as rejection signals to males, so males know not to court females (Milstead, 1965), as advertisement to signal consexuals, known as the female competition hypothesis (Zucker and Boecklen, 1990), or, a more recent study found that the coloration may not act as a rejection signal, yet a signal to stimulate male courtship when females are receptive (Baird, 2004). The early summer is when mating behavior of *C. c. collaris* is at its climax (Trauth et al., 2004).

All collared lizard females mature early and have large, multiple-brooded clutches. The age at first breeding is one year or less. Females reach sexual maturity in 4 to 5 months (Fitch, 1956). Reproduction occurs seasonally, a few months after hibernation. *Crotaphytus collaris collaris* females are oviparous (Pianka and Vitt, 2003). Females can lay multiple egg clutches in one reproductive season, but the first year females only produce one clutch of eggs (Trauth et al., 1994). Survivorship and fecundity trade-off among lizard species have been studied (Pianka and Vitt, 2003). For all subspecies of *C. collaris*, females have a mean annual survivorship of 0.1 with a total fecundity around 16 per season (Tinkle, 1969; Pianka and Vitt, 2003).

There have been various studies carried out on the reproductive potential in *C. c. collaris.* The reproductive potential is equal to the total number of eggs produced by a female during a single reproductive season (Ballinger and Schrank, 1972). There are several methods to determine clutch size including counting yolked ovarian follicles, oviducal eggs or corpora lutea (Tinkle, 1961). All of these methods for estimating the reproductive potential and population structure of *C. c. collaris* have been carried out on Arkansas populations; however, each method gave a different result. Clutch size was estimated at 7.2 by the yolked ovarian follicles, 6.0 by the oviducal eggs, and 6.5 from counting corpora lutea; as a result the mean clutch size found from all of these methods was 6.4 for sampled Arkansas populations (Trauth, 1978). Estimations of clutch size vary upon location, probably due to diverse environmental conditions. Clutch size was smallest in New Mexico with 5.3 (Parker and Pianka, 1973), largest in Texas with 7.2 (Hipp, 1977), and was intermediate in Arkansas with 6.4 (Trauth, 1978).

The male reproductive cycle is also important in determining the total reproductive pattern of a species (Newlin, 1976; Schrank and Ballinger, 1973). The duration of spermiation was studied to facilitate measurement of male reproductive effort (Trauth, 1979). Spermiation is defined as the process of the release of spermatids into the seminiferous tubule lumen (O'Donnell et al., 2011), or simply the release of gametes (Licht, 1979). Duration of spermiation varies with species (O'Donnell et al., 2011). The testes start to mature in *C. c. collaris* when hatchlings are becoming juveniles. Both young and old adult males participate in breeding in the early summer. There is an inverse relationship with the size of testes and fat body weight (Brenner and Brenner, 1973). Similar results were found in Arkansas populations; in the spring, testes enlarge and lizard fat body weight decreases; male testes are at their maximum size during breeding season (Trauth, 1979). The decrease in fat body weight during breeding season can be explained by the energy costs of reproductive activities (Trauth, 1979). Because fat body weight and testes size are important for the male reproductive pattern, body condition and mass thus may be an indicator of reproductive health of individuals and of potential population growth or decline (Savage et al., 2004). Habitat deterioration has a negative impact on body condition index (Amo et al., 2007), which in turn negatively affects reproduction and indirectly causes population declines (Savage et al., 2004). Though the reproduction of *C. c. collaris* is not the focus of this thesis, having the knowledge of habitat pressures and reproductive and mating pressures can help give scientists a better understanding of the health of the populations in Arkansas, and can therefore help with the conservation efforts to keep this species thriving.

COLLARED LIZARD HABITAT

Thermal environment is an important factor for lizards due to a range of temperatures (thermal minimum and maximum) each species can survive in; consequently, species are confined to particular microhabitats. For instance, *C. c. collaris* is a saxicolous (rock dwelling) species that is only found in limited habitat types (Angert et al., 2002), including rocky limestone and sandstone habitats with warm, desiccated conditions (Conant and Collins, 1998). These xeric habitats usually include exposed rocky glades, which absorb plenty of sunlight for heat (Trauth, 1970). Locations include rugged terrain of river canyons, bluffs, buttes, rocky foothills of mountain ranges, abandoned rock quarries, rocky shorelines, old mining areas, areas with boulders at the base of cliffs, and rocky ridges on ledges at higher altitudes (Fitch and Tanner, 1951; Trauth, 1970). For all subspecies of the common collared lizard, the main ecological requirement includes rocks or boulders which serve as places to bask and as lookouts for prey, predators, and rivals (Fitch and Tanner, 1951). In the Ozarks of Arkansas, *C. c. collaris* populations live on glades at an average elevation varying from 1250 to 1700 feet (381-518 meters) above sea level (Trauth, 1970). *Crotaphytus collaris collaris* in the Ozarks are generally found on south to west facing slopes on the top and sides of mountains and bluffs (Templeton et al., 2011), around river shorelines and bluffs, and were historically found around lake shorelines of Bull Shoals Reservoir, Beaver Lake, and Norfork Lake (Trauth, 1970; 2011) where their thermal requirements can be achieved.

Crotaphytus collaris collaris first spread into Missouri, Kansas and Arkansas during the warmer, drier Hypsithermal Period, around 7000 years ago (Burt, 1929; Mondy, 1970; Smith and Tanner, 1974; Trauth, 1989; Sexton et al., 1992; Hutchison, 1997). They invaded from Texas and Oklahoma as the Great Plains and the Ozark Plateau developed more suitable (warm, dry, and rocky) conditions (Hutchison and Templeton, 1999). As the climate cooled, forests began to grow around the habitats of populations (Hutchison, 2003). As the oak-hickory and short leaf pine forests grew, the habitats of *C. c. collaris* became fragmented and reduced (Templeton et al., 1990).

The rocky fragmented areas formed are known as microhabitat islands, or glades. The term glade, depending on vegetation type and other characteristics, consists of cedar glades (Baskin and Baskin, 2003), diabase glades (LeGrand, 1988), dolomitic glades (Erickson et al., 1942), limestone glades (Baskin et al. 1995), and sandstone glades (Jeffries, 1985). *Crotaphytus collaris collaris* is usually found on cedar, limestone and sandstone glades in Arkansas. In a broader sense, there are two major types of glades including larger glades, with prairie-like vegetation, that can be up to several hundred of acres, and smaller glades that can be less than an acre with a more xeric environment (Templeton et al., 1990). Invasion of trees into the glade openings has increased in the last 50 years (Baskin and Baskin, 1988; 2003; Baskin et al., 1995). The two major types of glades, although reduced in size from the past, provide adequate habitats for *C. c. collaris* survival. Collared lizard species are of the few organisms endemic to glades that can occupy both prairie and xeric rocky types (Templeton et al., 1990). *Crotaphytus collaris collaris* abundance was affected by number of crevices or refuges for hiding, rock height, amount of rock cover, and vegetation complexity, possibly for prey habitat, on glades in the northern Flint Hills of Kansas (Blevins et al., 2011); thus showing the importance of habitat factors on populations. Both glade types are characterized by thin soil (average depth in glades of southwest Missouri Ozarks of 4.8+/-3.93 inches) (Kucera and Martin, 1957) and xeric plant communities (Angert, 2002); vegetation around the rocky glade habitats of collared lizards usually includes scattered trees (eastern red cedar, *Juniperus virginiana*, and a mix of hardwoods) shrubs, and a cover of prairie grasses (Trauth, 1970), many of which are often endemic and relictual (Zandt, 2005). Other examples of species adapted to this type of glade environment include scorpions and tarantulas, but the largest vertebrate predator restricted to these glades is the collared lizard. Natural enemies of *C. c. collaris* that can be found on glades include birds, snakes, mammals (Sexton et al., 1992; Ostman et al., 2007) and humans.

HABITAT CHANGE, LOSS, AND FRAGMENTATION

Loss of suitable habitat is the greatest threat to the survival of species worldwide (Barabault and Sastrapradja, 1995). When individuals are lost due to habitat loss, a population decline may be produced (Bender et al., 1998). Habitat destruction is the leading cause of species extinction (Pimm and Raven, 2000). Habitat destruction, a process that removes habitat cover usually due to anthropogenic events (Bender et al., 1998), includes both habitat loss and fragmentation (Fahrig, 1997). The primary impact of humans on animal populations is habitat loss and fragmentation (Templeton et al., 1990). Remaining habitat becomes more fragmented and divided into what can be called ‘habitat islands’ (Templeton et al., 1990). It is suggested that biodiversity is negatively affected by habitat loss and fragmentation (Kruess and Tscharntke, 1994; Pimm and Raven, 2000). Negative effects of habitat reduction and fragmentation on species are due to two main factors: the probability that patches will become too small to sustain certain populations (Pimm and Raven, 2000; Fahrig, 2003) and that edge effects may increase mortality rate and reduce reproductive rate of populations. Edge effects would increase probability that individuals will leave patches and enter the matrix (Fahrig, 2003). Habitat loss alone is the cause in generalist species decline (Bender et al., 1998). Interior species, that are restricted to fragments and unable to use the matrix (Debinski and Holt, 2000), decline in population size both from habitat fragmentation and loss (Bender et al., 1998) because habitat specialists are restricted to fragments and are unable to use the matrix (Debinski and Holt, 2000) and edge habitats. In the case of *C. c. collaris*, the matrix would be forests surrounding glades; forests are unsuitable habitats due to lack of rock crevices, basking rocks, and sunlight, and where they can become easy prey items for predators (Trauth, 2011).

In the past, natural fires caused from lightning and fires started by the Native Americans (Baskin et al., 1994) kept the forests reduced and maintained glade microhabitats. When European settlers moved in, they reduced Native American populations in Arkansas by introducing new diseases and causing warfare and migration (Cutter and Guyette, 1994; Guyette and Dey, 1995; Rollings, 1995; Dey and Guyette, 2000b). Human populations were positively correlated with fire from 1680 to 1880, yet negatively correlated with fire (no evidence of fires) from 1881 to 1910, due to increased population densities. Guyette and Spetich (2003) found that Europeans began active fire suppression in North America in 1920, as there is no evidence of fire after this date. Fire suppression and prevention of European settlers (Guyette et al., 2006) caused red cedar encroachment and the deterioration of the glade microhabitats. The prevention of fires had a direct result of habitat fragmentation and isolation throughout the peripheral Ozark populations (Hutchison, 2003). Dense undergrowth and fragmentation isolated populations and prevented dispersal (Mader, 1984; Hutchison and Templeton, 1999; Templeton et al., 2001). *Crotaphytus collaris collaris* found on glades with cedar encroachment had decreased growth rates, adult size and period of juvenile activity in the northeastern limit of their distribution in Missouri (Sexton et al., 1992), and overall worse body condition in Arkansas (Grimsley, unpublished data). In Kansas grasslands, cedar density is increasing at a rate of 56.9 trees per hectare per year (Price et al., 2010) and according to the Kansas Forest Service, cedar volume has increased 23,000% since 1965 (Moser et al., 2008). Missouri's Ozarks are now dominated by closed canopy oak-hickory forest (Cutter and Guyette, 1994). A study in Stone County, Arkansas found that Oaks dominated pre-European settlement forests (74%) in 1830, but by 1995 oaks accounted for only 40% of the trees due to increased eastern red cedar, shortleaf pine (*Pinus echinata*), hickory (*Carya spp.*), and dogwood (*Cornus florida*) (Heitzman et al., 2004). Native Americans also documented that forest communities in Northern Arkansas were more open in the past than they are today (Guyette et al., 2006); ecosystems were described as prairies, oak savannas and oak-pine forests (Schoolcraft, 1821). Increased frequency of cedar in Arkansas likely has had similar negative impacts on *C. c. collaris* given that the habitat is unquestionably changing in the Ozarks of Arkansas.

Because of human activity, there has been major loss and change of habitat (Polis et al., 1997; Pimm and Raven, 2000), species' extinctions (Diamond, 1989; Wilson, 1992), and disrupted communities (Polis et al., 1997), causing overall damaged ecosystems and influencing ecological processes and biodiversity (Horncastle et al., 2005; Templeton et al., 2001) . There has also been an environmental change on a global scale over the past 100 years (Climate Change, 2001); and as a consequence to these patterns of change, it is estimated that more than half of extant species will go extinct in the next 200 to 300 years (Smith et al., 1993). Species are now either forced to adapt to changes or face extinction. Adapting to these changes requires genetic diversity in populations, and at all spatial scales, diversity is declining (Sax and Gaines, 2003). Genetic diversity results as a balance of mutation, drift and selection. Diversity, the amount and distribution of genetic diversity within a species, is impacted by humans (Templeton et al., 2001). Before human disturbance, species diversity was much higher (Sax, 2003). The impact of human disturbance can be seen throughout all levels of biodiversity, through the evolutionary processes of adaptation and speciation (Templeton et al., 2001). Genetic variation is affected by both genetic drift and gene flow. As gene flow increases and drift decreases, variation within populations increases and variation among populations decreases. On the contrary, as gene flow declines and drift increases, variation within a population decreases and variation among populations increases (Templeton et al., 1990; 2001). As geographic distance increases, there is more variability between populations. *Crotaphytus collaris collaris* dispersal among populations, as briefly mentioned earlier, is constrained by geographic distance because dispersal is obstructed by fragmentation (Mader, 1984) and dense forest undergrowth, influences gene flow and drift among collared lizard populations (Hutchison and Templeton, 1999).

Recent *C. c. collaris* populations have reduced in size and genetic drift has become an important factor because of loss of genetic variation (Hutchison, 2003). Local extinction becomes more probable when individual populations are small because of inbreeding (decreasing variability causing bottle-neck events), changes in the environment, and demographic stochasticity (Hutchison, 2003). So as would be expected, populations that are both fragmented and small have very high rates of local extinction. If many populations of the same species are fragmented and small, due to habitat loss, the species as a whole has a higher probability of global extinction (Diamond, 1989; Wilson, 1992). It is suggested that *C. c. collaris* populations have already gone through local extinction on many glades and other habitat patches. Many glades are not inhabited by lizards that are near existing populations, giving further evidence for local extirpation in the Ozarks (Hutchison, 2003). Conservationists are concerned about predicted increased extinction rates because of ‘Allee’ effects caused by habitat fragmentation (Templeton et al., 1990). An Allee effect occurs because decreased growth rates reduce reproduction, population densities, and overall fitness (Allee, 1931; Dennis, 1989; Lewis and Kareiva, 1993; Kunin and Iwasa, 1996). Because of negative factors of Allee effects, knowledge of population dynamics and the sizes and quality of glade habitats are extremely important to the survival of *C. c. collaris*.

Crotaphytus collaris collaris is potentially threatened throughout its distribution, but populations in the Ozarks are at a higher risk of extinction for several reasons related to being on the edge of the species range. Latitudinal effects such as increased winter mortality, reduced seasonal activity, and reduced reproductive periods also make peripheral locations less favorable for *C. c. collaris* (Fitch, 1956; Legler and Fitch, 1957; Malaret, 1983; Ballinger and Hipp, 1985; Sexton et al., 1992). There is also a trend of increasing habitat degradation toward the peripheral *C. c. collaris* habitats or glades, generating smaller and more isolated populations. With small and genetically isolated populations due to decreasing habitat sizes, these populations have a lack of genetic variability and have the potential for inbreeding impacts (Lande, 1988; Hutchison, 2003). Hutchinson (2003) carried out a study looking at the more peripheral, Ozark *C. c. collaris* populations in order to compare them to healthier, more central populations. The warmer, Hypsithermal Period, between 8000 and 5000 years ago, invaded the Ozarks later than other locations of *C. c. collaris* habitats and the settlers adopting fire prevention reached the area first (Hutchison, 2003). All of these factors have a negative impact on reproductive fitness and produce a circumstance of Ozark populations existing for a shorter time in stressful environmental conditions (Fitch, 1956; Legler and Fitch, 1957; Malaret, 1983; Ballinger and Hipp, 1985; Sexton et al., 1992; Hutchison, 2003). Because of a lack of divergence, speciation, and adaptation, these small, isolated populations at the periphery of their range encourage extinction (Allee et al., 1949; Templeton et al., 1990; Hutchison, 2003).

Templeton et al. (2001) found that 68% of *C. c. collaris* local populations had gone extinct on Stegall Mountain in the southeastern Ozarks. Similarly, for northeastern Ozark populations, it was estimated that at least 75 % of glade populations had gone extinct by 1980 (Templeton, 1982). The populations on the periphery of their range occurred on small glades with extreme habitat fragmentation due to fire suppression (Hutchison, 2003; Guyette et al., 2006). In order to prevent the disruption of evolutionary processes and isolation of populations, habitat fragmentation and cedar encroachment must be reduced (Templeton et al., 2001; Hutchison, 2003; Horncastle et al., 2005). Promoting controlled burns can help to connect isolated populations by removing vegetation and clearing the dense undergrowth (Templeton et al., 2001; Brisson et al., 2003). After fire management, there have been dramatic increases in local population sizes. There was an original population that consisted of only 28 adult collared lizards on Stegall Mountain before controlled burns. In 1994 and 1996, there was no obvious increase in population size, but in 1999, after continued burns, the population had a 10-fold increase. A population of 233 individuals, with 107 adults and 126 hatchlings, were captured, showing a rapidly expanding population. The fires are both increasing the area of the glades inhabited, and increasing the quality of these existing glades (Templeton et al., 2001).

As mentioned above, Templeton et al. (2001) showed that there is a large, positive impact of prescribed fires on lizard populations in glades in the Ozarks. Templeton kept managing the glades around Stegall Mountain and found positive results for dispersal under fire management. Templeton et al. (2011) stated that “dispersal tends to increase as similarity of the matrix with the patch increases.” Younger lizards (hatchlings) dispersed more from small glades with a high density of lizards, possibly because of the territorial adults, while yearlings and adults dispersed from small glades and small population size, possibly looking for potential mates. Studies at Stegall Mountain have demonstrated that with continued burn management, glade matrices can go from a series of isolated fragmented populations to a metapopulation with connected local populations (Templeton et al., 2011). The study on Stegall Mountain carried out by Templeton et al. (2001; 2011) should prove to be an informative guide of how to manage other struggling Ozark *C. c. collaris* populations in fragmented glades, with cedar encroachment on many of my sites (Grimsley, unpublished data).

Other factors such as flooding have impacted *C. c. collaris* populations inhabiting reservoirs, lakes, and rivers. One site, Tuttle Creek Dam, flooded and water covered the rock habitat and more than likely drowned the lizards (Blevins and With, 2011). Trauth (2011) recently published a study on *C. c. collaris* populations on Bull Shoals Reservoir and Norfork Lake where populations formerly occurred. Over the years, flooding events occurred where usual water levels were exceeded. In 2008, catastrophic flooding occurred before most of the lizards had left there hibernation burrows and the lizards were drowned (Trauth, 2011). Some lizards during the floods could have moved to higher elevations; however, the area above the lizard habitat is now encroached by cedar and does not have suitable habitat for the lizards to survive. Flooding has potentially led to the local extinction of *C. c. collaris* populations around shoreline habitats of both Bull Shoals and Norfork (Trauth, 2011).

Because of the multiple known problems, such as flooding and isolation impacting *C. c. collaris* populations in Missouri and Arkansas, it is important to determine the habitat requirements needed to support healthy populations in order to attempt to prevent the extirpations of more local populations, and eventual global extinction. As explained previously, there are many suitable glade habitats in the Ozarks that are for some reason not inhabited by *C. c. collaris*. It is important to see how specific factors influence the distribution and presence or absence of this species of special concern. Acquired data in the following chapter provides information on the specific environmental, habitat, and tree structure requirements of *C. c. collaris* that are needed in order to support populations of this potentially threatened species. Additionally, surveys will contribute to the knowledge of glade habitat which is a habitat of greatest conservation need.

OBJECTIVES

In order to determine the distribution of *C. c. collaris* populations in central and northwest Arkansas, I carried out a distributional survey in the summer of 2010. The distributional assessment showed that *C. c. collaris* populations were not as numerous as they apparently once were. The lack of *C. c. collaris* populations on various glades led me to carry out a preliminary study in the spring of 2010. I compared six rocky glade sites (three with *C. c. collaris* present and three with the species absent) to determine what factors were influencing the presence or absence of *C. c. collaris* populations. The habitat analysis showed a strong trend of absent sites with high canopy cover and low open rock cover and present sites with low canopy cover and high open rock cover. Due to the results of the preliminary study carried out in 2010, I proposed a study for the spring and summer of 2011 to determine factors influencing the presence or absence of populations on a larger scale. The main goal of this thesis was to verify if there are environmental, habitat, and tree structure differences between sites that are affecting the presence or absence of *C. c. collaris* populations. Objectives of the study were to (1) verify presence or absence of *C. c. collaris* populations, (2) determine if environmental variables are correlated with the presence *C. c. collaris* populations, (3) determine how habitat variables are correlated with presence of *C. c. collaris* populations, (4) establish how tree structure differs between and within present and absent sites, and (5) to ascertain how body condition of individual lizards is associated with the habitat of each site with lizard presence.

CHAPTER 2. CORRELATION OF HABITAT FACTORS ON THE PRESENCE OR ABSENCE OF THE EASTERN COLLARED LIZARD *(CROTAPHYTUS COLLARIS* COLLARIS) IN ARKANSAS

INTRODUCTION

The eastern collared lizard, *Crotaphytus collaris collaris* (Say, 1823), is a reptile of special concern in the state of Arkansas (ANHC, 2011). *Crotaphytus collaris collaris* live on rocky, dry, fragmented glades found in the Ozarks (Templeton et al., 1990). Glade habitats are also of special concern in Arkansas (ANHC, 2011). The distribution, abundance and presence or absence of *C. c. collaris* has not been thoroughly studied or published in Arkansas since the early 1970s in the Ozarks and since 1989 in the River Valley (Trauth, 1970; 1989); yet more recently, a smaller set of populations were studied by McAllister (1985) and in 2011, the decimation of populations on lake shorelines was reported (Trauth, 2011). *Crotaphytus collaris collaris* populations are at risk for local extirpation and reduced distribution due to a change in habitat. *Crotaphytus collaris collaris* populations have been negatively impacted by habitat loss from human expansion (Hutchison and Templeton, 1999; Templeton et al., 2001; Guyette et al., 2006) and habitat fragmentation and overall increase in stand density, resulting from past fire suppression over the last 60 years (Smokey Bear—Donovan and Brown, 2007). Due to habitat fragmentation in the Ozarks, isolation of lizard populations and prevention of dispersal (Mader, 1984) has caused loss of genetic variation and high rates of local population extinction, leading to higher probability of global extinction (Templeton et al., 1990).

Crotaphytus collaris has an extensive, yet specific distribution that includes central and western North America and northern Mexico (Pianka and Vitt, 2003). The eastern collared lizard subspecies, *Crotaphytus collaris collaris*, however, has a restricted range from southwestern United States and Northern Mexico (Davis, 1934; Conant and Collins, 1998), to more peripheral locations in the Ozarks of Missouri and Arkansas (Hutchison, 2003). More specifically, *C. c. collaris* has a geographic range, including Oklahoma, Missouri, Kansas, and Arkansas, south to mid-western and northwest Texas and west to eastern New Mexico (Burt, 1929; Stejneger and Barbour, 1933). The range also has been found to extend to the interior highlands of Arkansas and northern Coahuila, Mexico (Dellinger and Black, 1938; Dowling, 1957).

The collared lizard is a saxicolous species that is only found in limited habitat types (Angert et al., 2002). *Crotaphytus collaris collaris* live in warm, desiccated conditions including rocky limestone and sandstone habitats (Conant and Collins, 1998). These xeric habitats usually include exposed rocky glades or outcroppings, which absorb plenty of sunlight for heat (Trauth, 1970). Locations include the rugged terrain of river canyons, bluffs, buttes, rocky foothills of mountain ranges, abandoned rock quarries, rocky shorelines, old mining areas, areas with boulders at the base of cliffs, and rocky ridges on ledges at higher altitudes (Fitch and Tanner, 1951; Trauth, 1970). In the Ozarks of Arkansas, *C. c. collaris* populations live at an average elevation varying from 1250 to 1700 feet (381 to 518 meters) above sea level, including river and lake shoreline habitats, although they can be and are found outside of this elevation range (Trauth, 1970). Glades are characterized by thin soil (average depth in glades of southwest Missouri Ozarks of 9.98 cm to 12.19 cm) (Kucera and Martin, 1957) and xeric plant communities (Angert, 2002). Vegetation around the rocky glade habitats of *C. c. collaris* usually includes scattered trees (Eastern red cedar, *Juniperus virginiana*, and various hardwoods), shrubs, and a cover of prairie grasses (Trauth, 1970), many of which are often endemic and relictual (Zandt, 2005).

Crotaphytus collaris collaris are terrestrial heliothermic lizards which first spread into Missouri, Kansas and Arkansas during the warmer, drier Hypsithermal Period, around 7000 years ago (Burt, 1928; Mondy, 1970; Smith and Tanner, 1974; Trauth, 1989; Sexton et al., 1992; Hutchison, 1997). They invaded from Texas and Oklahoma as the Great Plains and the Ozark Plateau developed more suitable (warm, dry, and rocky) conditions (Hutchison and Templeton, 1999). As the climate cooled, forests began to grow around the habitats of *C. c. collaris* populations (Hutchison, 2003). Fragmentation and isolation of glades due to invasion of trees has increased in the last 50 years (Kimmel and Probasco, 1980; Baskin and Baskin, 1988; 2003; Baskin et al., 1995). As the oak-hickory and short leaf pine forests grew, the habitats of the collared lizard became fragmented and reduced (Templeton et al, 1990). The rocky, fragmented areas are known informally as glades, which are a type of microhabitat island. There are many types of glades that differ according to vegetation type and other characteristics; *C. c. collaris* specifically live on cedar glades (Baskin and Baskin, 2003), limestone glades (Baskin et al., 1995), and sandstone glades (Jeffries, 1985). There are two major types of glades, as broadly defined by Templeton et al. (1990), both of which collared lizards can inhabit. These include larger glades, with prairie-like vegetation that can be up to several hundreds of acres, and smaller glades that can be less than an acre with a more xeric environment (Templeton et al., 1990).

In the past, natural fires caused from lightning and Native Americans (Baskin et al., 1994) kept the forests reduced and maintained the microhabitats. European settlers then moved in and introduced new diseases to the Native Americans, started warfare and caused migration, which reduced indigenous populations (Cutter and Guyette, 1994; Guyette and Dey, 1995; Rollings, 1995; Dey and Guyette, 2000b). Europeans then began repressing and preventing fires (Guyette et al., 2006) and the United States Government started the Smokey Bear campaign (Donovan and Brown, 2007), which caused the deterioration of these microhabitats and eastern red cedar encroachment (Hutchison, 2003). The dense undergrowth isolated populations and prevented dispersal of *C. c. collaris* (Mader, 1984; Hutchison and Templeton, 1999; Templeton et al., 2001). Consequently, *C. c. collaris* populations have reduced in size and genetic drift has become an important factor because it has caused loss of genetic variation within populations (Lande and Barrowclough, 1997). Local extinction becomes more probable when individual populations are small because of inbreeding (decreasing variability causing bottle-neck events), changes in the environment, and demographic stochasticity (Lande, 1998; Dennis, 2002; Hutchison, 2003). If many populations of the same species are fragmented and small, the species as a whole has a higher probability of global extinction (Diamond, 1989; Wilson, 1992). It is suggested that *C. c. collaris* populations have already gone through local extinction on many glades (Hutchison, 2003). Conservationists are concerned about predicted increased extinction rates because of 'Allee' effects caused by habitat fragmentation (Templeton et al., 1990). Allee effects are caused when growth rates of populations go below a critical threshold due to reduced fitness (Allee, 1931, 1949; Dennis, 1989; Lewis and Kareiva, 1993; Kunin and Iwasa, 1996). When populations of a particular species are rare, Allee effects can cause single populations to go extinct (Allee, 1931). Therefore, knowledge of the sizes and quality of the glade habitats along with population dynamics, such as density and reproductive rates, are extremely important to the survival of *C. c. collaris*.

Crotaphytus collaris collaris is potentially threatened throughout its distribution, but populations in the Ozarks are at a higher risk of extinction for several reasons. Hutchison (2003) carried out a study looking at the more peripheral, Ozark *C. c. collaris* populations in order to compare them to healthier, more central populations. The Hypsithermal Period invaded the peripheral part of *C. c. collaris* range later than the central part of their range. Also, Europeans reached the peripheral areas first, changing the habitat through fire prevention (Hutchison, 2003). Fire suppression became the official US government policy in 1905, which caused fragmentation and eventual tree encroachment of glade habitat. Latitudinal effects, including increased winter mortality and reduced time for activity and reproduction also have negative effects on *C. c. collaris* populations. Therefore, a circumstance has been created where *C. c. collaris* populations on the eastern edge of their range have existed for a shorter time in more stressful environmental conditions compared to central populations (Fitch, 1956; Legler and Fitch, 1957; Malaret, 1983; Ballinger and Hipp, 1985; Sexton et al., 1992; Hutchison, 2003). With small effective population sizes and genetic isolation due to decreasing habitat sizes, *C. c. collaris* populations on the edge of their range have a lack of genetic variability (Lande, 1988; Hutchison, 2003). Because of a lack of divergence, speciation, and adaptation, small, isolated populations encourage extinction (Allee et al., 1949; Templeton et al., 1990; Hutchison, 2003). Due to problems related to being on the periphery of *C. c. collaris* range, it is important to determine the habitat requirements needed to support *C. c. collaris* populations and to establish the health of populations, in order to attempt to prevent the extinction of populations.

OBJECTIVES/HYPOTHESES

In the past, extensive studies have been carried out on the distribution of *C. c. collaris* populations in the Ozark Eco-Region of Arkansas (Trauth, 1970) and in the River Valley Eco-Region of Arkansas (Trauth, 1989) (Figure 1). In order to determine the present distribution of *C. c. collaris* populations in Arkansas, I carried out a distributional survey of historically known *C. c. collaris* locations in the summer of 2010 by resurveying formerly occupied sites (Trauth, 1970; 1989; Bonati, 1980). *Crotaphytus collaris collaris* populations appeared to be not as widely distributed as they once were, according to my initial survey. The lack of *C. c. collaris* populations on various glades led me to carry out a preliminary habitat survey in 2010 comparing 6 sites (3 absent sites- 'absent' is defined as a site where no lizards were sighted and populations are apparently extirpated according to my time and space dependent surveys, as well as my distributional survey; 3 present sites-'present' is defined as a site where lizards were found during my surveys). I wanted to answer the question, is habitat associated with the presence or absence of *C. c. collaris* populations? A principle components analysis on my preliminary data gave the following results: (1) absent sites had high percent canopy cover and low percent open rock cover, and (2) present sites had low percent canopy cover and high percent open rock cover. Due to the results of my initial distributional survey and my preliminary habitat study carried out in 2010, I proposed a more complete study to determine what factors were associated with the presence or absence of lizard populations on a larger scale. The main goals of this thesis were to (1) determine if *C. c. collaris* populations are present or absent at each of my 17 sites, (2) verify if environmental or habitat differences exist among the sites, (3) determine if differences among sites are correlated with the presence or absence of *C. c. collaris* populations, and (4) conclude if there are consequences for individuals due to differences among sites. Therefore, after determining presence or absence of populations, I proposed to answer the following questions:

(1) Are environmental variables (wind speed, altitude, air temperature, and percent humidity) different among sites and are these variables correlated with presence or absence of *C. c. collaris* populations?

Null: Environmental variables will not be correlated with the presence or absence of *C. c. collaris* populations.

Alternative: Environmental variables will be correlated with the presence or absence of collared lizard populations.

(2) How are habitat variables (percent canopy cover and total ground cover: percent bare rock, vegetation, bare soil, and coarse woody debris) correlated with the presence or absence of *C. c. collaris* populations? Specifically, I want to know how the habitat variables are associated with each other, how the glade sites differ, and how the habitat structure is correlated with the presence or absence of *C. c. collaris* populations.

Null: There will be no significant difference in habitat variables among present and absent *C. c. collaris* sites.

Alternative: There will be a significant difference in habitat variables among present and absent *C. c. collaris* sites.

(3) How does tree structure vary between sites and how is tree community structure correlated with the presence or absence of *C. c. collaris* populations?

Null: Tree structure will not be correlated with the presence or absence of *C. c. collaris* populations.

Alternative: Tree structure will be correlated with the presence or absence of *C. c. collaris* populations.

(4) How is lizard body condition index (BCI) of individual lizards associated with the habitat structure (amount of open rock, bare soil, vegetation, coarse woody debris, and canopy cover) and tree community structure of glades with lizard presence?

Null: Body condition will not be associated with habitat structure.

Alternative: Body condition will be associated with habitat structure.

METHODS

Study Area

My study included 17 historical *C. c. collaris* sites throughout Arkansas, including the Ozark Highlands and the Arkansas River Valley. All sites had *C. c. collaris* populations in the last 20 to 40 years and were surveyed in my 2010 distributional assessment (Trauth, 1970; 1989; Bonati, 1980). Eight sites have collared lizards present; some of which seem to have persistent populations and a few sites with small numbers of individuals. Nine sites are characterized by populations of *C. c. collaris* that are absent or are apparently extirpated. Absent sites were chosen through the 2010 distributional data; however thorough surveys at each site in 2011, in both early summer, mid-summer, and late summer, sites were determined apparently extirpated. Though it is difficult to prove the 'absence' of a species, I am fairly confident there are no viable populations at these sites due to collared lizards being an easily detectable species because of their coloration, size, and behavior. Maps of all present and absent sites was created using

ArcMap (ESRI, 2002) (Figure 1 and 2). The GPS coordinates for each site were recorded using a Trimble Juno® SC GPS device (Table 1).

My sites with lizard presence are mostly in the Ozark Eco-Region of Arkansas, but a few also are in the River Valley Eco-Region (Figure 1). Leatherwood is located just outside of Eureka Springs on the trail that goes around Lake Leatherwood City Park. The Pruitt and Rush sites are on Federal Lands at the Buffalo National River. The Pruitt site is located in Pruitt, Arkansas on the Buffalo National River. Prescribed fires have been carried out to help open up the glades on Pruitt. Rush is located further east on the Buffalo National River. Rush has multiple rocky areas that are inhabited by *C. c. collaris*. Mining has historically occurred at Rush, but prescribed burns would improve and open up the rock piles to allow larger populations. Prairie View Rock Quarry is a privately owned large active rock mining quarry with a large population of lizards probably due to the habitat being open. Lizards inhabit the inactive portions of the quarry. Another site is found on Petit Jean Mountain along the Turtle Rocks trail in Petit Jean State Park. Pine trees are beginning to overgrow at this site and human traffic could be affecting the health of this population. Flippin Quarry is a large, non-active quarry near the town of Flippin and is privately owned. Flippin Quarry was used to build Bull Shoals Dam when active and has created good habitat for *C. c. collaris*. Lizards at Flippin Quarry have been extensively studied (Trauth, 1970). My final two sites with *C. c. collaris* present are located in the town of Calico Rock. The first site is privately owned and is on the western side of Calico Rock. The owner of this land explained that he believed a severe drought had dramatically reduced the population of lizards here. The second site is in southwest Calico Rock overlooking the White River. Calico Rock southwest is located across the river from Calico Rock west, and is owned by the city.

Eight of my sites had historical collared lizard populations that are now apparently extirpated. All of these sites have been inhabited by *C. c. collaris* populations in the past (Trauth, 1970; 1989; Bonati, 1980) but there is no recent sign of lizards through my research and research by others (Trauth, 1989). Shipp's Ferry is one past lizard site that has been overgrown in most areas by invasive plants, and is located along the White River. An old, inactive quarry in Mountain Home is another one of my absent sites. The Mountain Home site is a large quarry with cedar encroachment and pollution by humans. Pollution is one possible explanation for the absence of lizards at the Mountain Home site; pollution here includes trash, metal scraps, wires, old fireworks, and broken glass. Lost Bridge is located on Beaver Lake, where natural glades have been overgrown by oak-hickory forest intermitted with cedar trees. Beaver Quarry is located next to Beaver Dam and has a large open area, but few rock piles for the lizards to live on. Trees are beginning to grow in numerous locations in this quarry. Turkey Mountain is located near Buffalo City in the Buffalo National Park in the Lower Buffalo Wilderness Area. This area has had prescribed burns, but south and west facing slopes are still too overgrown to support many, if any, lizards. One of my sites is located at Mount Magazine State Park. Forest has overgrown the natural glade once inhabited by lizard populations. Another site is at Fort Chaffee, a woodland area with rocky glade habitat; disturbance from artillery shelling and prescribed fires occur here. Wedington is another site that is located northwest of Lake Weddington. There are rock outcroppings along a north to south directing mountain that are now mostly overgrown by forest. My last absent site is located at Old Joe Quarry in the town of Old

Joe. Old Joe Quarry is a non-active quarry that is still very open but polluted from humans with trash, metal and wire scraps, and broken glass. All absent sites had documented *C. c. collaris* populations in the past (Shipp's Ferry, Mountain Home, Lost Bridge, Beaver Quarry, Turkey Mountain, Mount Magazine, Fort Chaffee, Old Joe (Trauth, 1970; 1989; Trauth et al., 2004), and Wedington (Bonati, 1980; Trauth et al., 2004)).

The predominant tree species at my sites varies from eastern red cedar, pine, and oak to other assorted hardwoods. All locations have mostly rocky soils and ground cover, but some have been overgrown more than others. Shrubs, prairie grasses, and mosses are also abundant and cacti were observed at many locations.

Lizard Survey

In order to determine if collared lizard populations were present or absent at each site, I carried out a visual, time dependent survey for lizards for two hours per visit throughout the summer of 2011. It is important to note that besides each 2 hour visual lizard survey, I also visually searched for the lizards while carrying out environmental, habitat, and tree community structure surveys, which increased search time. Sites had also been surveyed during my 2010 distributional and habitat surveys. All absent sites were visited three times during the summer of 2011, at least once in early summer and once in late summer to assure populations are indeed undetectable according to my techniques. Lizards sighted were caught by hand or noose, if possible. The site location, date, time of day the lizard was caught, and the GPS coordinates were recorded. The amount of time it took before the first lizard was observed at each site was also recorded. Lizard weight was then measured in grams using a Pesola® Light Line Precision 60 gram scale, while lizard head width, tail length, and snout to vent length (SVL) were measured in millimeters using a calibrated tape measure. The gender of each specimen was recorded by either looking at adult coloration or size of juvenile post anal scales. Finally, the age class (hatchling, juvenile, adult) of each individual was estimated upon SVL, sex, and coloration (Trauth, 1970).

For each lizard seen or caught, behavioral, environmental, and habitat information was recorded. For behavioral information, body posture or position, sun exposure (flecked sun, partial sun, full sun, and full shade), shade source if applicable, visibility (fully visible or partially visible), and behavior (foraging, resting, digesting, moving, mating, basking or other) were recorded. Environmental data and habitat data were recorded in order to assess microhabitat use of *C. c. collaris*. Environmental data included weather (sunny, partly cloudy, and cloudy) and facing slope using a compass. Then, using a Kestrel® 4000 Wind and Weather instrument, environmental measurements were recorded as follows: air temperature (˚C), wind speed (m/s), percent humidity (percent), and altitude (meters). All lizard size and environmental data were placed into a spreadsheet to be later analyzed. I then estimated and recorded habitat data for a 2 by 2 meter squared area around the lizard location, when sighted. These data included percent bare rock and type (gravel, cobble, and or boulder), percent vegetation and type (grass, leafy, and or moss), percent bare soil and type (rock, leaf, and or dirt), and percent of coarse woody debris and size (small or large). Finally, percent canopy cover and tree type above the lizard, when applicable, was estimated and recorded. Any other important information or detail was also described such as other lizard species present, spots on gravid females indicating reproduction (Pianka and Vitt, 2003; Milstead, 1965), body condition of lizards (stubbed tail, injuries), courting or territorial behavior, change in the weather (such as a storm) during surveys, or any other pertinent information not already outlined on data sheets.

Environmental Survey

After determining presence or absence of *C. c. collaris* populations at each site, I wanted to know if biophysical factors were associated with presence or absence of populations. At each site various environmental variables were measured using a Kestrel® 4000 Wind and Weather instrument. Variables included percent humidity, air temperature, wind speed, and altitude. The facing slope was determined using a compass and cloud cover was recorded as cloudy, partly cloudy, or sunny. The date and time were also recorded.

Habitat Survey

In order to compare and contrast habitats among present and absent sites, I carried out a habitat analysis by using two 20 meter transects or lines through vegetation or habitat (Gates, 1949). Transects were haphazardly placed within the glade habitat (around rock piles where current or possible past lizard home ranges existed). I then measured 2.5 meters on both sides of each transect to create a 20 by 5 meter plot (Figure 3). For each transect, 100 square meters were measured and for each site, 200 square meters were measured. Overall, 1600 square meters of present sites were surveyed and 1800 square meters of absent sites were surveyed (34 transects).

With a random yet systematic approach, percent ground cover was estimated by looking at multiple predictor variables, including: bare rock, bare soil, vegetation, and coarse woody debris. For each site, 5 quadrats (each 2 m^2) were placed along the two transects. The percent of each ground cover variable was estimated using a major quadrat. A major quadrat is defined as a quadrat separated into four quarters (Clements, 1977). Data were recorded for each quadrat using a modified Daubenmire method (Daubenmire, 1959). The corresponding Daubenmire cover class (1-6) was assigned to each variable and later converted to midpoint data. In order to have better accuracy of percent estimation, I first measured each quarter of the quadrat and then averaged these values. There is an unavoidable degree of error when estimating by eye, so cover class estimates (Kent and Coker, 1992), such as Daubenmire, are helpful. To randomly determine the number of the quadrats on each transect, a coin was tossed. If the coin landed on heads, Transect 1 would have 3 quadrats and Transect 2 would have 2 quadrats. If the coin landed on tails, Transect 1 would have 2 quadrats and Transect 2 would have 3 quadrats. Only 5 quadrats were measured (as opposed to three on each) in order to obtain an even 20 square meters sampled per site. To randomly establish the location of the quadrats on each transect, a random numbers table was generated with numbers between 1 and 19. Each quadrat was placed (centered) on the transect meter according to the number generated from the random numbers table. Locations for placement of quadrats on each transect were determined before field work. If a number was duplicated in the random numbers table, a coin was flipped to determine if two above or two below the number should be chosen (Heads-below, Tails-above). For example, if the number 15 was duplicated in the random numbers table, heads would decide on meter 13 and tails would decide on meter 17 for the following quadrat. A total of 85 quadrats were sampled in this survey.

The next step of the habitat study was to measure percent canopy cover. I recorded every meter the canopy crossed each transect (two transects per site) using a densitometer and the line intercept method. I calculated the total percent canopy cover of each transect and averaged the two transect percentages to determine an estimated percent coverage of each site. The corresponding Daubenmire cover classes were then recorded, just as in the ground cover survey.

Tree Structure Survey

To determine differences in present and absent sites, each tree within the 20 by 5 meter plot was mapped, identified, and measured for each site. The tree type was identified as eastern red cedar, oak, pine, maple, ash, chinquapin oak, hickory or 'other deciduous' based on morphologic features. Each tree type was assigned a category; cedar = 1, oak (red or white) = 2, pine = 3, other deciduous = 4, maple (sugar and red) = 5, white ash = 6, chinquapin oak = 7, and hickory = 8. The diameter at breast height (DBH) was measured using a DBH tape in centimeters. The height of each tree was then measured in feet, using a SUUNTO Clinometer, and then later converted to meters.

Data Analysis

I carried out multiple tests using Microsoft Excel (2010) and various Statistical Software Packages including JMP 9.0 (SAS Institute), SYSTAT 12.0 (SYSTAT Software) and PC-ORD 5 (MJM Software Designs). Data were analyzed for normality (all data were not completely normal, however they were 'normal enough' for the tests conducted), outliers, and other assumptions for all tests carried out. All differences were considered significant at p-value = 0.05 or less.

Lizard Presence or Absence

Aiming to assure that lizard populations were indeed not present at my absent sites, I compared the time it took to find the first lizard at each present site with the total number of hours searched at each absent site. I also standardized the number of lizards found per person search hour at all of my present sites by first multiplying the number of people by number of search hours. I divided the number of lizards found at each site by the number of hours searched at each site to determine the average number of lizards found per hour.

Environmental Data

Principle components analysis (PCA) of environmental measurements was carried out in order to see if sites were different due to environmental or biophysical factors. Principle components analysis shows how all sites are related according to predictor variables (air temperature, wind speed, percent humidity, and altitude) and determines if environmental factors are correlated with presence of lizards. PCA allowed me to keep all my predictor variables, determine relationships across sites, and have appropriate sample size (Tabachnik and Fidell, 1989; McCune and Grace, 2002). A randomizations test was carried out with the PCA to determine the significance of the PCA test. Randomization tests use bootstrap values to assess significance of the results. The test shuffles values within my variables, recomputes the correlation matrix and eigenvalues, and then repeats this at least 999 times. Random eigenvalues are compared to actual eigenvalues. If random eigenvalues are smaller than actual eigenvalues, then the component contains more information than expected from chance alone (Jackson, 1993; McCune and Grace, 2002).

Habitat Data

In order to determine the difference in habitat variables (canopy cover and ground cover: bare rock, bare soil, coarse woody debris, vegetation) across sites, PCA was conducted on Daubenmire midpoint habitat data (predictor variables) across sites (response variables). PCA was chosen for several reasons: (1) to reduce the number of variables in order to have an appropriate sample size because it is recommended to have 25 sites for 5 variables (Tabachnik and Fidell, 1989; McCune and Grace, 2002), (2) PCA allows me to keep all 5 of my habitat variables, and (3) PCA deals with correlated variables well. Principle components analysis allowed me to determine the most important habitat variables describing the system, to look at how my sites separated according to habitat variables, and view presence or absence separated along habitat variables. The PCA was generated using the more common correlation coefficient cross-product matrix because there were no major outliers and each variable would be contributed equally to the total variance (McCune and Grace, 2002). Scatterplots were created, first to see how my sites split up according to the habitat variables and then to see the magnitude of each habitat variable at each site. A randomizations test was carried out to determine the significance of the test, as with the environmental survey. Analysis of variance (ANOVA) was generated on the PCA components explaining the most variation, components with eigenvalues greater than 1, and components considered significant from the randomizations test. Here, the response variables were principle component 1 and 2 (site loading scores) and the grouping variable was presence or absence of *C. c. collaris* populations. Least-squares means were used to determine differences of habitat variables on present or absent groups.

Tree Structure Data

Diameter at breast height (DBH) and tree height data were pooled for all present sites and then pooled for all absent sites. Means and Standard Errors were calculated for each group, present and absent. A T-test for a comparison of means between present versus absent groups was carried out for both DBH and tree height in order to determine a p-value for significance. Diameter at breast height and tree height were graphed to see the difference between present and absent sites. The Relative Density, Absolute Density, Absolute Basal Area, Relative Basal Area and the Importance Value Index for each tree type (Curtis and McIntosh, 1951; Kent and Coker, 1992) were calculated for present sites versus absent sites.

Each tree was placed into a DBH size class between I and VII in order to compare the tree size classes among present versus absent sites. The size classes included I = 2-4.99 cm, II = 5-9.99 cm, III = 10-14.99 cm, IV = 15-19.99 cm, V = 20-24.99 cm, VI = 25-29.99 cm, and VII = 30-35 cm. The frequency of trees in each size class was counted for all present sites and all absent sites. Contingency tables were constructed and chi square tests were used to determine significant differences for tree size class between present and absent groups and for tree size class across all sites. Tree size class across sites was carried out to determine variation within and among sites. Finally, ANOVA was carried out on DBH for all trees across sites and also all cedar trees across sites, in order to determine variation in tree DBH among individual sites.

Lizard Data

All habitat data recorded for each lizard capture were averaged in order to see the most common habitat variables exploited by lizards on the glades at a local scale, along with the type of habitat lizards tended to be found on. This was carried out by calculating the mean percent coverage of each habitat variable and the mode of the type of habitat lizards were found on.

Body condition of lizards at each site was analyzed looking at all sites where 5 or more lizards were caught and measured. A scatterplot of SVL (millimeters) as my dependent variable against Mass (grams) as my independent variable was created. An extreme outlier was removed from the data analysis because it was biologically unreasonable. The data point was presumed a measurement or recording error. A non-linear power trendline was fitted to my data with the outlier removed. Predicted body masses, based on my SVL were determined through the power equation generated from the trendline. The difference in my actual mass, M_A, and predicted mass, M_P, (residuals) gave me Body Condition Index values ($BCI = M_A - M_P$). In this case, positive BCI values indicate good body condition, whereas negative values indicate poor body condition. Body condition indices for each lizard at each site were then averaged and plotted against my principle component 1 scores that were found when analyzing the habitat data.

RESULTS

Lizard Survey: Presence or Absence

At present sites, lizards were typically sighted within thirty minutes of searching a site and were easily detected. Number of search hours (between 6 and 11 hours) for absent sites, compared to present sites, shows that absent sites have very few lizards or are apparently extirpated (Figure 4).

Environmental Survey

A principal components analysis was conducted on environmental variables: air temperature, wind speed, humidity, and altitude (Appendix A) in order to investigate relationships among glade sites (Figure 5). Two axes explained about 68 percent of the variation. Axis 1 was positively associated with air temperature and negatively with altitude, while Axis 2 was positively associated with both wind speed and humidity. The randomizations test was not significant (Axis 1, $p = 0.097$; Axis 2, $p = 0.985$), explaining there is no difference in environmental variables among sites (Tables 2-3).

Habitat Survey

A principal components analysis (PCA) was conducted in order to investigate relationships among glade sites and habitat variables. Principle components analysis was carried out on Daubenmire midpoint percent data (Table 4) which was calculated by use of Daubenmire cover classes recorded during the habitat survey (Table 5). The first two components (axes) produced by the PCA explained most of the variance (approximately 66 percent of the variance). The first principle component explained approximately 43 percent of the variance and showed a strong negative association with open rock cover and a positive association with CWD and total canopy cover. Principle component 2 explained approximately 23 percent of the variance. The second component had a negative association with plant cover and positive association with bare soil. Principle components 3, 4, and 5 had associations with all habitat factors. There are various ways to determine how many components are worth interpreting. It is recommended that components with the most variation should be interpreted. In the case of my habitat PCA, components 1 and 2 explained the most variation. It is also recommended, by the Kaiser Guttman criterion, that all components with eigenvalues greater than 1 should be interpreted

(McCune and Grace, 2002). Eigenvalues for the first two components were greater than one (PC-1 = 2.149; PC-2 = 1.144), whereas PC 3-5 were less than one (Table 6).

The majority of present sites had negative coordinate scores (associated with rock) while most absent sites had positive coordinate scores (associated with canopy cover and coarse woody debris) (Table 7). The separation of these sites can be viewed more easily in a scatterplot (Figure 6). Percent canopy cover changed across sites. The majority of present sites had low percent canopy cover and the majority of absent sites had high percent canopy cover (Figure 7). Rock cover changed across sites; present sites had high percent rock cover and most absent sites had low percent rock cover (Figure 8). Soil cover did not differ across sites; high and low amounts of bare soil were found for both present and absent sites (Figure 9). Vegetation cover had a change across sites. Vegetation cover was higher at absent sites and lower at present sites (Figure 10). Finally, coarse woody debris cover showed small values across sites with no noticeable difference between presence and absence (Figure 11). The randomizations test was significant for PC-1 ($p=0.041$); however, PC-2 ($p = 0.849$), 3 ($p = 0.509$), 4 ($p = 0.874$), and 5 ($p = 0.880$) were not significant. The data shows there is a significant difference in rock, canopy, and CWD cover among sites.

In order to determine how PC-1 and PC-2 components were different among present and absent lizard groups, a one-way ANOVA was carried out on each component (Table 8). A significant difference was found in present versus absent groups for Component 1 ($F = 6.1645$, $p = 0.0253$), with 24 percent of the variation explained (R square adjusted = 0.2440). Component 2 did not have a significant difference ($F = 3.1706$, $p = 0.0952$, R square adjusted = 0.1195) in present and absent groups. No other components were analyzed using an ANOVA because PC-2 was not significant.

Tree Structure Survey

Tree structure data (Appendix B) were analyzed in various ways. DBH means (present = 8.24 +/- 1.03 cm; absent = 14.07 +/- 0.93 cm) were found to be significantly different (p = 0.0003) when a T-test was carried out (Figure 12). A T-test found a significant difference (p = 0.0039) in mean tree height (present = 3.71 +/- 0.24 m; absent = 7.69 +/- 0.95 m) as well (Figure 13). Both tree height and DBH increased significantly with absent sites.

Tree structure was compared between present and absent sites (Table 9). There were 111 total trees measured, where the mean number of trees at each present site was 4.625 (n= 37; SE=0.4116) and 8.222 (n = 74; SE = 0.526) for each absent site. There are almost twice as many trees at absent sites than present sites; present sites had an Absolute Density 231.25 stems per hectare while absent sites had 411.11 stems per hectare. Cedar had the largest absolute density (Present = 106.25; Absent = 161.11) and relative density (Present = 46; Absent = 40). The absolute basal area was much smaller for present sites (0.2526 m^2) than for absent sites (1.1683 m^2). For present sites, cedar had the highest average absolute basal area (0.1127 m^2) and relative basal area (62.3), whereas for absent sites, oak had the highest average absolute basal area (0.306 m^2) and the highest relative basal areas were oak (34.83) and cedar (33.68). The mean Relative Basal Area for present sites was 0.083 (n= 37; SE= 0.0233) while absent sites was 0.19 (n=74; SE=0.0230). Eastern red cedar was the most important tree species for both present (IV= 54.1) and absent (IV= 36.43) sites, though many deciduous trees were also important for absent sites.

Tree DBH size class was examined in two ways using Contingency Tables: (1) all trees between present groups averaged and absent groups averaged and (2) all trees across all sites (Table 10). Pearson Chi-square test showed a significant difference (p=0.014) in DBH size class between present and absent groups (Figure 14), meaning absent sites had larger trees than present sites. Pearson Chi-square showed no significant difference (p=0.205) of size class among all sites (Figure 15).

To determine how DBH mean changed across all sites, two ANOVA's were carried out on all trees per site (Table 11) and on all cedar trees per site (Table 12). Diameter at breast height ANOVA was significant (F = 2.5047, p = 0.0037, R^2 adjusted = 0.1703), illustrating there are variations in DBH means among the sites. Cedar DBH ANOVA across sites was also significant (F = 2.4392, p = 0.0279), indicating there are variations in cedar DBH means (Table 13) among the sites.

Lizard Survey: BCI and Habitat

The habitat data collected at each lizard capture gave information about what lizards were doing at local habitat levels (Appendix C). For ground cover, lizards were found on an area with a mean or average of approximately 66 percent bare rock, 16 percent plant, 15 percent bare soil, and 3 percent CWD, while they were found in areas with 8 percent canopy cover. Captured lizards were found to be frequently and most often (mode was determined) associated with ground cover habitat type including cobble and boulder rock, grass vegetation, rocky bare soil, and small coarse woody debris. Lizards found near trees were most often associated with eastern red cedar canopy.

Sites with more appropriate *C. c. collaris* habitat (from PC-1 habitat scores), including bare rock and low canopy cover, had more lizards caught per person hour (Figure 16). Flippin, Calico West, and Prairie View had open habitat and the highest lizard frequency per person hour. The Calico Southwest site had very few lizards, which can be seen on the positive side of the y-axis (higher canopy cover than most sites). The Petit Jean data point was an outlier, with few lizards per search hour, but good, open habitat.

Snout vent length (SVL, millimeters) was plotted against Mass (grams) to determine body condition index (Figure 17). Data for each lizard, at sites where 5 or more lizards were measured, were applied to the analysis. The power equation for the trend line was found to be $Mass=4 \times 10^{-05} SVL^{3.0268}$, with an R^2 of 0.9004. Most all lizards captured and measured were adults. BCI was calculated from residuals of the Mass and SVL data, averaged for each site, and plotted against PC-1 from my habitat principle components analysis (Figure 18). The figure shows Flippin with the healthier individuals (positive BCI's), and Prairie View, Pruitt, Leatherwood, and Rush with negative BCI's. Body condition index results showed that sites with lower open rock and higher canopy cover had worse (more negative) BCI's than Flippin, with high bare rock and low canopy cover.

DISCUSSION

My first goal was to determine presence or absence of *C. c. collaris* populations at 17 historical sites. I then sought to determine differences across sites in environmental variables, habitat variables, and tree community structure. Finally, I was interested in determining if the differences in sites have negative consequences for individual lizards. Present and absent sites had no difference in environmental variables. Habitat variables and tree community structure at present sites were significantly different from absent sites. Locations with better habitat had better lizard body condition.

Lizard Survey: Presence or Absence

Though it is difficult to prove absence of a species in a particular area, I attempt here to give an explanation of why I believe populations to be absent at 9 of my sites. At 6 out of 8 of my present sites, *C. c. collaris* were detected in under half an hour and the other two sites, Petit Jean and Calico Southwest were detected in less than four hours of searching. Absent sites were all surveyed in 2011 for at least six hours, and 6 of 9 sites were surveyed for eight or more hours without any sign (including feces) of lizards. I surveyed these sites during my entire environmental, habitat, and tree structure surveys, adding on at least 2-3 hours of search time in 2011. Almost all of these sites were also surveyed in 2010 either during my distributional assessment or preliminary habitat survey. An important factor aside from search time is how detectable the species is. *Crotaphytus collaris collaris* is an easily detectable lizard due to the species vivid and bright coloration, the large size of the individuals, and their territorial behavior; so I can say with confidence that they are indeed absent. There is a possibility that very few lizards persist at my ‘absent’ sites, but it is doubtful that any viable populations remain. I define viable here as a population that is large and healthy enough to reproduce and survive in the wild without being at risk of natural disasters, demographic stochasticity, and other negative factors related to having small population size (Thomas, 1990).

Environmental Survey

Environmental variables (humidity, altitude, air temperature, and wind speed) were not found to be significantly different between present and absent lizard sites. Therefore, I fail to reject my null hypothesis. The environmental PCA results were expected because all 17 sites have been inhabited by *C. c. collaris* in the past. Because there is no difference in environmental variables among sites, it would be expected that I would have found lizards on a warm sunny day at all of my 17 sites. It is apparent, because I did not find lizards at my 9 absent sites, that factors other than biophysical are associated with the presence or absence of *C. c. collaris* populations. The results support that disappearing *C. c. collaris* populations could possibly be a habitat change and loss phenomenon, not environmental. If presence or absence of lizards is associated with habitat, there is a potential for absent sites to be recolonized with reintroduction of lizards if the habitat can be restored, since we know the environment is not associated.

Habitat Survey

There was a strong separation between present sites and absent sites for habitat variables. The PCA had a strong grouping of present sites having low plant, CWD, and canopy cover and high rock cover. Absent sites were strongly correlated with high canopy, CWD, and vegetation cover. There was some overlap with present and absent sites, including the present site Leatherwood and the following absent sites: Mount Magazine, Fort Chaffee, and Old Joe. Leatherwood is a present site that overlaps with absent sites because it has a lot of vegetation, yet still good open rock habitat. Mount Magazine had a large rock slide area with little vegetation. This area would not have been able to provide enough insects for *C. c. collaris* to prey on. Fort Chaffee had a woodland area with rock out-croppings, but much of the rock was in too much shade to provide the lizards with appropriate areas for basking. Old Joe is a small open quarry with appropriate habitat; however, human traffic has polluted this quarry, and has more than likely driven this species to extirpation here.

There was a significant difference in the present sites versus absent sites, which was expected. Present sites had more open rock while absent sites had more canopy cover. I therefore reject my null hypothesis that there would be no correlation of habitat variables and present or absent sites; there is a significant difference present and absent sites. Because of the habitat survey results, I can say with assurance that open habitat quality is indeed associated with *C. c. collaris* presence. Habitat quality for *C. c. collaris* includes open rocky areas that absorb plenty of sunlight for heat (Trauth, 1970), have rock crevices for hiding (Blevins and With, 2011) and have large rocks to bask, spot predators, prey, and mates, and to defend their territories (Fitch and Tanner, 1951; Chase, 1998; Angert et al., 2002). Conservation of habitat could include adding rock piles to both current *C. c. collaris* sites, past sites, and even to road sides.

Tree Structure Survey

The number, DBH, height, and size class of trees were all significantly different in present sites versus absent sites. Therefore the null hypothesis is rejected. The results explain that lizard presence is associated with the tree community structure. Vegetation structure is an important predictor for the presence of many species, including the lizard species *Psammodromus algirus* (Diaz et al., 2000). For *C. c. collaris* habitat, larger, older trees are more abundant and overall frequency of trees is increased at absent sites, due to earlier encroachment on the glades. The increase in DBH, height and frequency is a direct consequence of fire suppression. The Europeans caused an overall habitat change, including fragmentation of glades

(Guyette and Spetich, 2003; Guyette et al., 2006). For instance, the Ozarks were documented by Native Americans as having open prairie and woodland communities before European settlement (Schoolcraft, 1821; Guyette et al., 2006). Tree encroachment, due to fire suppression beginning in the 1900s and Smokey the Bear over 60 years ago, has caused a dramatic change in glade ecosystems. Findings from my tree structure survey could prove to be beneficial for conservation and reintroduction efforts because burning and opening of the glades would make the areas more appropriate for *C. c. collaris* populations. Burning of glades and regulating habitat and tree structure has already been demonstrated to benefit struggling *C. c. collaris* populations (Templeton et al., 2001; 2011).

Eastern red cedar encroachment is thought to be causing problems for the eastern collared lizard in the Ozarks (Templeton et al., 1990; Hutchison, 2003; Grimsley, unpublished data). My results explained that cedar was the most important tree for present sites, while cedar and oak were the most important for absent sites. Other deciduous trees, indicative of closed-canopy forests were also important for absent sites. Importance value results illustrate that not only cedar is encroaching and overgrowing the glades of Arkansas, but also oak and other deciduous trees. In Stone County, AR it was found that from 1830 to 1995, the tree community structure changed dramatically (Heitzman et al., 2004). As well, Kansas has documented cedar density increasing at 56.9 trees per hectare per year (Price, 2010), and Missouri's Ozarks are now documented for being dominated by closed canopy forest (Cutter and Guyette, 1994). The more trees, the more canopy cover, and the more canopy cover, the worse the habitat for *C. c. collaris*. Because cedar was important for both present and absent sites, present sites will probably become overgrown and encroached with time as well. *Crotaphytus collaris collaris* found on glades with cedar encroachment had decreased growth rates, adult size and period of juvenile activity in Missouri (Sexton et al., 1992), and overall worse body condition in Arkansas (Grimsley, unpublished data). In order to keep the lizard populations healthy at these present sites, work must be done to open up the sites, and reduce encroachment of red cedar and closed canopy species.

Lizard Survey: BCI and Habitat

Lizard capture frequency was associated with the quality of habitat at each site, which was expected. The more open the habitat, the more likely it is to sustain a large population; as well, it is easier to detect *C. c. collaris* in open areas than areas closed with cedar trees. Petit Jean was one site where there was open glade habitat but very few lizards. Few lizards at Petit Jean could be due to various reasons. It is possibly due to the increase in road runner populations in central Arkansas. The area is near a hiking trail and humans could be interfering by collection or possibly harming the lizards. There are also fewer rock crevices for lizards to hide, which has been proven to influence collared lizard abundance (Blevins and With, 2011). Other sites had a strong relationship showing an increase in lizard frequency with more open habitat.

For lizard body condition, the null hypothesis was that habitat quality of each site would not be associated with the body condition of lizards; whereas the alternative hypothesis was that better habitat quality would be associated with better body condition. Lizard body condition is associated with habitat structure. Lizards at the Pruitt site look to be in poor condition; the habitat is more associated with canopy cover than the other sites and has the most negative body condition index (it strays from the predicted mass). However, sites such as Flippin and Prairie View have open rock associated with their habitats and have better mean BCI indices. My null hypothesis is therefore rejected. My data compares to a study on *Iberolacerta cyreni* found in the Guadarrama Mountains, where body condition may be associated with increased predation risk that is due to habitat deterioration (Amo et al., 2007). It was also determined in forests of northwestern California that body condition of amphibians is worse with a decrease in habitat quality (Karraker and Welsh, 2006).

Conclusions/Conservation Efforts

One of the most important threats to diversity of species is habitat fragmentation (Pineda and Halffter, 2004). For instance, amphibian population declines are some of the most obvious cases of negative effects of habitat fragmentation and change (Alford and Richards, 1999; Heyer, 2000; Blaustein and Keisecker, 2002; Pineda and Halffter, 2004). Declines in gopher tortoises are suggested to also depend on a complex function including habitat change, period of time of change and amount of habitat (McCoy et al., 2006). Habitat change, loss, and fragmentation have been shown to have negative impacts on species worldwide. Many species cannot adapt to the effect of smaller patches (Pimm and Raven, 2000; Fahrig, 2003), isolation, limited dispersal (Mader, 1984; Hutchison and Templeton, 1999), edge effects (Fahrig, 2003), reduced heterogeneity across the landscape (Bazzaz, 1975; Tews et al., 2004), the Allee effect (Allee, 1931; 1949) and other issues related to this habitat change, loss, and fragmentation. Habitat change due to humans has damaged communities, ecosystems, ecological processes, and caused local and global extinctions (Diamond, 1989; Wilson, 1992; Polis et al., 1997; Pimm and Raven, 2000; Templeton, 2001; Horncastle et a., 2005).

The *C. c. collaris* is one species that is not adapting well to the circumstances brought on by anthropogenic events, including habitat destruction and fire suppression. Studying *C. c. collaris* 40 years after studies by Trauth in 1970, I have found at least 9 historical populations and Trauth (2011) has found many populations along lake shorelines that have been extirpated. If no action is carried out, continuing cedar and other tree encroachment and increased habitat change, loss, and fragmentation will likely lead to greater numbers of extirpations and eventually local extinction of *C. c. collaris* in the Ozarks. Because of the habitat destruction and isolation of populations, it has been suggested that *C. c. collaris* will be extirpated in the near future in peripheral parts of their range (Templeton, 1990; Hutchison, 2003). My study supports the fact that populations in the Ozarks are few and are struggling, mostly because of habitat change and fragmentation. With successful studies being demonstrated in the restoration of glades in the Missouri Ozarks (Templeton et al., 2001; 2011), it is probable that the population and possible metapopulation dynamics in Arkansas can also be enhanced.

It is evident through my environmental survey that there is not an association with biophysical factors and presence or absence of collared lizards. Therefore, we now know that my absent sites have the appropriate environment to sustain viable *C. c. collaris* populations, which is promising for reintroduction of this species on various glade sites. Because environment was not playing a role, habitat and tree community structure was studied. Results from my research show that habitat and tree structure is different in present and absent sites. Therefore, restoration projects should focus on restoring these factors in the glade systems. For example, habitat could be restored in simple ways such as adding rock piles to both present and absent sites, increasing available locations for *C. c. collaris* activities, as well as hand planting of glade endemic species

(Davis, 1982). Tree structure can be restored by several seasons of burning and removal of cedar and closed canopy species. Restoration projects should focus not only on absent sites, but present sites as well, so that lizard populations can have an increase in growth rate, survival rate, and reproduction.

It is important to conserve *C. c. collaris* for several reasons. Glades resemble prairie communities and share many plant and animals within those systems (Nelson and Ladd, 1980). Glade species are often relictual, endemic, and rare, and many species are typical of desert areas (Baskin et al., 1995; Baskin and Baskin, 2000; McClain and Ebinger, 2002). The presence of *C. c. collaris* can reduce insect abundance, which in turn reduces herbivory, which enhances the chance of the survival of rare plant species (Zandt, 2005). After successful restoration of glades, reintroduction of *C. c. collaris* can be accomplished. Reintroduction will be most successful if glades can not only be restored, but also connected with corridors, which will assist in dispersal of individual lizards. If glade habitat throughout the Ozarks can be restored and managed in the future with successful lizard reintroductions, *C. c. collaris* could prove to be a thriving species in Arkansas.

WORKS CITED

Alford, R. A. and S. J. Richards. 1999. Global amphibian declines: a problem in applied ecology. *Annual Review of Ecology and Systematics*, 30:133-165.

Allee, W. C. 1931. *Animal aggregations: A study in general sociology*. University of Chicago Press, Chicago.

Allee, W. C. 1949. *Principles of animal ecology*. Saunders.

Amo, L., P. Lopez, and J. Martin. 2007. Habitat deterioration affects body condition of lizards: A behavioral approach with *Iberolacera cyreni* lizards inhabiting ski resorts. *Biological Conservation*, 135: 77-85.

Angert, A. L., D. Hutchison, D. Glossip, and J. B. Losos. 2002. Microhabitat use and thermal biology of the collared lizard (*Crotaphytus collaris collaris*) and the fence lizard (*Sceloporus undulates hyacinthinus*) in Missouri glades. *Journal of Herpetology*, 36(1): 22-29.

Arkansas Natural Heritage Commission. 2011. *Annual Report 2011*. Arkansas Natural Heritage Commission, Little Rock.

Axtel, R. W. and R. G. Webb. 1995. Two new Crotaphytus from southern Coahuila and the adjacent states of east-central Mexico. *Bulletin of the Chicago Academy of Sciences*, 16:1-15.

Baird, T. A., S. F. Fox, and J. K. McCoy. 1997. Population differences in the roles of size and coloration in intra-and intersexual selection in the collared lizard, *Crotaphytus collaris*: Influence of habitat and social organization. *Behavioral Ecology*, 8(5):506-517.

Baird, T. A., D. K. Timanus, and C. L. Sloan. 2003. Intra- and intersexual variation in social behavior: effects of ontogeny, phenotype, resources, and season. *In*: Fox, S. F., McCoy J. K., Baird, T. A., editors. *Lizard social behavior*. Johns Hopkins University Press, Baltimore, pp. 7-46.

Baird, T. A. 2004. Reproductive coloration in female collared lizards, *Crotaphytus collaris*, stimulates courtship by males. *Herpetologica*, 60(3): 337-348.

Baird, T. A., J. M. Hranitz, D. K. Timanus, and A. M. Schwartz. 2007. Behavioral attributes influence annual male mating success more than morphology in collared lizards. *Behavioral Ecology*, 18:1146-1154.

Ballinger, R. E. and G. D. Schrank. 1972. Reproductive potential of female whiptail lizards, *Cnemidophorus gularis gularis*. *Herpetologica*, 28:217-222.

Ballinger, R. E. and T. G. Hipp. 1985. Reproduction in the Collared Lizard, *Crotaphytus collaris*, in West Central Texas. *Copeia*, 4:976-980.

Barabault, R. and S. D. Sastrapradja. 1995. Generation, maintenance and loss of biodiversity, In: V. H. Heywood, editor, *Global Biodiversity Assessment*. Cambridge University Press, Cambridge, pp. 193-274.

Baskin, J. M., C. C. Baskin, and E. W. Chester. 1994. The Big Barrens region of Kentucky and Tennessee: further observation and considerations. *Castanea*, 59:226-254.

Baskin, J. M., D. H. Webb, and C. C. Baskin. 1995. A floristic plant ecology study of the limestone glades of northern Alabama. *Bulletin of the Torrey Botanical Club*, 122:226-242.

Baskin, J. M. and C. C. Baskin. 1988. Endemism in rock outcrop plant communities of unglaciated eastern United States: an evaluation of the roles of the edaphic, genetic and light factors. *Journal of Biogeography*, 15:829-840.

Baskin, J. M. and C. C. Baskin. 2000. Vegetation of limestone and dolomite glades in the Ozarks and Midwest regions of the United States. *Annals of the Missouri Botanical Garden*, 87:286-294.

Baskin, J. M. and C. C. Baskin. 2003. The vascular flora of cedar glades of the southeastern United States and its phytogeographical relationships. *Journal of the Torrey Botanical Society*, 130:101-118.

Bazzaz, F. A. 1975. Plant species diversity in old-field successional ecosystems in southern Illinois. *Ecology*, 56:485-488.

Bender D. J., T. A. Contreras, and L. Fahrig. 1998. Habitat loss and population decline: A meta-analysis of the patch size effect. *Ecology*, 79(2):517-533.

Blaustein, A. R. and J. M. Kiesecker. 2002. Complexity in conservation: Lessons from global decline of amphibian populations. *Ecology Letters*, 5:597-608.

Blevins, E. and K. A. With. 2011. Landscape context matters: local habitat and landscape effects on the abundance and patch occupancy of collared lizards in managed grasslands. *Landscape Ecology*, 26:837-850.

Blevins, E., S. M. Wisely, and K. A. With. 2011. Historical processes and landscape context influence genetic structure in peripheral populations of the collared lizard (*Crotaphytus collaris*). *Landscape Ecology*, 26:1125-1136.

Bonati, R. L. 1980. *The amphibians and reptiles of northwest Arkansas: A report on their distribution and abundance*. Master's Thesis. University of Arkansas, Fayetteville, pp. 155.

Brenner, F. J., and P. E. Brenner. 1973. The relationship between body fat and reproductive cycle in two species of lizards (Reptilia: Iguanidae). *Proceedings of Pennsylvania Academy of Sciences*, 47:103-105.

Brisson, J.A., J. L. Strasburg, and A. R. Templeton. 2003. Impact of fire management on the ecology of collared lizard (*Crotaphytus collaris*) populations living on the Ozark Plateau. *Animal Conservation*, 6(3):247-254.

Burt, C. E. 1929. Insect food of Kansas lizards with notes on feeding habits. *Journal of the Kansas Entomology Society*, 1:50-68.

Chase, J. M. 1998. Central-place forager effects on food web dynamics and spatial pattern in northern California meadows. *Ecology*, 79:1236-1245.

Clements, F. E. 1977. *Research Methods in Ecology*. The University Publishing Company, Lincoln, Nebraska.

Climate Change. 2001. *Third Assessment Report of the Intergovernmental Panel on Climate Change IPCC (WG I & II).* Cambridge University Press, Cambridge.

Conant R. and J. T. Collins. 1998. *A Field Guide to Reptiles and Amphibians of Eastern and Central North America*. *Third Edition Expanded*. Houghton Mifflin Company, New York, New York.

Cooper, W.E., Jr., C.S. Adams, and J.L. Dobie. 1983. Female color change in the keeled earless lizard, *Holbrookia propinqua*: Relationship to the reproductive cycle. *Southwestern Naturalist*, 28:275-280.

Curtis, J. T. and R. P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, 32:476-496.

Cutter, B. E. and R. P. Guyette. 1994. Fire history on an oak-hickory ridgetop in the Missouri Ozarks. *American Midland Naturalist*, 132(2):393-398.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sciences*, 33:43-64.

Davis, D. D. 1934. *The collared lizard. A laboratory guide.* The Macmillan Company, New York.

Davis, W. 1982. Preface. In: E. A. McGinnes Jr., editor. *Proceedings of the Cedar Glade Symposium*, Missouri Academy of Science, Columbia. pp. v-vii.

Debinski, D. M. and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. *Conservation Biology*, 14(2):342-355.

Dellinger, S. C. and J. D. Black. 1938. Herpetology of Arkansas. Part one: The reptiles. *Occasional Papers of the University Arkansas Museum*, 1:1-47.

Dennis, B. 1989. Allee effects: population growth, critical density, and the chance of extinction. *Natural Resource Modeling*, 3:481-538.

Dennis, B. 2002. Allee effects in stochastic populations. *Oikos,* 96(3):389-401.

Dey, D. C. and R. P. Guyette. 2000b. Anthropogenic fire history and red oak forests in south-central Ontario. *Forest Chronicles*, 76(2):339-347.

Diamond, J. M. 1989. The present, past and future of human-caused extinctions. *Philosophical Transactions of the Royal Society London Series B*, 325:469-477.

Diaz, J. A., R. Carbonell, E. Virgos, T. Santos, and J. L. Telleria. 2000. Effects of forest fragmentation on the distribution of the lizard *Psammodromus algirus*. *Animal Conservation*, 3:235-240.

Donovan, G. H. and T. C. Brown. 2007. Be careful what you wish for: the legacy of Smokey Bear. *Frontiers of Ecology and the Environment*, 5(2):73-79.

Dowling, H. G. 1957. A review of the amphibians and reptiles of Arkansas. *Occasional Papers of the University of Arkansas Museum*, No.3. pg. 51.

Erickson, R. O., L. G. Brenner, and J. Wraight. 1942. Dolomitic glades of east-central Missouri. *Annuals of the Missouri Botanical Garden*, 29:89-101.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on species extinction. *Journal of Wildlife Management*, 61:603-610.

Fahrig, L. 2003. Effects of Habitat Fragmentation on Biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 34: 487-515.

Fitch, H. S. and W. W. Tanner. 1951. Remarks concerning the systematic of the collared lizard, (*Crotaphytus collaris*), with a description of a new subspecies. *Transactions of the Kansas Academy of Science*, 54(4):548-559.

Fitch, H. S. 1956. An ecological study of the collared lizard (*Crotaphytus collaris*). *University of Kansas Public Museum of Natural History*, 8:213-274.

Gates, F. C. 1949. *Field manual of plant ecology*. McGraw-Hill Book Company, Inc., New York.

Guyette, R. P. and D. C. Dey. 1995. A dendrochronological fire history of Openogo Lookout in Algonquin Park, Ontario. *Forest Research Report No. 134*. Ontario Forest Research Institute, Sault Ste. Marie, Ontario.

Guyette, R. P. and M. A. Spetich. 2003. Fire history of oak-pine forests in the Lower Boston Mountains, Arkansas. *Forest Ecology and Management*, 180(1-3):463-474.

Guyette, R. P., M. A. Spetich, and M. C. Stambaugh. 2006. Historic fire regime dynamics and forcing factors in the Boston Mountains, Arkansas. *Forest Ecology and Management*, 234:293-304.

Heitzman, E., D. C. Bragg, and A. Grell. 2004. A comparison of pre-European settlement and present day forests in Stone County, Arkansas. *Proceedings of the 14th Central Hardwoods Forest Conference,* pp. 511.

Heyer, W. R. 2000. Amphibian declines and extinctions: the situation in Latin America. In: J. E. Pefaur, editors, *Ecologia Latinoamericana*. Actas III Congreso Latinoamericano de Ecologia Universidad de Los Andes, Merida, pp. 47-55.

Hipp, T. G. 1977. *Reproductive cycle and correlated hermatological characteristics in Crotaphytus collaris in West Central Texas.* Unpublished Master's Thesis, Angelo State University, San Angelo, Texas.

Horncastle, V., E. Hellgren, P. Mayer, A. Ganguli, and D. Engle. 2005. Implications of invasion by *Juniperus virginiana* on small mammals in the Southern Great Plains. *Journal of Mammalogy,* 86(6):1144-1155.

Hutchison, D. W. 1997. *Population genetic consequences of the Holocene invasion of the Ozarks and Flint Hills by the eastern collared lizard (Crotaphytus collaris collaris) with subsequent habitat fragmentation.* Ph. D. dissertation, Washington University, St. Louis, Missouri.

Hutchison, D. W., and A. R. Templeton. 1999. Correlation of pairwise genetic and geographic distance measures: Inferring the relative influences of gene flow and drift on the distribution of genetic variability. *Evolution*, *53*(6):1898-1914.

Hutchison, D. W. 2003. Testing the Central/Peripheral model: Analyses of microsatellite variability in the eastern collared lizard (*Crotaphytus collaris collaris*). *American Midland Naturalist,* 149(1):148-162.

Ingram, W. and W. W. Tanner. 1971. A taxonomic study of *Crotaphytus collaris* between the Rio Grande and Colorado Rivers. *Biological Series,* 13(2):1-33.

Jackson, D. A. 1993. Stopping rules in principal components analysis: a comparison of heuristical and statistical approaches. *Ecology*, 74:2204-2214.

Jeffries, D. L. 1985. Analysis of the vegetation and soils of glades on calico rock sandstone in northern Arkansas. *Bulletin of the Torrey Botanical Club*, 112:70-73.

Karraker, N. E. and H. H. Welsh Jr. 2006. Long-term impacts of even-aged timber management on abundance and body condition of terrestrial amphibians in Northwestern California. *Biological Conservation*, 131:132-140.

Kent, M. and P. Coker. 1992. *Vegetation Description and Analysis: A practical approach*. CRC Press, Belhaven Press, London.

Kimmel, V. L. and G. E. Probasco. 1980. Change in woody cover on limestone glades between 1938 and 1975. *Transactions of the Missouri Academy Sciences*, 14:69-74.

Kruess, A. and T. Tscharntke. 1994. Habitat fragmentation, species loss, and biological control. *Science*, 264:1581-1584.

Kucera, C. L. and S. C. Martin. 1957. Vegetation and soil relationships in the glade region of the southwestern Missouri Ozarks. *Ecology*, 38(2):285-291.

Kunin, W. E., and Y. Iwasa. 1996. Pollinator foraging strategies in mixed floral arrays: density effects floral constancy. *Theoretical Population Biology*, 49:232-263.

Lande, R. 1998. Demographic stochasticity and Allee effect on a scale with isotropic noise. – *Oikos*, 83:353-358.

Lande, R. and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. In: M. E. Soule, editor, *Viable populations for conservation*. Cambridge University Press, Cambridge, pp. 87-123.

Legler, J. M. and H. S. Fitch. 1957. Observations on hibernation and nests of the collared lizard *Crotaphytus collaris*. *Copeia*, 1957:305-307.

LeGrand, H. E. 1988. Cedar glades on diabase outcrops: a newly described community type. *Castanea*, 53: 168-172.

Lewis, M. A., and P. Kareiva. 1993. Allee dynamics and the spread of invading organisms. *Theoretical Population Biology*, 43:141-158.

Licht, P. 1979. Reproductive endocrinology of reptiles and amphibians: gonadotropins. *Annual Review of Physiology*, 41:337-51.

Macedonia, J. M., Y. Brandt, and D. L. Clark. 2002. Sexual dichromatism and differential conspicuousness in two populations of the common collared lizard (*Crotaphytus collaris*) from Utah and New Mexico, USA. *Biological Journal of the Linnean Society*, 77:67-85.

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation*, 29:81-96.

Maralet, L. 1983. *Geographical and temporal variation in the life history of Crotaphytus collaris (Sauria: Iguanidae) in Kansas and Mexico.* Ph. D. Dissertation, The University of Kansas, Lawrence, Kansas, pg. 173.

McAllister, C. T. and S. E. Trauth. 1982. An instance of the eastern collared lizard, *Chrotaphytus collaris*, (sauria: Iguanidae), feeding on *Sigmodon hispidus* (rodentia: Cricetidae). *Southwestern Naturalist*, 27:358-359.

McAllister, C. T. 1985. Food habits and feeding behavior of *Crotaphytus collaris collaris* (Iguanidae) from Arkansas and Missouri. *The Southwestern Naturalist*, 30(4): 597-600.

McClain, W. E. and J. E. Ebinger. 2002. A comparison of the vegetation of three limestone glades in Calhoun County, Illinois. *Southeastern Naturalist*, 1:179-188.

McCoy, J. K., S. F. Fox, and T. A. Baird. 1994. Geographic Variation in sexual dimorphism in the collared lizard, *Crotaphytus collaris* (sauria: Crotaphytidae). *The Southwestern Naturalist*, 39(4):328-335.

McCoy, E. D., H. R. Mushinsky, and J. Lindzey. 2006. Declines of the gopher tortoise on protected lands. *Biological Conservation*, 128:120-127.

McCune, B. and J. B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software Design, Gleneden Beach, Oregon.

McGuire, J. A. 1996. Phylogenetic systematics of crotaphytid lizards (reptilia: Iguania: Crotaphytidae). *Bulletin of Carnegie Museum of Natural History*, 32:1-142.

Milstead, W. W. editor. 1965. *Lizard ecology, A symposium.* University of Missouri Press.

Mondy, M. D. 1970. A distributional study of the collared lizard, *Crotaphytus collaris collaris*. Master's Thesis, Southern Illinois University, Edwardsville, IL.

Moser, K., M. Hansen, R. Atxchison, G. Brand, B. Butler, S. Crocker, D. Meneguzzo, M. Nelson, C. Perry, W. Reading, B. Wilson, and C. Woodall. 2008. *Kansas Forest Manuscript*. Newtown: USDA Forest Service.

Nelson, P. and D. Ladd. 1980. Preliminary report on the identification, distribution and classification of Missouri glades. In*:* C. L. Kucera, editor. *Proceedings of the Seventh North American Prairie Conference.* Southwest Missouri State University, Springfield. pp. 59-76.

Newlin, M. E. 1979. Reproduction in the buchgrass lizard, *Sceloporus scalaris*. *Herpetologica*, 32:171-184.

O'Donnell, L., P. K. Nicholls, M. K. O'Bryan, R. I. McLachlan, and P.G. Stanton. 2011. Spermiation, the process of sperm release. *Spermatogenisis*, 1(1): 14-35.

Ostman, O., N. W. Griffin, J. L. Strasburg, J. A. Brisson, A. R. Templeton, T. M. Knight, and J. M. Chase. 2007. Habitat area affects arthropod communities directly and indirectly through top predators. *Ecography*, 30:359-366.

Parker, W. S. and E. R. Pianka. 1973. Notes on the ecology of the iguanid lizard, *Sceloporus magister*. *Herpetologica*, 29:143-152.

Pianka, E. R., and L. J. Vitt. 2003. *Lizards, windows to the evolution of diversity.* University of California Press, Berkeley.

Pimm, S. L. and P. Raven. 2000. Extinction by numbers. *Nature*, 403:843-845.

Pineda, E. and G. Halffter. 2004. Species diversity and habitat fragmentation: frogs in a tropical montane landscape in Mexico. *Biological Conservation*, 117:499-508.

Polis, G. A., W. B. Anderson, and R. D. Holt. 1997. Toward an integration of landscape and food web ecology: the dynamics of spatially subsidized food webs. *Annual Review of Ecology and Systematics*, 28:289-316.

Price, K., J. Brooks, D. Dobbeleare, T. Gaines-Bey, K. Loftus, and K. Starzec. 2010. The susceptibility of native grasslands to woody plant encroachment: A study of *Juniperus virginiana.* In: *A Report of the Natural Resources and Environmental Sciences*, Kansas State University. pg. 1-24.

Rollings, W. H. 1995. Living in a graveyard: Native Americans in colonial Arkansas. In: J. Whayne (Compiler), Cultural Encounters in the Early South. University of Arkansas Press, Fayetteville, Arkansas, pg. 208.

Savage, V. M., J. F. Gillooly, J. H. Brown, G. B. West, and E. L. Charnov. 2004. Effects of Body size and temperature on population growth. *The American Naturalist*, 163(3):429-441.

Sax, D. F. and S. D. Gaines. 2003. Species diversity: from global decreases to local increases. *Trends in Ecology and Evolution*, 18(11): 561-566.

Say, T. 1823. Long's Expedition to the Rocky Mountains. In: E. James, editor. *Account of an expedition from Pittsburgh to the Rocky Mountains. (Long's expedition to Rocky Mountains).* Longman, Hurst, Rees, Orme, and Brown, London. pp. 2-252.

Schoolcraft, H. R. 1821. Journal of a tour into the interior of Missouri and Arkansaw [sic] … performed in the year 1818 and 1819. Richard Phillips and Company, London. pg. 102.

Schrank, G. D. and R. E. Ballinger. 1973. Male reproductive cycles in two species of lizards (*Cophosaurus teanus* and *Cnemidophorus gularis*). *Herpetologica*, 29:289-293.

Sexton, O. J., R. M. Andrews, and J. E. Bramble. 1992. Size and growth rate characteristics of a peripheral population of *Crotaphytus collaris* (sauria: Crotaphytidae). *Copeia*, 4:968-980.

Smith, D. M., R. M. May, R. Pellew, and T. H. Johnson. 1993. Estimating extinction rates. *Nature, London*, 364:494-496.

Smith, N. M. and W. W. Tanner. 1974. A taxonomic study of the western collared lizards, *Crotaphytus collaris* and *Crotaphytus insularis*. *Brigham Young University Science Bulletin*, 19(4):1-29.

Stejneger, L. 1890. Results of a biological survey of the San Francisco Mountain region and Desert of the Little Colorado, Arizona. Part V. Annotated list of reptiles and batrachians collected by Dr. C. Hart Merriam and Vernon Bailey on the San Francisco Mountain Plateau. *North American Fauna,* 3:103-118.

Stejneger, L. and T. Barbour. 1933. *A checklist of North American amphibians and reptiles*. Harvard Univ. Press. Cambridge, Mass., pg. 125.

Tabachnik, B. G. and L. S. Fidell. 1989. *Using multivariate statistics, 3rd Edition*. Harper and Row, New York. pg. 746.

Templeton, A. R. 1982. Adaptation and the integration of evolutionary forces. In: R. Milkman, editor, *Perspectives on Evolution*. Sinauer, Sunderland, Maryland. pp. 15-31.

Templeton, A. R., K. Shaw, E. Routman, and S. K. Davis. 1990. The genetic consequences of habitat fragmentation. *Annals of the Missouri Botanical Garden*, 77(1):13-27.

Templeton, A. R., R. J. Robertson, J. Brisson, and J. Strasburg. 2001. Disrupting evolutionary processes: The effect of habitat fragmentation on collared lizards in the Missouri Ozarks. *Proceedings of the National Academy of Sciences of the United States of America, 98*(10):5426-5432.

Templeton, A. R., H. Brazeal, and J. L. Neuwald. 2011. The transition from isolated patches to a meta-population in the eastern collared lizard in response to prescribed fires. *Ecology*, 92:1736–1747.

Tews, J., U. Brose, V. Grimm, K. Tielborger, M. C. Wichmann, M. Schwager, and F. Jeltsch. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *Journal of Biogeography*, 31:79-92.

Thomas, C. D. 1990. What do real population dynamics tell us about minimum viable population sizes? *Conservation Biology*, 4(3):324-327.

Tinkle, D. W. 1961. Geographic variation in reproduction, size, sex ratio and maturity of *Sternothaerus odoratus* (Testudinata: Chelydridae). *Ecology,* 42:68-76.

Tinkle, D. W. 1969. The concept of reproductive effort and its relation to the evolution of life histories of lizards. *American Naturalist,* 103:501-516.

Trauth, S. E. 1970. *Demography and reproduction of the eastern collared lizard, Crotaphytus collaris collaris, from northern Arkansas*. Master's Thesis. University of Arkansas, Fayetteville.

Trauth, S. E. 1978. Ovarian cycle of *Crotaphytus collaris (*Reptilia, lacertilia, iguanidae) from Arkansas with emphasis on corpora albicantia, follicular atresia, and reproductive potential. *Journal of Herpetology,* 12:461-470.

Trauth, S. E. 1979. Testicular cycle and timing of reproduction in the collared lizard (*Chrotaphytus collaris*) in Arkansas. *Herpetologica,* 35:184-192.

Trauth, S. E. 1989. Distributional survey of the eastern collared lizard, *Crotaphytus collaris collaris* (squamata: Iguanidae), within the Arkansas River Valley of Arkansas. *Proceedings of the Arkansas Academy of Science,* 43:101-104.

Trauth, S. E., C. T. McAllister and W. Chen. 1994. Microscopic eggshell characteristics in the collared lizard, *Chrotaphytus collaris* (sauria: Crotaphytidae). *Southwestern Naturalist,* 39, 45-52.

Trauth, S. E., H.W. Robinson, and M. V. Plummer. 2004. *The Amphibians and Reptiles of Arkansas.* The University of Arkansas Press.

Trauth, S. E. 2011. Winter/Spring precipitation in Northern Arkansas and rapid reservoir inundation: Historic case of the eastern collared lizard, *Crotaphytus collaris*. *Journal of the Arkansas Academy of Science*, 65:1-5.

Wilson, E. O. 1992. *The Diversity of Life*, Norton, New York.

Vance, V. J., A. M. Richardson, and R. B. Goodrich. 1965. Brightness discrimination in the collared lizard. *Science*, 147(3659): 758-759.

Zandt, P. A., E. Collins, J. B. Losos, and J. M. Chase. 2005. Implications of food web interactions for restoration of Missouri Ozark glade habitats. *Restoration Ecology*, 13(2):312-317.

Zucker, N., and W. Boecklen. 1990. Variation in female throat coloration in the tree lizard (*Urosaurus ornatus*) relation to reproductive cycle and fecundity. *Herpetologica*, 46:387-394.

Table 1. GPS Coordinates for each site. A represents absence of lizards and P represents presence of lizards. Sites with stars (**) were part of the distributional survey of 2010, but are not part of my habitat thesis study.

Site Name	Presence	Longitude	Latitude
Beaver Quarry	A	-93.84550594720	36.41730042210
Bull Shoals**	A	-92.55822346250	36.40054626250
Calico Rock (W)	P	-92.17098165670	36.11778968080
Calico Rock (SW)	P	-92.18538590650	36.10241887110
Flippin Quarry	P	-92.62664847620	36.28637698100
Fort Chaffee	A	-94.04378872710	35.22087731610
Harrison Quarry**	A	-93.00572715120	36.16601245960
Leatherwood	P	-93.75081395490	36.44233059700
Lost Bridge	A	-93.89870113210	36.39999125540
Monarch**	A	-92.81471360180	36.36069761150
Mountain Home	A	-92.40738091500	36.33075231470
Mount Magazine	A	-93.68029700460	35.16273640600
Old Joe	A	-92.23606743940	36.17890241460
Petit Jean	P	-92.94675917600	35.09804070470
Prairie View	P	-93.54005352320	35.30562161620
Pruitt	P	-93.14365837830	36.06541480390
Rush	P	-92.56701586960	36.13273812940
Shipp's Ferry	A	-92.35958907740	36.21225540290
Turkey Mountain	A	-92.46027367760	36.15854587770
Wedington	A	-94.38668310000	36.11521550000

Table 2. Principal Components Analysis results for environmental variables including eigenvalues and eigenvectors for all five components. Cumulative variances are bolded along with the strongest variables for each component.

Principle Components Analysis				
	PC-1	**PC-2**	**PC-3**	**PC-4**
Variance Extracted				
Eigenvalues	1.838	0.901	0.829	0.432
% Variance	45.955	22.531	20.713	10.800
% Cum Variance	**45.955**	**68.486**	**89.200**	**100.000**
P-Values	0.097	0.985	0.482	0.621
Environmental Variable Eigenvectors				
Air Temp	**0.6329**	0.0590	0.0888	**-0.7669**
Wind Speed	0.5830	**0.6535**	-0.4229	0.2327
Humidity	-0.5229	**0.6780**	0.4996	-0.1313
Altitude	**-0.6990**	0.1066	**-0.6273**	-0.3264

Table 3. Principal components analysis coordinate scores for each site for environmental variables. Bolded sites (the first 8 sites) are sites with lizard populations present.

Site Name	**PC-1**	**PC-2**	**PC-3**	**PC-4**
Leatherwood	-0.7788	0.0590	0.4300	-0.4569
Pruitt	0.0557	-1.9696	-0.4958	0.1729
Rush	-0.5371	-0.2157	0.1792	0.8648
Prairie View	0.6389	0.3819	1.2144	0.0706
Petit Jean	0.8277	-0.7506	0.8569	-0.5656
Flippin	0.1594	-0.2035	0.3706	-1.1836
Calico (W)	1.8408	0.7034	-0.0560	-0.1475
Calico (SW)	0.9557	0.4327	0.3681	0.2516
Shipp’s Ferry	0.8313	-0.6433	0.7607	-0.3942
Old Joe	0.5202	0.7299	0.3442	-0.1122
Mt. Home	0.6735	0.3873	-0.9765	0.7225
Beaver Quarry	0.1350	-1.9595	-1.0833	0.4212
Lost Bridge	-2.9248	0.7512	0.5453	1.3442
Wedington	-0.2446	-0.5816	-1.1911	0.1033
Turkey Mt.	-1.1446	0.2004	1.5867	0.0309
Mt. Magazine	-3.0600	0.8434	-1.4930	-1.3458
Ft. Chaffee	2.0516	1.8352	-1.3602	0.2234

Table 4. Daubenmire cover class midpoint percent habitat data for canopy cover and ground cover (Rock, Plant, Soil, and Coarse Woody Debris) for each site. Present sites are bolded.

Site Name	Canopy (percent)	Rock (percent)	Plant (percent)	Soil (percent)	CWD (percent)
Leatherwood	37.5	62.5	15	37.5	2.5
Pruitt	37.5	37.5	37.5	15	2.5
Rush	15	62.5	37.5	2.5	2.5
Prairie View	2.5	62.5	37.5	15	2.5
Petit Jean	15	85	15	2.5	2.5
Flippin	15	62.5	2.5	15	2.5
Calico (W)	15	62.5	15	15	2.5
Calico (SW)	15	62.5	37.5	15	15
Shipp's Ferry	15	37.5	15	37.5	15
Old Joe	2.5	62.5	15	37.5	2.5
Mt. Home	15	37.5	15	37.5	2.5
Beaver Quarry	37.5	37.5	37.5	37.5	15
Lost Bridge	62.5	37.5	15	15	2.5
Wedington	62.5	37.5	37.5	15	15
Turkey Mt.	62.5	37.5	37.5	37.5	2.5
Mt. Magazine	37.5	62.5	15	15	2.5
Ft. Chaffee	37.5	62.5	15	15	2.5

Table 5. Daubenmire cover classes for canopy cover and ground cover (Rock, Plant, Soil, and Coarse Woody Debris) averaged for each site. Present sites are bolded.

Site Name	**Canopy**	**Rock**	**Plant**	**Soil**	**CWD**
Leatherwood	3	4	2	3	1
Pruitt	3	3	3	2	1
Rush	2	4	3	1	1
Prairie View	1	4	3	2	1
Petit Jean	2	5	2	1	1
Flippin	2	4	1	2	1
Calico (W)	2	4	2	2	1
Calico (SW)	2	4	3	2	2
Shipp's Ferry	2	3	2	3	2
Old Joe	1	4	2	3	1
Mt. Home	2	3	2	3	1
Beaver Quarry	3	3	3	3	2
Lost Bridge	4	3	2	2	1
Wedington	4	3	3	2	2
Turkey Mt.	4	3	3	3	1
Mt. Magazine	3	4	2	2	1
Ft. Chaffee	3	4	2	2	1

Table 6. Principal Components Analysis results including eigenvalues and eigenvectors for all five components. Cumulative variance is bolded, along with significant PC-1 p-value for emphasis. Strongest correlated variables for each component are bolded as well.

Principle Components Analysis					
	PC-1	**PC-2**	**PC-3**	**PC-4**	**PC-5**
Variance Extracted					
Eigenvalues	2.149	1.144	0.951	0.509	0.247
% Variance	42.974	22.876	19.016	10.188	4.946
% Cum Variance	**42.974**	**65.85**	**84.866**	**95.054**	**100.00**
P-Values	**0.041***	0.849	0.509	0.874	0.88
Habitat Variable Eigenvectors					
Tot Can	**0.4289**	0.0664	**0.7280**	-0.3156	**0.4267**
Rock	**-0.6063**	0.1977	-0.1481	-0.1135	**0.7474**
Soil	0.3747	**0.6449**	-0.1287	**0.6215**	0.2022
Plant	0.3493	**-0.7016**	-0.2776	0.3100	**0.4610**
CWD	**0.4314**	0.2197	**-0.5954**	**-0.6365**	0.0772

Table 7. Principal components analysis coordinate scores for each site. Bolded sites (the first 8 sites) are sites with lizard populations present.

Site	PC-1	PC-2	PC-3	PC-4	PC-5
Leatherwood	-0.2369	-1.3278	0.3058	0.9060	1.0692
Pruitt	0.8869	0.8011	0.8241	0.8951	-0.6852
Rush	-1.0114	1.7725	0.0076	0.7498	-0.3390
Prairie View	-0.9351	1.0260	-0.7363	1.2626	-0.1491
Petit Jean	-2.6606	0.8764	0.0164	-0.5895	0.4527
Flippin	-1.7504	-0.8068	0.1032	-0.7461	-0.4644
Calico (W)	-1.3613	-0.1371	-0.0304	-0.1008	-0.2544
Calico (SW)	0.3560	1.5865	-1.6746	-0.4397	0.3055
Shipp's Ferry	1.3409	-1.2300	-1.6778	-0.8440	-0.5395
Old Joe	-1.0046	-1.4467	-0.9971	0.6609	0.3055
Mt. Home	0.3239	-1.7481	-0.2743	0.6566	-0.7214
Beaver Quarry	2.5347	0.0519	-1.0809	-0.0455	0.3294
Lost Bridge	0.7350	-0.3195	1.9954	-0.6700	-0.5177
Wedington	2.4522	1.4041	0.3511	-1.0090	0.0422
Turkey Mt.	2.0662	-0.3812	1.2534	1.0516	0.6930
Mt. Magazine	-0.8677	-0.0606	0.8072	-0.4639	0.2365
Ft. Chaffee	-0.8677	-0.0606	0.8072	-0.4639	0.2365

Table 8. One way analysis of variance on Principal Components 1 and 2 of my habitat analysis by present and absent groups. PC-1 had a significant p-value while PC-2 did not. Explained variation is bolded along with p-values.

Summary of ANOVA on PCA scores					
PC-1					
ANOVA	DF	SS	MS	F-Ratio	Prob>F
PA	1	10.639	10.639	6.1645	**0.0253**
Error	15	25.889	1.726		
C. Total	16	36.528			
Summary of Fit					
R square	0.2913				
Adj R square	**0.244**				
Observations (N)	17				
PC-2					
ANOVA	DF	SS	MS	F-Ratio	Prob>F
PA	1	3.3929	3.3929	3.1706	**0.0952**
Error	15	16.0516	1.07011		
C. Total	16	19.4445			
Summary of Fit					
R square	0.1745				
Adj R square	**0.1195**				
Observations (N)	17				

Table 9. Tree structure for present versus absent sites. Abbreviations include RD = Relative Density, AD = Absolute Density, ABA = Absolute Basal Area, RBA = Relative Basal Area, IV = Importance Value Index.

PRESENT Site	RD	AD stems/ha	Avg ABA	RBA	IV
Eastern Red Cedar	46	106.25	0.1127	62.3	54.1
Oak	25	56.25	0.0997	29.17	26.8
Pine	24	56.25	0.026	7.6	16
Other Deciduous	5	12.5	0.0142	0.93	3.1
Maple	0	0	0	0	0
Ash	0	0	0	0	0
Chinquapin Oak	0	0	0	0	0
Hickory	0	0	0	0	0
Total	100	231.25	0.2526	100	100
ABSENT Site	**RD**	**AD stems/ha**	**Avg ABA**	**RBA**	**IV**
Eastern Red Cedar	40	161.11	0.1633	33.68	36.4343
Oak	21	88.89	0.306	34.83	28.22623
Pine	0	0	0	0	0
Other Deciduous	23	94.44	0.1519	18.37	20.67294
Maple	8	33.33	0.1785	7.62	7.862562
Ash	1	5.56	0.0608	0.43	0.892004
Chinquapin Oak	3	11.11	0.2112	3.01	2.853859
Hickory	4	16.67	0.0966	2.06	3.058105
Total	100	411.11	1.1683	100	100

Table 10. Results from ANOVA: Frequency of trees, mean DBH and standard error for each mean for each site. Present sites are bolded and overall have a lower frequency of trees and mean DBH.

ANOVA Mean Results Across Sites			
Glade Site	**Tree Frequency**	**Mean DBH**	**Standard Error**
Beaver Quarry	9	9.27	2.37
Calico (SW)	3	11.97	4.10
Calico (W)	8	5.1	2.51
Flippin	3	6.17	4.10
Fort Chaffee	6	15.63	2.90
Lost Bridge	15	11.47	1.83
Leatherwood	6	6.27	2.90
Mountain Home	4	16.43	3.55
Mount Magazine	9	16.34	2.37
Petit Jean	4	5.58	3.55
Prairie View	1	7.40	7.10
Pruitt	8	12.41	2.51
Rush	4	10.75	3.55
Shipp's Ferry	8	7.49	2.51
Turkey Mountain	10	18.35	2.25
Wedington	13	14.28	1.97

Table 11. Results from red cedar DBH ANOVA: Frequency of red cedar trees, mean DBH and standard error averaged for each site. Present sites are bolded. Not all sites are listed because cedar trees did not fall into the measuring plot at some sites.

All Red Cedar Trees DBH ANOVA Mean Results Across Sites			
Site Name	**Tree Frequency**	**DBH Mean**	**Standard Error**
Beaver Quarry	3	2.9	4.03
Flippin	2	7.00	4.94
Lost Bridge	11	9.94	2.11
Leatherwood	4	6.90	3.49
Mountain Home	3	19.60	4.03
Pruitt	8	12.41	2.47
Prairie View	1	7.40	6.98
Rush	2	13.50	4.94
Shipp's Ferry	7	7.96	2.64
Turkey Mountain	5	20.32	3.12

Table 12. One way ANOVA for DBH Size Class. ANOVA grouped by Site for all trees and for cedar trees only. There was a significant p-value for both DBH of all trees and cedar trees only.

Summary of ANOVAs on DBH					
Site—All Trees					
ANOVA	DF	SS	MS	F-Ratio	Prob>F
PA	15	655.4239	655.424	11.8464	**0.0008**
Error	95	6030.6054	55.327		
C. Total	110	6686.0293			
Summary of Fit					
R square	0.2834				
Adj R square	**0.1703**				
Observations (N)	111				
Site—Cedar Trees	DF	SS	MS	F-Ratio	Prob>F
ANOVA					
PA	9	1070.6893	118.965	2.4392	**0.0279**
Error	36	1755.8393	48.773		
C. Total	45	2826.5287			
Summary of Fit					
R square	0.3788				
Adj R square	**0.2235**				
Observations (N)	46				

Table 13. Contingency Table and Pearson Chi Square Tests. Table shows number of trees from present or absent groups in each DBH size class and number of trees from each site in each DBH size class. Present sites are bolded.

DBH Size Class and Presence or Absence								
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**Total**
0 (Absence)	10	24	9	11	12	7	1	74
1 (Presence)	14	14	5	2	0	2	0	37
Total	24	38	14	13	12	9	1	111
Pearson Chi Square	Value	df	p-value					
	15.881	6	0.014					
DBH Size Class and Site								
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**Total**
Beaver Quarry	5	1	1	1	0	1	0	9
Calico (SW)	1	1	0	0	0	1	0	3
Calico (W)	6	1	1	0	0	0	0	8
Flippin	1	2	0	0	0	0	0	3
Fort Chaffee	0	1	0	4	1	0	0	6
Leatherwood	3	2	1	0	0	0	0	6
Lost Bridge	1	8	2	1	2	1	0	15
Mountain Home	0	2	0	0	1	1	0	4
Mount Magazine	0	2	2	1	3	1	0	9
Petit Jean	1	3	0	0	0	0	0	4
Prairie View	0	1	0	0	0	0	0	1
Pruitt	1	3	2	1	0	1	0	8
Rush	1	1	1	1	0	0	0	4
Shipp's Ferry	3	4	0	0	1	0	0	8
Turkey Mountain	1	2	1	1	3	1	1	10
Wedington	0	4	3	3	1	2	0	13
Total	24	38	14	13	12	9	1	111
Pearson Chi Square	Value	df	p-value					
	100.789	90	0.205					

Figure 1. Map of sites across the Eco-regions of Arkansas. Green circles are present sites and red circles are absent sites. Starred labels indicate sites from my 2010 survey, and are not included in the habitat survey.

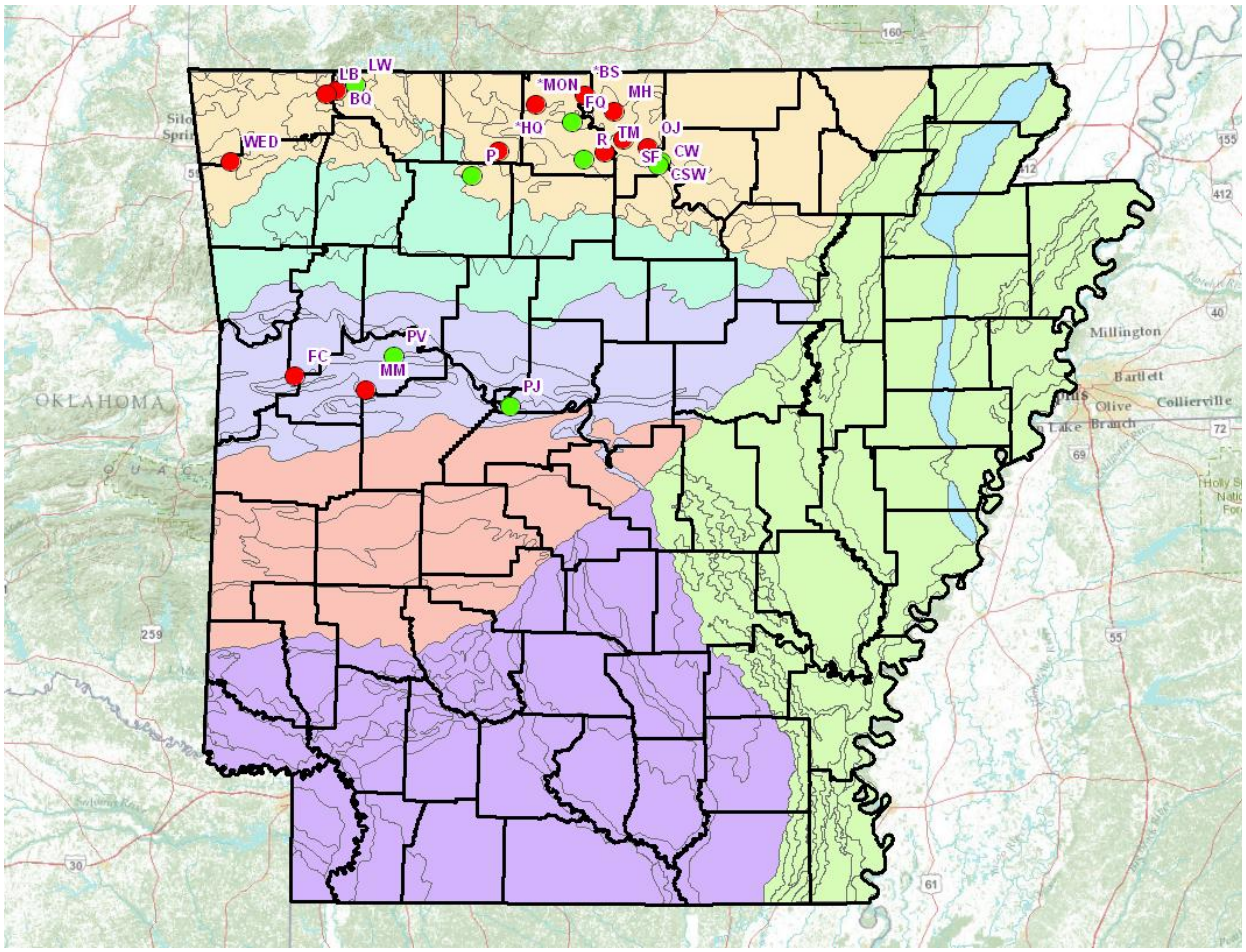

LB
LW
BQ
WED
*MON
*BS
FQ
MH
*HQ
P
R
TM
OJ
SF
CW
CSW
PV
FC
MM
PJ
OKLAHOMA
Millington
Bartlett
Collierville
Olive Branch

Figure 2. Map of sites with a close up view of northwest Arkansas. Green circles indicate present sites and red circle indicate absent sites. Starred labels indicate sites from my 2010 survey, and are not included in the habitat survey.

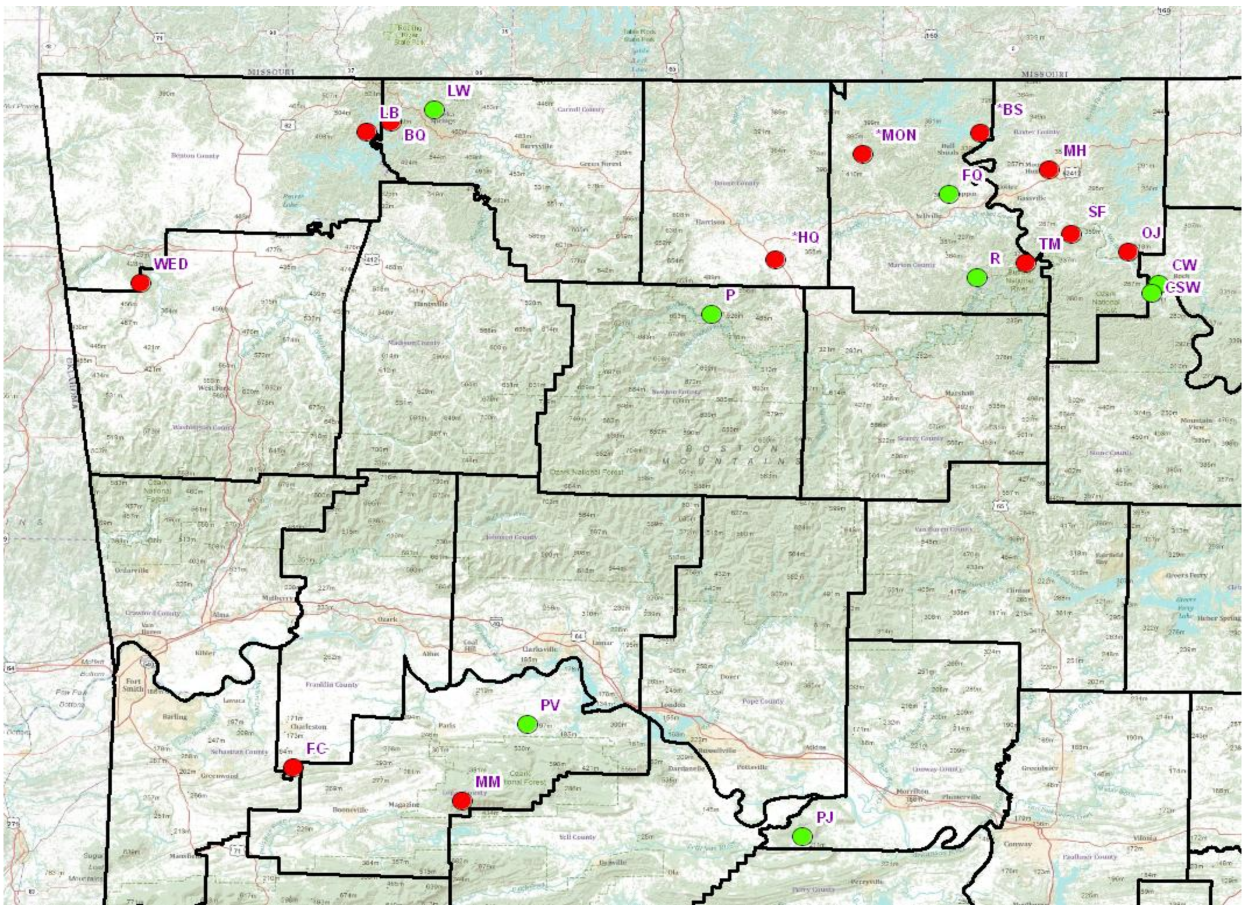

LW
LB
BQ
WED
*MON
*BS
MH
FQ
SF
*HQ
OJ
TM
R
CW
CSW
P
PV
FC
MM
PJ

Figure 3. Example of a habitat survey plot (not to scale). Plot is 20 meters long by 5 meters wide (100 square meters) along a central transect with 2 meter by 2 meter sampling quadrats.

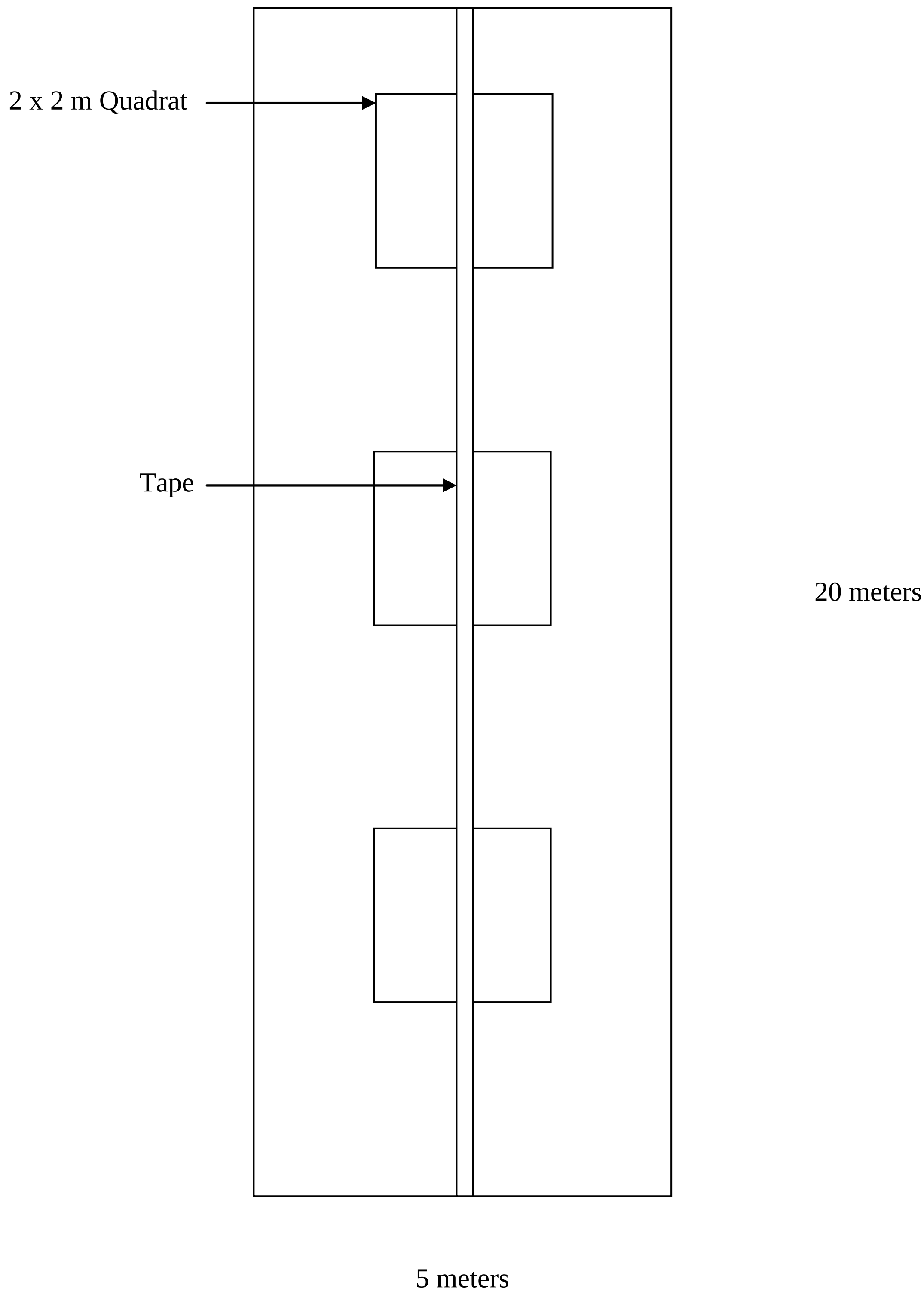

2 x 2 m Quadrat
Tape
20 meters
5 meters

Figure 4. Search time across site. For present sites (red), amount of time to find the first lizard is graphed. For absent sites (blue), amount of time searched without any lizard found is graphed.

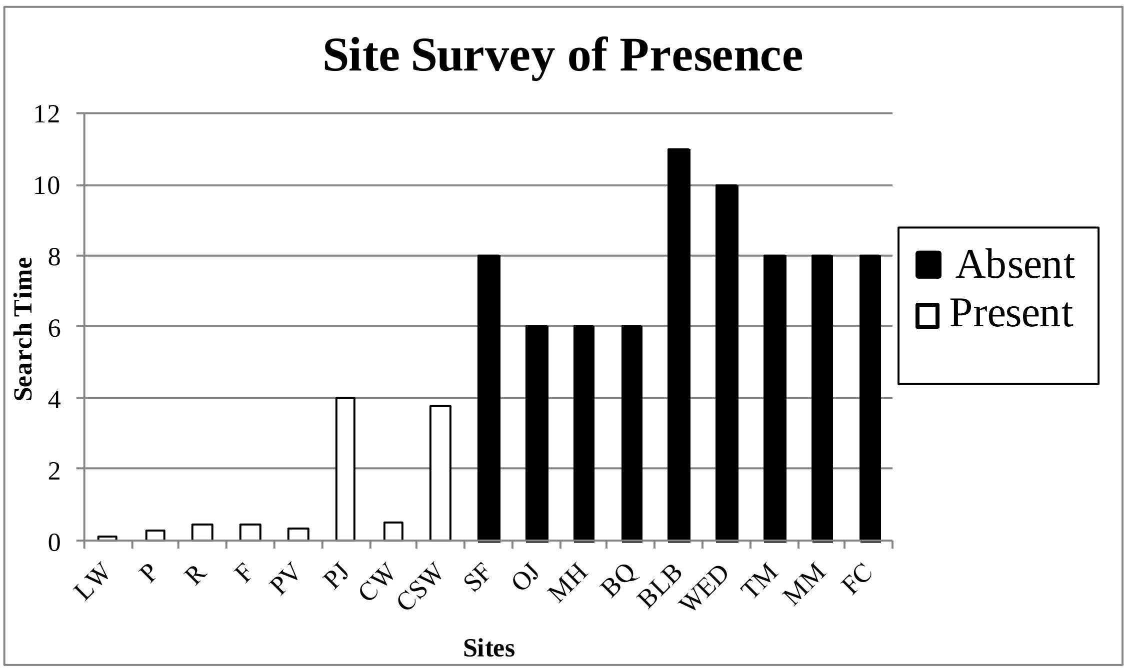
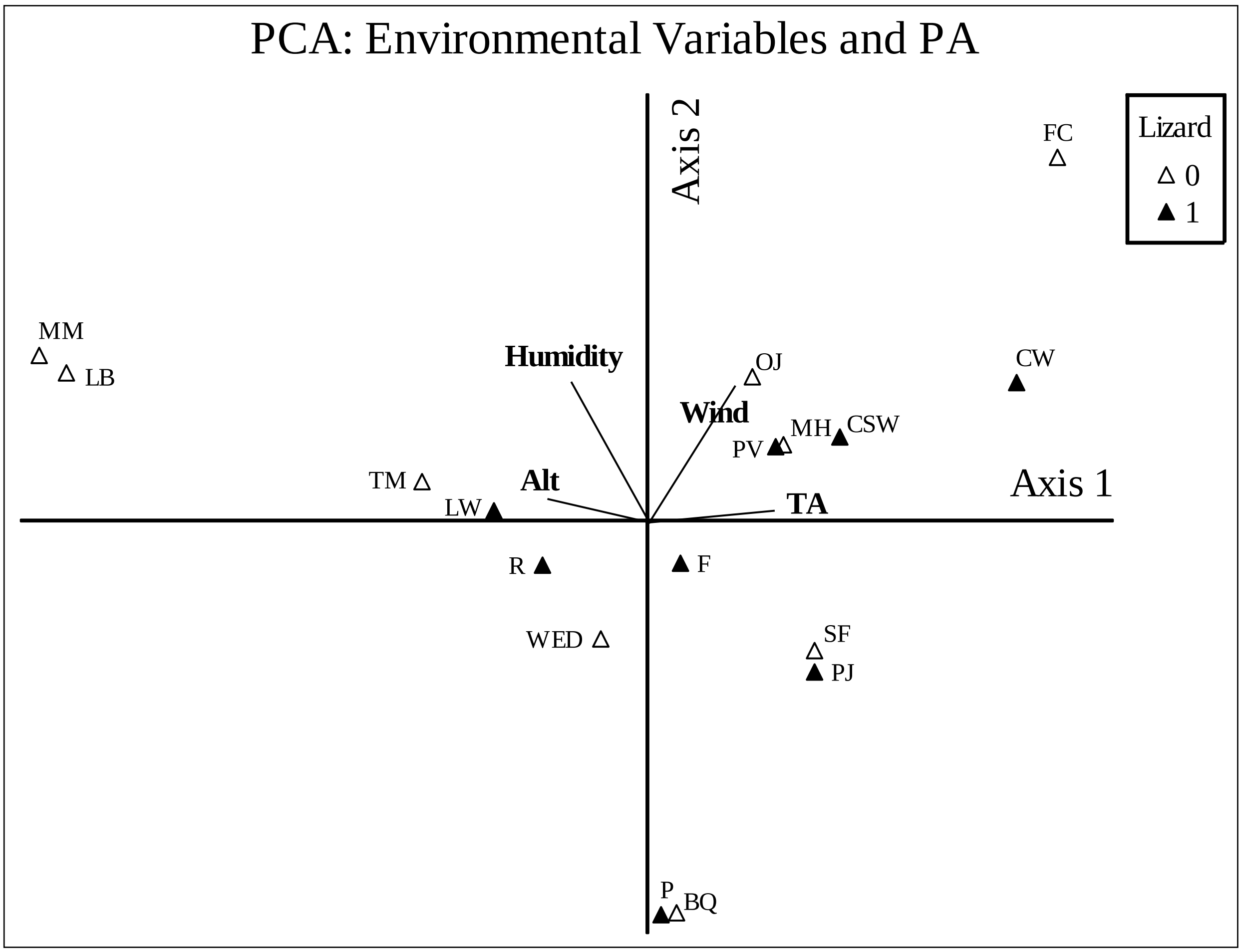
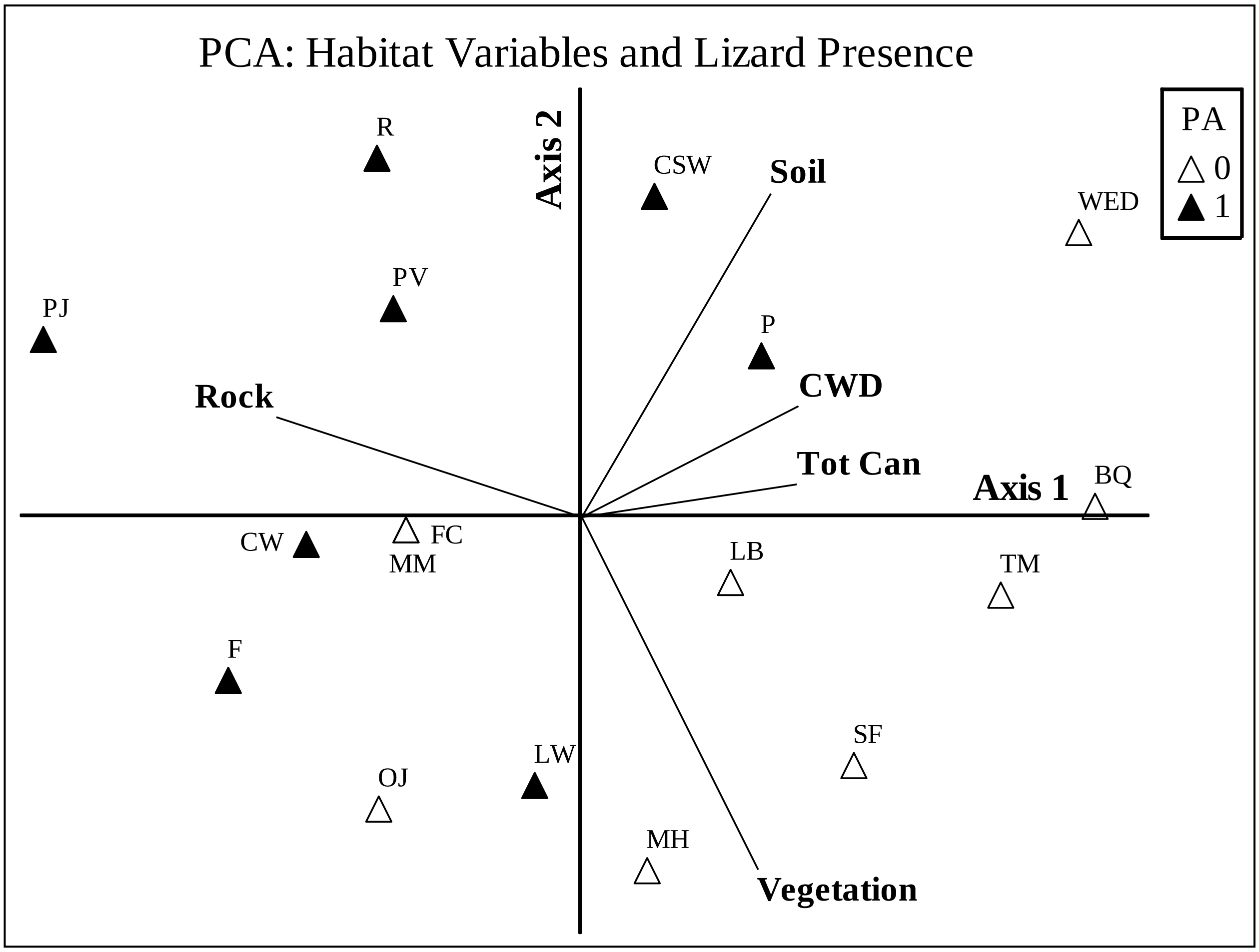

Site Survey of Presence
12
10
8
6
4
2
0
Search Time
LW
P
R
F
PV
PJ
CW
CSW
SF
OJ
MH
BQ
BLB
WED
TM
MM
FC
Sites
Absent
Present

Figure 5. Scatterplot of Environmental PCA: Sites separated in space according to environmental variables. Environmental variables include air temperature, percent humidity, wind speed, and altitude. Present sites are marked with solid triangles and Absent sites are marked with open triangles.



PCA: Environmental Variables and PA
Axis 2
Axis 1
Lizard
0
1
FC
MM
LB
Humidity
OJ
CW
Wind
MH
CSW
PV
TM
Alt
TA
LW
R
F
WED
SF
PJ
P
BQ

Figure 6. Scatterplot of PCA results: Sites separated in space according to habitat variables. Habitat variables include canopy cover and ground cover: open rock, bare soil, vegetation, and coarse woody debris (CWD). Present sites are marked with solid triangles and Absent sites are marked with open triangles.



PCA: Habitat Variables and Lizard Presence
PA
0
1
Axis 1
Axis 2
Soil
CWD
Tot Can
Rock
Vegetation
R
CSW
WED
PV
PJ
P
BQ
CW
FC
MM
LB
TM
F
SF
LW
OJ
MH

Figure 7. Scatterplot of PCA Canopy Cover: Sites separated in space according to habitat variables. Size of triangle indicates amount of canopy cover. Present sites are marked with solid triangles and Absent sites are marked with open triangles.

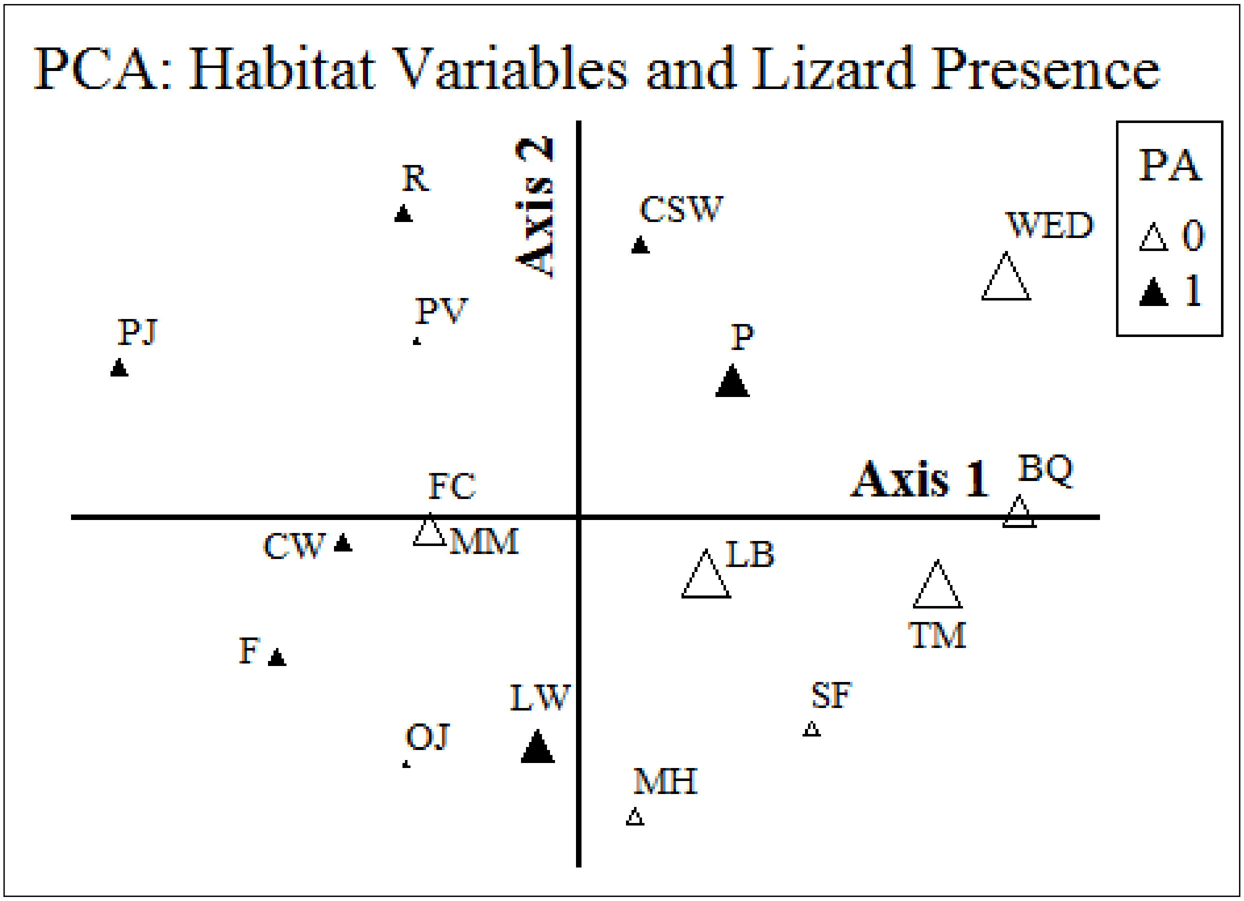

PCA: Habitat Variables and Lizard Presence
Axis 2
Axis 1
PA
0
1
R
CSW
WED
PV
PJ
P
FC
BQ
CW
MM
LB
TM
F
LW
SF
OJ
MH

Figure 8. Scatterplot of PCA Rock Cover: Sites separated in space according to habitat variables. Size of triangle indicates amount of rock cover. Present sites are marked with solid triangles and Absent sites are marked with open triangles.

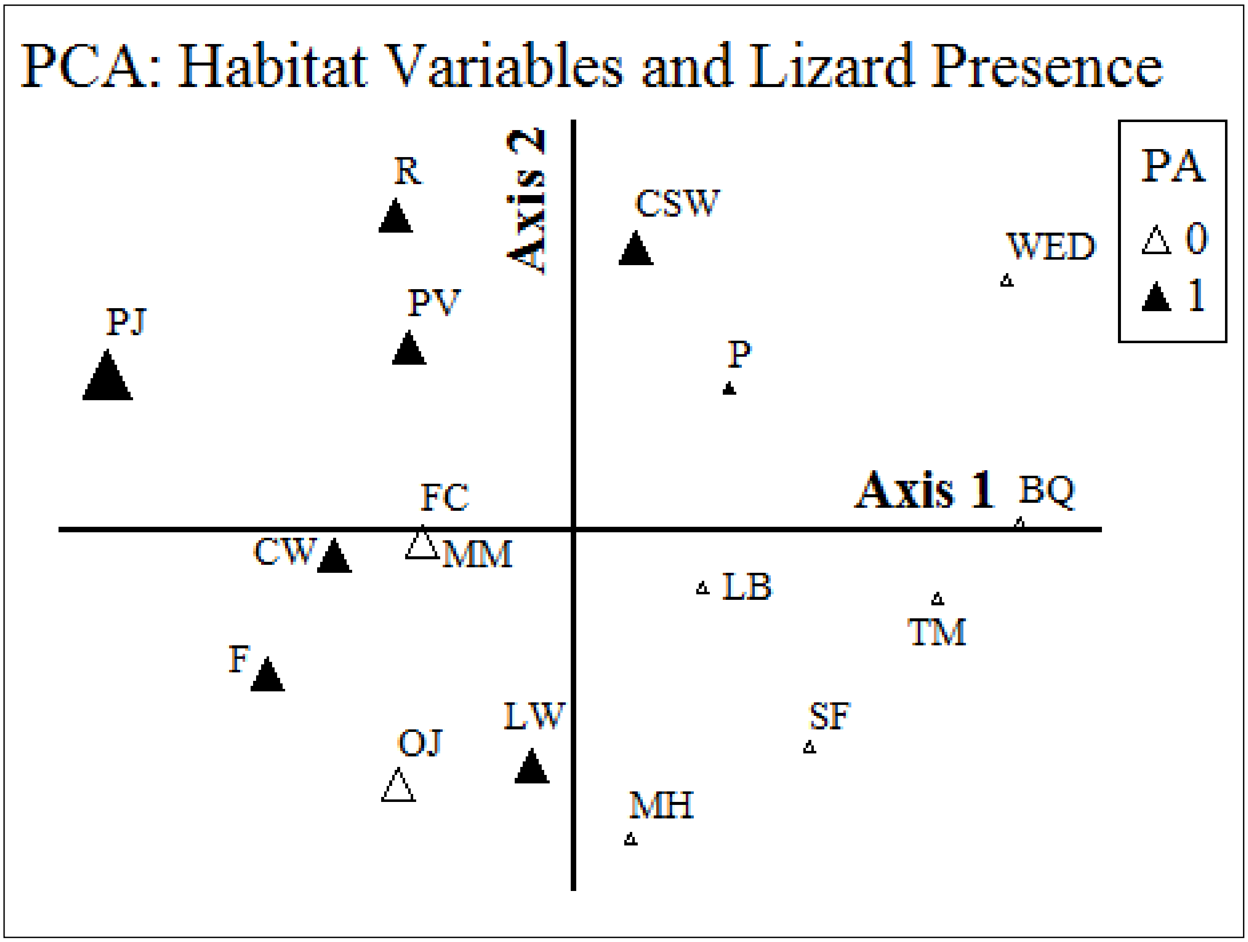
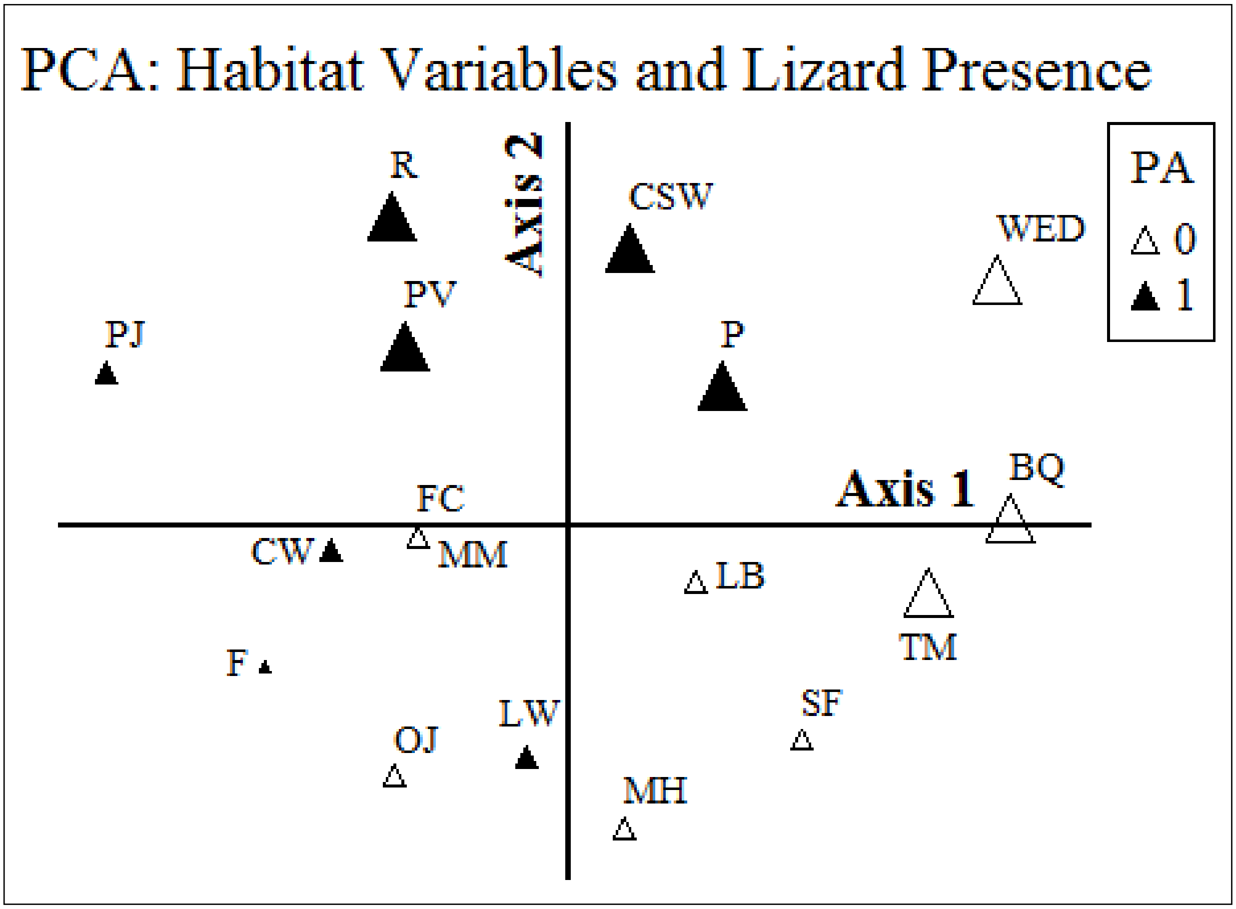

PCA: Habitat Variables and Lizard Presence
Axis 1
Axis 2
PA
0
1
R
CSW
WED
PJ
PV
P
FC
BQ
CW
MM
LB
TM
F
LW
SF
OJ
MH

Figure 9. Scatterplot of PCA Soil Cover: Sites separated in space according to habitat variables. Size of triangle indicates amount of soil cover. Present sites are marked with solid triangles and Absent sites are marked with open triangles.



PCA: Habitat Variables and Lizard Presence
Axis 2
Axis 1
PA
0
1
R
CSW
WED
PV
PJ
P
BQ
FC
CW
MM
LB
TM
F
SF
LW
OJ
MH

Figure 10. Scatterplot of PCA Vegetation Cover results: Sites separated in space according to habitat variables. Size of triangle indicates amount of vegetation cover. Present sites are marked with solid triangles and Absent sites are marked with open triangles.

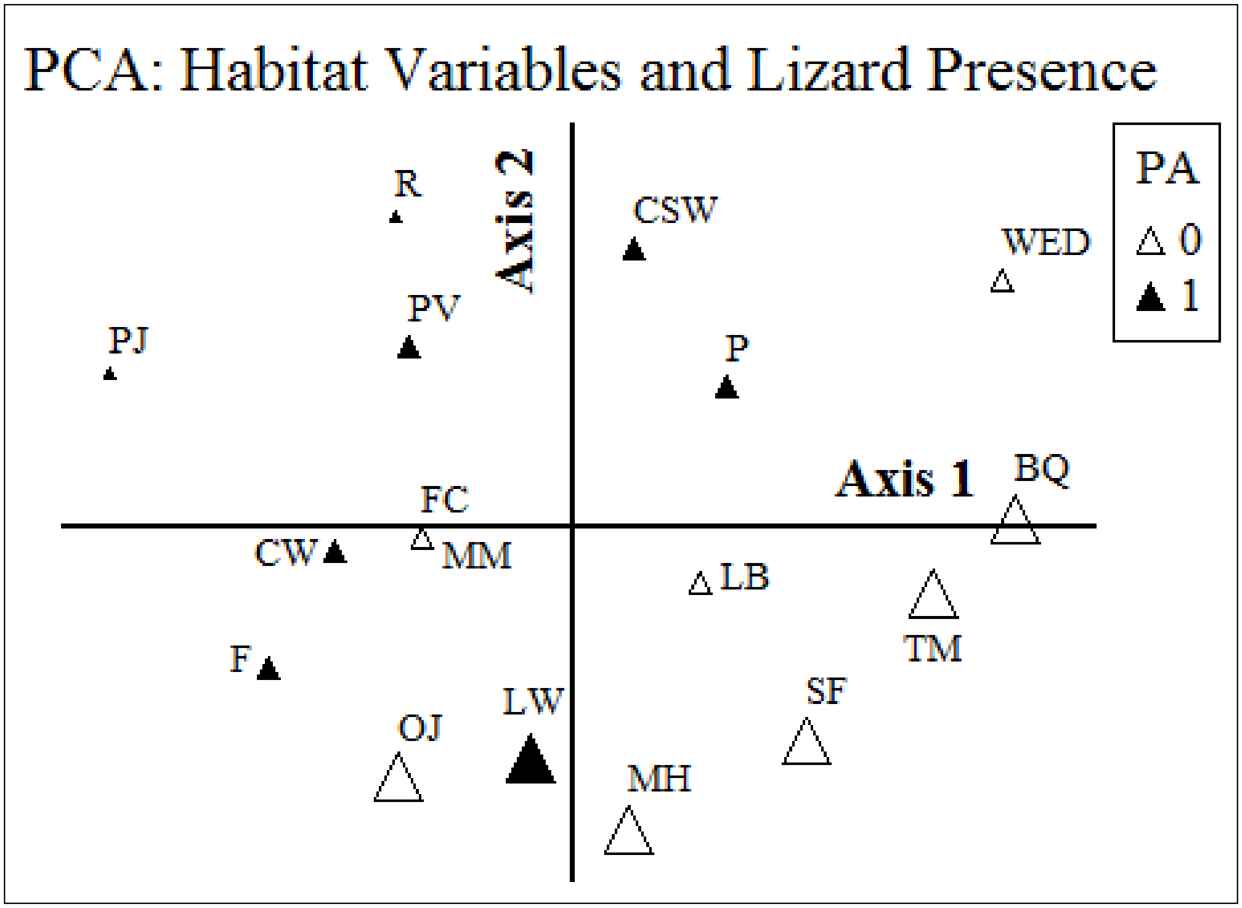

PCA: Habitat Variables and Lizard Presence
Axis 2
Axis 1
PA
0
1
R
CSW
WED
PV
PJ
P
BQ
FC
CW
MM
LB
TM
F
SF
LW
OJ
MH

Figure 11. Scatterplot of PCA Coarse Woody Debris Cover: Sites separated in space according to habitat variables. Size of triangle indicates amount of Coarse Woody Debris cover. Present sites are marked with solid triangles and Absent sites are marked with open triangles.

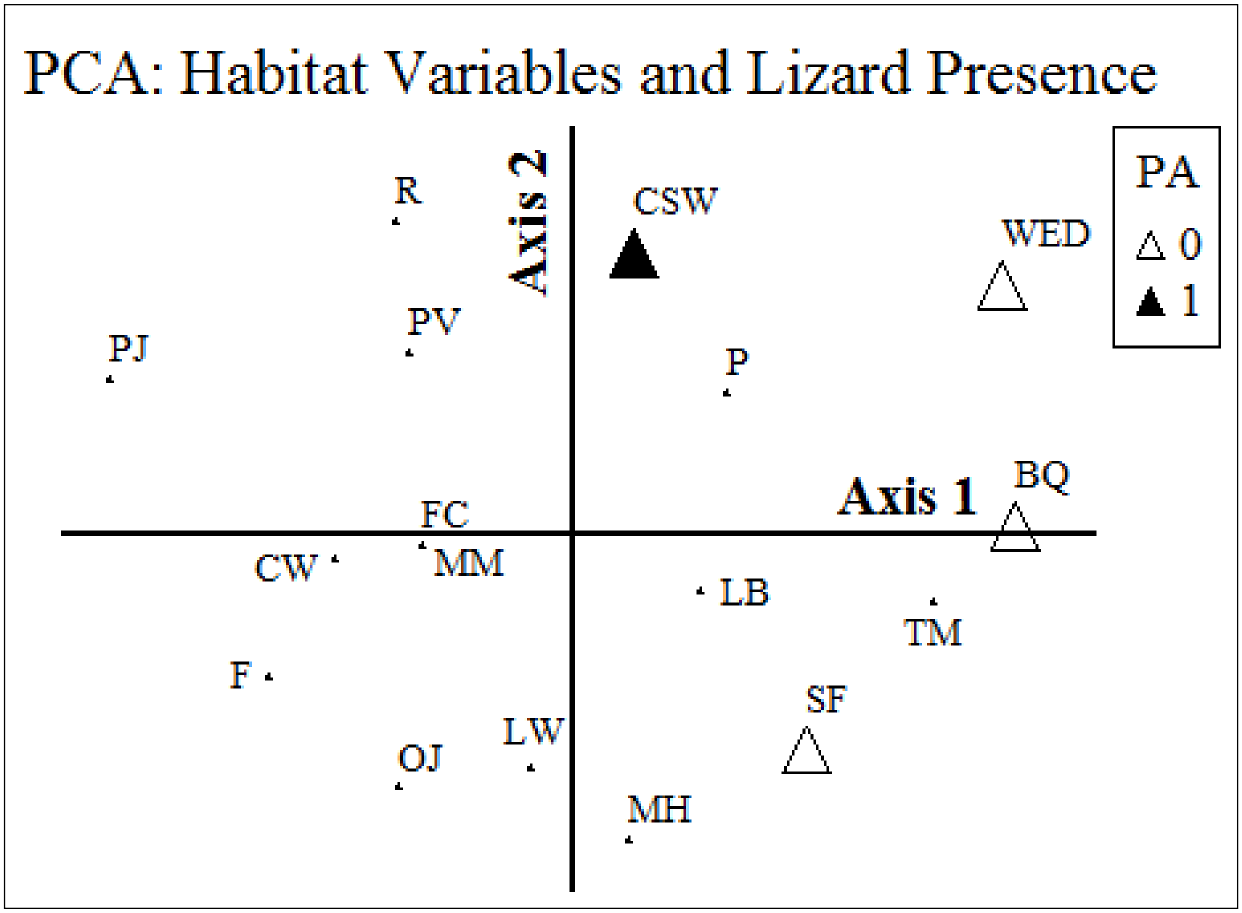
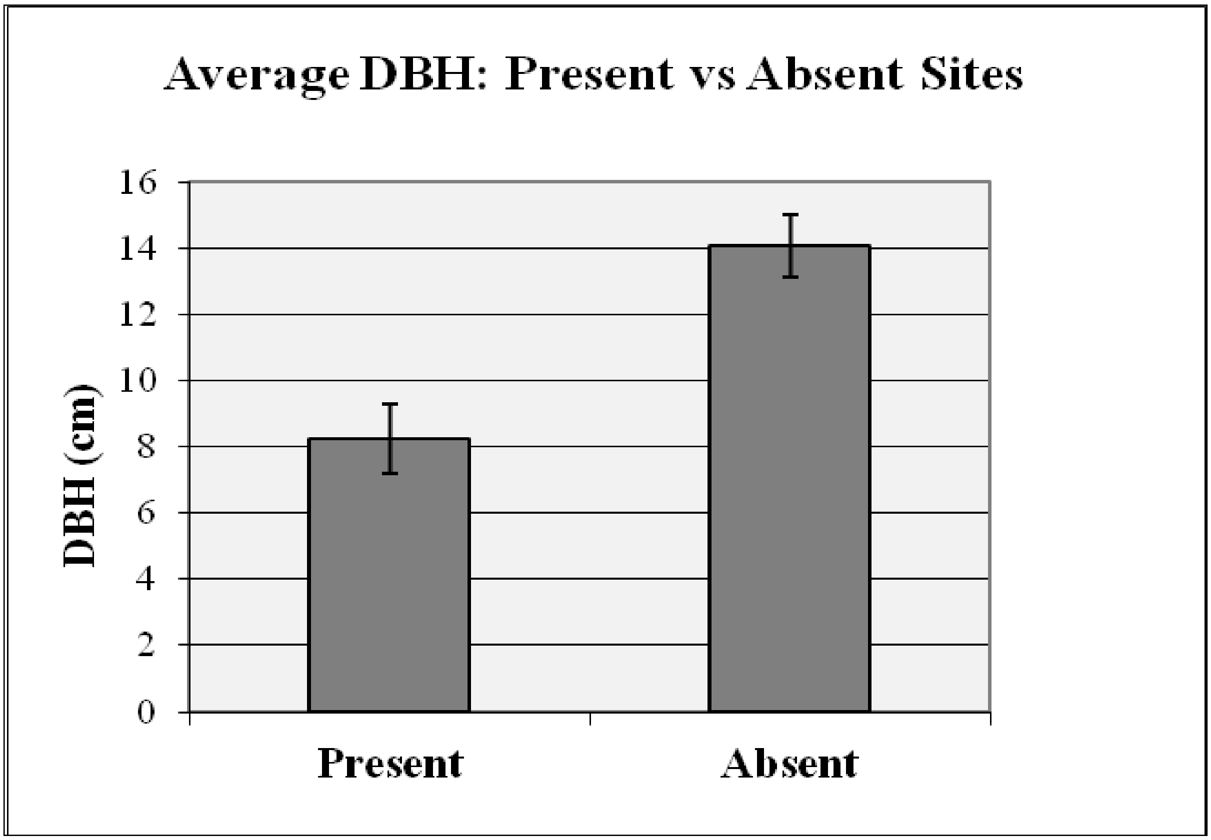

PCA: Habitat Variables and Lizard Presence
Axis 2
Axis 1
PA
0
1
R
CSW
WED
PV
PJ
P
BQ
FC
CW
MM
LB
TM
F
SF
LW
OJ
MH

Figure 12. Mean DBH of trees for all present and all absent sites. Standard error bars are included with values of 2SE: Absent 2SE = 1.8508 and Present 2SE =2.0538. A significant difference in means was found (p = 0.0003).



Average DBH: Present vs Absent Sites
DBH (cm)
0
2
4
6
8
10
12
14
16
Present
Absent

Figure 13. Mean height of trees for all present and all absent sites. Standard error bars are included with values of 2SE: Absent 2SE = 1.89272 and Present 2SE = 0.471. A significant difference in means was found ($p = 0.0039$).

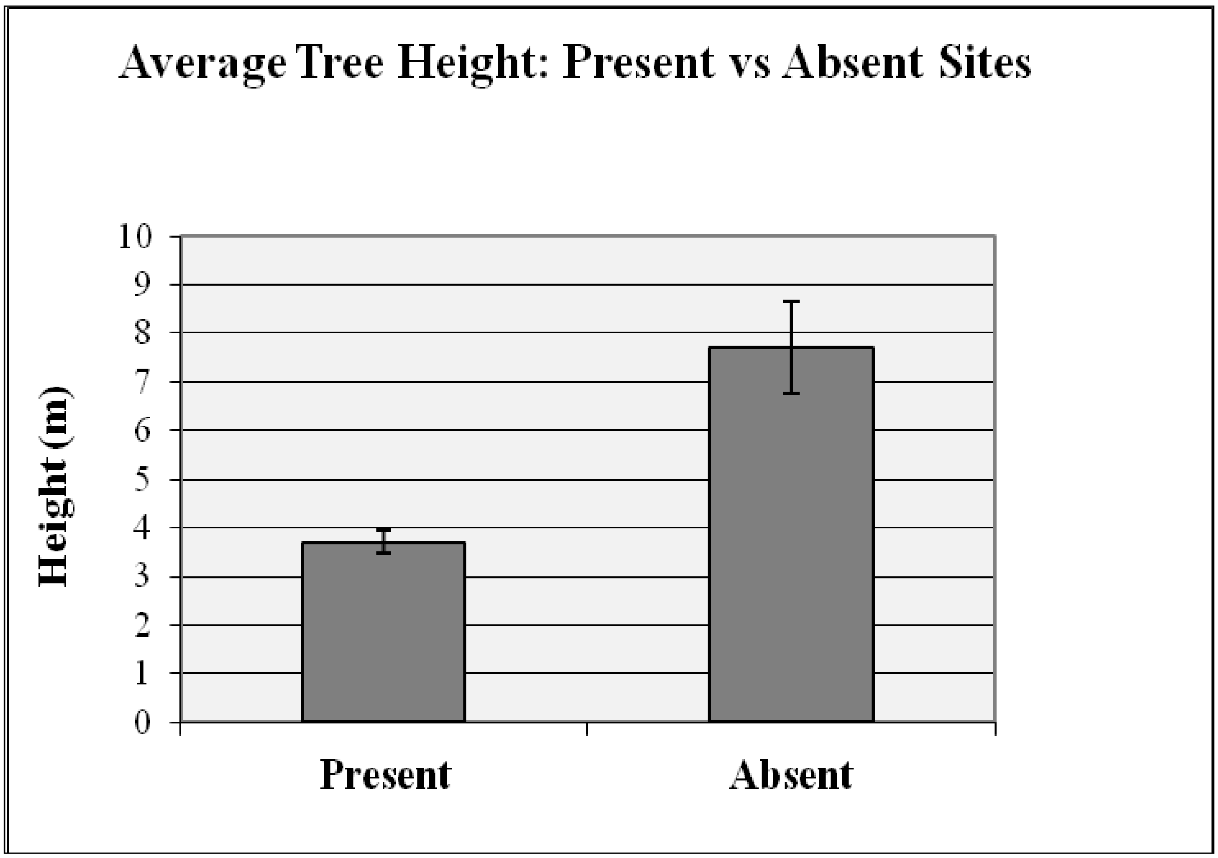
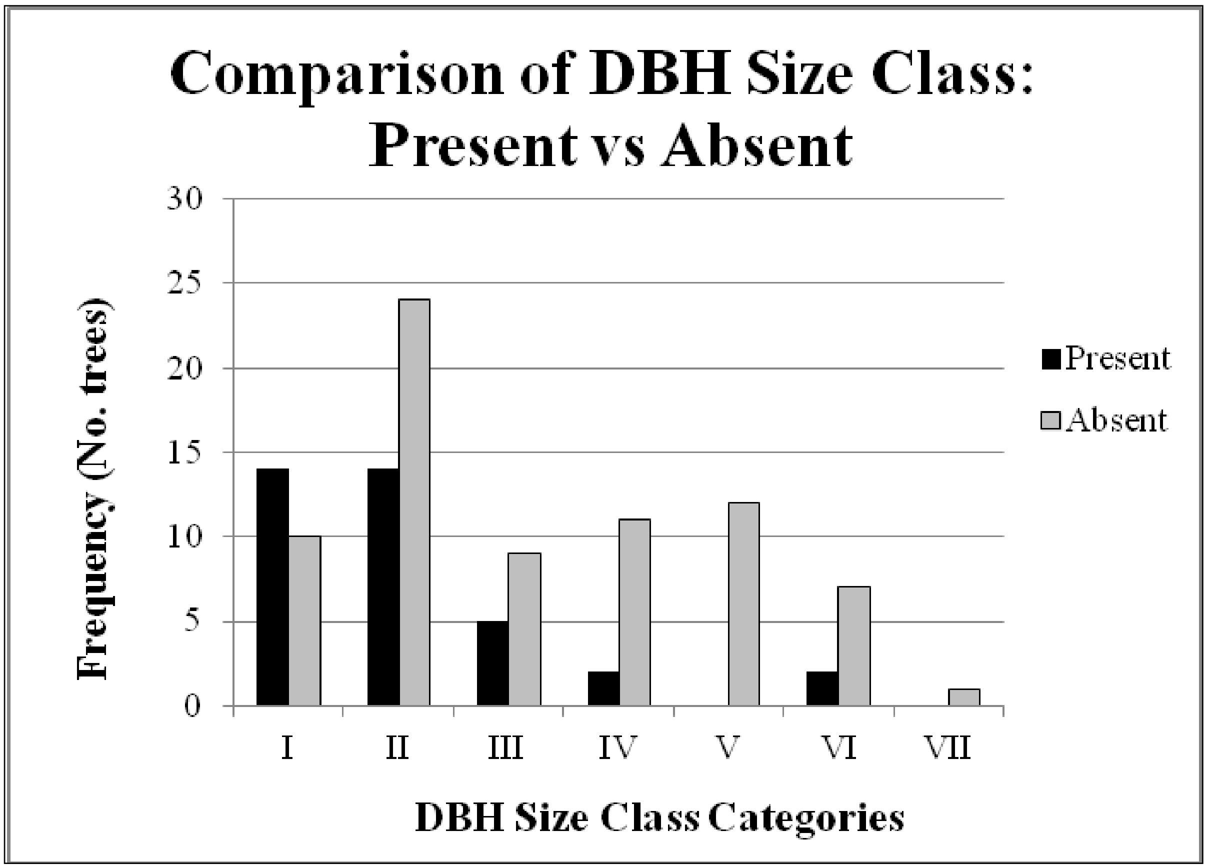

Average Tree Height: Present vs Absent Sites
Height (m)
10
9
8
7
6
5
4
3
2
1
0
Present
Absent

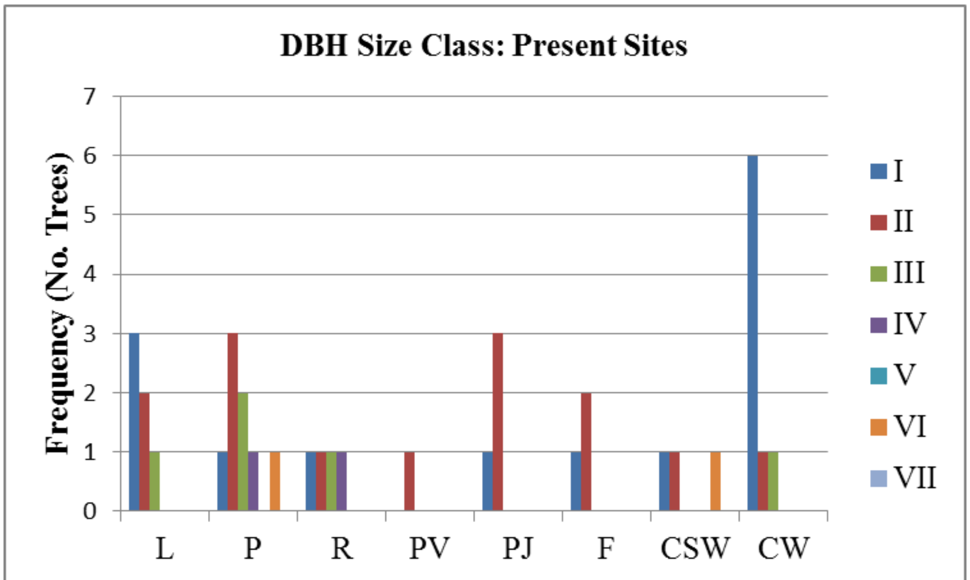
Figure 14. DBH Size Class of Present and Absent Lizard Sites. Frequency of trees in each size class for all present sites averaged (black bars) and all absent sites averaged (gray bars). The DBH size classes included I = 2-4.99 cm, II = 5-9.99 cm, III = 10-14.99 cm, IV = 15-19.99 cm, V = 20-24.99 cm, VI = 25-29.99 cm, and VII = 30-35 cm.



Comparison of DBH Size Class: Present vs Absent
Frequency (No. trees)
30
25
20
15
10
5
0
I
II
III
IV
V
VI
VII
DBH Size Class Categories
Present
Absent

Figure 15. Frequency of trees in each DBH Size Class for each site. Size classes are categorized by color. The DBH size classes include I = 2-4.99 cm, II = 5-9.99 cm, III = 10-14.99 cm, IV = 15-19.99 cm, V = 20-24.99 cm, VI = 25-29.99 cm, and VII = 30-35 cm. Graph A is for Present Sites and Graph B is for Absent Sites.

A.


DBH Size Class: Present Sites
Frequency (No. Trees)
0
1
2
3
4
5
6
7
L
P
R
PV
PJ
F
CSW
CW
I
II
III
IV
V
VI
VII

B.

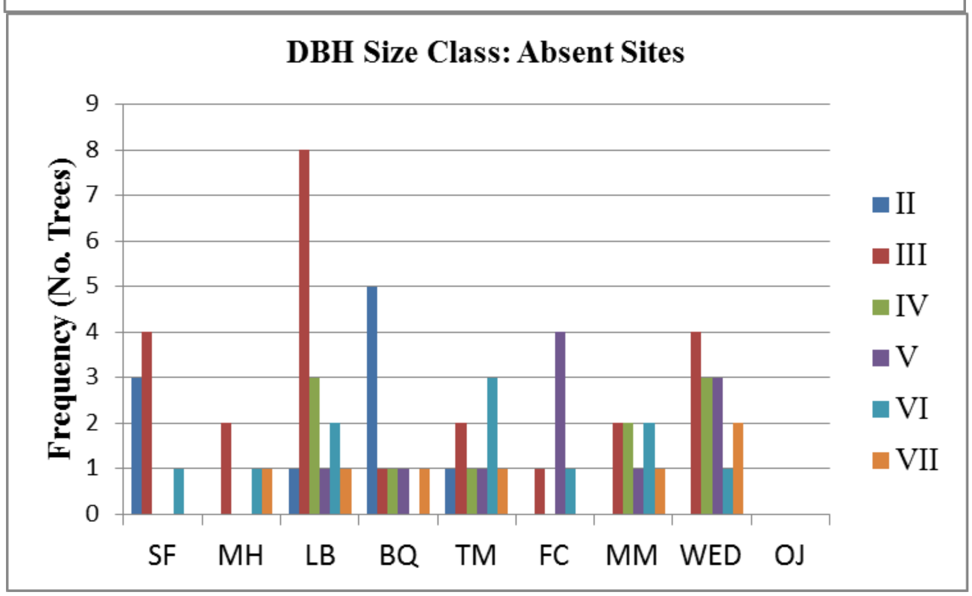
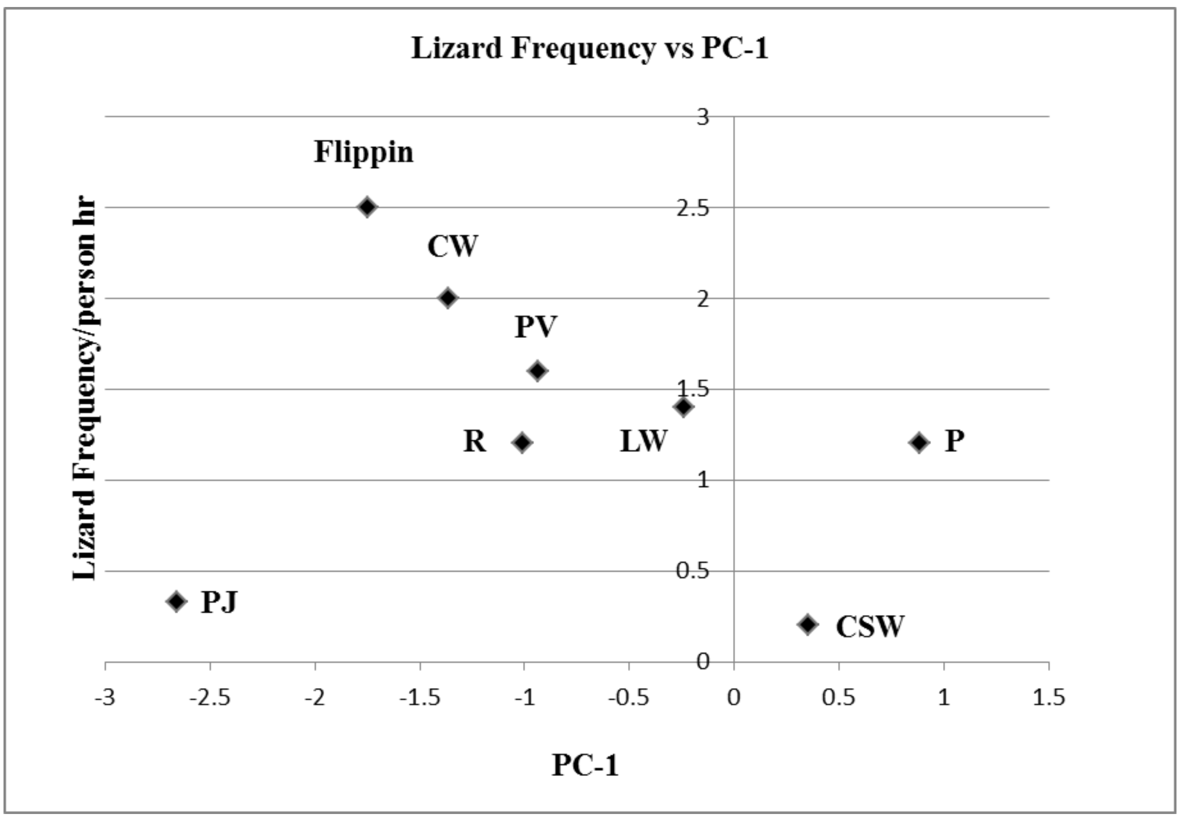
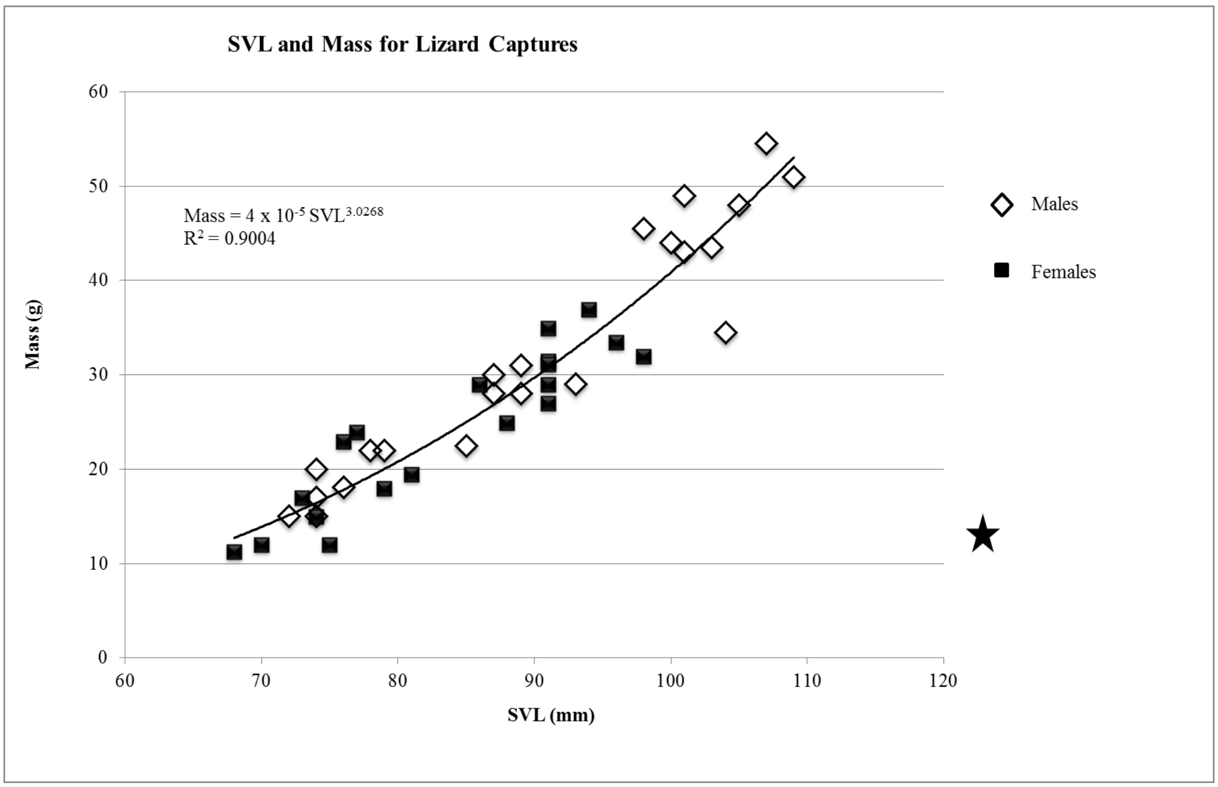

DBH Size Class: Absent Sites
Frequency (No. Trees)
0
1
2
3
4
5
6
7
8
9
SF
MH
LB
BQ
TM
FC
MM
WED
OJ
II
III
IV
V
VI
VII

Figure 16. Lizard frequency per person search hour at each site versus principal component one. Detectability was standardized for each site and plotted against PC-1 from the habitat PCA. More appropriate habitat gives higher detectability.



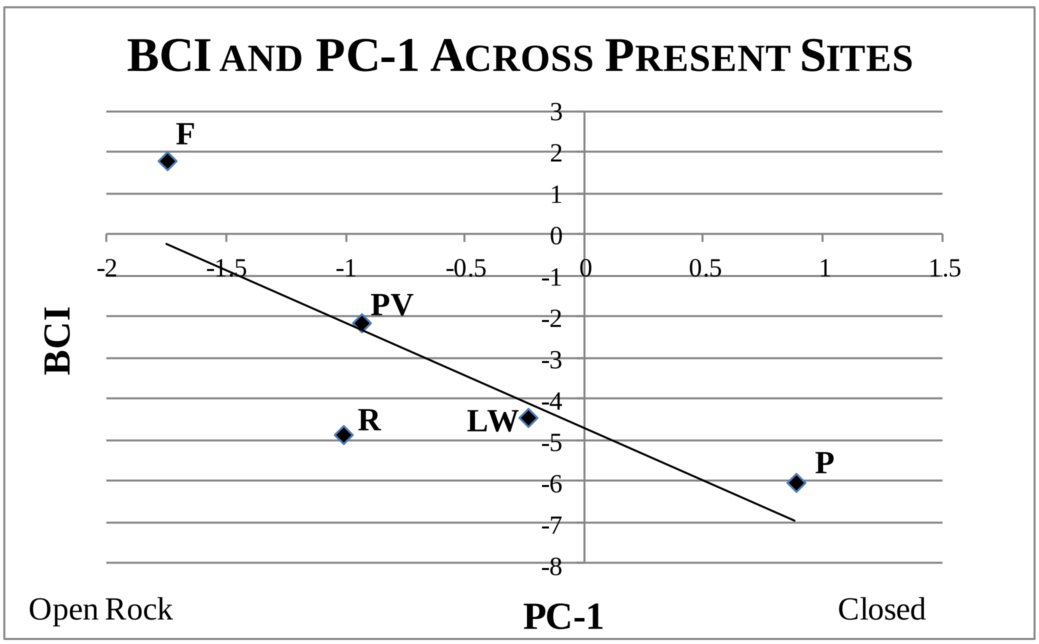
Lizard Frequency vs PC-1
Lizard Frequency/person hr
PC-1
Flippin
CW
PV
R
LW
P
PJ
CSW
3
2.5
2
1.5
1
0.5
0
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5

Figure 17. SVL and Mass for all sites where 5 or more lizards were captured and measured. A power trendline was fitted to the data. The trendline equation and R square is provided.



SVL and Mass for Lizard Captures
Mass = 4 x 10-5 SVL3.0268
R2 = 0.9004
Mass (g)
SVL (mm)
Males
Females
60
50
40
30
20
10
0
60
70
80
90
100
110
120

Figure 18. Average body condition index (BCI) for each site versus principal component one from the habitat PCA. BCI's for all sites with 5 or more lizards is included. Negative PC-1 is associated with open rock and positive PC-1 is associated with closed canopy.


BCI AND PC-1 ACROSS PRESENT SITES
BCI
PC-1
Open Rock
Closed
F
PV
R
LW
P
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-2
-1.5
-1
-0.5
0
0.5
1
1.5

Appendix A. Lizard data for all individual lizards captured, including body measurements, behavior, and location information. For Age: H = Hatchling, J = Juvenile, SA = Sub Adult, A = Adult. Activity: Sun: FS = Full Sun, SH = Full Shade, F = Flecked, P = Partial Sun. For Shade: CC = Canopy Cover, CL = Cloud Cover, N = No Cover, R = Rock. Star denotes outlier removed for data analysis.

ID	Site	Mass (grams)	SVL (mm)	Tail Length (mm)	Head Width (mm)	Body Temp (ºC)	Sex	Age	Activity	Sun	Shade
1	Leatherwood	-	-	-	-	-	-	-	R	SH	R
2	Leatherwood	12	70	133	18	-	F	J	R	SH	R
3	Leatherwood	11.3	68	140	18	-	F	J	R	SH	R
4	Leatherwood	19.5	81	stub	20	-	F	A	R	FL	CC
5	Leatherwood	27	91	165	23	41	F	A	B	FS	N
6	Leatherwood	31.5	91	176	23	39.5	F	A	M	FL	CC
7	Leatherwood	33.5	96	178	23	41.8	F	A	B	FL	CC
8	Pruitt	34.5	104	191	30	-	M	A	M	FS	N
9	Pruitt	10.4	131*	132	22	-	F	J	B	FS	N
10	Pruitt	12	75	138	23	-	F	SA	B	FS	N
11	Pruitt	15	74	141	21	-	F	SA	M	FS	N
12	Pruitt	28	89	166	27	-	M	A	B	FS	N
13	Pruitt	29	86	189	25	-	F	A	B	FL	C
14	Rush	32	98	173	24	-	F	A	B	FS	N
15	Rush	37	94	176	24	-	F	A	B	FS	N
16	Rush	25	88	stub	23	-	F	A	B	FS	N
17	Rush	15	74	149	22	-	M	SA	M	FS	N
18	Rush	15	72	133	21	-	M	J	B	FS	N
19	Rush	29	93	179	28	-	M	A	B	FS	N
20	Petit Jean	-	92	-	-	37.8	M	-	-	-	-
21	Petit Jean	-	98	-	-	-	M	-	-	-	-
22	Petit Jean	30	84	-	-	40.6	F	-	-	-	-
23	Flippin	23	76	171	22	-	F	A	M	FS	N
24	Flippin	45.5	98	213	33	-	M	A	B	FS	N

25	Flippin	22	78	180	26	-	M	SA	B	FS	N
26	Flippin	22	79	179	24	-	M	SA	M	FS	N
27	Flippin	49	101	221	30	-	M	A	B	FS	N
28	Calico W	21.5	78	159	23	-	F	A	R	FL	CC
29	Calico W	17	74	159	22	-	M	SA	R	FL	CC
30	Calico W	30	87	186	27	-	M	A	R	PS	CL/CC
31	Calico SW	14	74	144	19	-	F	J	B	FS	N
31	Calico SW	-	-	-	-	-	-	-	B	FS	N
32	Prairie View	17	73	146	19	-	F	-	B	FS	N
33	Prairie View	31	89	190	24	38.3	M	A	B	FS	N
34	Prairie View	54.5	107	232	33	39.2	M	A	B	FS	N
35	Prairie View	35	91	145	24	39.2	F	A	B	FS	N
36	Prairie View	43	101	211	31	37.4	M	A	B	FS	N
37	Prairie View	28	87	77	23	38	M	SA	B	FS	N
38	Prairie View	51	109	223	34	37.8	M	A	B	FS	N
39	Prairie View	43.5	103	216	30	36.1	M	A	B	FS	N
40	Prairie View	18.1	76	148	18	-	M	J	B	FS	N
41	Prairie View	31.2	91	179	23	37.5	F	A	B	FS	N
42	Prairie View	17	74	140	20	-	M	J	B	PS	CC
43	Prairie View	22.5	85	149	23	37.8	M	A	B	FS	N
44	Prairie View	30	87	179	24	-	M	A	M	-	-
45	Prairie View	24	77	137	19	38.6	F	A	B	-	-
46	Prairie View	44	100	197	31	40.2	M	A	B	FS	N
47	Prairie View	29	91	180	23	40.3	F	A	B	FS	N
48	Prairie View	18	79	150	20	41.8	F	A	B	FS	N

49	Prairie View	20	74	147	20	39.4	M	SA	B	FS	N
50	Prairie View	-	90	179	23	41.7	F	-	-	-	-
51	Prairie View	-	88	183	24		M	A	B	FS	N
52	Prairie View	48	105	209	30	40.9	M	A	B	FS	N

Appendix B. Lizard habitat data measured at each lizard capture location. Rock type included G = gravel, C = cobble, B = boulder. Vegetation type included G = grass, L = leaf, M = moss, or CT = cacti. Soil type included D = dirt, R = rocky, L = leafy. Coarse woody debris type included L = large, M = medium and S = small. Canopy type includes C = cedar, P = pine, and D = deciduous.

ID	Site Name	Rock %	Rock Type	Plant %	Plant Type	Soil %	Soil Type	CWD %	CWD Size	Canopy %	Tree Type
1	LW	80	C	10	G	10	R/D	0	-	0	-
2	LW	70	C	20	G	10	R/D	0	-	0	-
3	LW	70	C	20	G	10	R/D	0	-	0	-
4	LW	40	C/B	30	G	10	L/D	20	L/S	50	C/D
5	LW	60	B	10	G	30	R/D	0		0	
6	LW	40	C	20	L	20	R/D	20	M	50	C
7	LW	-	C	-	-	-	-	-	-	-	C
8	P	70	B	20	G/M	5	R/L/D	0	-	30	C
9	P	65	C/B	30	G	0	-	5	S	20	C
10	P	80	C	10	G/M	5	L/D	5	S	20	C
11	P	65	C/B	30	G	5	R	0	-	10	C
12	P	70	B	30	G/M	0	-	0	-	0	-
13	P	60	C/B	40	G	0	-	0	-	0	-
14	R	40	C	10	G	0	-	50	L	0	-
15	R	40	B	40	G	0	-	10	M	10	C/D
16	R	70	C	0	-	5	R	25	S/L	0	-
17	R	40	G	20	G	30	D	10	S	0	-
18	R	65	B	5	G	30	R	0	-	0	-
19	R	65	B	5	G	30	R	0	-	0	-
20	PJ	-	-	-	-	-	-	-	-	-	-
21	PJ	-	-	-	-	-	-	-	-	-	-
22	PJ	-	-	-	-	-	-	-	-	-	-
23	F	70	C/B	10	G	20	R	0	-	0	-

24	F	90	B	0	-	10	R	0	-	0	-
25	F	90	C/B	0	-	10	R	0	-	0	-
26	F	90	C/B	0	-	10	R	0	-	0	-
27	F	90	C/B	0	-	10	R	0	-	0	
28	CW	60	C	30	M	10	L	0	-	60	P
29	CW	70	C/B	5	CT	25	L	0	-	60	P/D
30	CW	35	C	40	M	10	R/D	15	S	50	P
31	CSW	80	B	10	G/M	10	R/D	0	-	0	-
31	CSW	50	B	25	G	25	R/D	0	-	30	P
32	PV	60	G/C	20	G/L	20	D	0	-	0	-
33	PV	30	C	10	G	60	R/D	0	-	0	-
34	PV	40	B	30	G/L	30	R	0	-	0	-
35	PV	80	C/B	10	G/L	10	R	0	-	0	-
36	PV	90	C/B	10	G	0		0	-	0	-
37	PV	80	C/B	10	G	10	R	0	-	0	-
38	PV	80	C/B	20	G	0	-	0	-	0	-
39	PV	80	C/B	0		20	R	0	-	0	-
40	PV	65	C/B	5	G	30	R	0	-	0	-
41	PV	50	C/B	40	G	10	R	0	-	0	-
42	PV	60	G	0		40	R/D	0	-	0	-
43	PV	60	C/B	30	G/L	10	R/D	0	-	0	-
44	PV	-	-	-	-	-	-	-	-	-	-
45	PV	-	-	-	-	-	-	-	-	-	-
46	PV	80	C/B	0	-	20	R	0	-	0	-

47	PV	80	C/B	0	-	20	R	0	-	0	-
48	PV	60	C/B	30	G	10	R/D	0	-	0	-
49	PV	50	C/B	40	G	10	R/D	0	-	0	-
50	PV		-	-	-	-	-	-	-	-	-
51	PV	90	C/B	10	G	0	-	0	-	0	-
52	PV	90	C/B	0	-	10	R	0	-	0	-
AVG	ALL	66.1	C/B	15.98	G	14.1	R	3.48	S	8.48	C

Appendix C. Tree structure data for each tree measured at each site. Data includes DBH, height, size class and tree type. DBH size classes include: I = 2-4.99 cm, II = 5-9.99 cm, III = 10-14.99 cm, IV = 15-19.99 cm, V = 20-24.99 cm, VI = 25-29.99 cm, and VII = 30-35 cm. Tree types include Cedar = 1, Oak (Red or White) = 2, Pine = 3, other deciduous = 4, Maple (Sugar and Red) = 5, White Ash = 6, Chinquapin Oak = 7, and Hickory = 8.

Site	DBH (cm)	Height (m)	DBH Size Class	Tree Type
Leatherwood T1	4	3.99	1	1
Leatherwood T2	6.2	3.69	2	2
Leatherwood T3	14.3	5.36	3	1
Leatherwood T4	3.8	3.84	1	2
Leatherwood T5	4.3	4.60	1	1
Leatherwood T6	5	4.30	2	1
Pruitt T1	3.9	1.28	1	1
Pruitt T2	9.3	3.01	2	1
Pruitt T3	16.5	3.93	4	1
Pruitt T4	5.8	2.88	2	1
Pruitt T5	14.3	4.89	3	1
Pruitt T6	8.6	3.83	2	1
Pruitt T7	26.5	5.52	6	1
Pruitt T8	14.4	4.50	3	1
Rush T1	12	6.50	3	2
Rush T2	4	1.65	1	4
Rush T3	8	4.89	2	1
Rush T4	19	7.80	4	1
Prairie View T1	7.4	5.52	2	1
Petit Jean T1	6.3	3.23	2	3

Petit Jean T2	5.9	2.58	2	3
Petit Jean T3	3.3	2.37	1	3
Petit Jean T4	6.8	2.88	2	3
Flippin T1	6	2.69	2	1
Flippin T2	4.5	1.89	1	4
Flippin T3	8	2.69	2	1
Calico (W) T1	11	3.16	3	3
Calico (W) T2	4.5	2.80	1	2
Calico (W) T3	4.4	2.93	1	3
Calico (W) T4	3.2	2.47	1	3
Calico (W) T5	4	3.35	1	2
Calico (W) T6	3.4	3.23	1	3
Calico (W) T7	4.7	2.93	1	2
Calico (W) T8	5.6	3.44	2	2
Calico (SW) T1	28.8	6.73	6	2
Calico (SW) T2	5.1	3.14	2	2
Calico (SW) T3	2	2.77	1	3
Shipp’s Ferry T1	5.2	3.14	2	1
Shipp’s Ferry T2	5.7	4.30	2	1
Shipp’s Ferry T3	8.2	3.84	2	1
Shipp’s Ferry T4	20.2	8.11	5	1
Shipp’s Ferry T5	4.2	3.23	1	2
Shipp’s Ferry T6	4.4	3.69	1	1

Shipp’s Ferry T7	8.1	3.69	2	1
Shipp’s Ferry T8	3.9	2.93	1	1
Mt. Home T1	8.3	3.08	2	1
Mt. Home T2	28.4	4.15	6	1
Mt. Home T3	22.1	4.26	5	1
Mt. Home T4	6.9	3.99	2	4
Lost Bridge T1	6.3	4.75	2	1
Lost Bridge T2	14.9	10.24	3	2
Lost Bridge T3	8.6	6.28	2	1
Lost Bridge T4	5.5	5.36	2	2
Lost Bridge T5	22.3	16.95	5	2
Lost Bridge T6	5.6	18.47	2	1
Lost Bridge T7	5.7	3.84	2	1
Lost Bridge T8	7.6	4.45	2	1
Lost Bridge T9	4.3	4.15	1	1
Lost Bridge T10	20	17.56	5	4
Lost Bridge T11	19.5	10.24	4	1
Lost Bridge T12	27.1	18.47	6	1
Lost Bridge T13	5.9	4.15	2	1
Lost Bridge T14	7.2	4.75	2	1
Lost Bridge T15	11.5	5.36	3	1
Beaver Quarry T1	2.8	1.71	1	1
Beaver Quarry T2	3.2	3.66	1	1

Beaver Quarry T3	29	4.15	6	5
Beaver Quarry T4	3.4	3.05	1	5
Beaver Quarry T5	8.9	3.96	2	5
Beaver Quarry T6	4.9	3.78	1	5
Beaver Quarry T7	15.1	3.93	4	5
Beaver Quarry T8	13.4	4.02	3	5
Beaver Quarry T9	2.7	2.16	1	1
Turkey Mt. T1	31.8	13.11	7	2
Turkey Mt. T2	24	10.36	5	1
Turkey Mt. T3	18.1	11.28	4	7
Turkey Mt. T4	4.3	3.02	1	1
Turkey Mt. T5	8.8	6.71	2	6
Turkey Mt. T6	21.4	11.28	5	1
Turkey Mt. T7	23	11.28	5	1
Turkey Mt. T8	8.7	5.79	2	8
Turkey Mt. T9	14.5	11.58	3	7
Turkey Mt. T10	28.9	14.02	6	1
Mt. Magazine T1	22.3	12.37	5	4
Mt. Magazine T2	7.7	5.52	2	4
Mt. Magazine T3	10.3	6.73	3	4
Mt. Magazine T4	15.9	18.25	4	4
Mt. Magazine T5	23.2	44.38	5	2
Mt. Magazine T6	25.8	53.52	6	2

Mt. Magazine T7	11.4	6.07	3	4
Mt. Magazine T8	9.7	4.89	2	4
Mt. Magazine T9	20.8	11.13	5	2
Ft Chaffee T1	16.4	4.37	4	2
Ft Chaffee T2	20.85	3.57	5	2
Ft Chaffee T3	18.4	4.75	4	2
Ft Chaffee T4	15.2	4.15	4	2
Ft Chaffee T5	7.5	4.04	2	8
Ft Chaffee T6	15.4	6.73	4	8
Wedington T1	16.3	4.89	4	4
Wedington T2	19.1	7.23	4	4
Wedington T3	16	4.89	4	4
Wedington T4	11.2	3.56	3	4
Wedington T5	7	3.39	2	4
Wedington T6	7.7	6.97	2	4
Wedington T7	11.5	3.65	3	4
Wedington T8	6.7	3.01	2	4
Wedington T9	20.1	9.63	5	4
Wedington T10	25.2	6.07	6	2
Wedington T11	27.5	7.51	6	2
Wedington T12	7.4	3.65	2	2
Wedington T13	10	1.92	3	2

Appendix D. Environmental data measured for each site. Measurements include time of day, air temperature, wind speed, percent humidity, altitude, facing slope, and weather. Facing slope includes N = north, S = south, E = east, W = west, and F = flat. Weather includes S = sunny, PC = partly cloudy, and C = cloudy.

Site Name	Time	$Temp_{Air}$ (ºC)	Wind Speed (m/s)	Humidity (percent)	Altitude (meters)	Aspect	Weather
Leatherwood	3:50	25.4	0	50.1	1188	F	PC
Leatherwood	3:30	22.4	0.5	51.6	1195	F	PC
Leatherwood	3:10	18.5	1	62.8	1171	F	C
Leatherwood	2:15	36.9	0.9	44.3	977	F	PC
Leatherwood	2:00	40.2	0	32.4	979	F	PC
Leatherwood	1:30	36.3	0.5	41.8	969	F	PC
Leatherwood	2:45	36.9	0.9	44.3	977	F	PC
Pruitt	1:50	26.3	0.5	27.9	888	S	S
Pruitt	2:04	29.2	0	26.6	892	S	S
Pruitt	2:16	31.4	0.7	13.7	890	S	S
Pruitt	2:30	35.6	0	18.2	920	S	S
Pruitt	3:00	27.6	0.6	20.5	912	SE	S
Pruitt	3:40	31.8	0.5	21.1	900	SE	S
Rush	11:25	26.4	0.3	49.9	740	S	S
Rush	11:45	29.7	0.6	35.9	730	S	S
Rush	12:00	28.3	0.4	42.3	735	S	S
Rush	12:25	24.6	0.9	39.4	751	F	S
Rush	12:50	27.6	1.1	34.6	766	F	S
Rush	12:50	27.5	1.2	34.6	770	F	S
Prairie View	10:30	30.1	0.7	50.9	311	F	C
Prairie View	10:50	32.4	0	52.5	324	F	PC

Prairie View	11:00	30.6	0.8	52.3	303	F	PC
Prairie View	11:10	32.6	1.2	49.4	292	SE	PC
Prairie View	11:35	32.1	0.4	52.9	276	F	C
Prairie View	11:50	32.5	0.8	55.6	290	F	C
Prairie View	12:00	31.9	0.8	53.7	288	F	PC
Prairie View	12:15	31.3	2.4	47.4	291	F	PC
Prairie View	12:15	31.3	2.4	47.4	291	F	PC
Prairie View	12:15	31.3	2.4	47.4	291	F	PC
Prairie View	12:45	35	0.3	41.4	281	F	PC
Prairie View	12:45	35	0	41.4	281	F	PC
Prairie View	12:55	36	0	43.2	283	F	PC
Prairie View	1:00	34.6	0.7	41.9	288	F	PC
Prairie View	1:00	34.6	0.7	41.9	288	F	PC
Prairie View	1:05	34.6	0.7	41.9	288	F	PC
Prairie View	1:25	32.9	0.2	45	282	F	PC
Prairie View	2:10	34.1	0.7	45.2	464	F	PC
Prairie View	2:15	34.3	1.1	47.1	453	F	S
Prairie View	2:30	35.7	0.4	42.7	467	F	PC
Prairie View	2:35	35.7	0.4	42.7	467	F	PC
Petit Jean	11:45	35.3	0.5	36.8	491	SE	S
Flippin	10:10	35.6	0.4	37.3	1016	F	S
Flippin	9:55	33.3	0.3	48.8	1010	F	S
Flippin	11:00	35.7	0.4	42	1002	F	S

Flippin	10:30	36.2	0.7	41.5	1020	F	S
Flippin	11:25	36.5	0.9	41.1	1002	F	S
Calico W	3:05	36.3	1.4	34.1	554	SE	S
Calico W	12:45	36.4	1.6	38.6	479	F	PC
Calico W	1:50	37.1	1	39.7	533	SE	PC
Calico SW	12:00	33.6	0.8	38	496	F	S
Calico SW	1:05	31.5	1.3	47.5	516	F	S
Calico SW	1:45	36.5	0.9	38.7	513	F	PC
Calico SW	9:45	31.3	1.3	38.4	435	F	PC
Shipp's Ferry	3:35	36.7	0.7	37.3	436	S	PC
Shipp's Ferry	4:00	36.5	0.5	34.8	643	SW	PC
Shipp's Ferry	3:20	33.1	0.4	43	428	SW	S
Shipp's Ferry	9:00	32.8	0.7	31.6	440	SW	S
Old Joe	9:00	33.2	1.2	46	754	F	S
Old Joe	11:15	31.9	1.2	53.4	688	F	PC
Old Joe	12:10	34.8	0.7	36.5	704	F	S
Mt. Home	10:00	33.7	2.1	41.4	874	F	S
Mt. Home	8:30	26.7	1.7	51.2	811	F	PC
Mt. Home	1:40	33.4	1.8	36.4	785	F	S
Mt. Home	12:55	27	0.7	16.3	1020	F	S
Mt. Home	2:35	32.1	0.4	18	1023	F	S
Lost Bridge	12:10	13.5	0	68	1347	S	C
Lost Bridge	1:15	16.2	0.5	85	1356	F	C

Lost Bridge	11:00	22.3	1.7	31.6	1001	S	S
Lost Bridge	12:11	24.5	0.4	51.7	1071	SW	PC
Lost Bridge	1:30	24.5	0.4	51.7	1071	F	PC
Wedington	2:45	30.9	1.3	26.8	1335	S	PC
Wedington	1:50	28.8	0.4	31.5	1282	F	PC
Turkey Mt.	1:10	27	0.6	67.1	770	N	C
Turkey Mt.	10:00	28.5	0	76.1	626	S	S
Turkey Mt.	12:40	31.4	0.5	21.8	559	SW	S
Mt. Magazine*	12:00	27.4	0.6	52.7	2566	E	S
Ft. Chaffee*	10:30	35.8	2	36.8	885	S	PC