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Effects of Different Burn Regimes on Tallgrass Prairie Herpetofaunal Species Diversity and Community Composition in the Flint Hills, Kansas

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ABSTRACT.—The Flint Hills region of Kansas is the largest contiguous area of tallgrass prairie remaining today. Historically, the tallgrass prairie burned every 2–3 yr on average, but current land managers have altered burn regimes, resulting in a range of habitats from annually burned to long-term unburned. We used drift fence/funnel trap arrays and coverboards to estimate species richness, evenness, and diversity of herpetofauna within three different burn regimes: annual, 4-yr, and long-term unburned at Konza Prairie Biological Station, Riley County, Kansas. During the spring and fall of 2003–2004, 315 individuals from 20 species were captured across all burn regimes. Herpetofaunal species richness, evenness, and diversity estimates were not different between the three burn treatments. However, because of species-specific responses to individual burn regimes, community composition was significantly different between the habitats (χ^2 = 158.19, df = 20, $P < 0.001$). Four species exhibited preferences among burn regimes, which differed significantly from independent assortment, with *Eumeces obsoletus* and *Phrynosoma cornutum* preferring annual burn treatments, *Scincella lateralis* preferring 4-yr burn treatments, and *Diadophis punctatus* preferring long-term unburned treatments. Species-specific responses were likely because of changes in vegetation structure and microhabitat (temperature and moisture content) created through different frequencies of fire disturbances. Maximizing large-scale herpetofaunal diversity across the Flint Hills' rangelands could be accomplished by creating a large number of small scale habitat types through a mosaic style burning plan.

Fire is an essential component in the development and persistence of the tallgrass prairie ecosystem (Axelrod, 1985). Regular burning of tallgrass prairie increases plant productivity (Briggs and Knapp, 1995), decreases aboveground litter (Hulbert, 1988), and decreases woody vegetation (Heisler et al., 2003). The Flint Hills encompass over 1.6 million ha extending throughout much of eastern Kansas from near the Kansas-Nebraska border south into northeastern Oklahoma and contain the largest re-

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maining area of unplowed tallgrass prairie in North America. Ranchers throughout the Flint Hills practice prescribed burning. However, the frequency at which the prairie is burned varies depending upon management practices of individual ranchers. The spatial, and in some cases temporal, extents to which these burns are carried out differ noticeably from historical fire regimes of the area (Anderson, 1990). Historically, tallgrass prairie burned every 1–5 yr (Collins and Gibson, 1990), which is an average of approximately 2–3 fires every 5 yr. Recent human land-use altered this frequency in various directions (Briggs et al., 2002). Annually burned rangelands became prevalent in the early 1980s because of a switch in cattle grazing practices from traditional season-long to early-intensive stocking (Robbins et al., 2002), whereas land in close proximity to developed areas remained unburned for long periods of time (> 20 yr).

Various fire regimes result in differences in ground cover, refuges (Hulbert, 1988), potential prey species (Clark and Kaufman, 1990), temperatures (Knapp and Seastedt, 1986), moisture levels (Blair, 1997), and other important ecological variables. One can consider habitats created by different fire regimes as a continuum within the tallgrass prairie ecosystem, with both extremes tending toward homogeneity. Annually burned areas are dominated by C_4 grasses. As time since last burn increases, shrub islands of roughleaf dogwood (*Cornus drummondii*) and smooth sumac (*Rhus glabra*) grow larger, leading to an increase in woody vegetation. Intermediate burn frequencies (2–10 yr) form habitats with different proportions of warm-season C_4 grasses and woody vegetation, while long-term unburned sites are at the beginning of domination by woody vegetation (Heisler et al., 2003).

Past studies in many different ecosystems indicate that presence of fire affects community composition and species abundances either directly (e.g., mortality caused by fire), or indirectly (e.g., postfire habitat changes). There is abundant literature on the effects of fire on some animal species inhabiting tallgrass prairie, including small mammals (Clark and Kaufman, 1990; Kaufman et al., 1990; McMillan et al., 1995), birds (Zimmerman, 1992, 1993, 1997), and arthropods (Evans et al., 1983; Evans, 1984, 1988a,b; Seastedt, 1984). Changes in herpetofaunal communities caused by fire disturbances have been reported in deserts (Fyfe, 1980), forests (McLeod and Gates, 1998; Bury, 2004), tropical forests (Fredericksen and Fredericksen, 2002), savannas (Braithwaite, 1987; Hannah and Smith, 1995), and spinifex grasslands (Masters, 1996; Pianka, 1996). However, few studies have been conducted on herpetofauna in tallgrass prairie (Heinrich and Kaufman, 1985; Busby et al., 1994; Busby and Parmelee, 1996), and fewer studies have investigated the effects of fire on herpetofauna inhabiting the tallgrass ecosystem (Cavitt, 2000; Setser and Cavitt, 2003). These latter studies examined reptile abundance preburn versus postburn (Cavitt, 2000), and snake abundance within annual and long-term unburned areas (Setser and Cavitt, 2003). The current study includes an intermediate burn frequency and multiple animal groups (anurans, turtles, snakes, and lizards). The intermediate burn frequency (in this case a 4-yr frequency) represents the historic burn regime and thus considerable portions of the management practices within the tallgrass prairie.

We hypothesized that community composition and species diversity would differ between annual, intermediate, and long-term unburned treatments. Because intermediate burn frequencies contain a mixture of woody vegetation and grasses creating many different microhabitats, we predicted that this area would contain the greatest number of species. Postfire habitats in annually burned areas can be very stressful on animal populations, so they were predicted to contain the fewest number of species and long-term unburned areas were predicted to have intermediate numbers in species.

Materials and Methods

Study Site.—Herpetofaunal surveys were conducted during spring and fall 2003–2004 at the Konza Prairie Biological Station (KPBS; Fig. 1), located in the Flint Hills region of northeastern Kansas (39°05′N, 96°35′W). KPBS is a 3847-ha tallgrass prairie preserve owned by the Nature Conservancy and Kansas State University (KSU) and managed for ecological research by the KSU Division of Biology.

Vegetation on KPBS is dominated by a matrix of perennial, warm-season C_4 grasses and a highly diverse mixture of other less abundant forb and woody species (Kuchler, 1967; Freeman and Hulbert, 1985; Freeman, 1998; Hartnett and Fay, 1998). Average monthly temperatures at KPBS range from a January low of –2.7°C to a July high of 26.6°C. Average annual total precipitation is 835 mm with 75% falling during the growing season (Bark, 1987). Limestone outcrops are common along slopes and hilltops (Oviatt, 1998), providing shelter and habitat for much of the herpetofauna of the area.

KPBS is divided into 60 watershed units (average size = 0.55 km^2; Fig. 1), each of which is subjected to a specific burn treatment (burned at 1-, 2-, 3-, 4-, 10-, and 20-yr intervals). Trapping occurred in six different watersheds of three different burn treatments, including two annual (AB), two 4-yr (FYB), and two long-term un-

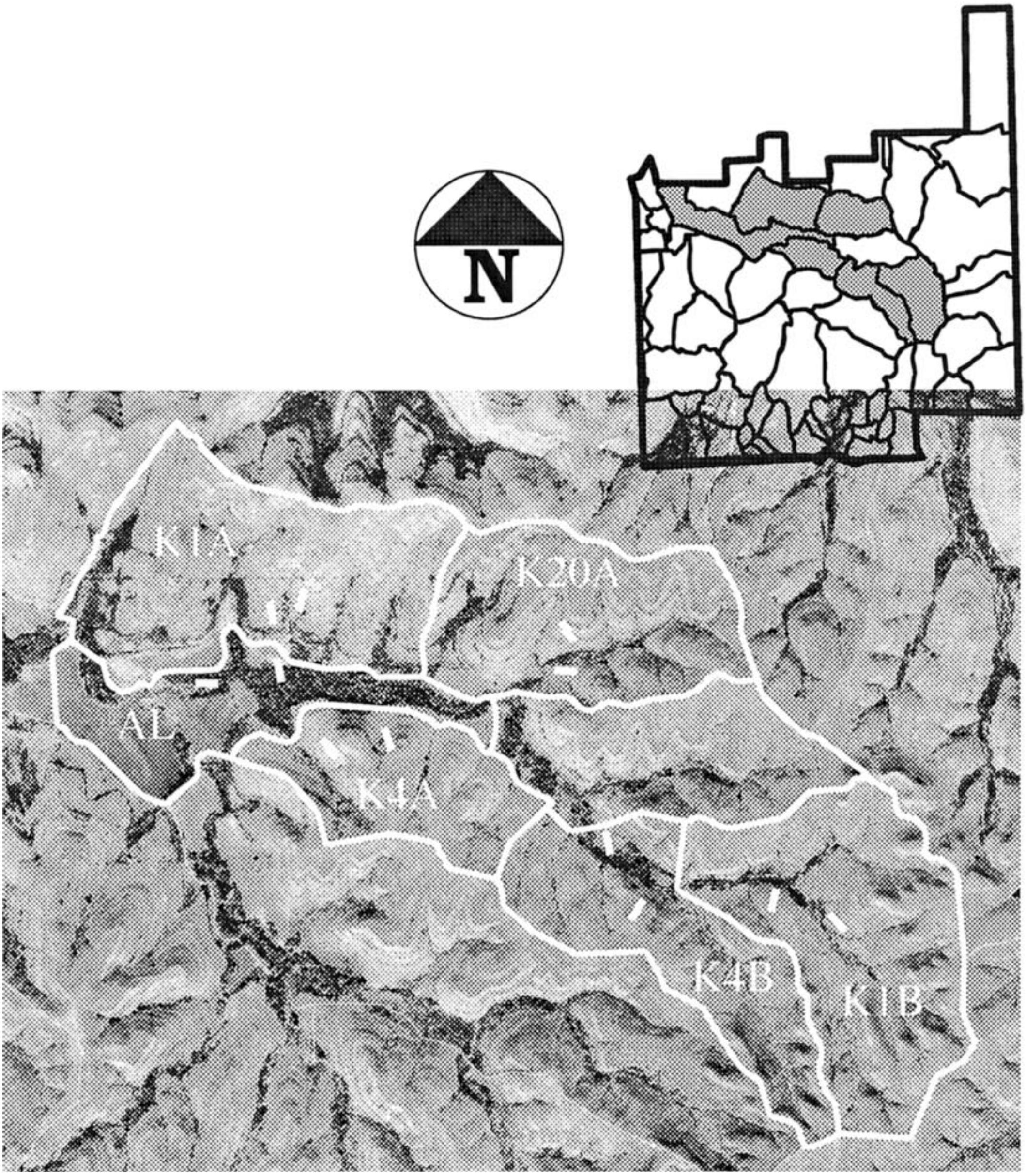

FIG. 1. Map of Konza Prairie Biological Station (KPBS). Gray shaded areas denote the watersheds used for herpetofaunal surveys during 2003–2004. White lines within watersheds indicate placement of trapping transects within burn treatments on KPBS. Two transects were placed within each of six watersheds, two of each of the three different burn frequencies. K1A and K1B = Annual burn treatment, K4A and K4B = 4-yr burn treatment, K20A and AL = Long-term unburned treatment.

burned (LTU) watersheds (Fig. 1). The AL watershed is burned on a variable schedule. However, our trap sites were located in the gallery forest portion of the watershed, which rarely burns because of low amounts of fuel on the forest floor. Thus, trap sites at this location were representative of a long-term unburned area.

Field Protocol.—Surveys consisted of two y-trap arrays 75 m apart, with a line of evenly spaced coverboards, two large (122 × 122 × 1.2 cm) and three small (30 × 40 × 1.2 cm) between (Fig. 2A). Y-trap arrays (Fig. 2B) consisted of three 16 m drift fence arms (30 cm tall) made of plastic woven geotextile silt fence, connected at the

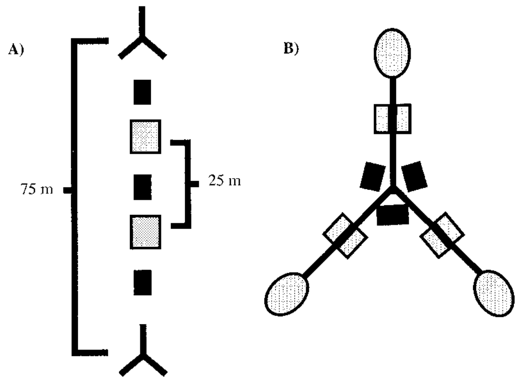

FIG. 2. Sampling methods for herpetofaunal surveys. (A) Trap transect with two y-trap arrays, one on each end. Gray squares represent large coverboards (122 × 122 × 1.2 cm), black rectangles represent small coverboards (30 × 40 × 1.2 cm). (B) Y-trap array design. Thatched ovals represent large collapsible funnel traps (68 × 48 × 20 cm), thatched rectangles represent small collapsible funnel traps (24 × 24 × 40 cm), solid rectangles represent small coverboards (30 × 40 × 1.2 cm).

middle, and held tight to the ground by wooden stakes and bolts. Three large collapsible mesh funnel traps (68 × 48 × 20 cm) were located at the end of each arm. Six small collapsible mesh funnel traps (24 × 24 × 40 cm) were situated one to each side of the fence, in the middle of each arm. Three small coverboards (30 × 40 × 1.2 cm) were located in each fork of the y-trap array. All coverboards were made from oriented strand board (OSB) plywood. Two transects were placed within each watershed (Fig. 1) for a total of 36 traps and 22 boards per watershed. Traps and boards were open 24 h/day and checked daily until daytime temperatures reached 32°C. A funnel trap day (ftd) was defined as any 24-h time period in which animals could enter a single trap. A board day (bd) was defined as any 24-h time period in which animals could shelter beneath the board. Both measurements were combined using the general notation of trap day (td).

Watersheds were sampled as two replicate sets of the three burn treatments. Each set contained one replicate of each of the three burn treatments (Set 1 = K1B, K4B, K20A; Set 2 = K1A, K4A, AL). During 2003, traps in each set were open for alternating five-day periods, whereas all sets were open simultaneously in 2004. Trapping began in spring 2003 on 21 April for set 1 and 30 May for set 2, and ended 23 June. Fall 2003 trapping began on 5 September and ended on 15 October. Spring 2004 started on 9 April for set 2 and 3 June for set 1, and ended 28 June. Fall 2004 trapping began on 16 September for set 2 and 22 September for set 1, and trapping ended on 17 October. Across both years, set 2 was open 25 days longer than set 1 (Set 1 = 115 days, Set 2 = 140 days).

Captured animals were identified to species and individually marked if possible. Larger snakes (*Thamnophis sirtalis*, *Coluber constrictor*, *Lampropeltis triangulum*, *Lampropeltis getula*, *Elaphe emoryi*, and *Pituophis catenifer*) were marked by clipping ventral scales (Brown, 1976). Smaller snakes (*Diadophis punctatus*, *Storeria dekayi*, *Tropidoclonion lineatum*, and *Carphophis vermis*), lizards, and anurans were not marked. However, individuals of *S. dekayi*, *T. lineatum*, *C. vermis*, *Eumeces obsoletus*, *Ophisaurus attenuatus*, and all anuran captures could be analyzed for recaptures caused by low numbers of individuals caught, and site of each capture caused by nonmovement. Snout–vent length (cm) and mass (g) were recorded for each individual. Species identification and trap or board location were recorded for all animals whether or not they were handled.

Statistical Analysis.—Species diversity was evaluated using count data and Shannon's Index (Shannon and Weaver, 1949), which works well for nonparametric data with small sample sizes and rare species occurrences.

Comparisons between burn frequencies were performed using four estimators: (1) species richness; (2) Shannon's index (H); (3) Shannon's equitability index (E_H); and (4) number of individuals. Because of the short time frame of this study (2 yr), we did not have enough yearly replicates to address annual variation in activity patterns related to weather. However, analyzing data by season may be biologically meaningful because of fundamental differences in herpetofaunal behavior between spring and fall. So estimates were compared between watersheds and seasons, pooling across years. Species richness estimates were equated across all watersheds by multiplying the number of td sampled in the least sampled watershed divided by number of td sampled in the most sampled watershed. Comparisons were made using one-way ANOVA with equal samples via STATISTICA statistics software (Statsoft Inc., Tulsa, OK).

Community composition was analyzed using categorical data analysis. The Pearson chi-square test was used to test for independence of response of a species to different burn treatments. Because many species were rarely captured, the proportion of cell counts > 5 was 22%. Agresti (1996) warns of possible biases in the results when < 25% of the cell counts > 5. Therefore, different tables were created, the first included all species detected regardless of number captured, and the second included only those species with total captures across all burn frequencies > 5, resulting in 42% of the cells with counts > 5. However, Pearson chi-square values from both were extremely large and had the same outcome; hence, inferences hereafter will refer to the table containing all 20 species captured. In an additional, post hoc analysis of the data, groups of species consisting of all anurans and small snakes specializing on earthworms were tested a second time. The Pearson chi-square statistic was calculated using SAS (version 8.0, SAS Institute, Cary, NC).

Similarity between communities in different burn treatments was assessed using Jaccard's similarity indices (JSI; Pielou, 1984) and adjusted residuals. Adjusted residuals were calculated to identify which cells violated independence (Agresti, 1996). A positive residual indicates more observed individuals than expected in the area, whereas a negative residual indicates fewer observed individuals in the area than expected. A species with a large negative residual for a specific habitat may be avoiding that habitat. Adjusted residuals $> |3|$ for an individual species are in clear violation of independence between samples, whereas adjusted residuals $> |2|$ are a possible rejection of independence. Adjusted residuals for the table were calculated using SAS (version 8.0, SAS Institute, Cary, NC). Significance testing was performed using a chi-square test on any species containing an adjusted residual of $> |2|$ in any burn treatment.

Significance testing between trap types (traps and coverboards) and seasons were performed using two-sample paired *t*-tests. Trap types and seasons for each watershed were paired together (i.e., K1B boards vs. K1B traps, or K1B spring vs. K1B fall) across all watersheds to compute the mean and variance. Analysis of size differences between individuals of *D. punctatus* (the most numerous species captured) was performed using a one-way ANOVA. Alpha was set at 0.05. For all other statistical tests, because the capture data were used multiple times, we adjusted alpha to 0.01 using Bonferroni's correction.

Results

Seventeen of the 29 species that have been reported to occur on KPBS (Heinrich and Kaufman, 1985) were captured, plus an additional three species previously unrecorded: *Bufo americanus*, *S. lateralis*, and *S. dekayi*.

Summing across trap sets and years, the study consisted of 27,540 individual funnel trap days (ftd) and 16,830 individual board days (bd). A total of 315 individuals, including 21 recaptures, representing 20 species were captured (Appendix 1).

Results from different survey methods (boards and traps) differed across the study. Coverboards were seven times more efficient than funnel traps, detecting 242 individuals (mean = 0.014 ind./bd, SE $<$ 0.001, N = 12) when compared to the low trap efficiency of 54 individuals (mean = 0.002 ind./ftd, SE $<$ 0.001, N = 12) resulting in significantly more individuals per trap day detected by cover boards across all burn frequencies within each season (t = 4.78, df = 11, $P <$ 0.001). For all burn treatments, cover boards were almost twice as efficient, detecting 15 total species (mean = 0.003 sp/bd, SE $<$ 0.001, N = 12) compared to trap captures of 13 total species (mean = 0.001 sp/ftd, SE $<$ 0.001, N = 12; t = 4.79, df = 11, $P <$ 0.001). Four species were captured only in traps, whereas nine species were only captured under boards. These species would be missed if only one trap type as used.

Species Diversity.—Overall species richness (SR) was generally higher in annually burned (SR = 15) and long-term unburned areas (SR = 14), than 4-yr burn treatments (SR = 9). However, high variability existed between watershed-replicates of the same burn frequency (Fig. 3). Number of species captured within each burn frequency was not significantly different for either season when pooling across years (Spring: F = 0.56, df = 3, P = 0.620; Fall: F = 0.02, df = 3, P = 0.982). Species capture rates were slightly higher, though nonsignificant, in fall (mean = 0.11 sp/td) than in spring (mean = 0.08 sp/td; t = 1.92, df = 6, P = 0.113). However, because of the shorter fall season, total species richness estimates over the entire season were similar to those of spring.

Estimates of species evenness showed similar patterns to those of species richness (Fig. 3). Species evenness estimates were higher in annually burned areas (E_H = 85.1) when compared to 4-yr burn treatments (E_H = 59.7) and long-term unburned areas (E_H = 67.5). Low evenness estimates in the 4-yr frequency may have been caused by a high proportion (63%) of total captures within one species (*S. lateralis*). However, because of insufficient replication and variability within replicates, evenness was not significantly different between burn treatments for either season (Spring: F = 6.52, df = 3, P = 0.081; Fall: F = 2.69, df = 3, P = 0.215). When pairing estimates for each watershed, the fall season (mean = 85.98) had moderately higher estimates of evenness among captures than the spring season (mean = 69.98) across all burn treatments (Fig. 3; t =2.88, df = 6, P = 0.035).

Species diversity indices include measures of species richness and relative abundances (evenness), thus patterns in diversity estimates were similar to those already discussed. Annually burned areas showed the highest diversity when pooling across all seasons and watersheds (AB H = 3.3, FYB H = 1.9, LTU H = 2.6). Results were inconsistent across watersheds of the same burn treatment for years and seasons creating high variability (Fig. 3); hence, Shannon diversity in-

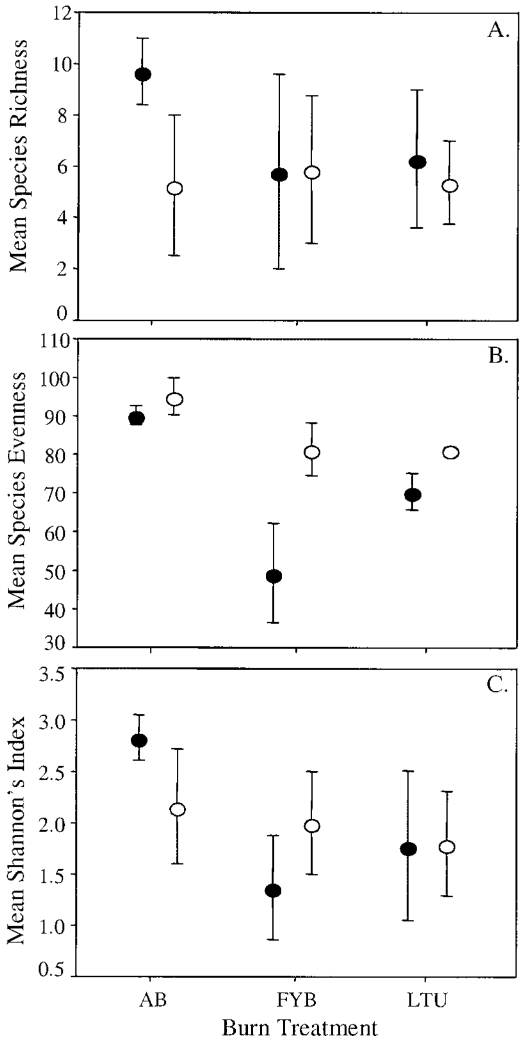

FIG. 3. Herpetofaunal community parameters estimated within different burn treatments for spring (•) and fall (○). All estimates were averaged across watersheds of similar burn treatment. Error bars represent ± 1 SE. (A) Species richness estimates for each burn treatment pooled across years within both seasons. Estimates are averages of direct counts of the number of species detected for both years. Unequal sampling efforts were equilibrated by multiplying the number of days sampled in least sampled watershed divided by the number of days sampled in most sampled watershed. (B) Species evenness (E_H) estimates for each burn treatment pooled within each season across both years. Estimates were calculated using Shannon's evenness index. (C) Species diversity estimates (H) for each burn treatment pooled within each season across both years. Diversity estimates were calculated using Shannon's index. AB = Annually burned, FYB = 4-yr burn, LTU = Long-term unburned.

dices were not significantly different between burn frequencies for either season when pooling across years (Spring: $F = 2.05$, df = 3, $P = 0.275$; Fall: $F = 0.12$, df = 3, $P = 0.893$). Estimates of species diversity also did not differ between seasons when watershed estimates were combined (Spring $H = 1.97$, Fall $H = 1.98$; $t = 0.029$, df = 6, $P = 0.98$).

Community Composition.—Although overall species diversity and total abundance were relatively similar between different burn treatments, Jaccard's similarity indices (JSI) indicated that many species were not shared between different burn treatments. Indices for both seasons differed with more species being shared between treatments during spring than fall. However, patterns within burn treatment remained constant between seasons. Habitats closer to each other on the burn continuum shared more species than those further apart. Annually burned areas were more dissimilar to long-term unburned sites (Spring JSI = 0.70; Fall JSI = 0.27) than they were to 4-yr burn treatments (Spring JSI = 1.0; Fall JSI = 0.50), which were in turn more similar to long-term unburned sites (Spring JSI = 0.86; Fall JSI = 0.57).

Analysis of species captures pooled across all watersheds (Appendix 1) within burn treatments rejects independence of species captures and burn frequency ($\chi^2 = 158.19$, df = 20, $P < 0.001$); thus, some species captured exhibit preferences for one of the different habitats created. The adjusted residuals for each species within a burn treatment (Table 1), suggest that some species may exhibit a positive response to specific burn treatments, whereas other species exhibit a negative response. Only one of five anuran species showed significant habitat preferences. *Gastrophryne olivicea* ($\chi^2 = 7.0$, df = 2, $P = 0.03$) exhibited marginal preferences for annually burned areas and avoidance of 4-yr burn areas. Three of four lizard species exhibited significant preferences among habitats. *Eumeces obsoletus* ($\chi^2 = 16.63$, df = 2, $P < 0.001$) and *P. cornutum* ($\chi^2 = 34.00$, df = 2, $P < 0.001$) were found in much greater numbers in annually burned areas than would be expected if habitat choice was independent of burn regime. *Scincella lateralis* ($\chi^2 = 63.75$, df = 2, $P < 0.001$) was found in much higher numbers in 4-yr burn treatments. There is also a clear avoidance of annually burned areas for this species and low numbers were found in long-term unburned areas.

The small snake, *Diadophis punctatus*, also exhibited significant habitat preferences ($\chi^2 = 11.53$, df = 2, $P = 0.003$), being found in much higher numbers than expected in long-term unburned areas, and in fewer numbers in areas of higher burn frequencies. *Diadophis punctatus* was the only species with sufficient captures to

TABLE 1. Adjusted residuals of χ^2-table for independence of herpetofaunal communities in habitats of different burn frequencies.

		Burn frequency			
Common name (Scientific name)	Preference	AB	FYB	LTU	P*
Amphibians					
Northern Cricket Frog (*Acris crepitans*)		1.4	−1.4	0.1	—
Western Chorus Frog (*Pseudacris triseriata*)		−0.7	−0.8	1.5	—
Plains Leopard Frog (*Rana blairi*)		2.1□	−1.1	−0.9	0.14
American Toad (*Bufo americanus*)		1.5	−0.8	−0.7	—
Great Plains Narrowmouth Toad (*Gastrophryne olivicea*)	AB	2.8□	−2.0□	−0.7	0.03
Reptiles					
Ornate Box Turtle (*Terrapene ornata*)		2.1□	−0.6	−1.4	0.15
Ground Skink (*Scincella lateralis*)	FYB	−5.7■	7.9■	−2.7□	<0.01
Great Plains Skink (*Eumeces obsoletus*)	AB	4.5■	−2.2□	−2.2□	<0.01
Texas Horned Lizard (*Phrynosoma cornutum*)	AB	6.4■	−3.4■	−2.8□	<0.01
Slender Glass Lizard (*Ophisaurus attenuatus*)		−0.7	−1.1	2.0□	0.37
Ringneck Snake (*Diadophis punctatus*)	LTU	−1.3	−3.2■	4.7■	<0.01
Brown Snake (*Storeria dekayi*)		−2.0□	0.3	1.7□	0.10
Lined Snake (*Tropidoclonion lineatum*)	AB	2.6□	−1.4	−1.1	0.05
Western Worm Snake (*Carphophis vermis*)		−0.7	−0.8	1.5	—
Common Garter Snake (*Thamnophis sirtalis*)		−0.5	−1.8	2.4□	0.07
Eastern Yellow-bellied Racer (*Coluber constrictor*)	Avoid LTU	1.3	1.0	−2.4□	0.04
Milk Snake (*Lampropeltis triangulum*)	LTU	−1.3	−1.5	2.8□	0.05
Common Kingsnake (*Lampropeltis getula*)	FYB	−1.3	2.5□	−1.3	0.02
Great Plains Rat Snake (*Elaphe emoryi*)		−0.7	−0.8	1.5	—
Gopher Snake (*Pituophis catenifer*)		1.5	−0.8	−0.7	—

Overall χ^2 table rejects H_o for independence of community composition (χ^2 = 158.19, df = 20, P < 0.001).
□ |2| Possible rejection of independence, ■ |3| Rejection of independence.
AB = Annually burned, FYB = 4-yr burn, LTU = Long-term unburned.
* Significance testing for each species through Pearson χ^2-test for independence.

analyze differences in body size. Individuals residing in long-term unburned areas were significantly larger in SVL (cm; F = 3.26, df = 46, P = 0.047) and mass (g; F = 3.81, df = 43, P = 0.030) than individuals residing in the other burn treatments (Fig. 4).

Four other snake species exhibited only marginal deviance in adjusted residuals ≥ |2| resulting in only marginally insignificant habitat preferences (Table 1). *Tropidoclonion lineatum* (χ^2 = 6.0, df = 2, P = 0.05) preferred annually burned areas, and *L. getula* (χ^2 = 8.0, df = 2, P = 0.018) preferred an intermediate burn frequency. *Lampropeltis triangulum* (χ^2 = 6.14, df =2, P = 0.046) was found in greater number in long-term unburned habitat, whereas *C. constrictor* (χ^2 = 6.33, df = 2, P = 0.042) was least common there, indicating possible avoidance of unburned habitat.

Species with common habitat or food requirements, responded in similar ways. Overall, amphibian abundances across all detected species indicated a general deficiency in amphibians within the intermediate burn frequency. Although no single species exhibited significant avoidance of this habitat, when summing standard residuals across each of the five species captured, the total captures were in lower abundances than expected (AB = 7.1, FYB = –6.1, LTU = –0.7). When summed across feeding niches, four small-bodied earthworm eating snakes (*D. punctatus*, *S. dekayi*, *T. lineatum*, and *C. vermis*) were found in much lower abundances than expected in the two higher burn frequencies (AB = –1.4; FYB = –5.1; LTU = 6.8).

DISCUSSION

This study indicates that different burn treatments in tallgrass prairie do not result in significantly different species richness, evenness, or diversity of reptiles and amphibians. However, community compositions within habitats created by these burn treatments are significantly different from one another. Similarities in species composition followed the burn continuum, with more species shared between more closely related habitats.

This study was designed to discover initial differences of herpetofauna between burn treatments. KPBS watershed design limited the possible areas of study based on size and

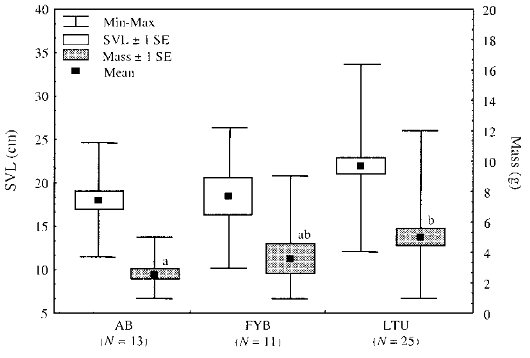

FIG. 4. Body measurements of *Diadophis punctatus* captured in different burn treatments. Significant differences were found between burn frequencies for SVL ($F = 3.26$, df = 46, $P = 0.047$) and mass ($F = 3.81$, df = 43, $P = 0.030$). Different letters indicate significant pairwise differences. AB = Annually burned, FYB = 4-yr burn, LTU = Long-term unburned.

treatment, leading to insufficient replication. The variability in habitat types within our burn treatment replicates also limits the conclusions of this study. Sufficient replicate sites of the same general size and type are difficult to come by. The 4-yr burn treatments were one year apart in their burn cycle. Observed abundances may depend on species-specific recovery times postburn; thus, patterns within the 4-yr replicates may have been different from each other. Both of the long-term unburned sites were similar in time since fire; however, the habitat types were very different, a 20-yr burn treatment prairie and a gallery forest. The suites of species may be completely different between these sites. Because of the limited replicate possibilities, choice of watersheds was solely based on burn treatment. An increase in transects or watersheds would increase the number of individuals captured within each species, allowing for more treatment comparisons. The small number of individuals captured for each species often limited our conclusions. The trapping protocol used in this study was unable to account for all species found on KPBS, *Spea bombifrons*, *Bufo woodhousii*, *Hyla chrysoscelis*, *Rana catesbeiana*, *Crotaphytus collaris*, *Elaphe obsoleta*, *L. calligaster*, and *Agkistrodon contortrix* are known to be in the area, but no individuals were detected. Biases in diversity indices are possible when all species in an area are not detected. However, we were unable to correct for these biases because of lack of burn regime preferences on all species. The short-term nature of the project may also limit the power of our study to detect significant differences. In this study, sampling was not performed during the summer months (July and August). Because of the intense heat, herpetofaunal activity dramatically decreases and, thus, sampling during this time period is ineffective and can result in increased mortality. Differences in initial sample dates during both seasons were due to different spring burn dates of watersheds used and time constraints. Long-term research may enhance this study and decipher some of the minor difference in species richness and diversity levels.

Fredericksen and Fredericksen (2002) found increased species diversity in tropical forests in postfire habitats. However, the majority of studies in ecosystems similar to tallgrass prairie report confounding results at the community level, with evidence for no change in overall herpetofaunal species diversity (Braithwaite, 1987; Greenberg et al., 1994; Hannah and Smith, 1995) and for decrease in overall herpetofaunal diversity (Mushinsky, 1986; Masters, 1996). Most often, direct responses are evident at the species (Braithwaite, 1987; Fair and Henke, 1997; Woinarski et al., 1999; Cavitt, 2000; Setser and Cavitt, 2003) or niche level (Fyfe, 1980; Greenberg et al., 1994; McLeod and Gates, 1998; Bury, 2004), which confounds results at a community level. Species with positive responses toward the habitat created by a given fire regime will replace those species with negative responses that have emigrated or been extirpated from the area, resulting in an insignificant net change of overall species diversity, such as was found in this study.

Burn regimes can affect species abundances in three ways: (1) direct mortality of individuals caused by fire; (2) alteration of vegetation structure and microhabitat; and (3) alteration in abundance of prey items (earthworms, insects, mammals, birds, and other reptiles) and/or predator abundance. Studies focused on direct mortality on herpetofauna caused by fire have found little impact on the community (Erwin and Stasiak, 1979; Floyd et al., 2001). Mortality rates are likely to be variable between both species and years and based on specific climatic conditions. Air temperature fluctuations also influence body temperature, which directly influences escape speed (Martin and Lopez, 2000; Cooper, 2003). Escape speed and proximity of individuals to shelter could influence probability of direct mortality. Similarly, the loss or change of the vegetation structure in a postburn environment led to increased predation pressures on large snakes by raptors (Wilgers, 2005).

In the few cases in which species specialize on prey types (i.e., earthworm and ant obligates), direct effects on prey abundance may influence the number of species and individuals able to reside in a specific area. The suite of earthworm feeding snakes at KPBS (*D. punctatus*, *S. dekayi*, *T. lineatum*, and *C. vermis*) tended to avoid intermediate and annually burned areas, which may be caused by an increased abundance of

European earthworms within areas of high soil moisture and organic nutrients characteristic of habitats without fire disturbance (Callaham and Blair, 1999). However, most herpetofaunal species found in tallgrass prairie tend to be generalist feeders. Individuals can shift to other prey types when one becomes unavailable, thus, responses of species to different burn regimes may be based on the resulting vegetation structure.

Anurans were found in lower abundances than expected within the intermediate burn frequency. Although there are many intermittent streams running near the transects, no permanent water sources are nearby. Capture of individuals could be caused by movement between major water sources. A few species captured in the study (*Acris crepitans*, *Rana blairi*, and *Pseudacris triseriata*) are known to travel large distances away from water (Collins, 1993). The more extreme and variable microhabitats within annually burned areas could force amphibians to move more frequently to find suitable temperatures and moisture. Thus, it is possible that anuran abundances are similar among burn regimes but that they are more easily detected in annually burned areas caused by increased activity. Low capture numbers limits conclusions drawn from these results and should be taken with caution, future studies on the effects of burning on amphibians are needed.

This study found four species exhibiting significant preferences and/or avoidances of specific burn treatments, whereas five species exhibited preferences that were only marginally insignificant. These trends most often can be explained based on individual species life-history characteristics. Habitats within annually burned areas are typically more spatially variable in vegetation cover, caused by the lack of a litter layer. This leads to a warmer, drier microclimate with an increased number of open basking rocks especially during early spring. Habitat requirements for *E. obsoletus*, and *P. cornutum* (Collins, 1993) suggest that annually burned areas are ideal habitat and our results support this hypothesis. Only one snake species showed clear habitat preferences, whereas four others exhibited marginally insignificant preferences, resulting from a reduction in alpha. *Diadophis punctatus* significantly preferred long-term unburned habitat, which concur with each species' habitat requirements (Collins, 1993). The increased moisture level of soils in long-term unburned areas, along with an abundance of its primary prey, earthworms, makes this an ideal habitat for *D. punctatus*.

Scincella lateralis exhibited the most extreme response to any burn frequency across all species. It is the only species showing much larger abundances in the intermediate burn frequency than would be expected with independent assortment, which was unexpected based on the favored habitat of wooded areas as reported by Collins (1993). The cool-moist habitat created by coverboards, which is more similar to their preferred habitat, may attract individuals within the 4-yr burn treatment. Thus, the capture probability may simply be higher in intermediate burn regime, and abundances are similar between watersheds of lower burn frequencies.

Coluber constrictor exhibited a marginally insignificant avoidance of long-term unburned areas; which is not surprising as it is a more open prairie species (Collins, 1993). This finding is contrary to both Cavitt (2000) and Setser and Cavitt (2003) in which *C. constrictor* was found less often in recently burned areas, and in greater numbers in unburned habitats. In newly burned habitats, activity levels should decrease because of limited amounts of cover for the first several weeks postburn. Coverboards provide an ideal detection method for herpetofauna where activity is limited and cover is at a premium. Across the entire study about 61% of captures of *C. constrictor*, including 50% from annually burned areas across the entire study were from coverboards. The lack of coverboards in previous studies (Cavitt, 2000; Setser and Cavitt, 2003) may have resulted in biased sampling through underestimates of this species' abundance.

Annual burning of the Flint Hills region of the tallgrass prairie is widespread. This management plan gives little regard to most of the wildlife inhabiting the region. Instead of the traditional mosaic of burn frequencies across the landscape, much of the area is left devoid of grass and cover more than a few centimeters high until late spring (Robbins et al., 2002). One single large scale burn frequency across an entire managed area eliminates heterogeneity of habitats, decreasing the likelihood of species replacement similar to that of metapopulation dynamics. To maintain herpetofaunal diversity at its highest level, we endorse the recommendations of Fuhlendorf and Engle (2004) and Seig (1997) that the large number of habitats created by a shifting mosaic burn schedule should include a maximum number of species and niche levels.

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APPENDIX 1. Herpetofaunal captures on Konza Prairie Biological Station in different burn frequencies from 2003–2004.

	Burn frequency									
	Annual			4-yr			Extended			Overall
Common name (Scientific name)	K1B	K1B	(Totals)	K4A	K4B	(Totals)	K20A	AL	(Totals)	total
Amphibians										
Northern Cricket Frog (*Acris crepitans*)	1	1	(2)	0	0	(0)	0	1	(1)	3
Western Chorus Frog (*Pseudacris triseriata*)	0	0	(0)	0	0	(0)	0	1	(1)	1
Plains Leopard Frog (*Rana blairi*)	2	0	(2)	0	0	(0)	0	0	(0)	2
American Toad (*Bufo americanus*)	1	0	(1)	0	0	(0)	0	0	(0)	1
Great Plains Narrowmouth Toad (*Gastrophryne olivicea*)	5	0	(5)	0	0	(0)	0	1	(1)	6
Reptiles										
Ornate Box Turtle (*Terrapene ornata*)	6	0	(6)	1	2	(3)	0	1	(1)	10
Ground Skink (*Scincella lateralis*)	5	5	(10)	39	33	(72)	2	19	(21)	103
Great Plains Skink (*Eumeces obsoletus*)	10	3	(10)	1	1	(2)	0	1	(1)	16
Texas Horned Lizard (*Phrynosoma cornutum*)	17	0	(17)	0	0	(0)	0	0	(0)	17
Slender Glass Lizard (*Ophisaurus attenuatus*)	2	0	(2)	0	1	(1)	0	4	(4)	7
Ringneck Snake (*Diadophis punctatus*)	15	3	(18)	11	6	(17)	16	22	(38)	73
Brown Snake (*Storeria dekayi*)	0	0	(0)	1	3	(4)	4	1	(5)	9
Lined Snake (*Tropidoclonion lineatun*)	3	0	(3)	0	0	(0)	0	0	(0)	3
Western Worm Snake (*Carphophis vermis*)	0	0	(0)	0	0	(0)	0	1	(1)	1
Common Garter Snake (*Thamnophis sirtalis*)	0	1	(1)	0	0	(0)	0	4	(4)	5
Eastern Yellow-bellied Racer (*Coluber constrictor*)	5	3	(8)	1	8	(9)	1	0	(1)	18
Milk Snake (*Lampropeltis triangulum*)	0	2	(2)	0	3	(3)	1	8	(9)	14
Common Kingsnake (*Lampropeltis getula*)	0	0	(0)	1	3	(4)	0	0	(0)	4
Great Plains Rat Snake (*Elaphe emoryi*)	0	0	(0)	0	0	(0)	0	1	(1)	1
Gopher Snake (*Pituophis catenifer*)	0	1	(1)	0	0	(0)	0	0	(0)	1
Total Individuals	72	19	(91)	55	60	(115)	24	65	(89)	294
Total Species	12	8	(15)	7	9	(9)	5	13	(14)	20