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Assessment of fall season habitat and coverboard use by snakes in a restored tallgrass prairie community

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Abstract. We assessed habitat use and preference with respect to artificial coverboards for the snake community of a restored tallgrass prairie. Coverboards offer herpetofauna protection from predators and space to thermoregulate their body temperature. These covers also create microhabitats that differ from their surrounding habitat. We placed plywood and metal coverboards along a transect that crossed from prairie floodplain into upland prairie. Coverboards were checked over a three-week period during the fall season, during morning, afternoon, and dusk. Snake species were identified and counted, and ambient temperatures and humidity were checked under each coverboard. We found four snake species across the habitat gradient, common gartersnake (*Thamnophis sirtalis*), plains gartersnake (*T. radix*), Dekay's brownsnake (*Storeria dekayi*), and Western foxsnake (*Pantherophis ramspotti*). Species richness was greatest in the floodplain habitat and microhabitat associated with metal coverboards. The floodplain habitat was also the habitat predominantly used by common gartersnake and Dekay's brownsnake. Dekay's brownsnakes, furthermore, preferred utilizing metal coverboards over wood. The composition of snake species we observed suggests that the restoration efforts on this tallgrass prairie system have attracted some grassland snake species, but the possibility of a greater snake community remains. Our data suggest that using metal coverboards during the cooler active seasons, such as fall and spring, will increase capture success and more efficiently sample snake communities. Studies such as ours to better understand habitat and coverboard use will result in more efficient sampling of herpetofauna for conservation and monitoring efforts.

Keywords. *Thamnophis*, *Pantherophis*, *Storeria*, microhabitat use, thermal environment, humidity, artificial cover objects, snake ecology.

Prairie restoration is a common management strategy to increase the biodiversity of an ecosystem, restore native populations and communities, and store large amounts of available carbon (Jordon et al., 1988; Samson and Knopf, 1994; Anderson, 2009; Guiden et al., 2021). Restorations typically include the removal of agriculture plots, replanting native plant species, and relying on the "Field of Dreams" paradigm that if you build it species native to the area will come (Guiden et al., 2021). As such, this paradigm involves building a suitable habitat for organisms in hopes they will find and stay in the restored area. Research shows prairie restorations can increase the abundance of animals, including herpetofauna such as snakes (King and Vanek, 2020). Although not readily observed because of their elusive nature, snakes can reach high abundance and greatly influence natural communities by influencing abundance and behavior of other species (Hisaw and Gloyd, 1926; Kotler et al., 1993; Sperry et al., 2008; Willson and Winne, 2018; King and Vanek, 2020). Accurately monitoring success of restoration efforts is dif-

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ficult, however, because each restoration effort is unique, including the sampling techniques utilized.

Sampling herpetofauna in tallgrass environments can be difficult due to the cryptic nature of reptiles and amphibians (Fitch, 1987; Szaro et al., 1988). Visual sampling is a common method for sampling snake species (Foster, 2012), however, small, cryptic, or camouflaged species are often difficult to detect in areas of thick vegetation due to their slender bodies (Turner, 1977; Ward et al., 2017). One efficient form of sampling includes the use of coverboards constructed out of sheets of various heat conducting materials, such as metal, wood, rubber, or asphalt roofing (Fitch, 1987; Engelstoft and Ovaska, 2000). Coverboards can significantly increase detection of snakes compared to simple visual surveys (Halliday and Blouin-Demers, 2015). These covers provide attractive areas for snakes and other herpetofauna to seek refuge and an efficient way for scientists to observe, count, or capture snakes (Halliday and Blouin-Demers, 2015).

Coverboards of different types provide microhabitats of varying temperatures and humidities allowing individuals a choice regarding suitable areas for cover (Engelstoft and Ovaska, 2000). These microhabitats are impacted by the habitats in which they are placed and seasonality due to falling or rising temperatures. During the cooler months, for instance, snakes may utilize substrates or objects that absorb or retain heat to maintain their optimal body temperature more efficiently (Engelstoft and Ovaska, 2000). Individual preferences for specific microhabitats can arise through various needs associated with age, sex, shedding, food ingestion, circadian rhythms, and reproductive condition (Lilywhite, 1987). Sampling efficiency associated with coverboard type can therefore vary based on target species, habitat type, season, and interactions among these factors. These relationships mean that the coverboard types used can impact species-specific encounter rates during surveys and biodiversity assessments and can influence the herpetofaunal community composition detected (Grant et al., 1992; Engelstoft and Ovaska, 2000; Hampton, 2007).

Identifying habitat and microhabitat use of snake species in the tallgrass prairies of the Great Plains of North America has received relatively little attention, despite prairies being the largest vegetative community in North America (Samson and Knopf, 1994) and the Great Plains constituting one-third of the United States (Deitz, 2022). Understanding these preferences can be beneficial to conservation efforts and lead to more accurate and efficient sampling for specific species and communities. In this study, we used metal and plywood coverboards to assess snake habitat and coverboard preference in a restored tallgrass prairie system that includes a habitat gradient from prairie floodplain to upland prairie. We specifically compared the preferences of the snakes for metal or wooden coverboards in association with habitat type, humidity, and ambient temperatures.

We sampled snakes within the Allwine Tract of Glacier Creek Preserve (41.19759N, -96.29893W), a 212 ha (525 acres) preserve that encompasses an entire sub watershed in eastern Nebraska, United States. The Allwine Tract (65 ha; 160 acres) was donated to the University of Nebraska at Omaha in 1959. In 1970, 57 ha (140 acres) of agricultural land within the Allwine Tract were seeded with five native prairie grass species and then over-seeded with a diverse mix of local native forbs in the following years. Between 2009 and 2019 an additional 147 ha (365 acres) were purchased and added to the preserve, including a mix of agriculture, wetlands, and woodlands. The reconstructed prairie is managed with a 3-year prescribed fire return interval that occurs in mid-spring, where no more than 2 of the 5 units are burned in one year. Additional details about the site can be found in Bragg et al. (2016), Dere et al. (2019), and Manning et al. (2022).

Data was collected during a 3-week period from September 17 to October 4, 2021, during three time blocks of 7:00-9:00, 14:00-16:00, and 18:00-20:00 CT (morning, afternoon, and dusk, respectively). Four data collection events occurred during each of the time blocks. We sampled 10 stations that were established in spring of 2018, reflecting 41 months since establishment. Sampling efficiency of artificial retreats can increase with time since establishment; however, studies have found that efficiencies reach asymptotic maximums within 12 months, well within our time frame (Grant et al., 1992; Croak et al, 2010). The stations ran along a north-south transect (800 m) that crossed Glacier Creek with 5 stations on the south slope and 5 stations on the north slope (104 m average distance between stations; min = 27 m, max = 145 m). Each station consisted of two artificial coverboards: a uniformly sized metal (corrugated, galvanized sheet metal) and plywood (12.2 mm or 1/2 inch thickness) coverboard each measuring approximately 122 x 122 cm (L x W) and placed approximately 1.5 m from each other. Therefore, there were 20 artificial retreats evenly divided between the two types of material. A Kestrel 5000 environmental meter (Nielsen-Kellerman Company) was used to collect relative humidity and temperature data.

During each sampling event each board was lifted, and the area underneath scanned to count number of individuals and identify snake species and life stage as either juvenile or adult. The Kestrel was then placed under the board to acclimate for 90 seconds. We recorded the relative humidity and temperature from the Kestrel and repeated this process for each of the stations along the transect, whether or not snakes were present. For each station we also measured distance to creek using an aerial map in Arc Map GIS and recorded habitat type (prairie floodplain, floodplain-upland transition zone, and upland prairie). Because the transect ran across and perpendicular to the creek, the floodplain and transition zone were relatively narrow habitats with four coverboards (two stations) in each habitat and the remaining twelve coverboards (six stations) in the upland prairie.

We assessed snake species richness and encounters with respect to multiple covariates and factors such as time of day, date, coverboard type, habitat type, distance to creek, humidity, and temperature. Life stages of juvenile and adult were grouped for analyses because of low juvenile numbers. We employed generalized linear models (GLM) including covariates and factors as independent variables and species richness (a count of number of species) or species-specific encounters (a count of number of individual encounters) as the dependent variable. We tested dependent variables for normality and transformed data when necessary or ran models with the appropriate distribution, such as Poisson for count data or non-parametric tests. We also checked for relationships among our independent variables using analyses of variance (ANOVA), Pearson or Spearman correlations, or linear regressions where appropriate. When variables were related, we chose one to include in our initial model or used residuals from a regression of one variable on the other. Temperature and humidity were related, for instance, thus the residuals from a regression of humidity on temperature were used in the initial models. The date, or sequence of sampling days, did not influence species richness and was therefore not included in further models (Wald χ^2 = 0.423, P = 0.516). Because of relationships between some of our independent variables (see results) our initial models included coverboard type, habitat type, and temperature. Interactions that were not significant were eliminated from final models. All statistical analyses were conducted with IBM SPSS for Windows, Version 29.0.

Habitat and coverboard type both influenced species richness and individual species encounters (Table 1, Fig. 1 and 2). More species were found in the prairie floodplain than in the transition zone or drier upland prairie (Fig. 1). We also found more species, almost double the number, underneath the metal coverboards than the wooden coverboards. Similar trends were observed at the individual level of species encounters (Fig. 2). We encountered significantly more common gartersnakes (*Thamnophis sirtalis*, n = 27) and Dekay's brownsnakes (*Storeria dekayi*, n = 24) in the prairie floodplain than the other habitats (Fig. 1) and more Dekay's brownsnakes under the metal coverboards (Fig. 2). We found too few plains gartersnakes (*Thamnophis radix*, n = 3) to statistically examine their abundances across habitat and coverboard types and no significant patterns in Western foxsnakes (*Pantherophis ramspotti*, n = 6, GLM all P > 0.4). We caution direct interpretation of our encounters as relative abundances because we did not mark individuals, thus it is possible some were recounted, which could bias the count data.

Table 1. Effects of habitat and coverboard type on snake species richness and encounters of individual species in a restored tallgrass prairie. Habitats consisted of prairie floodplain, floodplain to upland transition zone, and upland prairie. Coverboard types included plywood and corrugated sheet metal. Sampling occurred at Glacier Creek Preserve in Bennington, Nebraska, across 240 sampling occasions during the fall season. Bold text denotes statistical significance at the α = 0.05 level based on generalized linear models.

		Species Richness		Common Gartersnake Encounters		Dekay's Brownsnake Encounters	
Predictors	df	Wald χ^2	P	Wald χ^2	P	Wald χ^2	P
Intercept	1	12.704	**< 0.001**	18.499	**< 0.001**	299.111	**< 0.001**
Coverboard Type	1	4.229	**0.040**	2.042	0.153	10.964	**0.001**
Habitat Type	2	24.077	**< 0.001**	16.865	**< 0.001**	35.427	**< 0.001**
Temperature	1	0.226	0.635	2.727	0.099	2.421	0.120

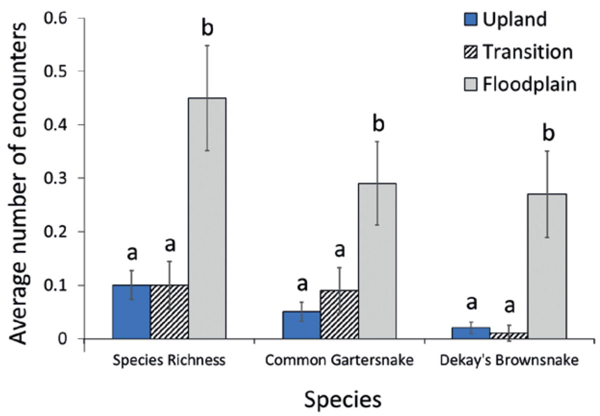

Fig. 1. Average species richness and number of encounters for each species (per coverboard) found under coverboards in each habitat type. Averages are estimated marginal means based on the generalized linear model for a Poisson distribution of count data. Associated count totals for Common Gartersnakes (*Thamnophis sirtalis*) and Dekay's Brownsnakes (*Storeria dekayi*) in the Upland = 8 and 4, Transition = 5 and 1, and Floodplain = 15 and 18, respectively. Upland translates to prairie upland, Transition to upland/floodplain transition zone, and Floodplain to prairie floodplain. A low occurrence of individuals precluded a species-specific analysis of Plains Gartersnakes (*Thamnophis radix*) and pattern detection in Western Foxsnakes (*Pantherophis ramspotti*). Different letters above bars denote significant differences between habitats (α = 0.05). Error bars are ± 1 SE.

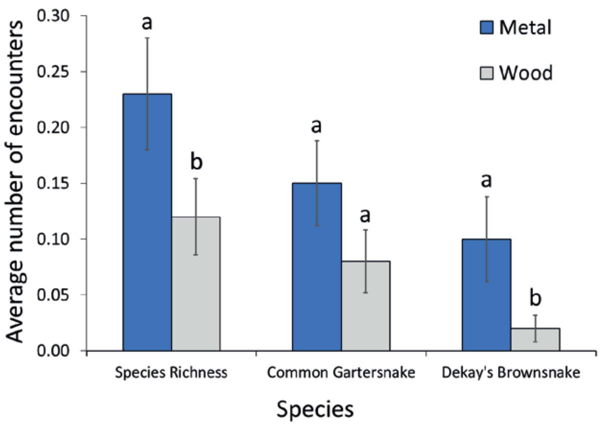

Fig. 2. Average species richness and number of encounters for each species (per coverboard) found under wood and metal coverboards. Averages are estimated marginal means based on the generalized linear model for a Poisson distribution of count data. Associated count totals for Common Gartersnakes (*Thamnophis sirtalis*) and Dekay's Brownsnakes (*Storeria dekayi*) found under wood = 10 and 4, and metal = 18 and 19, respectively. A low occurrence of individuals precluded a species-specific analysis of Plains Gartersnakes (*Thamnophis radix*) and pattern detection in Western Foxsnakes (*Pantherophis ramspotti*). Different letters above bars denote significant differences between treatments (α = 0.05). Error bars are ± 1 SE.

Relative humidity under the coverboards was not influenced by coverboard type (as humidity residuals on temperature; $F_{1, 238}$ = 3.002, P = 0.084), but it was influenced by habitat type (as humidity residuals on temperature; $F_{2, 237}$ = 8.961, P < 0.001) and negatively related to temperature ($F_{1, 238}$ = 279.76, P < 0.001, R^2 = 0.54). Temperature under the coverboards also was not influenced by coverboard type ($F_{1, 238}$ = 0.246, P = 0.620), but was related to time of day ($F_{2, 237}$ = 207.78, P < 0.001) with afternoons being the warmest period (Mean ± SE for Morning = 17.3 ± 0.5° C, Afternoon = 30.7 ± 0.5° C, Dusk = 26.0 ± 0.5° C). The distance between coverboards and the creek was related to both the relative humidity underneath coverboards (residuals on temperature; Spearman's rho = -0.163, P = 0.012) and to habitat type (Kruskal-Wallis H = 185.406, df = 2, P = < 0.001).

The results of our study revealed habitat use and coverboard preference of the snake community in a restored tallgrass prairie system during the fall season. We found four snake species at Glacier Creek Preserve including the common gartersnake (*Thamnophis sirtalis*; Fig. 3A), plains gartersnake (*T. radix*), Western foxsnake (*Pantherophis ramspotti*; Fig. 3B), and Dekay's brownsnake (*Storeria dekayi*). We also observed one lizard species, the Northern prairie skink (*Plestiodon septentrionalis*). Snake species richness was greatest in the prairie floodplain as were snake encounter rates in general (Table 1, Fig. 1). The greater overall snake encounters were a result of the significantly higher average number of individuals among common gartersnakes and Dekay's brownsnakes in the floodplain compared to the transition areas and upland prairie (Fig. 1). More snakes may have occupied the prairie floodplain because the proximity of a known hibernaculum used for overwintering (TJC, personal observation; Fig. 3). Because this study occurred in the fall, snakes may have been moving from the upland areas toward their hibernacula in preparation for winter brumation (McAllister, 2018; Bridger and Geluso, 2021).

Using both metal and plywood coverboards provided snakes with an opportunity to choose specific microhabitats. A greater number of common gartersnakes and Dekay's brownsnakes chose to settle under metal coverboards than wood, which is consistent with other studies for *Thamnophis* (Engelstoft and Ovaska, 2000, Hampton, 2007) and *Storeria* species (Halliday and Blouin-Demers, 2015). Snakes often seek materials with higher heat conductivity especially in cooler seasons (Hoyer, 1974; Fitch, 1987; Barker and Hobson, 1996; Engelstoft and Ovaska, 2000). Common gartersnakes in British Columbia, for instance, preferred metal and asphalt coverboards over wood during fall and spring (Engelstoft and Ovaska, 2000). Coverboards may be used less often generally during summer (e.g., mid-August) because associated microhabitat temperatures often rise above 40 °C, which is above critical thermal maximum for most reptile species (Engelstoft and Ovaska, 2000; Angilletta, 2009). One might hypothesize that wooden coverboards would be used more during warmer summer months because they maintain both higher humidities and more stable temperatures compared to metal (Grant et al., 1992), often providing thermal environments similar to ambient conditions (Engelstoft and Ovaska, 2000). In other Nebraska grasslands reptile preference for wooden coverboards has been observed during the warmer months (Brown and Geluso 2022; approximately 370 km southwest of Glacier Creek Preserve). However, plywood coverboards were not used by reptiles in the British Columbia community more often in the summer compared to spring and fall (Engelstoft and Ovaska, 2000). Coverboard use may similarly vary with other herpetofauna such as amphibians, where some studies have found more amphibian species under wood coverboards than metal (Grant et al., 1992), and others have found no difference in amphibian abundance under metal versus wood coverboards (Hampton, 2007). During the lower fall season temperatures, the preference of snakes at Glacier Creek Preserve for metal coverboards likely occurred because these spaces heated up more quickly allowing snakes to more efficiently attain optimal body temperature for various behaviors and bod-

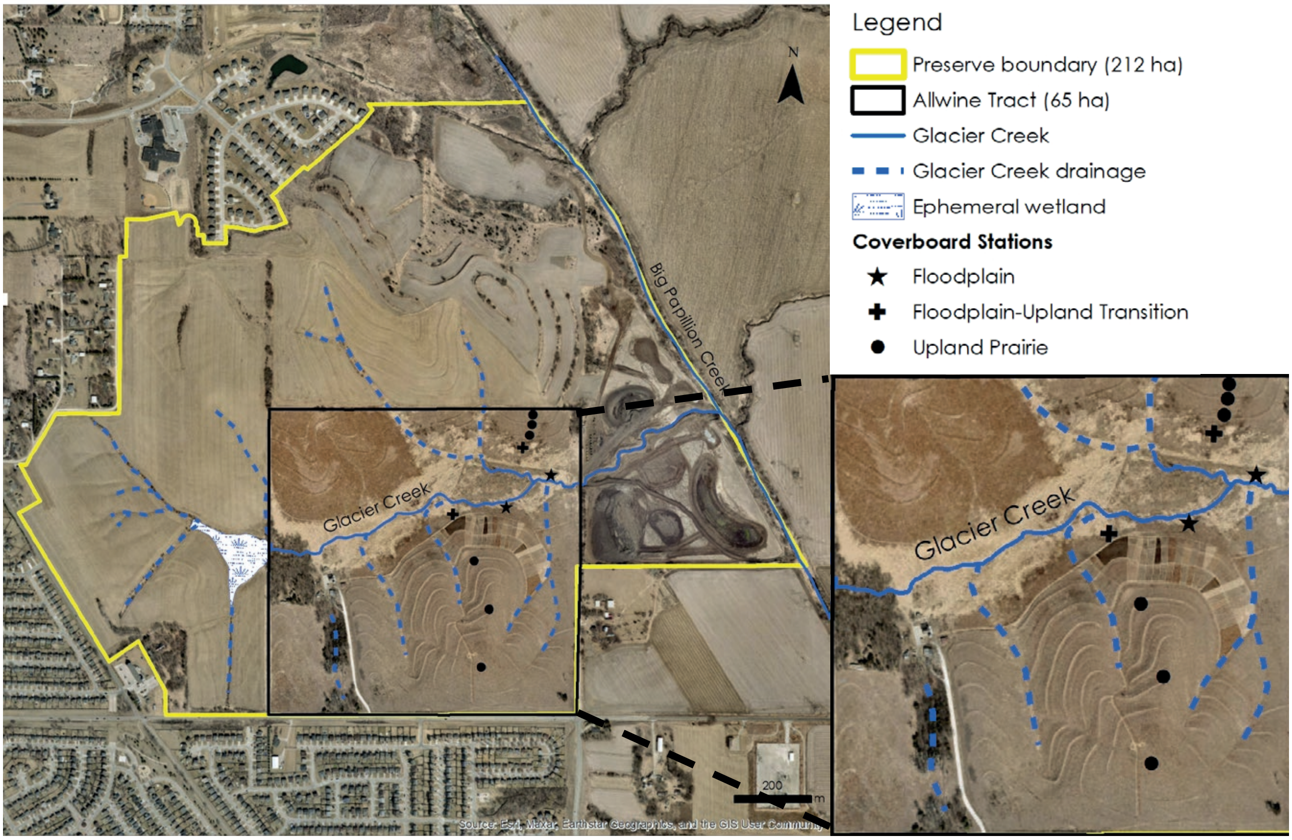

Fig. 3. Map of Glacier Creek Preserve, a tall grass prairie restoration site located in Bennington, Nebraska, United States in the heart of the Great Plains ecosystem of North America. The inset highlights the placement of coverboard stations along the habitat gradient from floodplain to upland prairie. The floodplain is depicted by the lighter beige strip of vegetation (75-300 m) covering both sides of Glacier Creek. The upland prairie is depicted by the darker tan areas of vegetation moving both north and south of the floodplain, up the slopes (200-600 m). The transition zone consists of the narrow strip (20-30 m) where the floodplain habitat (light beige vegetation) transitions into the upland prairie (darker tan vegetation).

ily functions such as foraging and digestion (Grant et al., 1992; Lillywhite, 1987).

Relationships among our environmental variables have ecological implications for habitat and coverboard use by snakes. Our final model only contained coverboard type, habitat type, and temperature as independent variables and temperature was the only variable that did not directly influence species encounters or richness. Interestingly, coverboard type was not directly related to either humidity or temperature in our study, which contrasts with other studies (Engelstoft and Ovaska, 2000; Grant et al., 1992). This is a case where the statistical significance may not match the biological significance as we found increased snake presence under metal coverboards even though we did not observe significantly greater temperatures or relative humidity. The relatively mild fall season climate likely diminished environmental effects of coverboard type that may be more significant during late spring and summer seasons (Engelstoft and Ovaska, 2000). It may also be a dissociation of measured temperatures at time of capture versus biologically significant temperatures during snake movement and microhabitat choice. Our analyses of relationships among environmental variables determined that temperature was related to time of day (afternoons the warmest) and habitat type was related to humidity and distance from the creek. Neither relative humidity nor temperature were significant factors in our models of coverboard selection, but our temperature and humidity data were collected at the time of sampling. It is possible that temperature and humidity influence habitat and coverboard use most when the snake first moves to the space, which may occur within a specific window during the day, although we did not observe an effect of time of day on species presence or absence. We do not know when during the day snake activity and coverboard choice occurred, but future studies examining daily temperature cycles along with snake activity and microhabitat preferences could shed light on this relationship. Habitat type, humidity, and distance from creek were all related, with humidity decreasing with distance from creek as habitat changed from the prairie floodplain and transitioned to the upland prairie. The prairie floodplain had the greatest species richness, suggesting that greater humidity and creek proximity could attract more snake species. Whether it was the humidity itself or proximity to the creek, however, we cannot discern.

Because our study was limited to three weeks of a single climatic season, we caution against any definitive conclusion regarding the overall snake community. However, comparing this prairie snake community with assessments of other prairie snake communities within a day's drive suggests that the Glacier Creek restoration effort at least partially reflects the "Field of Dreams" paradigm. The Nachusa Grassland is a tallgrass prairie system in the State of Illinios, 600 km to the east of our restoration site. An extensive survey of the Nachusa Grassland system detected a snake community nearly identical to ours, including the common gartersnake (*Thamnophis sirtalis*), plains gartersnake (*Thamnophis radix*), and Dekay's brownsnake (*Storeria dekayi*), in addition to the Eastern foxsnake (*Pantherophis vulpinus*) rather than our Western foxsnake (*Pantherophis ramspotti*; King and Vanek, 2020). The Konza Prairie is another well surveyed tallgrass prairie in the State of Kansas, approximately 500 km south of our site with a reported snake community of ten species (Wilgers and Horne, 2006). The Konza Prairie snake community overlapped with two of our species, the common gartersnake and Dekay's brownsnake, but contained eight more species, four of which are known to occur in Douglas County, Nebraska, where Glacier Creek Preserve resides, the Gophersnake (*Pituophis catenifer*), Eastern Racer (*Coluber constrictor*), Lined Snake (*Tropidoclonion lineatum*), and Ring-necked Snake (*Diadophis punctatus*; Fogell, 2010). Together, these comparisons show two snake species common to all three prairies and the possibility of four more species inhabiting Glacier Creek Preserve.

Our collective knowledge about maintaining, restoring, and monitoring prairie communities is of global importance because grasslands cover one-third of the world's land area (Nunez, 2019). Our study is an important first step in the assessment of restoration success with regard to the reptile community of this tallgrass prairie ecosystem in the Great Plains. Our study determined a baseline estimate of the current reptile community (four snake and one lizard species) and the relative efficacy of coverboard type (metal coverboards created a preferred microclimate) in the tallgrass prairie ecosystem. Our data suggest that fall surveys should incorporate metal coverboards and focus on the prairie floodplain if the goal is to assess snake diversity. Using an array of different coverboard types may be beneficial across seasons because of the different microclimates that they create along with different preferences exhibited by the different species, life stages, or physiological state of individual snakes (Halliday and Blouin-Demers, 2015). Although the snake community we recorded was similar to one comparable system, it was different than another. Further studies in this system, such as a long-term monitoring program over multiple years and seasons will provide further insight into the restored snake community such as seasonal influence on habitat and coverboard use, and possibly the season in which sampling should be conducted for highest detection rates.

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