Transactions of the Kansas Academy of Science
Vol. 123, no. 1-2
p. 137-150 (2020)

Habitat assessment of the Broad-headed Skink (*Plestiodon laticeps*) and the associated squamate community in eastern Kansas

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During the summers of 2015-2017, we performed standardized surveys across the known range of the Broad-headed Skink in eastern Kansas. We used a combination of drift fence arrays with funnel traps and visual encounter surveys (VES) to collect occurrence data on the Broad-headed Skink. A Canonical Correspondence Analysis (CCA) was used to determine which habitat variables explained the variation observed in the squamate assemblage. The position of the Broad-headed Skink was explained by average log length and overstory tree size. A secondary analysis implies the Broad-headed Skink is also associated with presence of 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 the Broad-headed Skink prefers mature patches of forest, and habitat structure rather than tree species composition is more useful in predicting Broad-headed Skink presence.

Keywords: Broad-headed Skink, Plestiodon laticeps, *critical habitat, herpetofauna, squamate*

INTRODUCTION

Reptiles are in decline worldwide and these declines are precipitated by several threats, including habitat loss and degradation, where it is estimated that 40-49% of reptiles will lose greater than 10% of their habitat in the next 30 years. This estimated loss of habitat for reptiles is higher than estimates for birds and amphibians (Martinuzzi et. al. 2015). Competition from invasive species has led to declines in native species (Gibbons et. al. 2000; Crooks 2002) and pollution has been documented as causal in the change of function in organ systems in lizards (Guillette and Gunderson 2001; 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). 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) also threaten reptiles. Models predicting the vulnerability of reptile species to climate change suggest 80.5% of species are sensitive to climate change, while 22% of species are highly vulnerable to climate change (Böhm et. al. 2016).

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, represented by 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).

In Kansas, there are six skink species represented in two genera, *Scincella* and *Plestiodon* (Taggart 2019). The Little Brown Skink (*Scincella lateralis*) occupies leaf litter present on forest floors in the southeastern United States (Conant and Collins 1991) and occurs in the eastern third of Kansas and along the southern border. Plestiodon species in Kansas include the Coal Skink (*P. anthracinus*), Common Five-lined Skink (*P. fasciatus*), Great Plains Skink (*P. obsoletus*), Prairie Skink (*P. septentrionalis*), and Broad-headed Skink (*P. laticeps*) (Taggart 2019). Skinks in Kansas are found across a wide variety of habitats ranging from forests to prairies and can be observed under logs, rocks, and other debris (Mitchell 1994; Collins, Collins, and Taggart 2010).

The Broad-head Skink is the largest skink in Kansas reaching a maximum snout-vent-length (SVL) of 143 mm (Conant and Collins 1991). The species is sexually dimorphic with males having wider heads, which become bright red-orange during the breeding season. Broad-head Skinks mate from April to early June across their range and females lay eggs from late June-August (Vitt and Caldwell 2014). Eggs are laid in trees and logs, particularly decomposing hardwoods, with clutch sizes ≥ 18 (Vitt and Caldwell 2014). Broad-head skinks are semi-arboreal (Collins, Collins, and Taggart 2010) and primarily forage on invertebrates, and occasionally smaller vertebrates including other lizards (Vitt and Cooper 1986).

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 2019). 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 and unsustainable grazing decreases the availability and quality of habitat for the Broad-headed Skink (Rohweder 2015). Another conservation concern is the modification of natural systems, such as fire suppression that results in forest structure change by favoring mesic adapted species (Agee 1993). 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). Pollution and unsustainable resource use (e.g. timber harvest) are also potential threats to Broad-headed Skink populations (Rohweder 2015). Diseases have recently contributed to declines in reptiles and many of these diseases are not well understood (Schumacher 2006). Climate change is also a concern (Davis et. al. 1998) and is especially threatening to reptiles as they have low dispersal capabilities (Gibbons et. al. 2000). Climate change models performed with Kansas lizards predict that distributions will shift to the north and become fragmented for some species (Prowant 2014).

The Broad-headed Skink is listed as threatened in the state of Kansas and protected under the 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 (Rohweder 2015). We surveyed 11 public land areas (PLAs) to assess the conservation status of the Broad-headed Skink and define habitat characteristics that predict occurrence for the species. Additionally, we make inferences about occurrences of other squamates observed during our sampling efforts.

MATERIALS AND METHODS

Study Area: In 2015, we initiated preliminary surveys at nine PLAs distributed throughout the range of the Broad-headed Skink in Kansas (Table 1). These sites were in mature oak-hickory woodlands (Clawson, Baskett, and Armbruster 1984, Miller and Collins 1993). This preliminary year allowed us to experiment with our sampling methodology, but data collected were not used in statistical analyses as habitat assessment procedures were not comparable.

Table 1. Number of sites sampled at each public land area (PLA) per year. 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).

	2015	**2016**	**2017**
MDCR	3	39	12
MDCWA	3	39	12
LCWA	3	39	12
MSFL	3	-	12
NWA	3	-	12
NSFL	3	-	9
HWA	3	-	24
CSP	3	-	12
SRWA	3	-	12
BSFL	-	-	12
WMU	-	-	12

In 2016, we surveyed the three PLAs with the highest numbers of Broad-headed Skink captures in 2015. Collectively, these areas comprised the largest and least fragmented areas of the eastern deciduous forest in Kansas. Sites within the PLAs where Broad-headed Skinks were documented previously were surveyed first. Subsequently, each week, we surveyed three new sites at each PLA (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), and within a 400 m buffer around access roads. A total of 117 sites were surveyed; 39 at each PLA.

In 2017, we re-surveyed all PLAs visited in 2015 using standardized methodology developed in 2016 and added Bourbon County State Fishing Lake and West Mineral Units (Fig. 1). PLAs sampled in 2017 exhibited more heterogenous habitats than those sampled in 2016. Sample sites were then distributed throughout three habitat categories 1) mature forest - trees larger than 20 cm diameter at breast height (DBH), 2) immature forest - trees less than 20 cm DBH, and 3) open canopy - no trees (e.g., grassland). We distributed sites equally in each habitat category, unless habitat availability was limited. A total of 141 sites were surveyed.

Sampling Methodology: A sample site consisted of one drift fence array. 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" and nine additional funnel traps were placed around the array (Fig. 2). Traps were open for three nights at each site and checked every morning. The drift fence arrays were removed once sampling ceased.

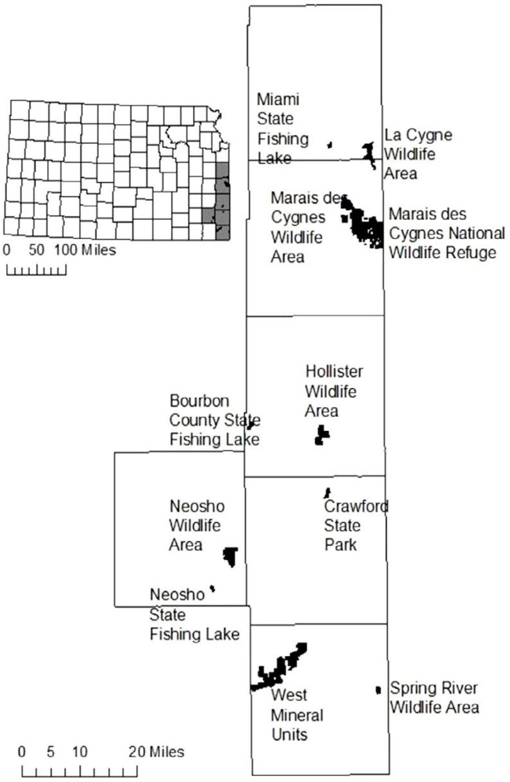

Figure 1. Areas surveyed in 2017. In 2016, survey efforts were focused on La Cygne Wildlife Area, Marais des Cygnes Wildlife Area, and Marais des Cygnes National Wildlife Refuge.

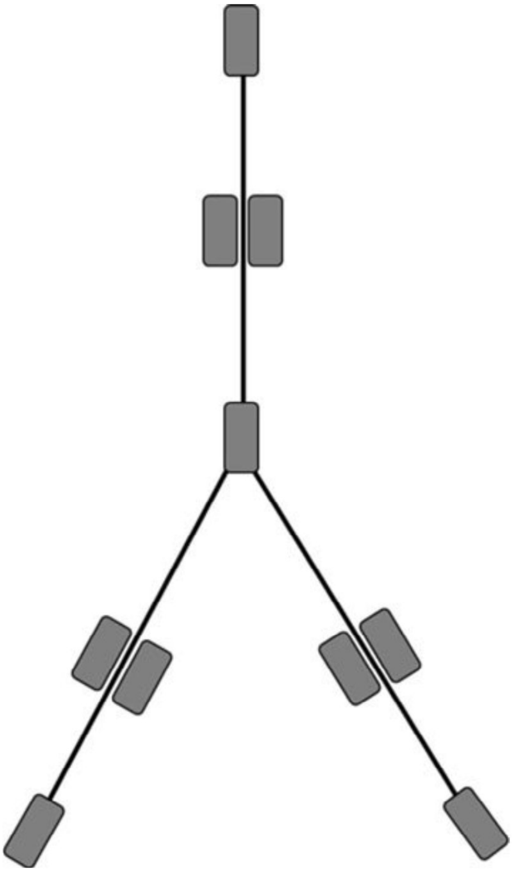

Figure 2. Design of the drift fence arrays used in 2016 and 2017. The arms were 25' in length each centered on a funnel trap in the center. Three additional funnel traps were placed around each arm.

We identified, weighed, measured snout-vent length (SVL), and recorded sex for every reptile caught in the traps. We recorded presence of all captured amphibian species. Relative abundance was summarized as captures per array night.

Visual encounter surveys (VES) (Graeter et. al. 2013) were performed within a 30 m radius of the center trap at each array. We looked under natural cover, including logs, leaf litter, and sloughing tree bark. Broad-headed Skinks were incidentally encountered while we walked from site to site and when we briefly checked areas with viable habitat at each PLA where we were not able to deploy sampling gear.

When a Broad-headed Skink was incidentally encountered, we collected morphological data and performed a habitat assessment using its initial location as the center point.

Habitat Assessment: All habitat assessments were initiated from the center trap of the drift fence array and were modified from Dueser and Shugart (1978). We 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, percent soil moisture, and presence of woody species (Table 2). Each transect bisected the center trap in a randomized direction. These transects were divided in half and offset from the center trap to avoid trampled vegetation in the quadrat (Fig. 3). Randomization was achieved by using a pre-determined list of degrees from north, produced in Excel.

Using a radius of 10 m from the center trap, we divided the site into quarters: northeast, southeast, southwest, and northwest. In each

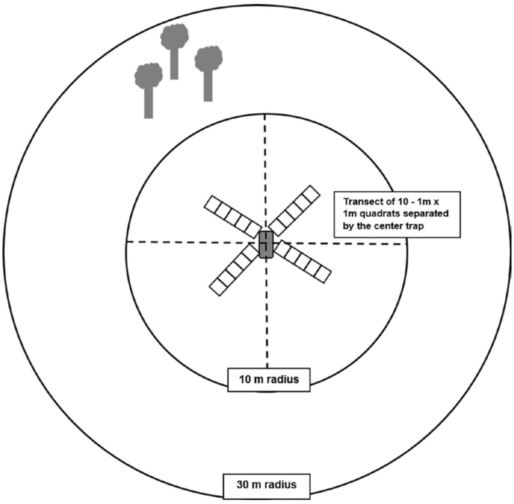

Figure 3. Illustration of the design of habitat assessments. Two transects comprised of 10, 1m X 1m quadrats were deployed through the center trap; six habitat variables were measured in quadrats. All other variables were measured within a 10-m radius of the center trap and in each quarter. Trees were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

Table 2. A description for how each habitat variable was measured. These measurements were modified from Deuser and Shugart (1978). For variables 7 and 9, trees were only included if they had a Diameter at Breast Height (DBH) of 15 cm or greater.

Variable	Methods
1) Canopy closure (%)	Average of 20 densiometer estimates of canopy closure; five in each quarter.
2) Vegetative cover (%)	Average of 20 estimates of vegetative cover; five in each quarter.
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 quarter and measured at the center of each quadrat.
5) Soil moisture (%)	Same as (4), with soil moisture. This was measured with a Field ScoutTM 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 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 nearest 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.

quarter, we recorded the distance to the nearest overstory tree and understory tree and their respective DBH (Cottam and Curtis 1956). We also measured the distance to the nearest log with a diameter over 7.5 cm. We measured the lengths of all fallen logs in the quarter and recorded an average for the site. We 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, we identified and counted all trees with a DBH of 15 cm or larger (Table 2).

Statistical Analyses: We used CANOCO 5 (ter Braak and Šmilauer 2012; Šmilauer and Lepš 2014) to generate a constrained Canonical Correspondence Analysis (CCA) to determine which habitat variables explained the greatest amount of variation in the squamate assemblage. 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

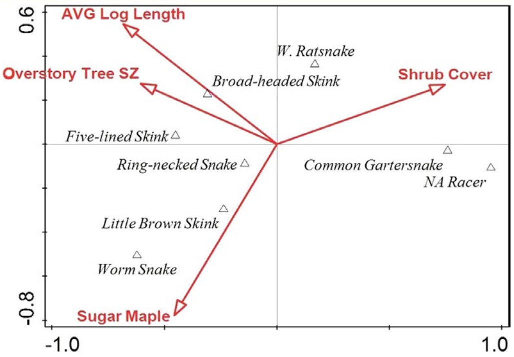

Figure 4. Visualization of the constrained Canonical Correspondence Analysis (CCA) of presence / absence of squamate species ordinated by habitat. Habitat variables depicted in red explained 100% of the constrained variation in the squamate assemblage. Public land area, as indicated in Figure 1, was used as the covariate. The dashed line indicates the association of Black Walnut as derived from a secondary exploration in the CCA.

environmental variables. Only species observed in a minimum of 10% of all sites were used for this analysis. We then used a logistic regression to determine which variables were significant in predicting Broad-headed Skink presence with 2016 data and 2017 data, separately. This statistical analysis was performed in R (version 3.3.2) (R Core Team 2013) and used a significance level of alpha = 0.05.

RESULTS

In 2015, we observed 1,256 individuals of amphibians and reptiles, though 501 of these individuals were juvenile Southern Leopard Frogs (*Lithobates sphenocephalus*). These individuals represented 28 species within 27 sites. Nine Broad-headed Skinks were captured during the 2015 sampling season; 5 during visual encounter surveys and 4 by using trapping methods.

In 2016, a total of 568 individuals of amphibians and reptiles representing 32 species were observed across 117 sites (Table 3). Forty-two Broad-headed Skinks were captured; 12 during visual encounter surveys, 15 by using trapping methods, and 15 through incidental encounters. In 2017, a total of 1,223 individuals of amphibians and reptiles representing 31 species were observed across 141 sites (Table 3). Eighty Broad-headed Skinks were observed; 17 during visual encounter surveys, 43 by using trapping methods, and 20 through incidental encounters.

During 2016 and 2017, samples included 774 array nights resulting in a catch-per-unit-effort (CPUE) of 1.44 captures per array night and 0.07 Broad-headed Skink captures per array night. A total of 293.5 person hours were dedicated to visual encounter surveys. The CPUE for visual encounter surveys was 1.64 captures per person hour and 0.15 Broad-headed Skink captures per person hour.

All squamate species that were not observed at a minimum of 10% of sites were removed prior to the analysis. During our study, 16,249 trees representing 40 species were identified (Table 4). Because of the number of tree species and habitat variables included in our ordination analysis, we performed an Interactive Forward Selection to determine which subset of the variables explained the greatest proportion

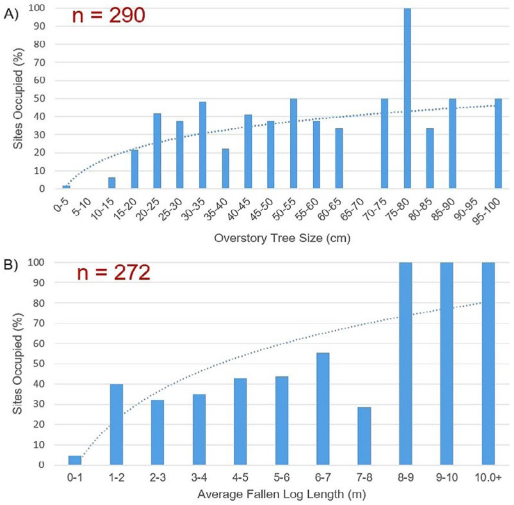

Figure 5. A) Percent of sites occupied by the Broad-headed Skink by overstory tree size categories. B) Percent of sites occupied by the Broad-headed Skink by average fallen log length categories.

Table 3. Number of each species observed at each public land area surveyed during the 2016 and 2017 field seasons. 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).

	MSFL	LCWA	MDCR	MD-CWA	BSFL	HWA	NWA	NSFL	WMU	CSP	SRWA
LIZARDS											
Broad-headed Skink *Plestiodon laticeps*	9	22	20	28	8	10			5	15	7
Little Brown Skink *Scincella lateralis*	8	18	3	11	4	1		1		1	3
Common Five-lined Skink *Plestiodon fasciatus*		16	5	5		1	1	2		2	7
Six-lined Racerunner *Aspidoscelis sexlineata*					1	13			3	8	
Great Plains Skink *Plestiodon obsoletus*						3				1	
Slender Glass Lizard *Ophisaurus attenuatus*										1	
Eastern Collared Lizard *Crotaphytus collaris*						13					
Prairie Lizard *Sceloporus consobrinus*											8
SNAKES											
Ring-necked Snake *Diadophis punctatus*	1	24	25	10	2	2		1			14
Western Wormsnake *Carphophis vermis*	1	19	4	6		2				1	
North American Racer *Coluber constrictor*		10	12	2	4	4	2	2	5	7	1
Western Ratsnake *Pantherophis obsoletus*	1	8	3	5	1	2	2	3	2		3
Eastern Copperhead *Agkistrodon contortrix*	3	5		3	1	3					1
Common Gartersnake *Thamnophis sirtalis*	1	5	5	5		2	4		1	1	
Rough Greensnake *Opheodrys aestivus*		3								1	
Western Milksnake *Lampropeltis gentilis*		2									

Table 3 continued

	MSFL	LCWA	MDCR	MD-CWA	BSFL	HWA	NWA	NSFL	WMU	CSP	SRWA
Diamond-backed Watersnake *Nerodia rhombifer*		1		5			2				
Western Ribbonsnake *Thamnophis proximus*	1		2	8		1	4		1		
Red-bellied Snake *Storeria occipitomaculata*		1									
Prairie Kingsnake *Lampropeltis calligaster*			1			2		1			
Plain-bellied Watersnake *Nerodia erythrogaster*			1	5						1	
Dekay's Brown snake *Storeria dekayi*	1			5			1				
Speckled Kingsnake *Lampropeltis holbrooki*				1				1			1
Common Watersnake *Nerodia sipedon*							1				
Rough Earthsnake *Haldea striatula*									2		3
TURTLES											
Eastern Box Turtle *Terrapene carolina*		7	2	4	3	1	2	1	2	2	7
Pond Slider *Trachemys scripta*				4			1		1		
Snapping Turtle *Chelydra serpentina*				1							
Painted Turtle *Chrysemys picta*				1							
Spiny Softshell *Apalone spinifera*				1							
Ornate Box Turtle *Terrapene ornata*	1					1			1		
AMPHIBIANS											
American Toad *Anaxyrus americanus*	6	38	9	3		8	2	4	6	2	1
Southern Leopard Frog *Lithobates sphenocephalus*	35	52	113	550	7	18	88	5	145		3

Table 3 continued

	MSFL	LCWA	MDCR	MD-CWA	BSFL	HWA	NWA	NSFL	WMU	CSP	SRWA
Blanchard's Cricket Frog *Acris blanchardi*		7	6	11	1	1	1	2		5	2
American Bullfrog *Lithobates catesbeianus*	3	4	9	21		2			12		
Gray Treefrog spp. *Hyla spp.*		3	2								
Spring Peeper *Pseudacris crucifer*			1								
Eastern Newt *Notopthalmus viridescens*			2	1							
Boreal Chorus Frog *Pseudacris maculata*				1							
Small-mouthed Salamander *Ambystoma texanum*				1							
Eastern Narrow-mouthed Toad *Gastrophryne carolinensis*											1

of variation in the squamate assemblage. The PLAs were used as a covariate to eliminate the variation associated with a perceived north to south gradient and differences among management objectives. Percent canopy cover, soil moisture, and percent rock cover were removed from analysis for failure to meet normality.

The constrained CCA explained a relatively small (12%) but interpretable portion of the overall variation (Table 5). The variable explaining the majority of variation on the x-axis was overstory tree size; a measure of the DBH of the closest overstory tree to the center trap. It appears habitat variables and squamate species were ordinated along a forest to grassland habitat gradient (Fig. 4). The Common Gartersnake (Thamnophis sirtalis) and North American Racer (Coluber constrictor) were placed directly opposite overstory tree size (e.g., grassland). The Little Brown Skink and Western Wormsnake (Carphophis vermis) were associated with the Sugar Maple (Acer saccharum) and ordinated opposite of shrub cover (e.g., secondary forest). The Broad-headed Skink was positively associated with average fallen log length and overstory tree size (e.g. mature forest). Had we not used Sugar Maple during the Interactive Forward Selection, Black Walnut (Juglans nigra) would have been the next most explanatory 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 predictive of the presence of the Broad-headed Skink (Fig. 4).

A logistic regression model was developed from the habitat variables and presence of Broad-headed Skink from 2016. There was one significant variable in the model; overstory tree size ($z = 2.389$, $df = 53$, $p = 0.0169$). In 2017, we surveyed a broader range of habitats and expanded surveys across the historical range of the Broad-headed Skink in Kansas but quantified the same variables. A single model including data from both years could not be developed because the habitat variables between years were significantly different from one another. This is due to a greater diversity of surveyed sites in 2017 compared to

Table 4. Tree species and total number observed during surveys in 2016 and 2017. 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**	**Species**	**Total**
American Elm	2440	Kingnut Hickory	253
Basswood	68	Mulberry	108
Bitternut Hickory	373	Norway Maple	1
Black Cherry	51	Osage Orange	927
Black Locust	34	Pecan	1126
Black Walnut	999	Persimmon	95
Black Willow	20	Pin Oak	1509
Blackjack Oak	6	Pine spp.	10
Box Elder	328	Post Oak	254
Bur Oak	384	Red Elm	20
Chinquapin Oak	1125	Shagbark Hickory	613
Chokecherry	6	Shumard's Oak	256
Cottonwood	130	Silver Maple	109
Eastern Red Cedar	399	Sugar Maple	803
Eastern Redbud	143	Sugarberry	3
Green Ash	1590	Swamp White Oak	2
Hackberry	1381	Sycamore	106
Honey Locust	491	Tree of Heaven	12
Ironwood	1	Western Buckeye	1
Kentucky Coffee Tree	55	Wooly Buckthorn	17

TOTAL = 16249

2016. Accordingly, a logistic regression model was developed with data from 2017. Four variables were included in the best model (Table 6): overstory tree size (z = 2.159, df = 93, p = 0.0309), average log length (z = 2.667, df = 93, p = 0.0077), overstory tree dispersion (z = -1.664, df = 93, p = 0.0962), and understory tree dispersion (z = 1.840, df = 93, p = 0.0657). Overstory tree size had an increasingly positive effect on Broad-headed Skink presence at a DBH of 20-25 cm and greater (Fig. 5a). Average log lengths of 2 m or greater were positively associated with Broad-headed Skink presence (Fig. 5b).

DISCUSSION

The squamates used in the analysis were species that were encountered most frequently, but we did make observations of many of the amphibian and reptile species that comprise the herpetofaunal assemblages of eastern Kansas. Occurrence records were reported for several sensitive species, including the Red-bellied Snake (Storeria occipitomaculata) and the Rough Earthsnake (Haldea striatula). Most importantly, valuable information regarding occurrence and habitat preferences of the Broad-headed Skink were obtained. Prior to this study there were only 51 observations of the species in Kansas (Taggart 2019).

The Broad-headed Skink was ordinated with variables consistent with 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 replaced by those large trees through forest succession.

In 2016, the habitat at sites was more homogenous because we targeted oak-hickory forests where the Broad-headed Skink had been documented historically. This might have limited the capacity of the logistic regression to discern patterns in presence based on habitat variables 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

Table 5. 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 6. All 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	∆AIC
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

∆AIC = Change in Akaike weight compared to the “best” model.

* = Indicates the best model as determined using AIC scores.

tree size, average log length, and understory tree dispersion, and negatively with overstory tree dispersion. These relationships suggest 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 indicate occurrence is likely limited to mature patches of Eastern Deciduous Forest in eastern Kansas. Canopy cover, soil moisture, and percent rock cover could not be included within the analysis due to the failure to meet normality. The habitats sampled did not provide an actual gradient among these measured variables, but rather an either-or situation. Canopy cover was either high (80-100%) or absent. Soil moisture was dependent on canopy cover, being high at sites with dense canopy and low within grassland habitats. Rock cover was limited to wooded riparian habitat. While not used in the analyses, canopy cover is strongly interrelated to variables important to Broad-head Skinks, overstory tree size and average log length, so provides an easily measured variable when discussing critical habitat for the species.

The percent occurrence of Broad-headed Skinks increased markedly when average overstory tree size was 20-25 cm DBH or greater (Fig. 9a). Similarly, percent occurrence of the Broad-headed Skink increased if average log length was 2 m or greater (Fig. 9b). In addition to providing opportunities to forage and shelter, fallen logs might be essential for reproduction. During surveys, we observed three Broad-headed Skink nests; the first nests observed since 1992 and the first time they were observed in natural cover in Kansas. Two nests with 19 eggs each were located in Bourbon County and one nest with a clutch of 12 eggs was located in Linn County. All of these clutches were located within rotten Pin Oaks (Quercus palustris) (Hullinger et. al. 2018). Certainly, additional confirmation is necessary but based on these observations, large decayed logs are likely a keystone resource for the species.

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

Our field observations indicate additional variables might be useful in predicting habitat quality for the Broad-headed Skink. An index to measure sloughing bark could prove useful because these recesses provide protection from predators and thermal retreats. Quantifying burn scars and other shelter-providing characteristics of trees and counting snags might also improve our ability to predict the occurrence of Broad-headed Skink. Our quantified results suggest the Broad-headed Skink inhabits mature forest patches with trees 20 cm or greater DBH and fallen logs 2 m or greater. Protecting the current mature deciduous forests in eastern Kansas should be a priority as well as enhancement and mitigation of these forests. Maintaining the integrity of these systems can be accomplished by conducting controlled burns and Timber Stand Improvement (TSI). For herpetofauna, controlled burns conducted before 1 April are recommended (MWPARC 2009). The Broad-headed Skink takes advantage of the escape cover provided by burn scars or sloughing bark. These damaged trees become fallen logs and as they decay, become important 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 patterns of dispersion in mature forests. Management actions that support the maintenance of oak-hickory forests will benefit the Broad-headed Skink whether that be direct or indirect. Applying easements to properties with current Broad-headed Skink habitat is also recommended.

ACKNOWLEDGMENTS

This project was funded by a State Wildlife Grant. We thank David Bender, Carl Bowden, Emma Foltz, Chelsea Hofmeier, Jordan Hofmeier, Diedre Kramer, Zach Quick, Jeff Seim, Emily Davis, Ryan D. Waters, Ryan L. Waters, Kali Boroughs, Melissa Skelton, Brandi McCoy, and Dylan Osterhaus for their help in the field. We also thank all area managers for their assistance and allowing us access.

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