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Critical Habitat Assessment and Recovery Plan for the Kansas State Threatened Broad-Headed Skink

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CRITICAL HABITAT ASSESSMENT AND RECOVERY

PLAN FOR THE KANSAS STATE THREATENED

BROAD-HEADED SKINK

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ABSTRACT

The Broad-headed Skink (*Plestiodon laticeps*) is listed as threatened in the state of Kansas and protected under that Kansas Nongame and Endangered Species Conservation Act of 1975. It is also listed as a Tier I species in the State Wildlife Action Plan (SWAP) for Kansas. To be protected under the Kansas Nongame and Endangered Species Conservation Act of 1975, a Recovery Plan must be approved by the Secretary of the Kansas Department of Wildlife Parks and Tourism. An important part of the Recovery Plan requires defining critical habitat for the Broad-headed Skink. During the summers of 2015-2017, I performed standardized surveys across the known range of the Broad-headed Skink in eastern Kansas. I used drift fence arrays with funnel traps and performed visual encounter surveys (VES) to collect occurrence data on the Broad-headed Skink. I also performed a habitat assessment at each site.

A Canonical Correspondence Analysis (CCA) was used to determine which habitat variables explained the variation observed in the squamate assemblage in eastern Kansas. The position of the Broad-headed Skink was explained by average log-length and overstory tree size. A secondary analysis implies that the Broad-headed Skink is also associated with presence of the Black Walnut (*Juglans nigra*). A logistic regression was used to determine which habitat variables were significant in predicting presence of the Broad-headed Skink. The variables from the most successful model included average log length, overstory tree size, understory tree dispersion, and overstory tree dispersion. These habitat attributes suggest that the Broad-headed Skink prefers more mature patches of the forest and that habitat structure rather than presence of any tree species is more

important in predicting the presence of the Broad-headed Skink, though the presence of some tree species may provide additional insight.

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PREFACE

This thesis is formatted as a Recovery Plan for threatened or endangered species as defined under the Kansas Nongame and Endangered Species Conservation Act of 1975 (KNESCA) under the regulating authority of the Kansas Department of Wildlife, Parks and Tourism.

IACUC protocol number: 18-0006 *A proposed recovery plan for the broad-headed skink*

I. INTRODUCTION

A. Background

Reptiles are in decline worldwide. There are 10,450 reptile species recognized by the International Union for Conservation of Nature (IUCN) and 1,090, or 10%, of these are listed as Threatened. The IUCN uses the term threatened to collectively describe those species that are critically endangered, endangered, and vulnerable. This number has increased from 1998, when only 253 reptile species were listed as Threatened (IUCN 2017).

Declines in reptile populations are caused by several threats but include habitat loss and degradation. It is estimated that 40-49% of reptiles will lose more than 10% of their habitat in the next 30 years. The estimated habitat loss for reptiles is greater than estimates for birds and amphibians (Martinuzzi *et. al.* 2015). Competition from invasive species has resulted in declines in native species (Gibbons *et. al.* 2000; Crooks 2002) and pollution has been documented causing function change in organ systems in lizards (McFarland *et. al.* 2011). Diseases, such as snake fungal disease (Lorch *et. al.* 2016), have been attributed to declines in reptile populations (Gibbons *et. al.* 2000; Lorch *et. al.* 2016). A population of the Eastern Massasauga (*Sistrurus catenatus*), a federally threatened species, has seen increased mortality due to snake fungal disease (Allender *et. al.* 2011). Unsustainable use, or overexploitation for trade (Gibbons *et. al.* 2000; Auliya *et. al.* 2016), and climate change (Gibbons *et. al.* 2000; Moreno-Rueda *et. al.* 2011; Böhm *et. al.* 2016) are also threats to reptiles. Models predicting the vulnerability of reptile species to climate change suggest that 80.5% of species are sensitive to climate change, while 22% of species were highly vulnerable to climate change (Böhm *et. al.* 2016).

It is important to monitor these threats and responses of reptile populations because these sensitive species act as indicators of ecological health (Siddig *et. al.* 2016), have aesthetic value to humans (NRIC 1944; Kieran 1997), and have demonstrated medicinal value. For example, venom from the African Black Mamba (*Dendroaspis polylepis*) contains peptides that block pain in humans without the side-effects caused by morphine (Diochet *et. al.* 2012). The venom of the Gila Monster (*Heloderma suspectum*) contains peptides used to help treat type II diabetes (Furman 2012).

Monitoring and protecting reptiles is also important for maintaining biodiversity. The importance of monitoring and protecting species, especially sensitive species, is evident in the success of the recoveries of the Whooping Crane (*Grus Americana*) and Shortnose Sturgeon (*Acipenser brevirostrum*), where reintroductions, and habitat management and protection brought these species back from the brink of extinction (NOAA 2012). The successful recovery of the American Alligator (*Alligator mississippiensis*) was the result of modifying hunting and trade regulations (USFWS 2008). Maintaining biodiversity is crucial to maintaining the productivity and health of ecosystems across the globe. If species interactions change, processes crucial to the ecosystem will change (Goudard and Loreau 2008).

Lizards are the most speciose group of reptiles, comprised of more than 6,200 species (Uetz, Freed, and Hošek 2017). There are 38 families of lizards that occupy all continents, except Antarctica. Scincidae is the largest family of lizards, representing 1,613 species (Pough *et. al.* 2016; IUCN 2017). Scincidae is also one of the most threatened families of lizards, where 95 species are listed as Threatened: 79 as Critically Endangered or Endangered and 16 as Vulnerable (IUCN 2017).

The Scincidae family, comprised of lizards that are referred to as skinks, is a diverse group of lizards, with wide variation in morphology that allows them to occupy many different habitats (Mitchell 1994): arboreal, litter, aquatic, anthropogenic structures (Pough *et. al.* 2016). Skinks differ from other lizards by the presence of smooth, shiny scales supported by osteoderms. These osteoderms make skinks appear larger than other lizards and more difficult for predators to eat them (Mitchell 1994). Skink species often provide more extensive parental care than other lizards. This includes regulating gas and water exchange in developing embryos by moving eggs periodically, coiling around the eggs, and creating more air space in the nest (Vitt and Caldwell 2014).

In Kansas, there are six skink species that belong to two genera, *Scincella* and *Plestiodon* (Collins, Collins, and Taggart 2010). The sole member of the *Scincella* genus is the Little Brown Skink (*S. lateralis*), which occupies leaf litter present on forest floors in the southeastern United States (Conant and Collins 1991) and occurs in the eastern third of Kansas as well as along the southern border (Collins, Collins, and Taggart 2010). The *Plestiodon* species in Kansas are the Coal Skink (*P. anthracinus*), Five-lined Skink (*P. fasciatus*), Great Plains Skink (*P. obsoletus*), Prairie Skink (*P. septentrionalis*), and the Broad-headed Skink (*P. laticeps*) (Collins, Collins, and Taggart 2010). These *Plestiodon* species can be observed on trees and under surface material, such as logs and other debris (Mitchell 1994). They occupy the central and eastern United States (Conant and Collins 1991) and can be found across the state of Kansas, but are most prevalent in eastern Kansas (Collins, Collins, and Taggart 2010). Five of these species do not have a designated conservation status in Kansas. However, the Broad-headed Skink is listed as threatened in the state (KDWPT 2017a).

B. Species Account

1. *Taxonomy*

The Broad-headed Skink was first described by Johann Gottlob Theaenus Schneider (1801) from a specimen in the Museum of Göttingen in Germany. There was no locality data provided with the specimen and the holotype is now lost. The name first used to describe this species was *Scincus laticeps* (Mitchell 1994). The Broad-headed Skink was then placed in the genus *Eumeces* by Peters (1864). *Plestiodon laticeps* is now the accepted species name for the Broad-headed Skink (Schmitz, Mausfeld, and Embert 2004).

2. *Description*

Adult Broad-headed Skinks are brown in color and become lighter as they mature. They have five olive-colored lines that extend the length of the dorsum, but males lose these as they mature (Mitchell 1994). The Broad-headed Skink is sexually dimorphic, with the head of males being wider than females. The head of males also becomes bright red-orange during mating season.

Juveniles hatch with a snout-vent length (SVL) of about 30 mm. They are brown to black with five olive-colored lines that extend the length of the dorsum. Juveniles have a bright blue tail that fades as they mature. Broad-headed Skink males and females become sexually mature at about 75-80 mm SVL (Mitchell 1994). They reach a maximum SVL of 143 mm (Conant and Collins 1991) and can live up to about 8 years (Cooper and Vitt 1987).

The Broad-headed Skink has eight labial scales; five anterior to the eye. They can have one or two small postlabial scales. The Five-lined Skink is often confused with the Broad-headed Skink because they share many characteristics throughout their ontogeny; however, the Five-lined Skink only has seven labial scales; four anterior to the eye. The Five-lined Skink also has two, large postlabial scales (Collins, Collins, and Taggart 2010).

3. *Reproduction*

The Broad-headed Skink mates in late spring and early summer, from April to early June across their range, and females lay a clutch of eggs in late summer, from late June to August (Vitt and Caldwell 2014). Some males will guard the female for about half of the breeding season, which lasts about two weeks (Cooper and Vitt 1997). Females nest in decayed trees and logs, specifically decomposing hardwoods. They lay a clutch of 18 eggs or more and rarely leave until the eggs have hatched (Vitt and Caldwell 2014).

4. *Diet*

The Broad-headed Skink preys on invertebrates (McCauley 1939; Vitt and Cooper 1986), but avoids velvet ants and millipedes (Vitt and Cooper 1986). The most prevalent invertebrates in the diet of these skinks are grasshoppers and crickets (Orthoptera) (McCauley 1939; Vitt and Cooper 1986), and beetles (Coleoptera) (Vitt and Cooper 1986). They also consume lizards, including those of the same species (McCauley 1939; Vitt and Cooper 1986). Broad-headed Skinks use chemosensory and visual cues to forage while on trees, both dead and alive, and in leaf litter by (Vitt and Cooper 1986).

5. *Distribution*

The Broad-headed Skink inhabits deciduous forests of the southeastern United States (Clawson, Baskett, and Armbruster 1984; Miller and Collins 1993). Southeastern Kansas is at the northwestern periphery of the overall range for the species. In Kansas, the Broad-headed Skink has been observed in Franklin, Miami, Linn, Bourbon, Crawford, Cherokee, and Neosho counties within the Marais des Cygnes, Marmaton, Spring, and Neosho river basins (Taggart 2017).

C. <u>Conservation and Management</u>

1. *Conservation status and protective laws*

The Broad-headed Skink was listed in the state of Kansas as threatened in 1987. It received this conservation status after recommendations from local experts were reviewed by the Kansas Nongame Wildlife Advisory Council. The Broad-headed Skink is protected under the Kansas Nongame and Endangered Species Conservation Act of 1975 (KNESCA). This act gives the Kansas Department of Wildlife, Parks and Tourism (KDWPT) the responsibility of protecting habitats of listed species through the use of action permits. Action permits are required by developers when they plan to alter the designated critical habitat of a state threatened or endangered species. To be protected under the KNESCA a Recovery Plan must be approved for use by the KDWPT. Recovery Plans outline the steps necessary for conserving a species and the requirements for delisting (KDWPT 2017b). Currently, a Recovery Plan has not been developed or approved for the Broad-headed Skink.

The Broad-headed Skink is also listed as a Tier I Species of Greatest Conservation Need (SGCN) in the State Wildlife Action Plan (SWAP) for Kansas. The Ecological Focal Areas (EFA) targeted for the conservation of the Broad-headed Skink within this plan are the Eastern Forest and the Ozark Plateau. The Eastern Forest focal area is located in the southeastern quarter of Miami County and the northeastern half of Linn County, and is coincident with the northern extent of the range for the Broad-headed Skink in Kansas. The Ozark Plateau focal area is located in the southeastern corner of Cherokee County, and represents the southeastern extent of the range of the Broad-headed Skink in Kansas (Rohweder 2015). The Broad-headed Skink is not listed as threatened or endangered by any other states in its range.

Protecting and preserving peripheral populations are important for the conservation of a sensitive species. These populations are often genetically unique from conspecific populations across the range of a species. This genetic uniqueness is caused by different natural selection forces these populations endure and increases the ability of the species to adapt (Lesica and Allendorf 1995).

2. *Potential threats*

Conservation concerns within the range of the Broad-headed Skink in Kansas include habitat loss and degradation, and fragmentation due to commercial and agricultural development. Conversion of forests for agriculture and unsustainable grazing decreases the availability and quality of habitat for the Broad-headed Skink (Rohweder 2015). Fragmentation disrupts the spatial dynamics of local populations by creating barriers to movement between habitat fragments (Graeter *et. al.* 2013). This fragmentation decreases immigration and gene flow (Young, Boyle, and Brown 1996), which reduces genetic diversity (Wiegand, Revilla, and Moloney 2005). Habitat loss and fragmentation are currently the most serious threats to reptile populations. (Mittermeyer *et. al.* 1992).

Another conservation concern is the modification of natural systems, such as fire suppression that results in forest structure change by favoring mesic adapted species. Impoundments and flood control structures interfere with the nutrient cycling events that support these systems (Agee 1993; Cappellen and Maavara 2016). Invasive species, such as the Japanese Honeysuckle (*Lonicera japonica*) and Black Locust (*Robinia pseudoacacia*), are also a potential threat (KFS 2018) as they may outcompete native species and change understory species compositions (Crooks 2002). Changing the species composition in an ecosystem can alter predator-prey interactions (Burkle, Mihaljevic, and Smith 2012).

Pollution and unsustainable resource use (e.g. timber harvest) are also potential threats to Broad-headed Skink populations (Rohweder 2015). Environmental contaminants affect development and reproduction of reptiles (Guillette and Gunderson 2001). Unsustainable resource use contributes to habitat degradation and fragmentation (Schulze and Zweede 2006). Overexploitation, where individuals are taken from the wild, contributes directly to population declines (Jensen and Camp 2003).

Diseases have recently contributed to declines in reptiles and many of these diseases are not well understood (Schumacher 2006). The Black-legged Tick (*Ixodes scapularis)*, the primary vector for Lyme disease in humans in the north-central and eastern United States, was collected from Broad-headed Skinks in Oklahoma (Garvin *et. al.* 2015), Georgia (Durden et al. 2002), and North Carolina (Apperson *et. al.* 1993). Immature Black-legged Ticks are parasitic to the Broad-headed Skink (Apperson *et. al.* 1993; Durden *et. al.* 2002). The Broad-headed Skink is one of the most prevalent hosts for the Black-legged Tick in the southeastern United States, and also has been found to act as a host in the Great Plains region (Durden et al. 2002).

Climate change is also a threat to the Broad-headed Skink. The climate is changing so rapidly that species cannot adapt quickly enough (Davis *et. al*. 1998). This is especially threatening to reptiles as they have low dispersal capabilities (Gibbons *et. al.* 2000). Climate change models performed with some Kansas lizards predict that distributions will shift north and become fragmented (Prowant 2014). This assumes that the development of new habitat will not lag behind changes to current habitat availability and that there will be corridors for dispersal.

3. *Confusing species*

As stated above, the Broad-headed Skink is often confused with the Five-lined Skink because of the morphological characteristics they share. They also are sympatric and are found within deciduous forests; however, the Broad-headed Skink is more arboreal than the Five-lined Skink. Both species will forage on the ground (Mansueti 1948), but may differ in vegetation preference. The Five-lined Skink has been observed in more densely forested areas and the Broad-headed Skink has been observed in less heavily forested areas (Moehn 1981). The Broad-headed Skink also has been documented to occur in areas of higher canopy within a more open forest (Watson and Gough 2012).

4. *Critical habitat*

The designated critical habitat for the Broad-headed Skink is currently defined as "mature oak woodlands in Miami, Linn, Bourbon, and Crawford counties," as well as suitable areas in its probable range as determined by a field survey (KDWPT 2017a). While these descriptions are useful political boundaries in distributing permits for commercial and agricultural development by state ecologists, they are not useful in guiding the conservation of the species or managing for the species at a local scale. A better defined critical habitat for the Broad-headed Skink is needed to construct a Recovery Plan for the species.

D. Study objectives

1. Verify distribution of the Broad-headed Skink in the state of Kansas.
2. Identify sites for monitoring trends and data collection.
3. Develop a more defined critical habitat for the Broad-headed Skink.
4. Develop a draft Recovery Plan.

II. METHODS

A. Study Sites

1. *2015*

May through August, I collected preliminary data on Broad-headed Skink presence and habitat at nine focal areas throughout the range of the Broad-headed Skink in Kansas: Marais des Cygnes National Wildlife Refuge, Marais des Cygnes Wildlife Area, La Cygne Wildlife Area, Miami State Fishing Lake, Hollister Wildlife Area, Spring River Wildlife Area, Crawford State Park, Neosho Wildlife Area, and Neosho State Fishing Lake. Three sites were surveyed within each focal area. These sites were located in mature oak-hickory woodlands because that is where the Broad-headed Skink had been documented (Clawson, Baskett, and Armbruster 1984, Miller and Collins 1993). Data collected during this preliminary year were not used in statistical analyses because habitat assessment procedures were not comparable.

2. *2016*

I intensively surveyed three focal areas with the highest numbers of Broad-headed Skink captures in 2015 (Appendix 1). Collectively, these focal areas comprised the largest and least fragmented pieces of the eastern deciduous forest, and presumably of Broad-headed Skink habitat, in Kansas. These focal areas were Marais des Cygnes National Wildlife Refuge, Marais des Cygnes Wildlife Area, and La Cygne Wildlife Area. Sites with historical Broad-headed Skink presence were surveyed first.

Subsequently, each week, I surveyed three new sites at each focal area (total of nine). Sites were chosen randomly in ArcGIS within an oak-hickory forest layer available from the Kansas GAP Land Cover Map (Egbert *et. al.* 2001), within a 400-meter buffer around access roads. A total of 117 sites were surveyed; 39 at each focal area.

3. *2017*

I surveyed all focal areas visited in 2015 during the third and final field season. I also surveyed two new focal areas, Bourbon County State Fishing Lake and West Mineral Units (Figure 1; Appendix 2). Twenty-four sites were surveyed at Hollister Wildlife Area. Twelve sites were surveyed at Crawford State Park, Spring River Wildlife Area, Neosho Wildlife Area, Bourbon County State Fishing Lake, West Mineral Units, Miami State Fishing Lake, La Cygne Wildlife Area, Marais des Cygnes Wildlife Area, and Marais des Cygnes National Wildlife Refuge. Nine sites were surveyed at Neosho County State Fishing Lake. These sites were distributed throughout three habitat categories: mature forest, - areas that had trees with a relatively large (> 20 cm) diameter at breast height (DBH), immature forest, - areas that had trees with a smaller DBH (< 20 cm DBH), and open canopy, - areas with no trees (e.g. grassland). I distributed sites equally in each habitat category, except when habitat availability was limited. A total of 141 sites were surveyed.

B. Herpetofaunal Surveys

1. *Drift fences*

I installed one drift fence array at each site. Drift fences are commonly used to sample reptiles and function by diverting reptiles to traps as the individuals move across the site (Graeter *et. al.* 2013). A drift fence array consisted of three fences deployed in a Y-formation. Each fence was 7.6 m with one end terminating in a funnel trap that formed the center of the "Y". Nine additional funnel traps were placed around the array; one at the distal end of each fence and two at the midpoint along each side of each fence (Figure 2). Traps were open for three nights at each site and checked every morning. I weighed, measured snout-vent length (SVL), and recorded sex for every reptile caught in the traps. I recorded presence of all captured amphibian species. Relative abundance was summarized as captures per array night.

2. *Visual encounter surveys (VES)*

Visual encounter surveys (Graeter *et. al.* 2013) were performed within a 30-m radius of the center trap at each array. I looked under natural cover, including logs and leaf litter and, because the Broad-headed Skink is semi-arboreal, I looked under sloughing tree bark. All measurements recorded for individuals captured in funnel traps also were recorded for individuals captured during visual encounter surveys. Captures were quantified as captures per person hour.

3. *Incidental encounters*

Broad-headed Skinks were incidentally encountered while I walked from site to site and when I briefly checked areas with viable habitat at each focal area where I was not able to deploy sampling gear (Appendix 3). When a Broad-headed Skink was incidentally encountered, I collected morphological data and performed a habitat assessment using its initial location as the center point.

C. Habitat Assessments

All habitat assessment procedures were initiated from the center trap of the drift fence array and were modified from Dueser and Shugart (1978) (Figure 3). I used two random transects of 10, 1 m X 1 m quadrats to estimate percent canopy cover, percent vegetative cover, percent soil exposure, leaf litter depth, and soil moisture to the nearest percentage. I also recorded presence of woody species in each quadrat. Each transect was divided in half by the center trap to avoid trampled vegetation in the quadrat. Randomization was achieved by using a pre-determined list of degrees from north, produced in Excel.

Using a radius of 10 meters from the center trap, I split the site into quarters through the center trap of the array: northeast, southeast, southwest, and northwest. In each quarter, I recorded the distance to the nearest overstory tree and understory tree and their respective DBH (Cottam and Curtis 1956). I also measured the distance to the nearest log with a diameter over 7.5 cm. I measured the lengths of all fallen logs in the quarter and recorded an average for the site. I also recorded the total number of fallen logs and the percent of rock cover in each quarter. Within a 30-m radius of the center trap, I recorded all tree species with a DBH of 15 centimeters or larger. Table 1 summarizes the variables and procedures used in estimation.

D. Statistical Analyses

I used a Canonical Correspondence Analysis (CCA) to determine which habitat variables explained the composition of the squamate assemblage (order Squamata: snakes and lizards). A CCA combines species scores with environmental variables, and maximizes the dispersion between them. It compares species compositions between sites and explains these compositions through a combination of environmental variables. Only species that were observed in a minimum of 10% of all sites were used for this analysis. An Interactive Forward Selection process was used to identity variables the explained the largest amount of variation and to improve interpretation. This analysis was performed in CANOCO 5.

I then used a logistic regression to determine the relationship between habitat variables and the occurrence of the Broad-headed Skink as observed in 2016 and 2017 separately. This statistical analysis was performed in R (version 3.3.2) and was evaluated with a significance level of alpha = 0.05.

III. RESULTS

In 2016, a total of 568 individuals representing 32 species was observed across 117 sites (Table 2). Forty-two Broad-headed Skinks were captured; 12 during visual encounter surveys, 15 by using trapping methods, and 15 through incidental encounters. In 2016, samples included 351 array nights resulting in a catch-per-unit-effort (CPUE) of 0.88 captures per array night for all species and for the Broad-headed Skink, 0.04 captures per array night. A total of 152.6 person hours were dedicated to visual encounter surveys. The 2016 visual encounter CPUE was 1.82 captures per person hour for all species and 0.08 Broad-headed Skink captures per person hour.

In 2017, a total of 1,223 individuals representing 31 species were observed across 141 sites (Table 2). Eighty Broad-headed Skinks were observed; 17 during visual encounter surveys, 43 by using trapping methods, and 20 through incidental encounters. In 2017, samples included 423 array nights resulting in a CPUE of 1.91 captures per array night for all species and for the Broad-headed Skink 0.10 captures per array night. A total of 140.9 person hours were dedicated to visual encounter surveys in 2017. The visual encounter CPUE was 1.43 captures per person hour for all species and 0.12 Broad-headed Skink captures per person hour.

A total of 41 species were observed in the summers of 2016 and 2017. I observed six species of turtle and the most often observed species was the Eastern Box Turtle (*Terrapene carolina*). Ten species of amphibians were observed and the species observed most often was the Southern Leopard Frog (*Lithobates sphenocephalus*). Two state threatened amphibian species were observed. The Eastern Newt (Notopthalmus viridescens) was observed in 2016 at Marais des Cygnes National Wildlife Refuge and Marais des Cygnes Wildlife Area, and the Eastern Narrow-mouthed Toad (*Gastrophryne carolinensis*) was observed in 2017 at Spring River Wildlife Area. The Spring Peeper (*Pseudacris crucifer*) is listed at a Species In Need of Conservation (SINC) in Kansas and was observed in 2016 at Marais des Cygnes National Wildlife Refuge. Twenty-five squamate species were observed during my surveys. The Broad-headed Skink was the only state threatened species observed, but two SINC species were observed. The Red-bellied Snake (*Storeria occipitomaculata*) was observed at La Cygne Wildlife Area in 2016 under leaf litter, and the Rough Earthsnake (*Haldea striatula*) was found at West Mineral Units and Spring River Wildlife Area in 2017.

I was surprised given the extensive effort expended in these surveys that the Coal Skink (*Plestiodon anthracinus*) was not observed. The majority of observations of the Coal Skink in Kansas were made before 1980 and only two observations have been made since 2000. The habitat of the Coal Skink parallels that of the Broad-headed Skink (Taggart 2017), so further surveys might be needed to verify the distribution and status of the Coal Skink in Kansas.

<u>Squamate assemblage</u>

All squamates observed at a minimum of 10% of sites were included in quantitative analyses. I removed 17 species and used presence/absence data for the analysis. During my study, I identified 16,249 trees representing 40 species (Table 3). Tree species that were not present at a minimum of 10% of sites were not used in this analysis. I removed 16 tree species. The remaining occurrences of tree species were incorporated as habitat variables.

Because there are many habitat variables included in the analysis, I performed an Interactive Forward Selection to determine which subset of the variables explain the greatest proportion of variation in the squamate assemblage. Focal area was used as a covariate to eliminate the uncontrollable variation that occurs within the sites in these focal areas, which could include variation associated with a perceived north to south gradient and unknown land use management objectives. Three habitat variables could not be used in the ordination for failure to meet test assumptions. These variables were percent canopy cover, soil moisture, and percent rock cover.

The variable explaining the majority of variation on the CCA I was overstory tree size (Table 4); a measure of the DBH of the closest overstory tree to the center trap (Figure 5). Moving from left to right on the graph, it appears that species were ordinated from forest habitat to grassland habitat. The Common Gartersnake (*Thamnophis sirtalis*) and North American Racer (*Coluber constrictor*) were placed directly opposite overstory tree size.

The Little Brown Skink and Western Wormsnake (*Carphophis vermis*) were associated with the Sugar Maple (*Acer saccharum*) and ordinated opposite of shrub cover (Figure 5). The Broad-headed Skink is adjacent to average fallen log length and is also explained by overstory tree size. Had I not used Sugar Maple during the Interactive Forward Selection, Black Walnut (*Juglans nigra*) would have been the next most significant variable in the ordination. Though Sugar Maple explains more of the variation in the squamate assemblage, Black Walnut explains the variation as it is most meaningful for the Broad-headed Skink. Black Walnut is ordinated in the same quadrant as the Broad-headed Skink in the analysis.

Critical habitat assessment

A logistic regression model was developed with the habitat variables I measured at each site and presence/absence data on the Broad-headed Skink from 2016. There was one significant variable in the model; overstory tree size ($z = 2.389$, $df = 53$, $p = 0.0169$) (Figure 6).

In 2017, I surveyed a broader range of habitats and I expanded surveys across the historical range of the Broad-headed Skink in Kansas, but quantified variables remained the same. A single model including data from both years could not be developed because the years were significantly different from one another. Accordingly, a logistic regression model was developed with just data from 2017. Three variables, percent canopy cover, soil moisture, and percent rock cover, could not be used in the model for failure to meet test assumptions. Four variables were included in the best model ($z = -3.292$, $df = 93$, $p < 0.001$) (Table 5): overstory tree size ($z = 2.159$, $df = 93$, $p = 0.0309$) (Figure 7), average log length ($z = 2.667$, $df = 93$, $p = 0.0077$) (Figure 8), overstory tree dispersion ($z = -1.664$, $df = 93$, $p = 0.0962$), and understory tree dispersion ($z = 1.840$, $df = 93$, $p = 0.0657$).

The significant variables from the 2017 logistic regression model and the CCA were then graphed to visualize the relationship between these variables and presence of the Broad-headed Skink. Overstory tree size had an increasingly positive effect on Broad-headed Skink presence when diameters of the trees were 20 cm and greater (Figure 9a). Average log lengths of 2 m or greater were positively associated with Broad-headed skink presence (Figure 9b).

IV. DISCUSSION

Prior to 2015, the Broad-headed Skink was documented 46 times from 28 distinct localities in Kansas. These data were provided by the Kansas Herpetofaunal Atlas (Taggart 2017) and the Kansas Biological Survey. The oldest occurrence record was from Franklin County in 1911; the only record of the species in that county. Many of these historical observations were in Bourbon (10) and Cherokee (11) counties with additional occurrences in Crawford (6), Linn (3), Miami (6), and Neosho (1) counties (Figure 4). These observations occurred along the Marais des Cygnes, Marmaton, and Spring river basins with one observation from within the Neosho River Basin. Four of these historic observations were in the focal areas I sampled in 2016. I surveyed one historic site each at Marais des Cygnes Wildlife Area and La Cygne Wildlife Area, and I surveyed two historic sites at Marais des Cygnes National Wildlife Refuge. Five Broad-headed Skinks were observed at historic sites at Marais des Cygnes National Wildlife Refuge but the Broad-headed Skink was not observed at the other two historic sites.

During my study, I increased the number of observations of the Broad-headed Skink in Kansas by more than 250%; however, this is only a total of 122 Broad-headed Skink observations at 80 localities across its entire range in the state. Given the relatively large and focused sampling effort required to make these observations, I do not recommend that the conservation status of the Broad-headed Skink be changed from the current category: Threatened.

I did not survey the area where the 1911 Broad-headed Skink observation was recorded in Franklin County. I did not find presence of Broad-headed Skinks at Neosho

Wildlife Area and Neosho State Fishing Lake, though there is one historical record of the species in Neosho County. Considering the absence of the Broad-headed Skink at these sites and the rigorous nature of our surveys, I would consider that the western extent of the Broad-headed Skink in Kansas lies to the east of Neosho Wildlife Area and Neosho State Fishing Lake. The Neosho River basin might be a dispersal barrier. A range extension for the Broad-headed Skink was not observed during my surveys; however, I did not survey far beyond their known range.

A. Squamate assemblage

The associations of the North American Racer and the Common Gartersnake in the CCA is expected based on their natural history. These species occupy grassland habitats and were not found in areas with overstory trees. The Little Brown Skink and the Western Wormsnake were associated with a secondary tree species, the Sugar Maple and were not found in areas with shrub cover. I found these species in more open, rocky areas within the forest.

The Broad-headed Skink was associated with variables representing mature forest patches. These variables were average log length, overstory tree size, (both positive) and secondarily, the presence of Black Walnut. Forest patches with large, mature trees had larger fallen logs that presumably will be replenished by those large trees in the future when they die. Knowing these associations of the Broad-headed Skink can help determine its presence at sites where the skink itself is not observed.

B. Critical habitat assessment

The habitat at sites sampled in 2016 was more homogenous because I focused on sampling oak-hickory forests where the Broad-headed Skink had been previously documented. This method of site selection might have limited the capacity of the logistic regression to discern patterns in presence and resulted in the reduced model (overstory tree size).

In 2017, surveys expanded to areas other than oak-hickory stands and represented more habitat types over a larger area in southeastern Kansas. These included areas across the known or suspected range of the Broad-headed Skink in Kansas. Overstory tree size was a significant variable in both the 2016 and 2017 logistic regression models. In the 2017 model, presence of the Broad-headed Skink was positively associated with overstory tree size, average log length, and understory tree dispersion, and negatively with overstory tree dispersion. These results suggest that the Broad-headed Skink prefers areas with large trees, longer fallen logs, and dispersed large trees. Similar observations have been made on the bases of field observations (Rakowitz 1983; Miller and Collins 1993). However, the current analyses arguably quantify the characteristics of habitat used by Broad-headed Skinks and indicate occurrence is likely limited to mature patches of Eastern Deciduous Forest in Eastern Kansas.

The occupancy of Broad-headed Skinks increased markedly when average overstory tree size was 20 cm DBH or greater (Figure 9a). Similarly, occupancy of Broad-headed Skinks increased if average log length was 2 m or greater (Figure 9b). In addition to providing opportunities to forage and shelter, fallen logs might be essential for reproduction. During my surveys, I observed three Broad-headed Skink nests; the first nests observed since 1992 and the first time nests were observed in natural habitat in Kansas. The nests were located under bark on rotting logs, specifically Pin Oaks (*Quercus palustris*). Certainly, additional confirmation is necessary but based on these new observations, large decayed logs may be a critical resource for the species. These observations of nesting habitat are consistent with other observations across their range (Vitt and Cooper 1985).

The results of the logistic regression and CCA suggest habitat structure is more important in predicting presence of the Broad-headed Skink than composition of tree species. This might be in part a function of the data types, ratio scale in habitat quantification, versus presence/absence in tree species. Certainly, a number of tree species ordinated with Broad-headed Skinks and might be useful in predicting presence or in evaluating habitat quality (e.g., Black Walnut). However, the quantitative variables explained a greater proportion of variation of Broad-headed Skink occurrence.

My own observations in the field indicate that additional variables might be useful in predicting habitat quality for the Broad-headed Skink. An index to describe how much bark on the trees was sloughing might be useful because Broad-headed Skinks take cover in these recesses on trees where they perch. Quantifying burn scars and other shelter-providing characteristics of trees, or counting snags might improve our ability to predict the occurrence of Broad-headed Skinks.

C. Critical habitat designation

During these surveys, the number of observations of the Broad-headed Skink in Kansas increased by almost 250%; however, this is only 122 Broad-headed Skinks in two years of focused effort spread across their range in the state. Such small numbers do not support a change in conservation status but they are useful in evaluating habitat used by the Broad-headed Skink.

The results of the CCA and logistic regression were used to define a new, more detailed critical habitat description for the Broad-headed Skink in Kansas. The new critical habitat designation incorporates the size of overstory trees used by the Broad-headed Skink and average log length, which might be a critical resource essential for successful reproduction of the species.

This new critical habitat definition is proposed to read as follows:

a) *Mature, hardwood forest patches in Miami, Linn, Bourbon, Crawford, and Cherokee counties within the Marais des Cygnes, Marmaton, and Spring river basins that have an average tree diameter >19 cm, representatives of trees with diameters >40 cm, and dispersed, decaying logs over 2 m in length.*

b) *Hardwood forests in the probable range of the Broad-headed Skink as determined by a field survey.*

In an effort to estimate the extent of this critical habitat, I used ArcMap and the Kansas GAP Land Cover shapefile (Egbert *et. al.* 2001) to visualize possible high-priority critical habitat based on sites where I documented the Broad-headed Skink (Appendix 15). The land covers included are Maple-Basswood Forest, Oak-Hickory

Forest, Mixed Oak Floodplain, Post Oak-Blackjack Oak, Pecan Floodplain, and Mixed Oak Floodplain. I also added the Bur Oak Floodplain land cover because it fits the habitat profile and only one site was surveyed in this land cover type.

A 100-m buffer was added to these areas to estimate dispersal capability and to visualize habitat connectivity. The Broad-headed Skink could disperse between forest habitats. I captured one juvenile in grassland habitat that was surrounded by forest, but the effectiveness of these dispersal events is not documented.

The resulting patches are proposed high-priority, critical habitats. These patches should be evaluated systematically using a standardized field protocols that includes the predictive variables in this study; overstory tree size, average log length, overstory tree dispersion and possibly the addition of estimates of log dispersion, number of snags, and number of trees with sloughing bark. These surveys will hopefully verify and refine the habitat relationships established by the 2016 and 2017 efforts. The surveys also are necessary because the landcover shapefile from which these patches were generated is 17 years old.

D. Proposed Sampling

In the summer of 2018, I suggest that surveys for the Broad-headed Skink occur within high-priority critical habitat (Appendix 15). The assessment should consist of visual encounter surveys so that more patches can be surveyed. Habitat assessment could be limited to fewer variables to improve sampling efficiency in the field (overstory tree size, average log length, overstory tree dispersion, log dispersion, number of snags, and number of trees with sloughing bark.). These surveys could verify current analyses and refine estimates of habitat quality across the range. Additional work could provide insights into occupancy, detectability, and relative abundance of the Broad-headed Skinks and habitat patch sizes. Such surveys would be the next step in developing a practical protocol for quantitatively assessing populations; a necessary tool in evaluating conservation status and criteria for a change in conservation status.

E. Management suggestions

1. Protect Broad-headed Skink habitat through state permits.

1.1. Require permits for any land use alterations within designated critical habitat.

1.2. Require mitigation for areas of designated critical habitat that are altered by development.

2. Enhance mitigation

2.1. Habitat variables that should be included in planning for mitigation are overstory tree size and average log length. Overstory trees should have a minimum Diameter at Breast Height (DBH) of 20-25 cm. Fallen, decayed logs should be incorporated at lengths of 2 m and greater. Time should be considered in mitigation planning as developing this habitat may take 15 or more years.

3. Maintain native oak-hickory forests on public lands and encourage participation on private lands.

3.1. Maintain forest structure with controlled burns and Timber Stand Improvement (TSI).

3.1.1. The Broad-headed Skink appears to have evolved in mature forests that rely on natural disturbances, such as fire, to maintain habitat structure. The Broad-headed Skink uses the escape cover provided by burn scars or sloughing bark. These damaged trees become fallen logs and as they decay, they become reproductive habitat for the Broad-headed Skink. TSI projects help maintain the integrity of the ecosystem by removing invasive species and thinning the forest to improve existing tree growth and dispersion patterns in mature forests. Management that supports the maintenance of oak-hickory forests will benefit the Broad-headed Skink.

3.2. Incorporate management of sensitive species in to management practices.

3.2.1. Conduct controlled burns in winter, before emergence occurs (MWPARC 2009).

3.2.2. Patch burning might be beneficial. This allows some habitat to be available at all times.

4. Limit potential threats to the Broad-headed Skink

4.1. Threat: Habitat loss and degradation, fragmentation

4.1.1. Solution: Protect areas of critical habitat for the Broad-headed Skink. Reduce fragmentation of these areas caused by installing access roads or field crops.

4.2. Threat: Modification of the natural system

4.2.1. Solution: Practice natural fire regimes on public lands and encourage surrounding landowners to participate. Thin forests and manage for native oak-hickory hardwoods through TSI procedures and facilitate maintenance of the natural system. Remove dams to allow for natural flood events to facilitate natural seasonal pattern of nutrient cycling to occur.

4.3. Threat: Non-native and invasive species

4.3.1. Solution: Management of non-native and invasive species, such as the Black Locust and Japanese Honeysuckle. Monitor new invasive species. The earlier a potentially invasive species is identified, the more efficiently it can be eliminated. Statewide restrictions can be used to inhibit the spread of non-native species that could degrade or eliminate critical habitat.

4.4. Threat: Domestic cats

4.4.1. Solution: Because domestic cats are detrimental to native reptile populations among others, domestic cats should be kept indoors and eliminated from public lands.

4.5. Threat: Unsustainable use

4.5.1. Solution: Collection of Broad-headed Skinks is prohibited by the Kansas Nongame and Endangered Species Conservation Act of 1975 without proper permits. However, this is not easily monitored, so public education programs focused on the effects of taking threatened and endangered wildlife from natural populations should be developed. Captive breeding is also a solution to this problem. Unsustainable use of other ecosystem resources, such as timber, should be monitored.

4.6. Threat: Disease

4.6.1. Solution: Disease is an emerging threat to reptiles, so monitoring diseases and parasites that could negatively affect the Broad-headed Skink is important. Diseases can be transmitted from captive bred individuals to native wild populations and diseases can be transmitted when individuals are released in areas other than where they were collected. The release of captive individuals and individuals that are not native to the area should be avoided. Monitoring the health of the Broad-headed Skink populations would allow for quick response by managers should a disease be introduced.

4.7. Threat: Climate change

4.7.1. Solution: Climate change models performed with some Kansas lizards predict that distributions will shift to the north and become fragmented for some species (Prowant 2014). This assumes that the development of new habitat will not lag behind changes to current habitat availability and that there will be corridors for dispersal. Preserving natural landscapes and discouraging large-scale fragmentation will be beneficial as it might allow the species to adapt more easily to climate change. Therefore, preserving large expanses of oak-hickory forests provides the best opportunity for Broad-headed Skinks to persist through the predicted change in climate. Interstate cooperation and management will be needed for this to be successful.

5. Conduct studies on genetics and population dynamics.

5.1. Determine the genetic diversity of these populations.

5.1.1. Develop models to track and predict changes in Broad-headed Skink populations. Metapopulation dynamics should be assessed and sink populations identified. Identify landscape features that function as barriers to dispersal.

5.2. Document the genetics distinctiveness of populations across the range of the Broad-headed Skink.

6. Implement education programs for state listed species.

6.1. Distribute education materials on the life history, conservation, and importance of protecting the Broad-headed Skink.

6.2. Conduct education events on the effects of potential threats to the Broad-headed Skink and other listed reptiles.

6.3. Publish the Recovery Plan on the Kansas Department of Wildlife, Parks and Tourism website.

7. Develop a long-term monitoring plan

7.1. Select areas of high Broad-headed Skink density and habitat availability.

7.1.1. Marais des Cygne Wildlife Area and Marais des Cygne National Wildlife Refuge would be ideal sites for monitoring the Broad-headed Skink because these areas make up the largest, unfragmented areas of Broad-headed Skink habitat. They are also part of the eastern forest Ecological Focal Area (EFA) and support habitat for other Species of Greatest Conservation Need (SGCN). Additional long-term monitoring at Crawford State Park and Spring River Wildlife Area would allow for monitoring trends across the range of the Broad-headed Skink.

7.2. Select areas that are more sensitive to population threats.

7.2.1. By surveying areas that are more sensitive to threats, such as encroachment by invasive species and habitat loss, impacts made to the Broad-headed Skink can be assessed. At the West Mineral Units there are on-going reclamation projects, which makes this area susceptible to encroachment by invasive species and a natural laboratory for investigating these interactions. There is also pollution from historical coal mines. We observed Broad-headed Skinks in small, fragmented patches of oak-hickory forest. The structure and dispersion of these populations should be determined.

7.3. Survey areas beyond the current range of the Broad-headed Skink that possess appropriate habitat.

7.3.1. Periodic surveys should continue at Neosho State Fishing Lake and Neosho Wildlife Area because of the historical records in the area. Surveys should also be conducted north of Miami State Fishing Lake.

8. Conduct a review every five years.

8.1. Determine whether Recovery Plan objectives are being met and whether down-listing or delisting criteria are met. Assessment should also be made on whether Broad-headed Skinks should be considered for further protection.

F. Proposed downlisting and delisting criteria

1. Down-list to Species in Need of Conservation (SINC)

The Broad-headed Skink can be down-listed from Threatened to SINC when at least *15* distinct populations are present throughout its range in Kansas. These populations must be represented in Miami, Linn, Bourbon, Crawford, and Cherokee counties. In each of these populations, there must be adults and juveniles present as well as evidence that reproduction has occurred for five consecutive years. These populations must occur in designated critical habitat for the Broad-headed Skink. Eighty percent of these sites should also occur on easements or other lands that are protected from conversion and development.

A group of Broad-headed Skinks are considered a distinct population when they occur in connected landscapes that are 40 hectares and are separated by 10 km from other suitable patches of Broad-headed Skink habitat. Reproduction is measured by the presence of hatchlings in late summer.

These sites should be monitored, but only by qualified individuals so that habitat is not destroyed in the process, especially decayed logs. Visual encounter surveys will be the most efficient method to monitor these populations. Threats to these populations should be considered when petitioning to down-list the Broad-headed Skink. Habitat destruction should not affect the population on protected land, but other threats, such as invasive species, should be monitored.

2. Delist

The Broad-headed Skink can be considered for delisting when self-sustained populations occupy 80% of available critical habitat in the currently designated range of the Broad-headed Skink. In these areas, there must be presence of adults and juvenile and adequate connectivity in the landscape. Threats to these populations should be considered when petitioning to delist the Broad-headed Skink.

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Table 1. A description for how each habitat variable was measured. These variables were measured at each site surveyed for the Broad-headed Skink in eastern Kansas in 2016 and 2017. These measurements were modified from Deuser and Shugart (1978).

Variable	Methods
1) Canopy closure (%)	Average of 20 densiometer estimates of canopy closure; five in each quadrant.
2) Vegetative cover (%)	Average of 20 estimates of vegetative cover; five in each quadrant.
3) Soil exposure (%)	Same as (2), with exposure of soil.
4) Leaf litter depth (mm)	Average of 20 measurements of leaf litter depth; five in each quadrant, and measured at the center of each quadrat.
5) Soil moisture (%)	Same as (4), with soil moisture. This was measured with a Field Scout™ TDR 300 Moisture Meter.
6) Presence of woody species	Average number of woody species over 2 m in 20 quadrats.
7) Overstory tree dispersion (m)	Average distance from the center trap to the nearest overstory tree taken in each quarter (Cottam and Curtis 1956).
8) Overstory tree size (cm)	Average diameter at breast height (DBH) of the nearest overstory tree in each quarter (Cottam and Curtis 1956).
9) Understory tree dispersion (m)	Average distance from the center trap to the nearest understory tree taken in each quarter (Cottam and Curtis 1956).
10) Understory tree size (cm)	Average DBH of the nearest understory tree in each quarter (Cottam and Curtis 1956).
11) Fallen log dispersion (m)	Average distance of the center trap to the nearest log that is at least 7.5 cm in diameter from each quarter.
12) Fallen log diameter (cm)	Average of the diameter from the closest fallen log with a diameter of at least 7.5 cm measured in each quarter.
13) Average fallen log length (m)	Average length of all logs with a diameter of at least 7.5 cm measured within the whole site.
14) Number of fallen logs	Average number of all fallen logs with a diameter of at least 7.5 cm in each quarter.
15) Rock cover (%)	Average of estimated percentage of exposed rock in each quarter.

Table 2. Species observed at each focal area surveyed during the 2016 and 2017 field seasons. Forty-one species were observed and included 1,791 individuals. Focal areas include Miami State Fishing Lake (MSFL), La Cygne Wildlife Area (LCWA), Marais des Cygnes National Wildlife Refuge (MDCR), Marais des Cygnes Wildlife Area (MDCWA), Bourbon County State Fishing Lake (BSFL), Hollister Wildlife Area (HWA), Neosho Wildlife Area (NWA), Neosho State Fishing Lake (NSFL), West Mineral Units (WMU), Crawford State Park (CSP), and Spring River Wildlife Area (SRWA).

Lizards	**MSFL**	**LCWA**	**MDCR**	**MDCWA**	**BSFL**	**HWA**	**NWA**	**NSFL**	**WMU**	**CSP**	**SRWA**
Broad-headed Skink	9	22	20	28	8	10			5	15	7
Little Brown Skink	8	18	3	11	4	1		1		1	3
Five-lined Skink		16	5	5		1	1	2		2	7
Six-lined Racerunner					1	13			3	8	
Great Plains Skink						3				1	
Slender Glass Lizard										1	
Eastern Collared Lizard						13					
Prairie Lizard											8
Snakes											
Ring-necked Snake	1	24	25	10	2	2		1			14
Western Wormsnake	1	19	4	6		2				1	
North American Racer		10	12	2	4	4	2	2	5	7	1
Western Ratsnake	1	8	3	5	1	2	2	3	2		3
Copperhead	3	5		3	1	3					1
Common Gartersnake	1	5	5	5		2	4		1	1	
Rough Greensnake		3								1	
Western Milksnake		2									
Diamond-backed Watersnake		1		5			2				
Western Ribbonsnake	1		2	8		1	4		1		
Red-bellied Snake		1									
Prairie Kingsnake			1			2		1			
Plain-bellied Watersnake			1	5						1	

Table 2. Continued

	MSFL	LCWA	MDCR	MDCWA	BSFL	HWA	NWA	NSFL	WMU	CSP	SRWA
Snakes											
Dekay's Brown snake	1			5			1				
Speckled Kingsnake				1				1			1
Common Watersnake							1				
Rough Earthsnake									2		3
Turtles											
Eastern Box Turtle		7	2	4	3	1	2	1	2	2	7
Pond Slider				4			1		1		
Snapping Turtle				1							
Painted Turtle				1							
Spiny Softshell				1							
Ornate Box Turtle	1					1			1		
Amphibians											
American Toad	6	38	9	3		8	2	4	6	2	1
Southern Leopard Frog	35	52	113	550	7	18	88	5	145		3
Blanchard's Cricket Frog		7	6	11	1	1	1	2		5	2
American Bullfrog	3	4	9	21		2			12		
Gray Treefrog spp.		3	2								
Spring Peeper			1								
Eastern Newt			2	1							
Boreal Chorus Frog				1							
Small-mouthed Salamander				1							
Eastern Narrow-mouthed Toad											1

Table 3. Tree species and total number that were identified in 2016 and 2017 in eastern Kansas. Only tree species that were present in at least 10% of sites (bold) were used as habitat variables in the Canonical Correspondence Analysis (CCA).

Species	Total
American Elm	**2440**
Basswood	68
Bitternut Hickory	**373**
Black Cherry	51
Black Locust	34
Black Walnut	**999**
Black Willow	20
Blackjack Oak	6
Box Elder	**328**
Bur Oak	**384**
Chinquapin Oak	**1125**
Chokecherry	6
Cottonwood	130
Eastern Red Cedar	**399**
Eastern Redbud	143
Green Ash	**1590**
Hackberry	**1381**
Honey Locust	**491**
Ironwood	1
Kentucky Coffee Tree	55
Kingnut Hickory	**253**
Mulberry	**108**
Norway Maple	1
Osage Orange	**927**
Pecan	**1126**
Persimmon	95
Pin Oak	**1509**
Pine spp.	10
Post Oak	254
Red Elm	20
Shagbark Hickory	**613**
Shumard's Oak	256
Silver Maple	109
Sugar Maple	**803**
Sugarberry	3
Swamp White Oak	2
Sycamore	106
Tree of Heaven	12
Western Buckeye	1
Wooly Buckthorn	17
TOTAL	**16249**

Table 4. A) Summary statistics for the constrained Canonical Correspondence Analysis (CCA) of the squamate community observed in eastern Kansas in 2016 and 2017. The first two axes explain 88.13% of 12.11% of the total variation. B) The coefficients of habitat variables from the CCA.

A)

Statistic	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Eigenvalues	0.3551	0.0837	0.056	0.0031
Explained variation (cumulative)	9.8	12.11	13.65	13.74
Explained fitted variation (cumulative)	71.32	88.13	99.38	100

B)

Variable	**Explains %**	**Contribution %**	**Pdeuso-F**	**P-value**
Shrub cover (%)	6.3	20.5	9.3	0.001
AVG Fallen Log Length (m)	3.9	12.9	6.1	0.001
Sugar Maple	1.9	6.2	2.9	0.003
Overstory Tree Size (cm)	1.7	5.4	2.6	0.008

Table 5. All of the competing models for the 2017 Logistic Regression. SHCO = vegetative cover, SOSE = soil exposure, LIDE = leaf litter depth, WVTH = presence of woody species, OTSZ = overstory tree size, OTDI = overstory tree dispersion, UTSZ = understory tree size, UTDI = understory tree dispersion, FLDA = fallen log diameter, FLDS = fallen log dispersion, AVFL = number of fallen logs, AVLL = average fallen log length.

Model	AIC	ΔAIC
pres.abs ~ SHCO + SOSE + LIDE + WVTH + OTSZ + OTDI +UTSZ + UTDI+FLDA + FLDS + AVFL + AVLL	110.6	7.4
pres.abs ~ OTSZ + UTDI + AVLL	104.6	1.4
pres.abs ~ OTSZ + OTDI + UTSZ + UTDI + AVLL	103.72	0.52
*pres.abs ~ OTSZ + OTDI + UTDI + AVLL	103.2	0

AIC = Akaike weight for each model
ΔAIC = Change in Akaike weight compared to the “best” model.
* = Indicates the best model as determined using AIC scores.

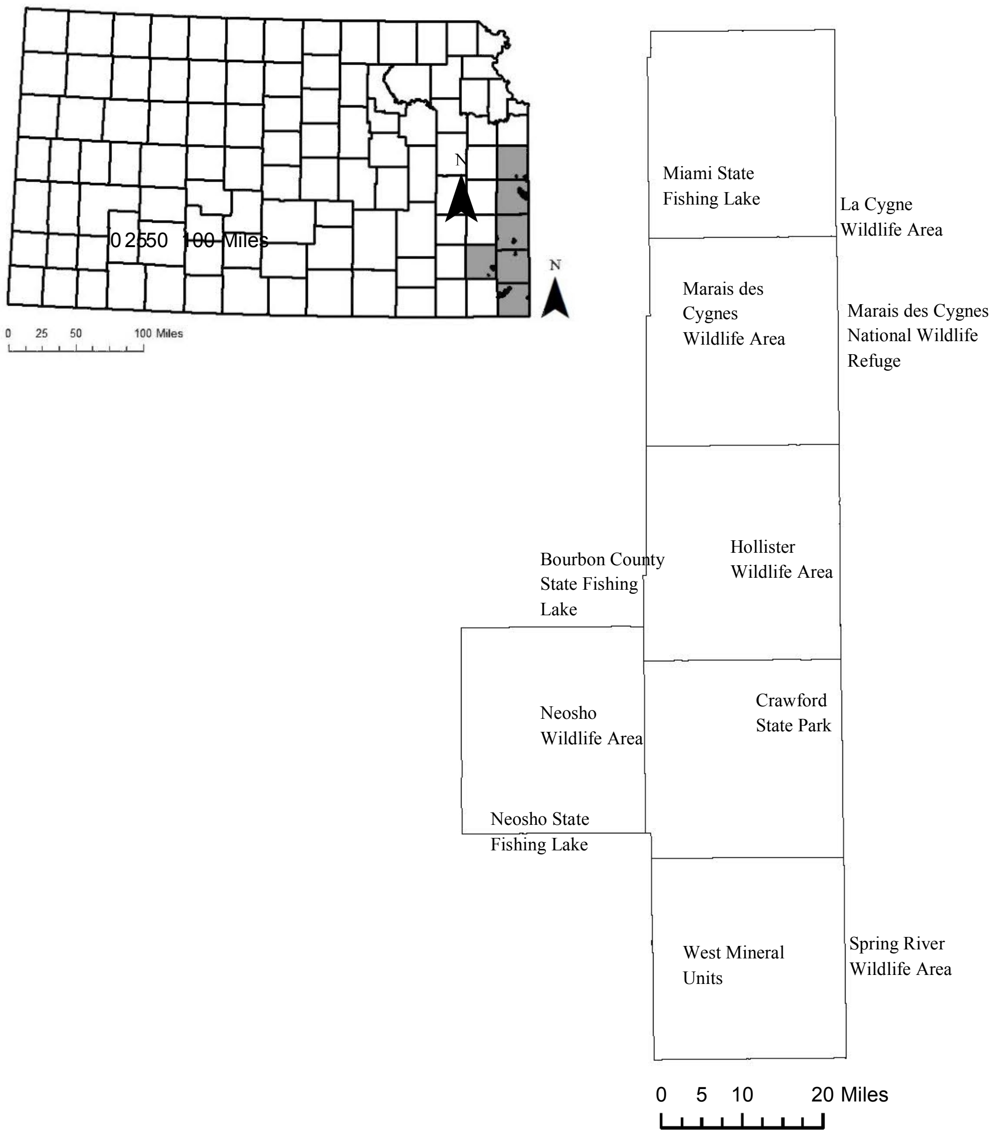


Figure 1. Focal areas surveyed for the Broad-headed Skink in eastern Kansas in 2016 and 2017. In 2016, survey efforts were focused on La Cygne Wildlife Area, Marais des Cygnes Wildlife Area, and Marais des Cygnes National Wildlife Refuge. In 2017, all eleven focal areas were surveyed for the Broad-headed Skink.

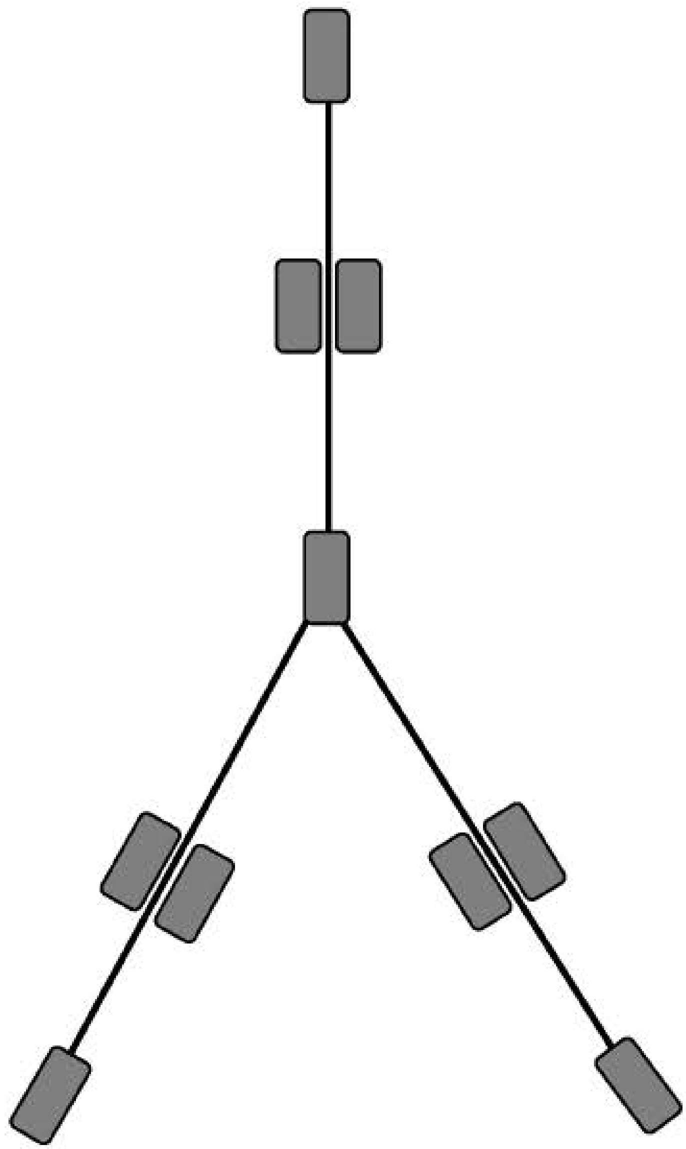


Figure 2. Design of the drift fence arrays used in 2016 and 2017. The arms were 7.6 m in length and centered on a funnel trap in the center of the array. Three additional funnel traps were placed around each arm.

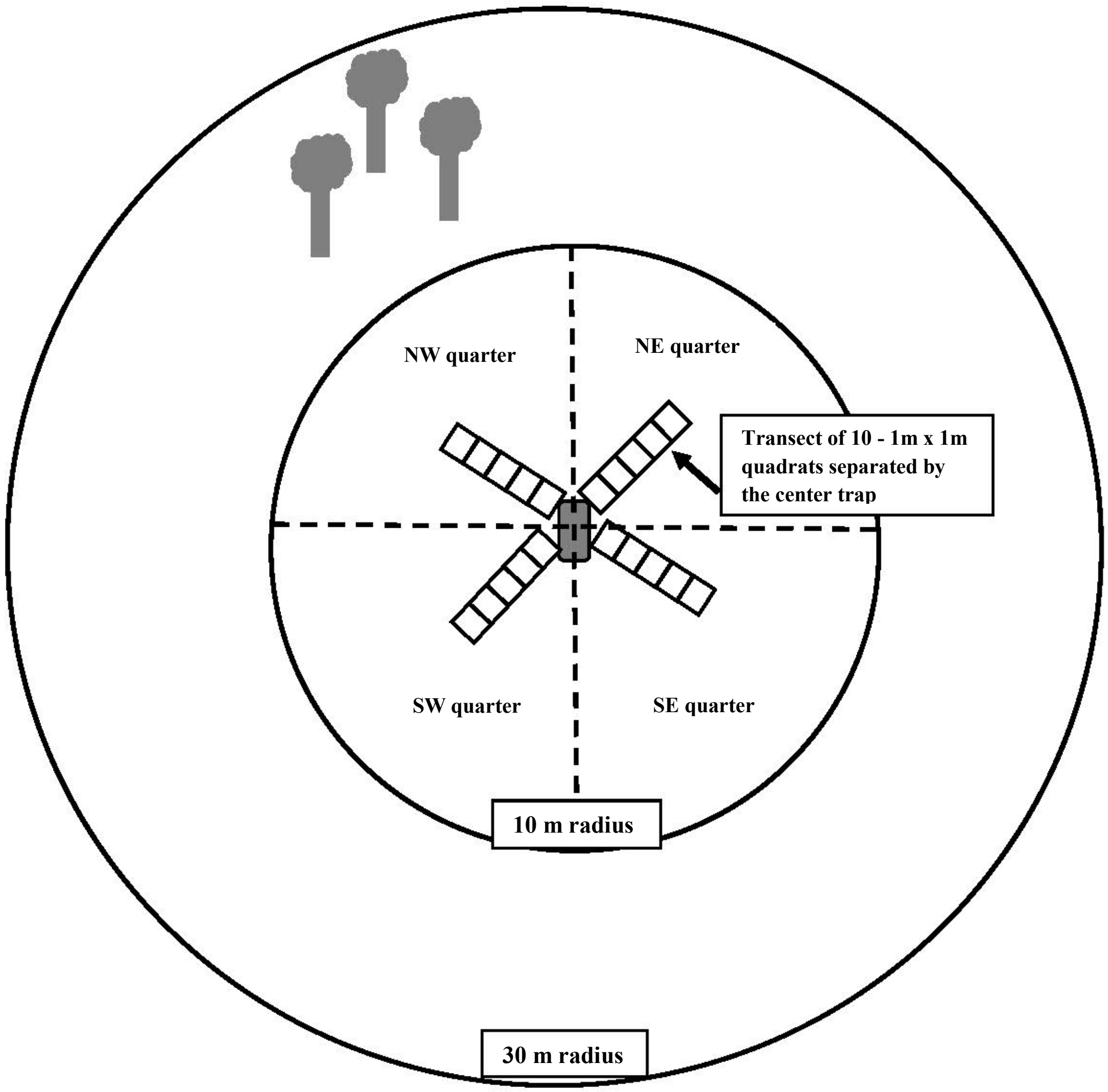


Figure 3. Illustration of the design of habitat assessments. Two transects comprised of 10, 1m X 1m quadrats were deployed through the center trap; six habitat variables were measured in quadrats. All other variables were measured within a 10-m radius of the center trap and in each quarter. Trees were identified within a 30-m radius of the center trap. Figure modified from Dueser and Shugart (1978).

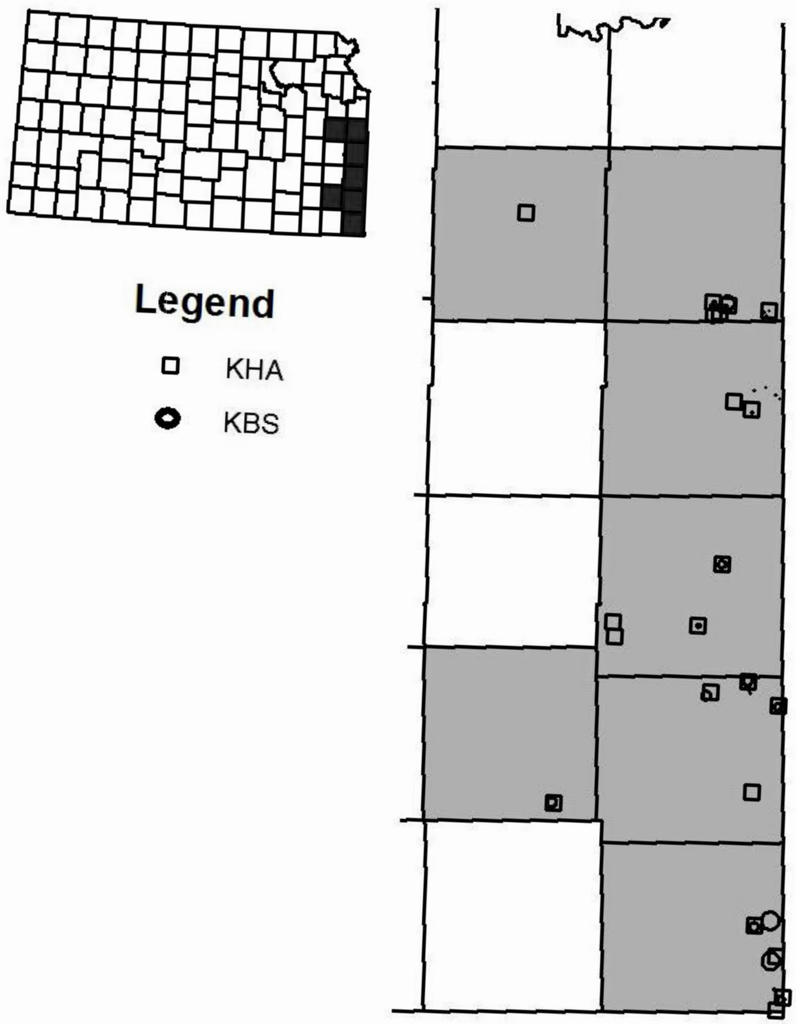


Figure 4. Historically documented localities for the Broad-headed Skink in Kansas. Forty-six Broad-headed Skinks were observed at 28 localities from 1950-2013. Data for this map were provided by the Kansas Herpetofaunal Atlas (KHA) (Taggart 2017) and the Kansas Biological Survey (KBS).

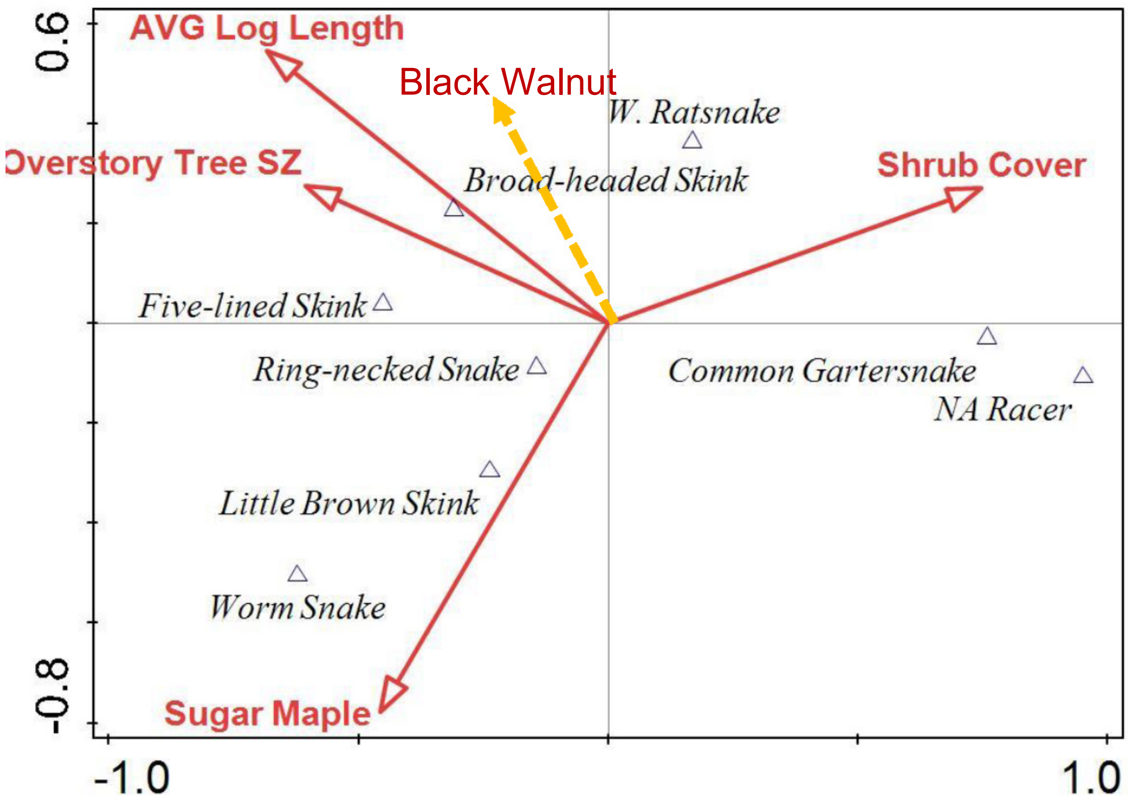


Figure 5. Visualization of the constrained Canonical Correspondence Analysis (CCA) of presence / absence of squamate species ordinated by habitat. The habitat variables, consisting of Average (AVG) Log Length, Overstory Tree Size (SZ), Sugar Maple, and Shrub Cover, explained 100% of the constrained variation in the squamate assemblage. Focal area, as indicated in Figure 1, was used as the covariate. The dashed line indicates the association of Black Walnut as derived from a secondary exploration in the CCA.

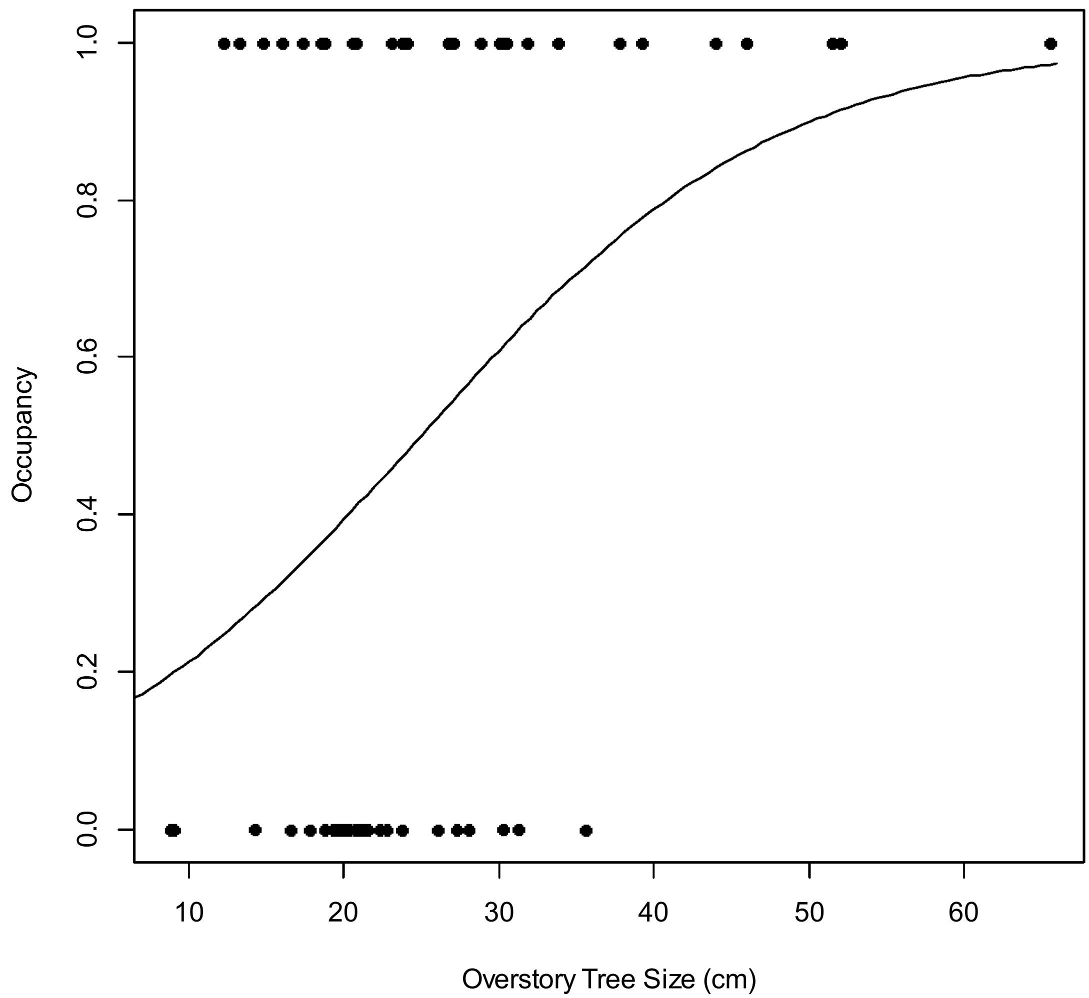


Figure 6. The positive relationship between Broad-headed Skink presence and overstory tree size, the significant variable from the 2016 logistic regression model.

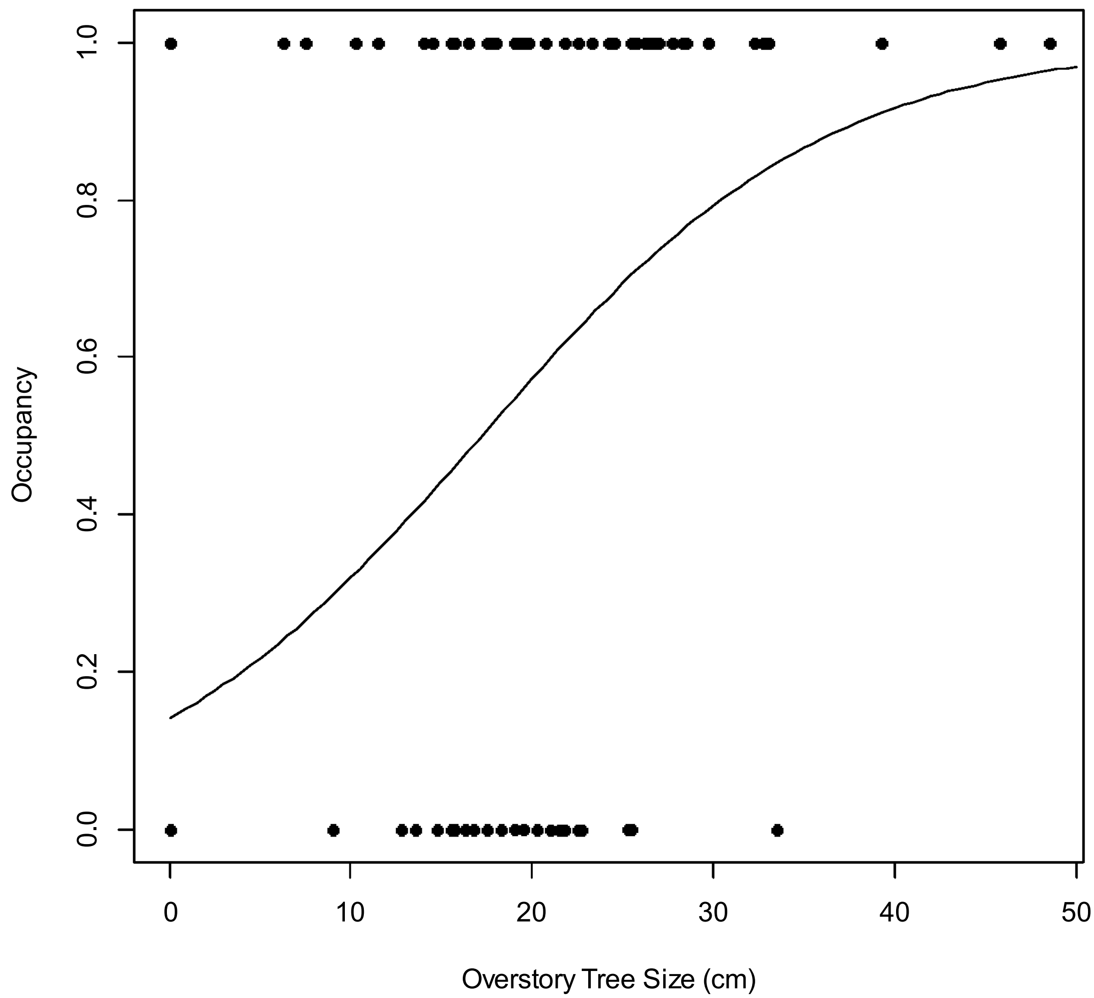


Figure 7. The positive relationship between Broad-headed Skink presence and overstory tree size, a significant variable from the 2017 logistic regression model.

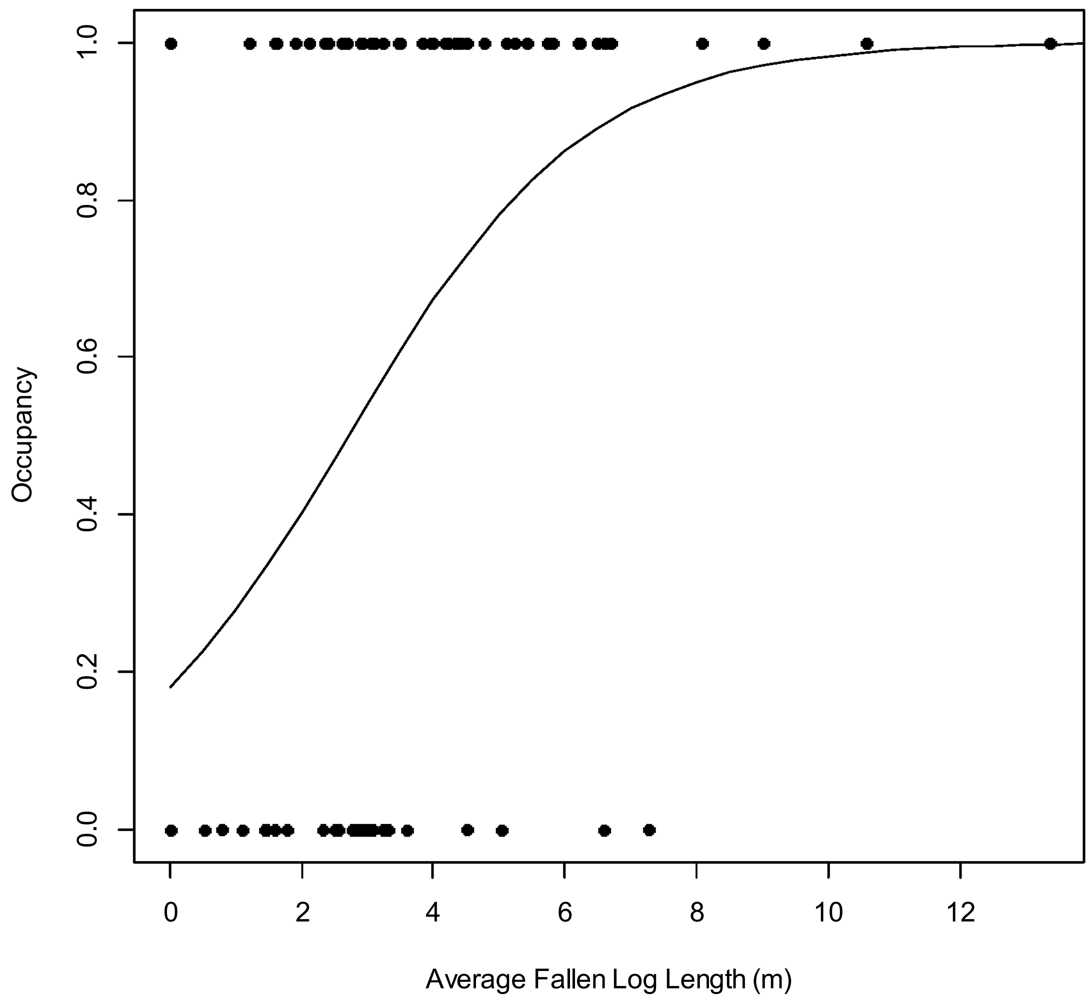


Figure 8. The positive relationship between Broad-headed Skink presence and average log length, a significant variable from the 2017 logistic regression model.

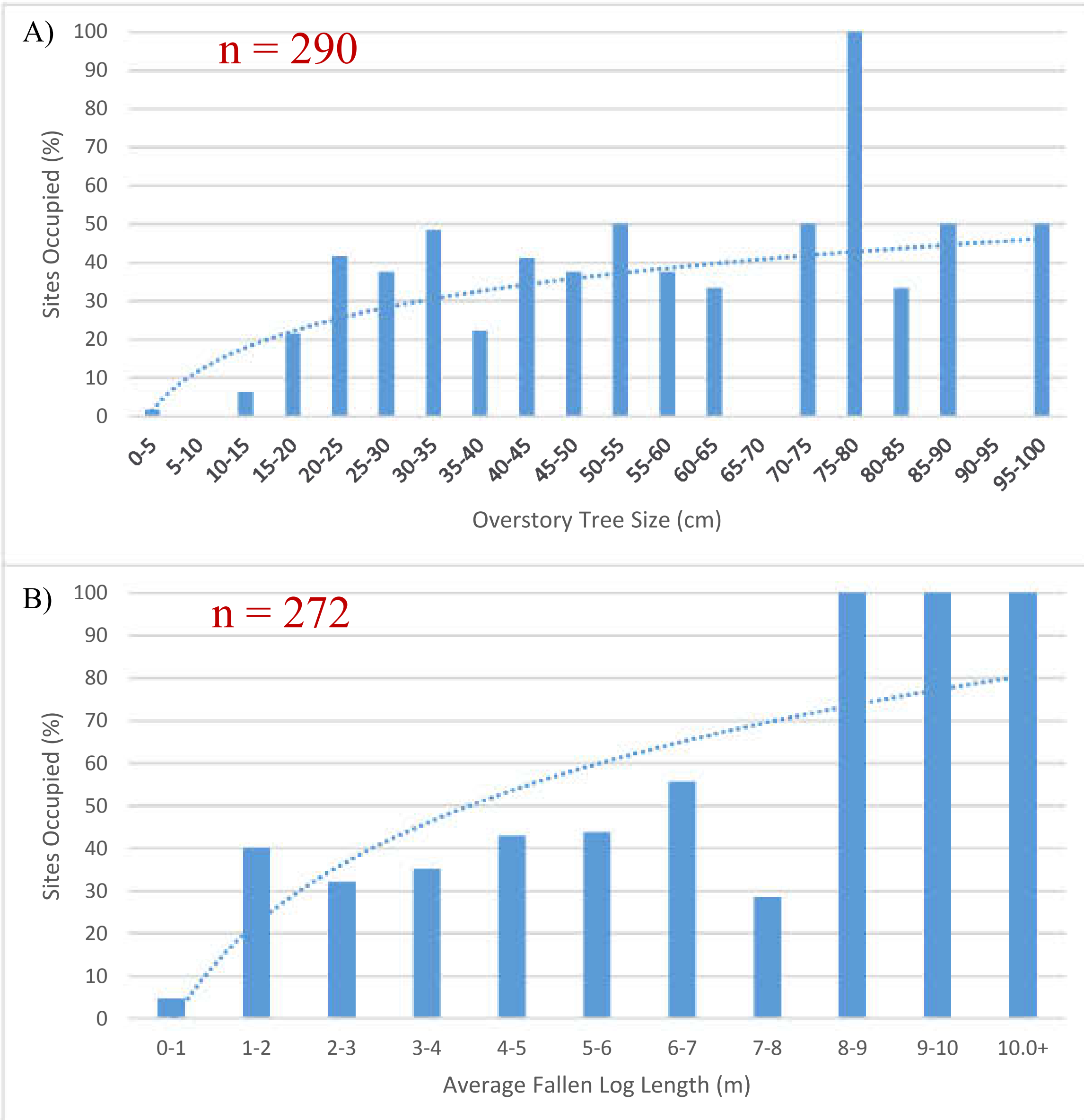


Figure 9. A) Percent of sites occupied by the Broad-headed Skink in overstory tree size categories measured in 2016 and 2017. B) Percent of sites occupied by the Broad-headed Skink in average fallen log length categories measured in 2016 and 2017. The dashed line represents a trend line.

Appendix 1. Date and location of survey sites in 2016. Presence of the Broad-headed Skink is indicated.

Date	Site Name	Latitude	Longitude	Accuracy (m)	Presence/Absence
5/17/2016	LCWA 1-1	38.40623	-94.66077	3	Absent
5/17/2016	LCWA 1-2	38.40752	-94.66129	3	Absent
5/17/2016	LCWA 1-3	38.40727	-94.66183	3	Absent
5/17/2016	MDCR 1-1	38.24047	-94.63147	6	Present
5/17/2016	MDCR 1-2	38.24003	-94.63047	5	Absent
5/17/2016	MDCR 1-3	38.24017	-94.63272	3	Absent
5/17/2016	MDCWA 1-1	38.25089	-94.68681	3	Absent
5/17/2016	MDCWA 1-2	38.25123	-94.68825	5	Absent
5/17/2016	MDCWA 1-3	38.25223	-94.68804	3	Absent
5/23/2016	MDCWA 2-1	38.25093	-94.69953	3	Absent
5/23/2016	MDCWA 2-2	38.24982	-94.69982	6	Absent
5/23/2016	MDCWA 2-3	38.25230	-94.69984	6	Absent
5/23/2016	MDCR 2-1	38.20592	-94.69176	5	Present
5/23/2016	MDCR 2-2	38.20548	-94.69283	4	Absent
5/23/2016	MDCR 2-3	38.20688	-94.69182	5	Absent
5/23/2016	LCWA 2-1	38.39826	-94.65211	6	Present
5/23/2016	LCWA 2-2	38.39735	-94.65231	3	Present
5/23/2016	LCWA 2-3	38.39894	-94.65136	3	Absent
5/31/2016	MDCWA 3-1	38.28393	-94.75060	3	Absent
5/31/2016	MDCWA 3-2	38.28333	-94.75126	3	Absent
5/31/2016	MDCWA 3-3	38.28379	-94.74929	4	Absent
5/31/2016	MDCR 3-1	38.25559	-94.65280	3	Absent
5/31/2016	MDCR 3-2	38.25593	-94.65149	3	Absent
5/31/2016	MDCR 3-3	38.25454	-94.65284	3	Absent
5/31/2016	LCWA 3-1	38.39177	-94.64787	3	Present
5/31/2016	LCWA 3-2	38.39115	-94.64874	3	Absent
5/31/2016	LCWA 3-3	38.39326	-94.64764	3	Present
6/6/2016	MDCWA 4-1	38.27580	-94.69252	3	Absent
6/6/2016	MDCWA 4-2	38.27579	-94.69377	3	Absent
6/6/2016	MDCWA 4-3	38.27480	-94.69316	3	Present
6/6/2016	LCWA 4-1	38.39263	-94.65425	3	Present
6/6/2016	LCWA 4-2	38.39260	-94.65561	3	Absent
6/6/2016	LCWA 4-3	38.39333	-94.65461	3	Absent
6/6/2016	MDCR 4-1	38.23094	-94.64135	4	Absent

6/6/2016	MDCR 4-2	38.23130	-94.64281	4	Absent
6/6/2016	MDCR 4-3	38.23001	-94.64102	4	Absent
6/13/2016	MDCWA 5-1	38.28805	-94.75107	4	Absent
6/13/2016	MDCWA 5-2	38.28891	-94.75039	5	Absent
6/13/2016	MDCWA 5-3	38.28683	-94.75117	7	Absent
6/13/2016	LCWA 5-1	38.41941	-94.67445	3	Present
6/13/2016	LCWA 5-2	38.42053	-94.67453	9	Present
6/13/2016	LCWA 5-3	38.41830	-94.67392	4	Absent
6/13/2016	MDCR 5-1	38.22318	-94.63938	5	Absent
6/13/2016	MDCR 5-2	38.22320	-94.64059	3	Absent
6/13/2016	MDCR 5-3	38.22437	-94.63920	3	Present
6/20/2016	MDCWA 6-1	38.26998	-94.67931	6	Absent
6/20/2016	MDCWA 6-2	38.26982	-94.68056	3	Absent
6/20/2016	MDCWA 6-3	38.27024	-94.68150	5	Absent
6/20/2016	LCWA 6-1	38.37505	-94.64294	5	Absent
6/20/2016	LCWA 6-2	38.37376	-94.64143	4	Present
6/20/2016	LCWA 6-3	38.37320	-94.64219	3	Present
6/20/2016	MDCR 6-2	38.22559	-94.64554	3	Absent
6/20/2016	MDCR 6-1	38.22484	-94.64558	7	Present
6/20/2016	MDCR 6-3	38.22514	-94.64445	4	Absent
6/27/2016	LCWA 7-1	38.40470	-94.65151	4	Absent
6/27/2016	LCWA 7-2	38.40560	-94.65099	4	Absent
6/27/2016	LCWA 7-3	38.40509	-94.65241	3	Absent
6/27/2016	MDCWA 7-1	38.21902	-94.69572	3	Present
6/27/2016	MDCWA 7-2	38.21941	-94.69466	3	Absent
6/27/2016	MDCWA 7-3	38.21902	-94.69691	3	Present
6/27/2016	MDCR 7-1	38.19175	-94.63326	5	Absent
6/27/2016	MDCR 7-2	38.19230	-94.63427	6	Absent
6/27/2016	MDCR 7-3	38.19097	-94.63289	7	Absent
7/11/2016	MDCWA 8-1	38.27289	-94.70591	5	Present
7/11/2016	MDCWA 8-2	38.27304	-94.70487	3	Absent
7/11/2016	MDCWA 8-3	38.27205	-94.70503	3	Absent
7/11/2016	LCWA 8-1	38.41996	-94.66370	3	Absent
7/11/2016	LCWA 8-2	38.41883	-94.66454	3	Absent
7/11/2016	LCWA 8-3	38.41984	-94.66495	3	Absent
7/11/2016	MDCR 8-1	38.22180	-94.66521	3	Absent
7/11/2016	MDCR 8-2	38.22151	-94.66629	4	Absent
7/11/2016	MDCR 8-3	38.22121	-94.66299	3	Absent
7/18/2016	MDCR 9-2	38.20422	-94.61944	6	Present

7/18/2016	MDCR 9-1	38.20462	-94.61874	4	Absent
7/18/2016	MDCR 9-3	38.20414	-94.61803	3	Absent
7/18/2016	MDCWA 9-1	38.22145	-94.66907	3	Present
7/18/2016	MDCWA 9-2	38.22205	-94.66969	3	Absent
7/18/2016	MDCWA 9-3	38.22097	-94.66824	3	Absent
7/18/2016	LCWA 9-1	38.37586	-94.64747	3	Present
7/18/2016	LCWA 9-2	38.37675	-94.64759	3	Absent
7/18/2016	LCWA 9-3	38.37551	-94.64627	3	Present
7/25/2016	MDCR 10-2	38.24150	-94.62907	3	Absent
7/25/2016	MDCR 10-1	38.24241	-94.62887	3	Absent
7/25/2016	MDCR 10-3	38.24282	-94.62992	3	Absent
7/25/2016	LCWA 10-1	38.39978	-94.66042	3	Absent
7/25/2016	LCWA 10-2	38.39945	-94.66151	3	Absent
7/25/2016	LCWA 10-3	38.39965	-94.66226	3	Absent
7/25/2016	MDCWA 10-2	38.25489	-94.71469	3	Absent
7/25/2016	MDCWA 10-1	38.25402	-94.71463	3	Absent
7/25/2016	MDCWA 10-3	38.25357	-94.71581	3	Absent
8/1/2016	MDCR 11-2	38.19736	-94.64412	3	Absent
8/1/2016	MDCR 11-1	38.19823	-94.64390	3	Absent
8/1/2016	MDCR 11-3	38.19948	-94.64370	3	Absent
8/1/2016	MDCWA 11-1	38.22499	-94.69299	3	Absent
8/1/2016	MDCWA 11-2	38.22527	-94.69211	3	Absent
8/1/2016	MDCWA 11-3	38.22400	-94.69299	3	Absent
8/1/2016	LCWA 11-1	38.39443	-94.65909	3	Absent
8/1/2016	LCWA 11-2	38.39529	-94.65853	3	Absent
8/1/2016	LCWA 11-3	38.39453	-94.66019	3	Absent
8/8/2016	MDCR 12-1	38.20403	-94.65257	3	Absent
8/8/2016	MDCR 12-2	38.20352	-94.65152	3	Absent
8/8/2016	MDCR 12-3	38.20462	-94.65157	3	Absent
8/8/2016	MDCWA 12-2	38.25538	-94.74857	3	Absent
8/8/2016	MDCWA 12-1	38.25449	-94.74847	3	Absent
8/8/2016	MDCWA 12-3	38.25382	-94.74770	3	Absent
8/8/2016	LCWA 12-1	38.41611	-94.66094	3	Absent
8/8/2016	LCWA 12-2	38.41552	-94.66187	4	Absent
8/8/2016	LCWA 12-3	38.41519	-94.66039	3	Absent
8/22/2016	LCWA 13-1	38.39479	-94.64825	6	Absent
8/22/2016	LCWA 13-2	38.39540	-94.64946	6	Present
8/22/2016	LCWA 13-3	38.39631	-94.65115	6	Absent
8/22/2016	MDCWA 13-1	38.29247	-94.73448	7	Absent

8/22/2016	MDCWA 13-2	38.29145	-94.73410	7	Absent
8/22/2016	MDCWA 13-3	38.29337	-94.73550	6	Absent
8/22/2016	MDCR 13-1	38.21482	-94.63435	5	Absent
8/22/2016	MDCR 13-2	38.21370	-94.63428	5	Absent
8/22/2016	MDCR 13-3	38.21293	-94.63573	4	Absent

Appendix 2. As above: Location and Broad-headed Skink presence/absence data for sites surveyed during the 2017 field season.

Date	Site Name	Latitude	Longitude	Accuracy (m)	Presence/Absence
6/19/2017	BSFL 1-1	37.78403	-95.06974	3	Present
6/19/2017	BSFL 1-10	37.78534	-95.07735	3	Present
6/19/2017	BSFL 1-11	37.78735	-95.07357	3	Absent
6/19/2017	BSFL 1-12	37.78819	-95.07391	3	Absent
6/19/2017	BSFL 1-2	37.78479	-95.06937	3	Absent
6/19/2017	BSFL 1-3	37.78558	-95.06932	3	Present
6/19/2017	BSFL 1-4	37.78409	-95.07283	3	Absent
6/19/2017	BSFL 1-5	37.78439	-95.07385	3	Absent
6/19/2017	BSFL 1-6	37.78447	-95.07457	3	Absent
6/19/2017	BSFL 1-7	37.78445	-95.07767	3	Absent
6/19/2017	BSFL 1-8	37.78412	-95.07823	3	Absent
6/19/2017	BSFL 1-9	37.78482	-95.07816	3	Present
5/15/2017	CSP 1-1	37.64551	-94.81549	3	Absent
5/15/2017	CSP 1-10	37.62955	-94.81149	3	Absent
5/15/2017	CSP 1-11	37.64729	-94.81092	3	Absent
5/15/2017	CSP 1-12	37.64794	-94.81157	3	Present
5/15/2017	CSP 1-2	37.64548	-94.81767	3	Absent
5/15/2017	CSP 1-3	37.64657	-94.81322	3	Absent
5/15/2017	CSP 1-4	37.64693	-94.81408	3	Present
5/15/2017	CSP 1-5	37.63781	-94.80687	3	Absent
5/15/2017	CSP 1-6	37.6377	-94.80769	3	Present
5/15/2017	CSP 1-7	37.63788	-94.80865	3	Absent
5/15/2017	CSP 1-8	37.63434	-94.81014	3	Present
5/15/2017	CSP 1-9	37.63152	-94.81134	3	Present
6/5/2017	HWA 1-1	37.7749	-94.80593	3	Absent
6/5/2017	HWA 1-10	37.78105	-94.82581	3	Absent
6/5/2017	HWA 1-11	37.7807	-94.82451	3	Absent
6/5/2017	HWA 1-12	37.78022	-94.82523	3	Present
6/5/2017	HWA 1-2	37.77538	-94.80679	3	Absent
6/5/2017	HWA 1-3	37.77545	-94.80907	3	Absent
6/5/2017	HWA 1-4	37.77485	-94.80865	3	Absent
6/5/2017	HWA 1-5	37.77556	-94.83186	3	Absent
6/5/2017	HWA 1-6	37.77531	-94.83246	3	Present

6/5/2017	HWA 1-7	37.77443	-94.83321	3	Absent
6/5/2017	HWA 1-8	37.77489	-94.83201	3	Absent
6/5/2017	HWA 1-9	37.78122	-94.82499	3	Absent
7/10/2017	HWA 2-1	37.76097	-94.84342	3	Absent
7/10/2017	HWA 2-10	37.77552	-94.82729	3	Absent
7/10/2017	HWA 2-11	37.77647	-94.82723	3	Absent
7/10/2017	HWA 2-12	37.77707	-94.82707	3	Present
7/10/2017	HWA 2-2	37.76099	-94.84247	3	Absent
7/10/2017	HWA 2-3	37.76089	-94.84169	3	Absent
7/10/2017	HWA 2-4	37.76089	-94.83476	3	Absent
7/10/2017	HWA 2-5	37.76269	-94.83411	3	Present
7/10/2017	HWA 2-6	37.76303	-94.83318	3	Absent
7/10/2017	HWA 2-7	37.7778	-94.8408	3	Present
7/10/2017	HWA 2-8	37.77798	-94.84	3	Absent
7/10/2017	HWA 2-9	37.77861	-94.83828	3	Absent
7/17/2017	LCWA 14-1	38.39286	-94.65842	3	Absent
7/17/2017	LCWA 14-10	38.41953	-94.66055	3	Absent
7/17/2017	LCWA 14-11	38.42007	-94.66053	3	Absent
7/17/2017	LCWA 14-12	38.42067	-94.66068	3	Present
7/17/2017	LCWA 14-2	38.39207	-94.65853	3	Present
7/17/2017	LCWA 14-3	38.39194	-94.6592	3	Absent
7/17/2017	LCWA 14-4	38.39774	-94.6561	3	Absent
7/17/2017	LCWA 14-5	38.39705	-94.65633	3	Present
7/17/2017	LCWA 14-6	38.39637	-94.65681	3	Absent
7/17/2017	LCWA 14-7	38.41592	-94.65513	3	Absent
7/17/2017	LCWA 14-8	38.41668	-94.65496	3	Absent
7/17/2017	LCWA 14-9	38.41751	-94.65457	3	Absent
8/7/2017	MDCR 14-1	38.24161	-94.64082	3	Absent
8/7/2017	MDCR 14-10	38.20737	-94.65795	3	Present
8/7/2017	MDCR 14-11	38.20798	-94.65784	3	Present
8/7/2017	MDCR 14-12	38.20833	-94.65702	3	Absent
8/7/2017	MDCR 14-2	38.24225	-94.64086	3	Absent
8/7/2017	MDCR 14-3	38.24291	-94.64082	3	Absent
8/7/2017	MDCR 14-4	38.24004	-94.62318	3	Absent
8/7/2017	MDCR 14-5	38.23934	-94.62312	3	Absent
8/7/2017	MDCR 14-6	38.23872	-94.62325	3	Absent
8/7/2017	MDCR 14-7	38.2127	-94.62659	3	Absent
8/7/2017	MDCR 14-8	38.21197	-94.62705	3	Present
8/7/2017	MDCR 14-9	38.2112	-94.62743	3	Absent

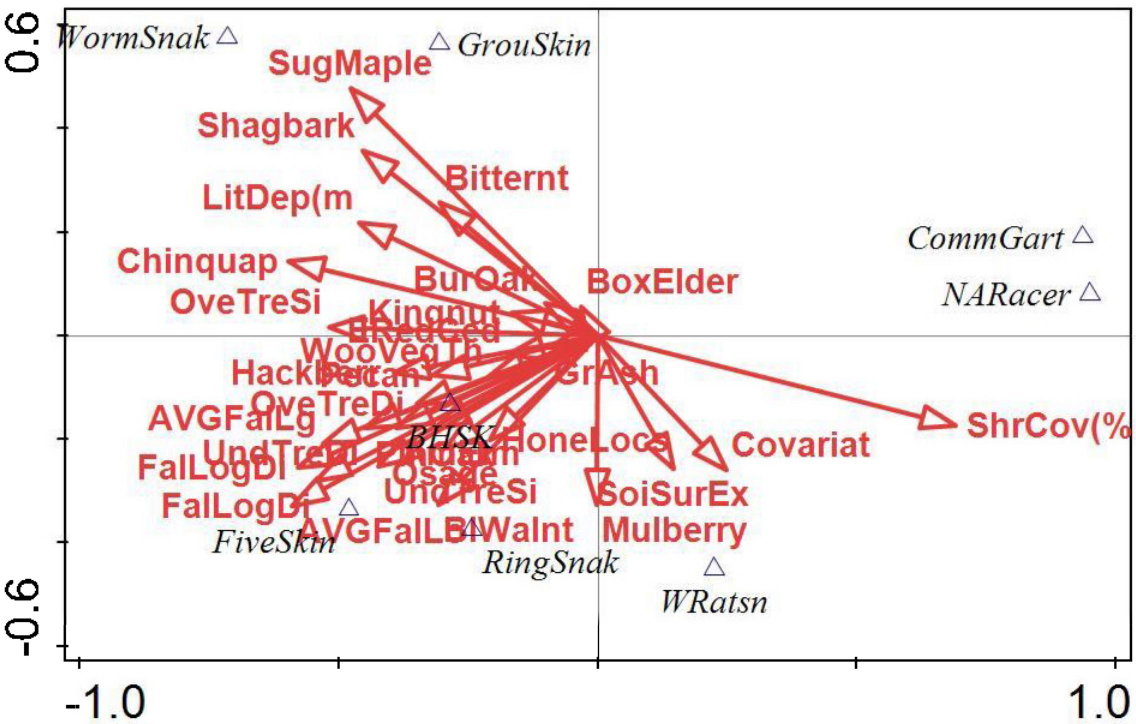
7/31/2017	MDCWA 14-1	38.25269	-94.7019	3	Absent
7/31/2017	MDCWA 14-10	38.27205	-94.69799	3	Absent
7/31/2017	MDCWA 14-11	38.27179	-94.69707	3	Present
7/31/2017	MDCWA 14-12	38.27161	-94.69579	3	Absent
7/31/2017	MDCWA 14-2	38.25314	-94.7024	3	Absent
7/31/2017	MDCWA 14-3	38.25349	-94.70302	3	Absent
7/31/2017	MDCWA 14-4	38.2543	-94.70379	3	Absent
7/31/2017	MDCWA 14-5	38.25464	-94.70461	3	Present
7/31/2017	MDCWA 14-6	38.25514	-94.70486	3	Present
7/31/2017	MDCWA 14-7	38.24078	-94.70096	3	Present
7/31/2017	MDCWA 14-8	38.24108	-94.70149	3	Present
7/31/2017	MDCWA 14-9	38.2415	-94.70212	3	Absent
7/24/2017	MSFL 2-1	38.42613	-94.7892	4	Absent
7/24/2017	MSFL 2-10	38.42191	-94.78565	5	Absent
7/24/2017	MSFL 2-11	38.42133	-94.78514	4	Absent
7/24/2017	MSFL 2-12	38.42092	-94.78456	5	Present
7/24/2017	MSFL 2-2	38.42683	-94.78897	5	Absent
7/24/2017	MSFL 2-3	38.42687	-94.78815	5	Present
7/24/2017	MSFL 2-4	38.42058	-94.78717	5	Present
7/24/2017	MSFL 2-5	38.42106	-94.78655	3	Absent
7/24/2017	MSFL 2-6	38.42115	-94.78607	3	Absent
7/24/2017	MSFL 2-7	38.42222	-94.78647	4	Present
7/24/2017	MSFL 2-8	38.42255	-94.7859	4	Present
7/24/2017	MSFL 2-9	38.42255	-94.78521	5	Present
5/30/2017	NSFL 1-1	37.4263	-95.19798	3	Absent
5/30/2017	NSFL 1-2	37.42686	-95.19909	3	Absent
5/30/2017	NSFL 1-3	37.42725	-95.198	3	Absent
5/30/2017	NSFL 1-4	37.42017	-95.19576	3	Absent
5/30/2017	NSFL 1-5	37.4186	-95.19668	3	Absent
5/30/2017	NSFL 1-6	37.41858	-95.19591	3	Absent
5/30/2017	NSFL 1-7	37.42488	-95.20354	3	Absent
5/30/2017	NSFL 1-8	37.42515	-95.20272	3	Absent
5/30/2017	NSFL 1-9	37.4244	-95.20171	3	Absent
6/12/2017	NWA 1-1	37.49477	-95.12523	3	Absent
6/12/2017	NWA 1-10	37.50365	-95.16119	3	Absent
6/12/2017	NWA 1-11	37.50355	-95.16021	3	Absent
6/12/2017	NWA 1-12	37.50335	-95.15934	3	Absent
6/12/2017	NWA 1-2	37.49461	-95.1262	3	Absent
6/12/2017	NWA 1-3	37.49408	-95.12786	3	Absent

6/12/2017	NWA 1-4	37.50023	-95.13058	3	Absent
6/12/2017	NWA 1-5	37.50089	-95.13099	3	Absent
6/12/2017	NWA 1-6	37.50153	-95.1304	3	Absent
6/12/2017	NWA 1-7	37.49991	-95.13158	3	Absent
6/12/2017	NWA 1-8	37.50072	-95.13189	3	Absent
6/12/2017	NWA 1-9	37.50143	-95.13212	3	Absent
5/22/2017	SRWA 1-1	37.19246	-94.65832	3	Absent
5/22/2017	SRWA 1-10	37.18361	-94.64899	3	Present
5/22/2017	SRWA 1-11	37.18208	-94.64862	3	Present
5/22/2017	SRWA 1-12	37.18235	-94.64764	3	Present
5/22/2017	SRWA 1-2	37.19158	-94.65813	3	Absent
5/22/2017	SRWA 1-3	37.19074	-94.65821	3	Absent
5/22/2017	SRWA 1-4	37.18991	-94.65829	3	Absent
5/22/2017	SRWA 1-5	37.18697	-94.65633	3	Absent
5/22/2017	SRWA 1-6	37.18753	-94.65643	3	Absent
5/22/2017	SRWA 1-7	37.18818	-94.65591	3	Present
5/22/2017	SRWA 1-8	37.18213	-94.65089	3	Absent
5/22/2017	SRWA 1-9	37.18213	-94.64963	3	Absent
6/26/2017	WMU 1-1	37.26033	-94.95704	3	Absent
6/26/2017	WMU 1-10	37.21663	-95.0145	3	Present
6/26/2017	WMU 1-11	37.21025	-95.01246	6	Present
6/26/2017	WMU 1-12	37.21082	-95.01214	3	Present
6/26/2017	WMU 1-2	37.26105	-94.95687	3	Absent
6/26/2017	WMU 1-3	37.26174	-94.9568	3	Absent
6/26/2017	WMU 1-4	37.23689	-94.96911	3	Absent
6/26/2017	WMU 1-5	37.23648	-94.9679	3	Present
6/26/2017	WMU 1-6	37.20893	-94.98631	3	Absent
6/26/2017	WMU 1-7	37.20897	-94.9881	3	Absent
6/26/2017	WMU 1-8	37.2088	-94.98895	3	Absent
6/26/2017	WMU 1-9	37.2164	-95.01524	3	Absent

Appendix 3. Locations of incidental encounters of the Broad-Headed Skink during the 2016 and 2017 field seasons.

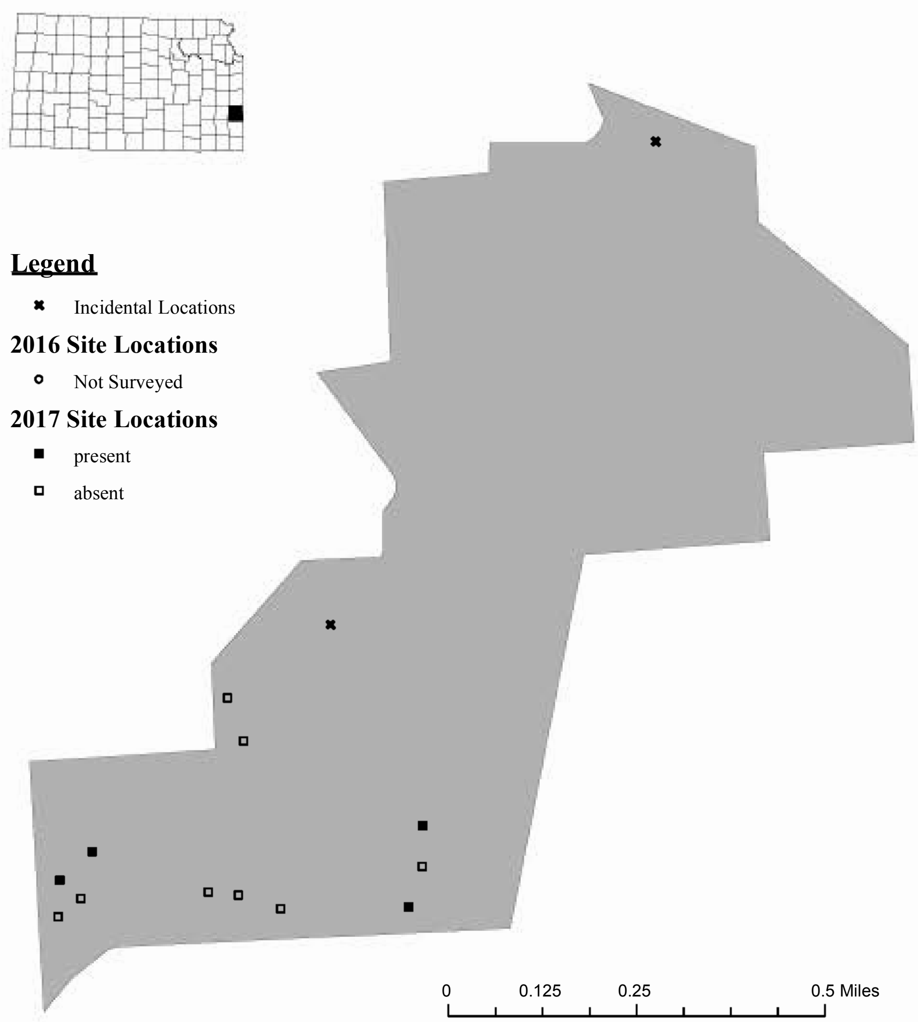
Date	Site Name	Latitude	Longitude
5/24/2016	MDCWAi7	38.25008	-94.70010
5/25/2016	MDCWAi7	38.25008	-94.70010
5/25/2016	MDCWAi7	38.25008	-94.70010
6/15/2016	MDCWAi10	38.26095	-94.68880
7/20/2016	LCWAi19	38.37491	-94.64681
7/20/2016	MSFLi20	38.42198	-94.78699
7/20/2016	MSFL 1	38.42207	-94.78729
7/25/2016	MDCWA 2	38.26087	-94.68539
7/26/2016	MDCR 3	38.23092	-94.61876
7/27/2016	MSFL 3	38.42087	-94.78814
8/2/2016	HWA 3	37.78415	-94.82764
8/3/2016	MSFL 3	38.42087	-94.78814
8/24/2016	MDCWA	38.27147	-94.69956
9/8/2016	MDCWAi27	38.25591	-94.75052
9/8/2016	MDCWAi27	38.25591	-94.75052
9/8/2016	MDCWAi27	38.25591	-94.75052
5/10/2017	HWAi36	37.77781	-94.83055
5/22/2017	SRWAi37	37.18284	-94.64851
5/23/2017	SRWAi37	37.18284	-94.64851
6/20/2017	BSFLi39	37.78951	-95.07134
6/20/2017	BSFLi40	37.79854	-95.06297
7/5/2017	MDCWAi27	38.25591	-94.75052
7/5/2017	MDCWAi27	38.25591	-94.75052
7/12/2017	INCi41	37.71031	-94.63465
7/12/2017	INCi41	37.71031	-94.63465
7/12/2017	INCi41	37.71031	-94.63465
7/19/2017	LCWAi42	38.41830	-94.67778
8/1/2017	MDCWAi43	38.25575	-94.74646
8/1/2017	MDCWAi27	38.25591	-94.75052
8/2/2017	INCi44	37.71014	-94.63565
8/9/2017	MDCWAi27	38.25591	-94.75052
8/9/2017	MDCWAi27	38.25591	-94.75052
8/9/2017	MDCWAi27	38.25591	-94.75052

8/9/2017	MDCWAi27	38.25591	-94.75052
8/9/2017	MDCWAi27	38.25591	-94.75052
8/9/2017	MDCWAi27	38.25591	-94.75052

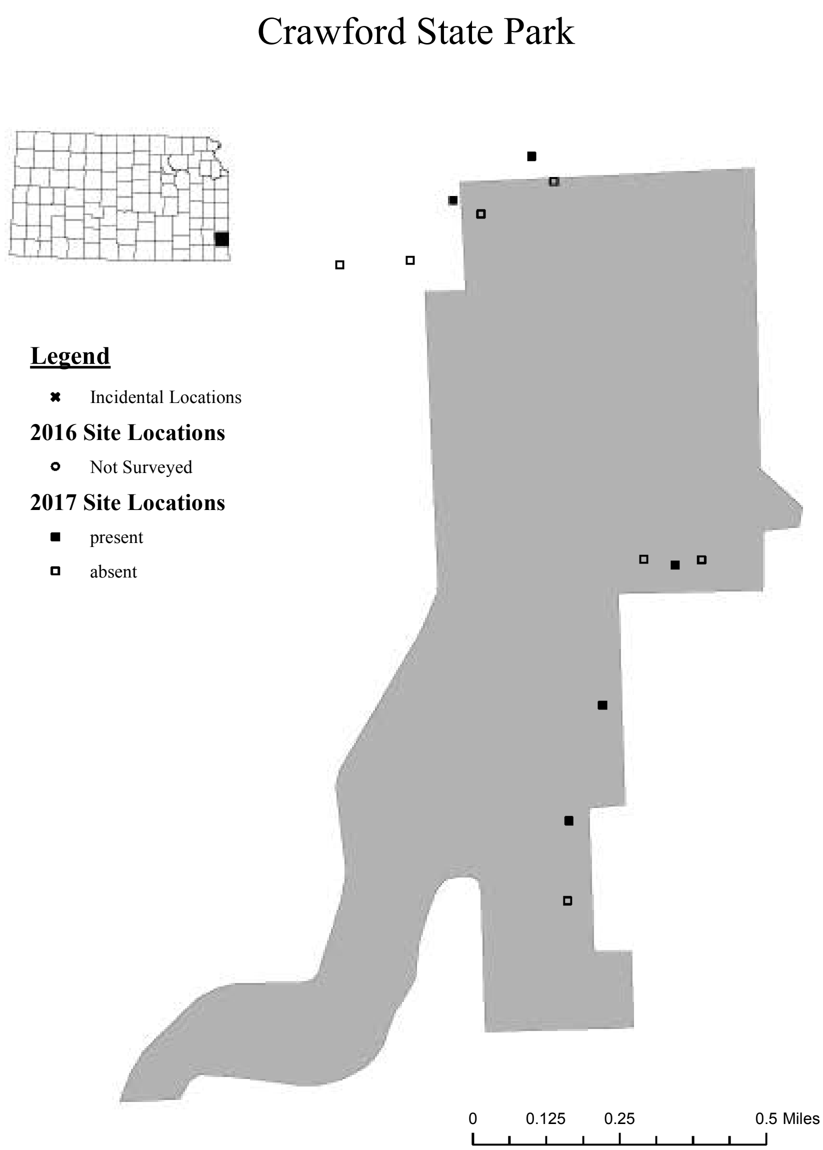


Appendix 4. Visualization of the constrained Canonical Correspondence Analysis (CCA). Interpretation is not possible with this analysis, so a constrained CCA with an Interactive Forward Selection was used.

Bourbon State Fishing Lake

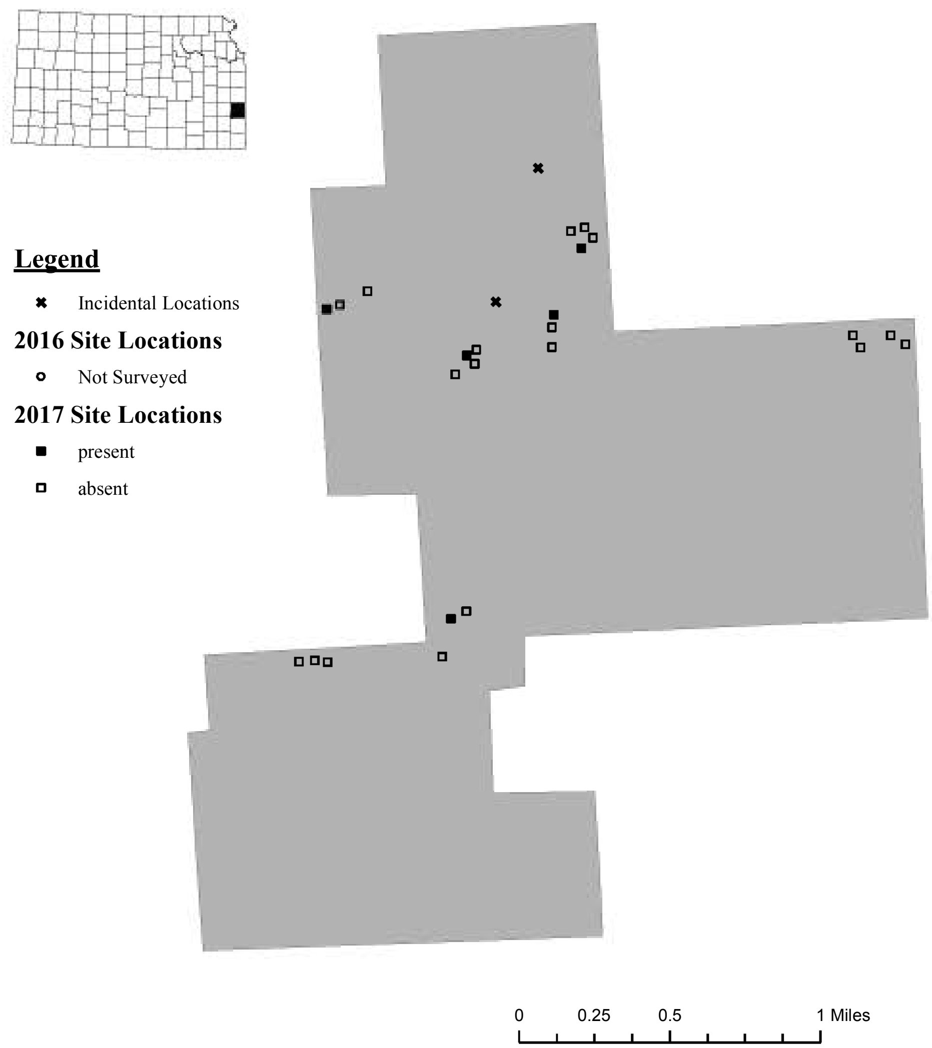


Appendix 5. Presence and absence of the Broad-headed Skinks at Bourbon State Fishing Lake during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

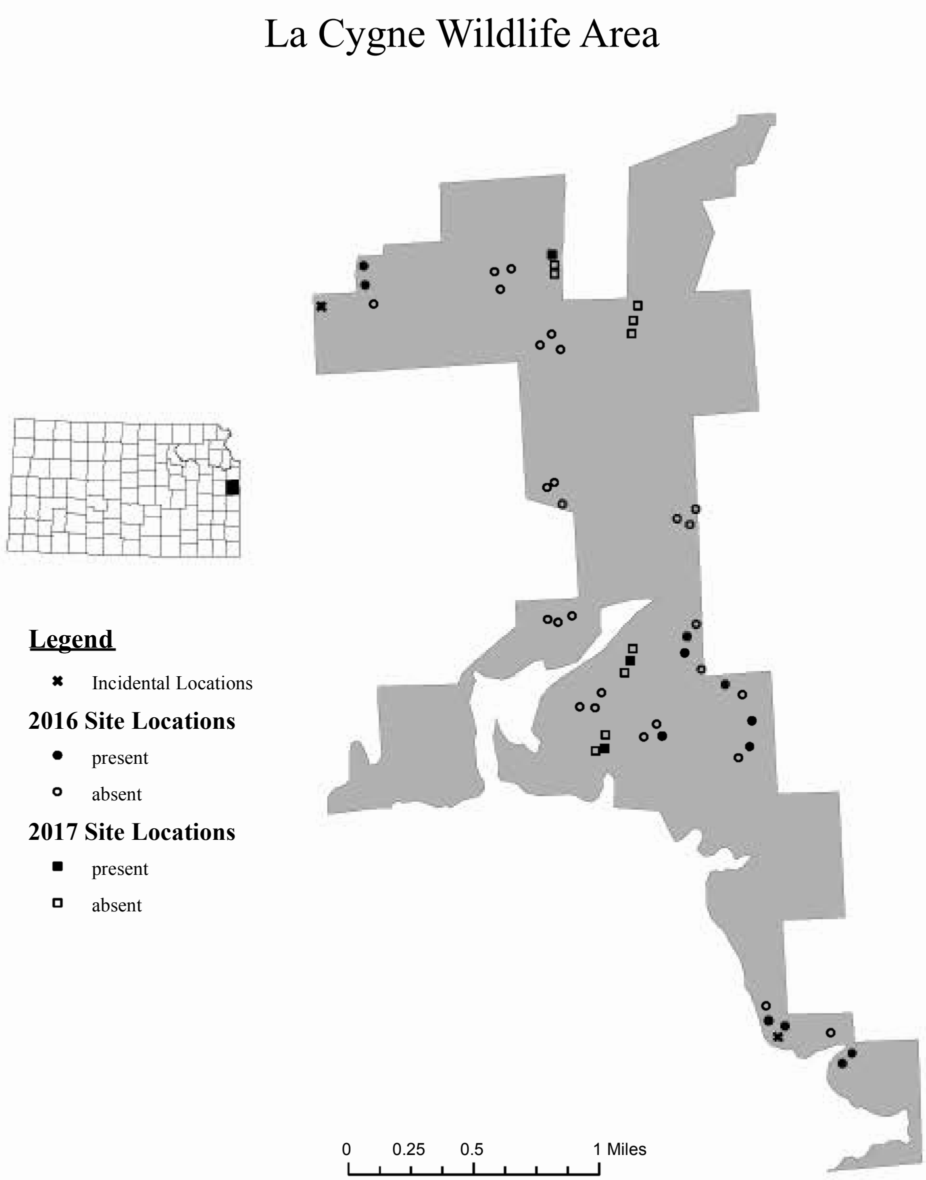


Appendix 6. Presence and absence of the Broad-headed Skinks at Crawford State Park during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed. The sites that occur outside of the shaded area were located at Farlington Fish Hatchery.

Hollister Wildlife Area

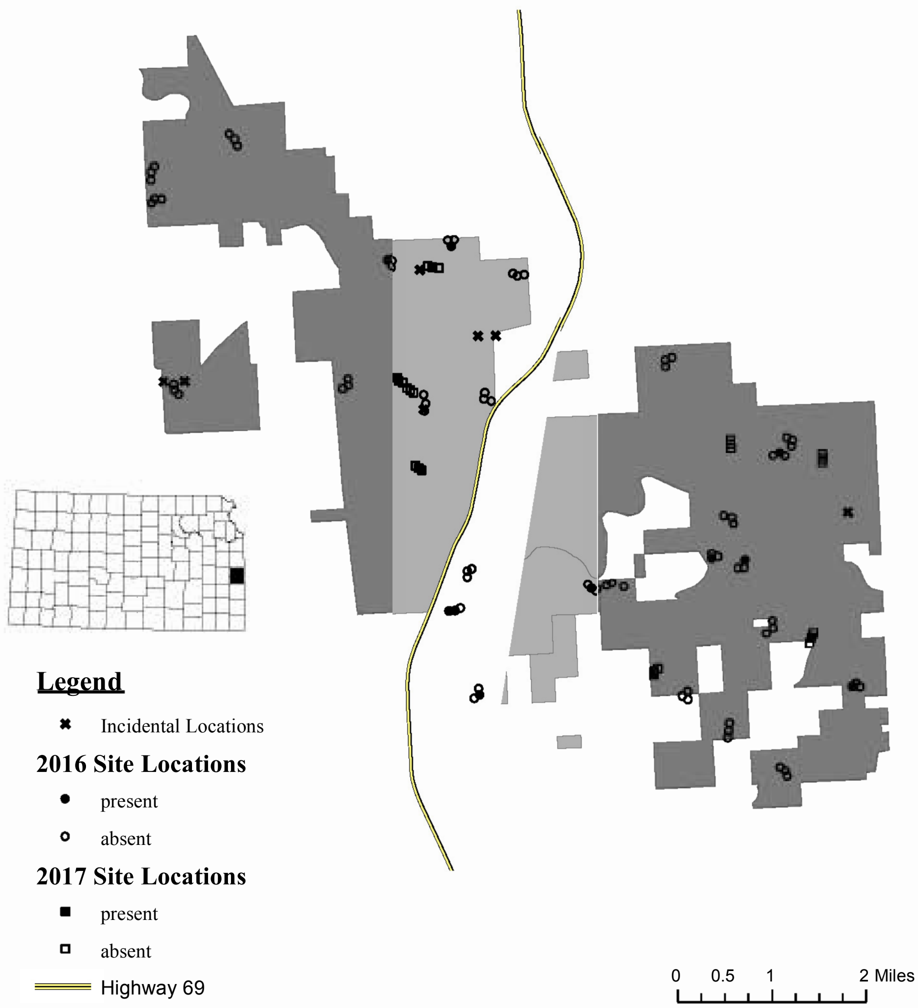


Appendix 7. Presence and absence of the Broad-headed Skinks at Hollister Wildlife Area during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

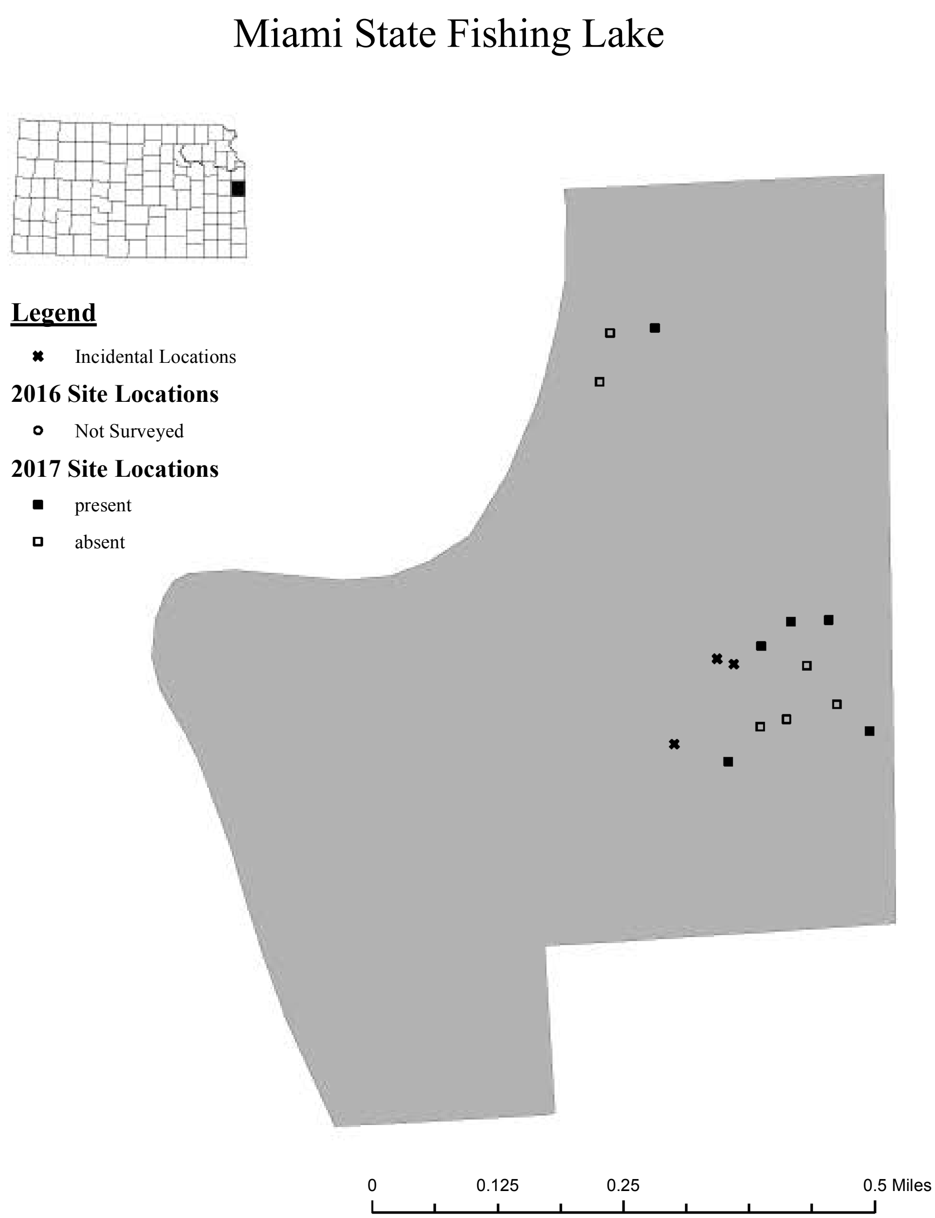


Appendix 8. Presence and absence of the Broad-headed Skinks at La Cygne wildlife Area during the 2016 and 2017 field seasons. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

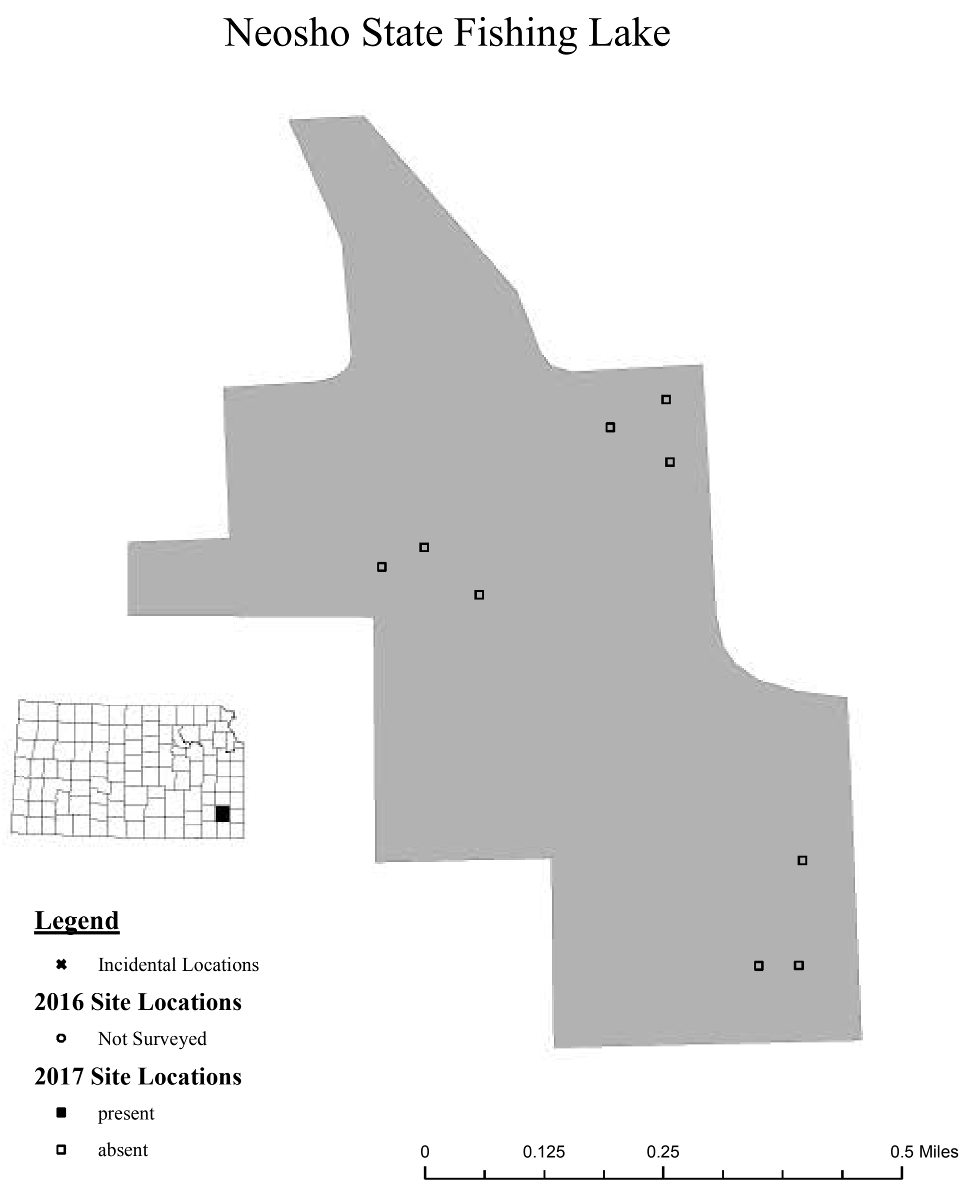
Marais des Cygnes Wildlife Area and Marais des Cygnes National Wildlife Area



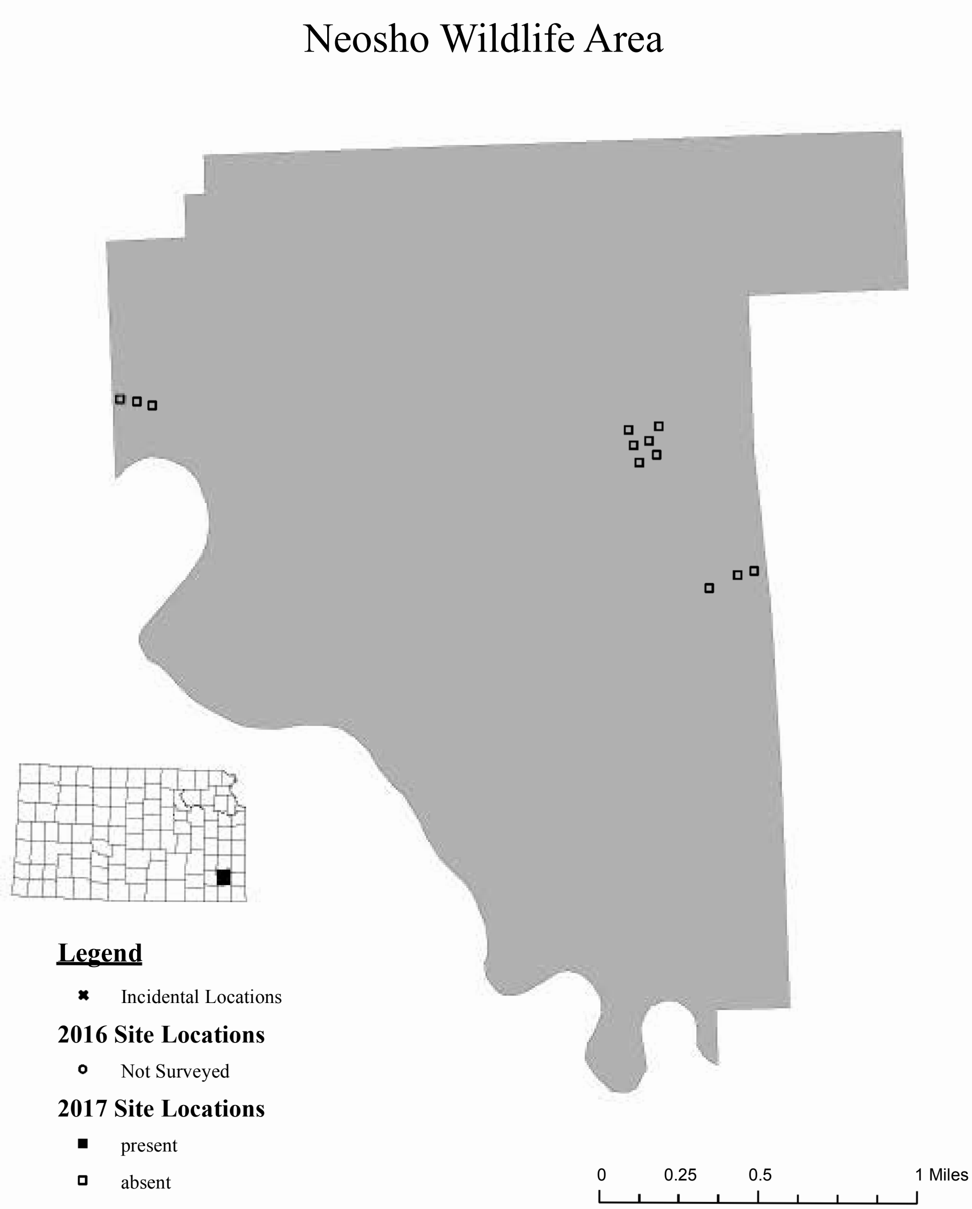
Appendix 9. Presence and absence of the Broad-headed Skinks at Marais des Cygnes Wildlife Area and Marais des Cygnes National Wildlife Refuge during the 2016 and 2017 field seasons. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.



Appendix 10. Presence and absence of the Broad-headed Skinks at Miami State Fishing Lake during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

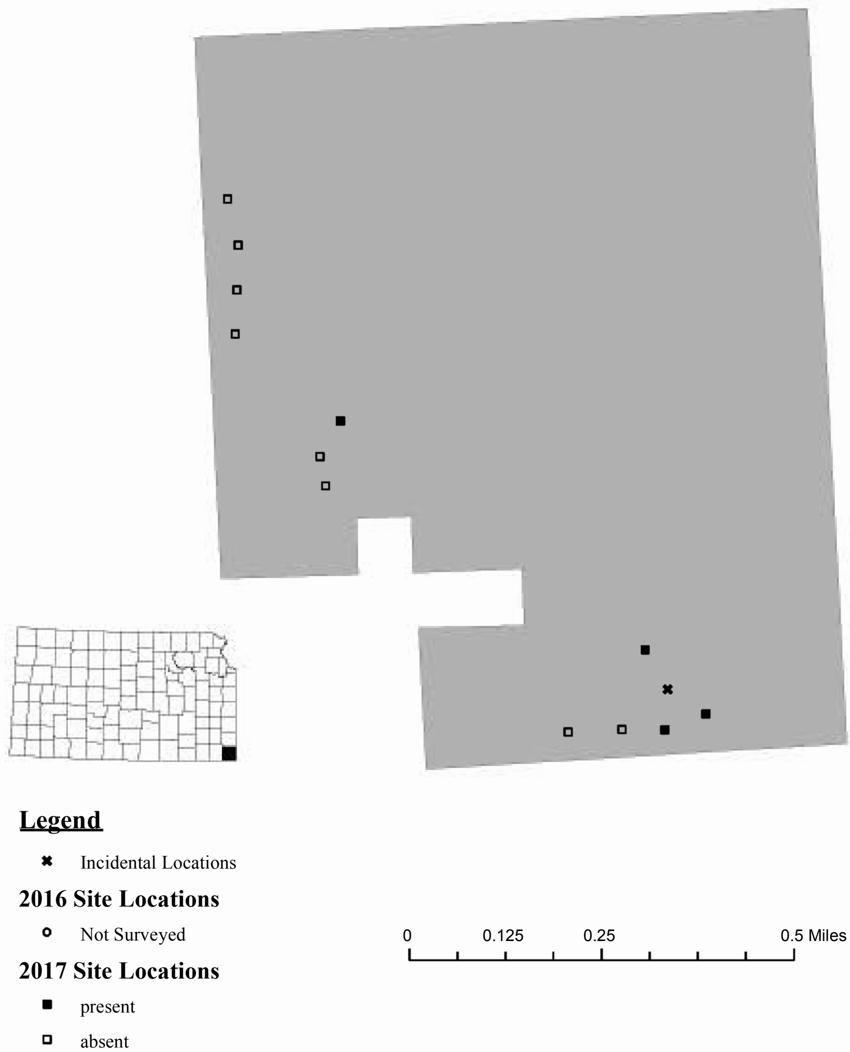


Appendix 11. Presence and absence of the Broad-headed Skinks at Neosho State Fishing Lake during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

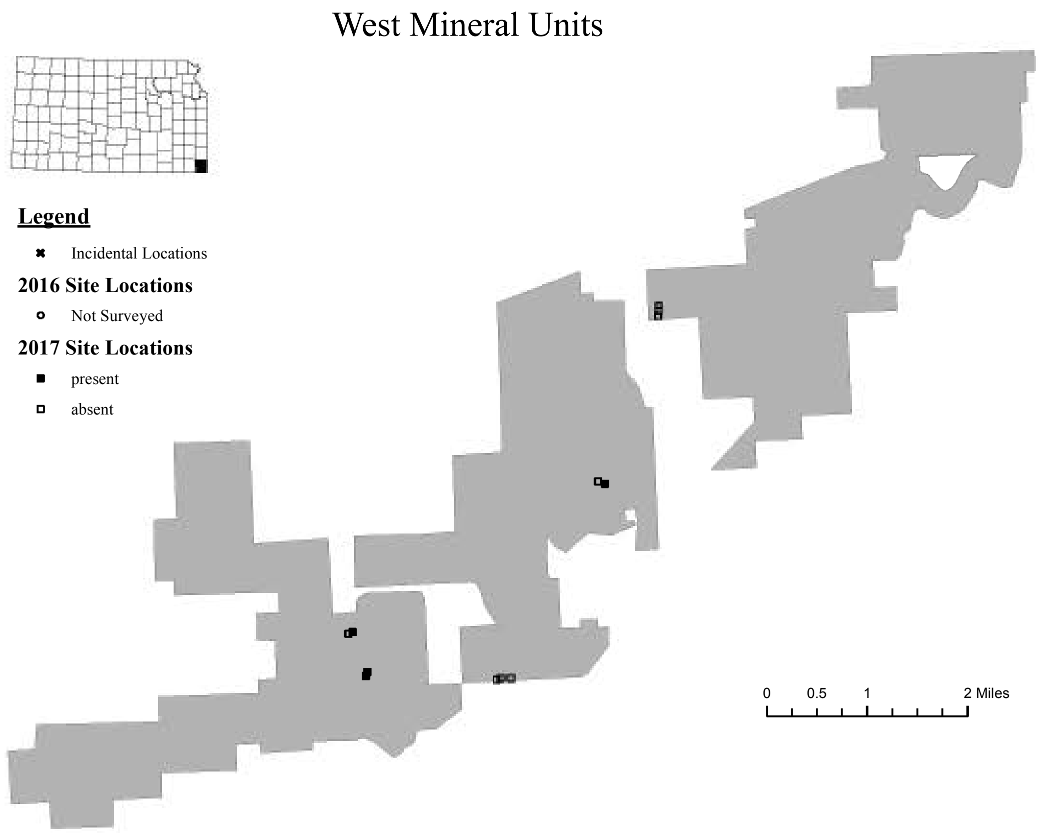


Appendix 12. Presence and absence of the Broad-headed Skinks at Neosho Wildlife Area during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.

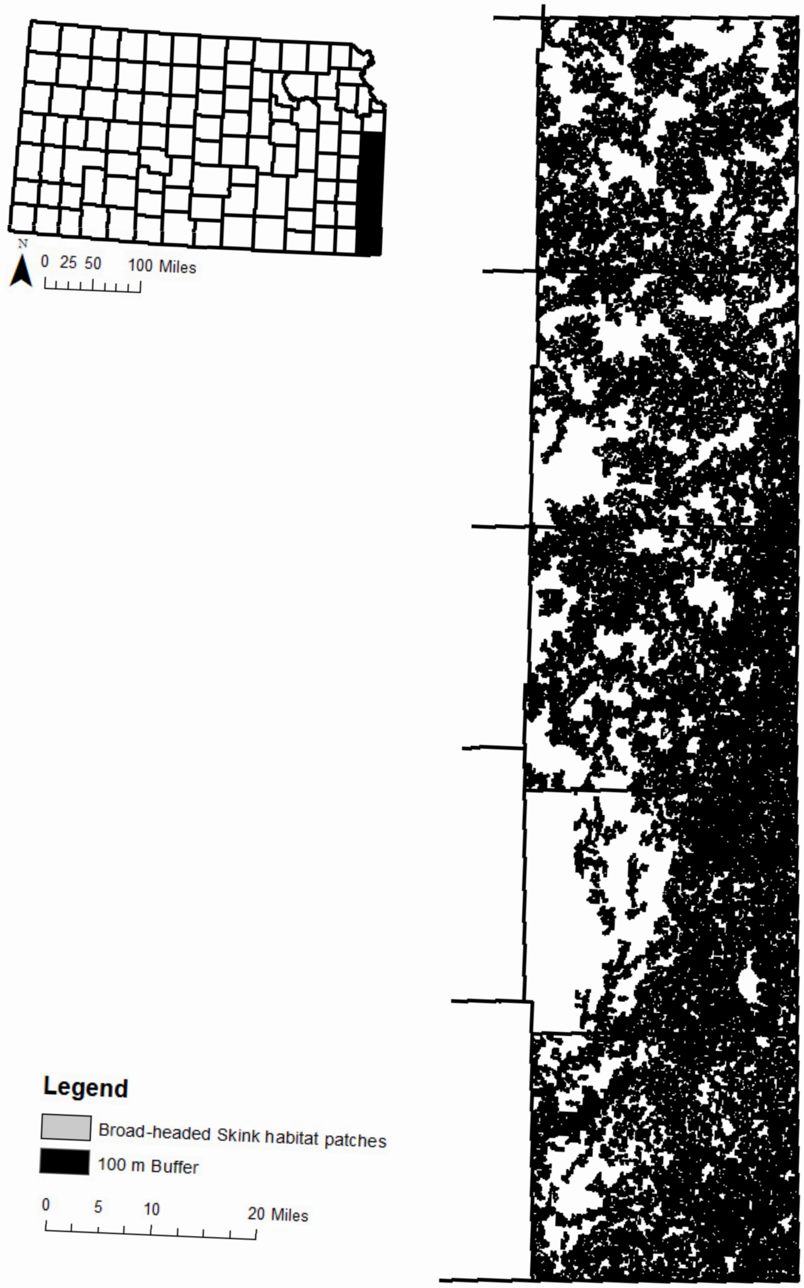
Spring River Wildlife Area



Appendix 13. Presence and absence of the Broad-headed Skinks at Spring River Wildlife Area during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.



Appendix 14. Presence and absence of the Broad-headed Skinks at West Mineral Units during the 2017 field season. Incidentals are sites where Broad-headed Skinks were encountered but where sampling equipment was not deployed.



Appendix 15. Distribution of land cover types where the Broad-headed Skink was observed from the Kansas GAP land cover data source (Egbert *et. al.* 2001). A 100-m buffer was placed around these land covers to visualize possible connectivity of the patches as it relates to the ecology of the Broad-headed Skink.