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# Fire and a Tallgrass Prairie Reptile Community: Effects on Relative Abundance and Seasonal Activity

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ABSTRACT.—**Few intensive studies have been conducted on reptile populations of the tallgrass prairie. In addition, the effects of fire on these populations are also largely unknown. I established drift fence arrays connected to funnel traps to study the community composition and seasonal activity of reptiles found on the Konza Prairie Research Natural Area located near Manhattan, Kansas. This design also gave me the opportunity to examine the response of reptile populations to a spring wildfire. A total of 657 individuals representing 12 species were captured from 1994–1996. The results suggest that one species, *Coluber constrictor*, may respond negatively to recent fire.**

While the distribution and natural history of most reptiles within the central Great Plains is well known (e.g., Fitch, 1963, 1982, 1989; Ballinger et al., 1979; Jones et al., 1981; Hopkins, 1983), few intensive studies have been conducted on those inhabiting tallgrass prairie (but see Heinrich and Kaufman, 1985; Busby et al., 1994). Fire

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is essential to the maintenance of tallgrass prairie; however, its effects on reptile populations are also largely unknown. This lack of basic information constitutes major impediments to the conservation of these species (Dodd, 1987; Corn and Peterson, 1996) and the tallgrass prairie in which they exist.

Periodic fire can have profound effects on the habitat structure and plant species composition (Collins and Gibson, 1990). This in turn has the potential to affect the reptile community through changes in food supply (e.g., insect abundance-Evans, 1984; 1988; Warren et al., 1987; small mammal abundance—Kaufman et al., 1990), cover (Hulbert, 1969, 1988), and microclimate (soil temperature—Hulbert, 1969; Rice and Parenti, 1978; soil moisture—Anderson, 1965; Hulbert, 1969). In addition, fires that occur when reptiles are active can cause injury and direct mortality (Babbitt and Babbitt, 1951; Erwin and Stasiak, 1979; Heinrich and Kaufman, 1985; Cavitt, unpubl. data).

The tallgrass prairie can be a hostile environment for reptiles because of extremes in temperature and precipitation. Consequently, a number of interesting behavioral adaptations and life history characteristics of ectotherms found in this ecosystem have evolved (e.g., Fitch, 1956, 1958). Studies in other fire-prone systems have documented the effects of fire on reptile behavior (Lillywhite and North, 1974; Withgott, 1996), population structure (Mushinsky, 1992), and community dynamics (Mushinsky, 1985; Pianka, 1996). The primary goal of this study was to examine the community composition of reptiles found within tallgrass prairie. The occurrence of a spring wildfire on one of the study sites also enabled me to examine the response of this reptile community to recent fire.

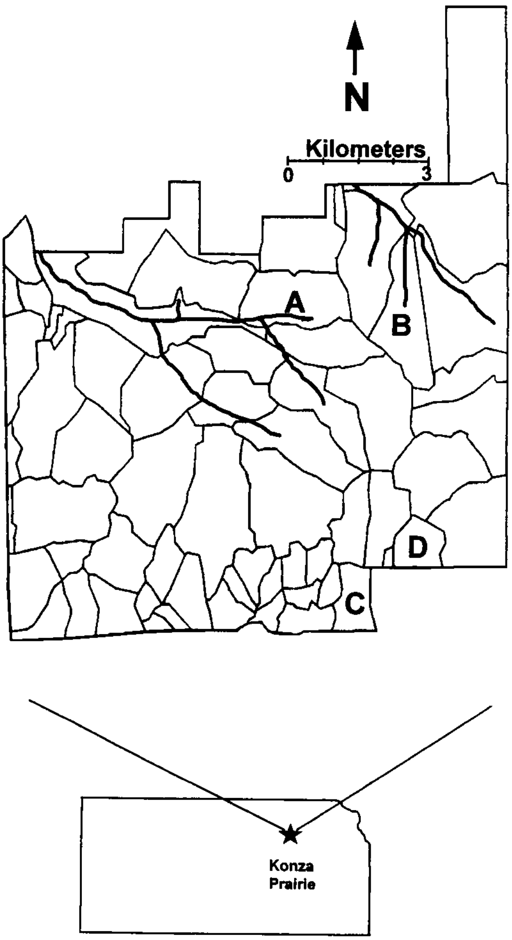


FIG. 1. Location of the Konza Prairie Research Natural Area in northeastern Kansas and detailed map of site. Subdivisions represent watershed units with various fire and grazing treatments, letters indicate study sites utilized in this study and thick lines outline the Konza gallery forest.

## MATERIALS AND METHODS

*Study Area.*—This study was conducted on the Konza Prairie Research Natural Area (3,487 ha) located in Riley and Geary Counties of Kansas (39°05′N, 97°35′W) from 1994–1996. Konza Prairie is an ecological preserve owned by the Nature Conservancy, managed by the Division of Biology of Kansas State University and serves as a National Science Foundation Long-term Ecological Research site (Fig. 1). Konza lies within the Flint Hills physiographic province, which is the largest remaining tract of unplowed prairie in North America. This region is characterized by steep-sided hills exposing alternating limestone-shale layers and is dominated by warm season prairie grasses with scattered shrubs and trees (Reichman, 1987). The management plan and experimental design for Konza are based on watershed-sized treatments affected by different fire frequencies (from annually to every 20 yr) and grazing treatments (by either cattle [*Bos taurus*] or bison [*Bos bison*] or ungrazed).

*Field Procedures.*—Hardware cloth drift fences (30 cm high, 0.635 $cm^2$ mesh) connected to funnel traps ([0.635 $cm^2$ mesh, 1 m long, 38 cm high [Imler, 1945]) were used to capture most reptiles, although a few individuals were captured by hand. Funnel traps were located every 5 m along a 30 m drift fence array, for a total of five traps per fence. Because of the shallow soils found throughout the Flint Hills, drift fence arrays were restricted to locations where soil depth was sufficient to bury the fence at least 6 cm below ground. Consequently, the majority (93%) of drift fence arrays were located along

TABLE 1. Number of individuals and relative abundance (#/100 Trap array days) by year and site for the 10 species of snakes and three species of lizards captured (* indicates focal species).

| Site | A | | | B | | C | | D | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | |
| Number of Trap arrays | 4 | 9 | 9 | 9 | 9 | 4 | 4 | 4 | 4 | Total |
| Snakes | | | | | | | | | | |
| *Coluber constrictor* | 33 | 44 | 52 | 58 | 20 | 4 | 31 | 15 | 28 | 285 |
| | 9.37 | 5.82 | 6.64 | 7.67 | 2.55 | 1.82 | 7.75 | 7.81 | 7.00 | |
| **Thamnophis sirtalis* | 5 | 12 | 9 | 15 | 10 | 21 | 10 | 26 | 7 | 115 |
| | 1.42 | 1.59 | 1.15 | 1.98 | 1.28 | 9.55 | 2.50 | 13.54 | 1.75 | |
| *Elaphe emoryi* | 2 | 13 | 3 | 3 | 7 | 5 | 3 | 8 | 4 | 48 |
| | 0.57 | 1.72 | 0.38 | 0.40 | 0.89 | 2.27 | 0.75 | 4.17 | 1.0 | |
| *Lampropeltis getula* | 5 | 5 | 6 | 7 | 7 | 1 | 1 | 1 | 5 | 38 |
| | 1.42 | 0.66 | 0.77 | 0.93 | 0.89 | 0.45 | 0.25 | 0.52 | 1.25 | |
| *Lampropeltis triangulum* | 3 | 1 | 3 | 7 | 4 | — | 1 | 3 | 4 | 26 |
| | 0.85 | 0.13 | 0.38 | 0.93 | 0.51 | — | 0.25 | 1.56 | 1.0 | |
| *Pituophis catenifer* | — | — | 2 | 3 | — | 2 | 2 | 5 | 12 | 26 |
| | — | — | 0.26 | 0.40 | — | 0.91 | 0.5 | 2.60 | 3.0 | |
| *Elaphe obsoleta* | 4 | 1 | 1 | — | 2 | — | — | — | — | 8 |
| | 1.14 | 0.13 | 0.13 | — | 0.26 | — | — | — | — | |
| *Tropidoclonion lineatum* | 2 | — | — | — | — | — | — | — | — | 2 |
| | 0.57 | — | — | — | — | — | — | — | — | |
| *Lampropeltis calligaster* | — | — | 1 | — | — | — | — | — | — | 1 |
| | — | — | 0.13 | — | — | — | — | — | — | |
| *Storeria dekayi* | — | — | — | — | — | — | — | 1 | — | 1 |
| | | | | | | | | 0.52 | | |
| Lizards | | | | | | | | | | |
| **Ophisaurus attenuatus* | 17 | 22 | 10 | 30 | 10 | 2 | — | — | — | 91 |
| | 4.83 | 2.91 | 1.28 | 3.97 | 1.28 | 0.91 | — | — | — | |
| *Eumeces obsoletus* | 1 | 2 | — | 6 | 1 | — | 1 | — | — | 11 |
| | 0.28 | 0.26 | — | 0.79 | 0.13 | — | 0.25 | — | — | |
| *Eumeces septentrionalis* | — | 1 | — | 5 | — | — | — | — | — | 6 |
| | — | 0.13 | — | 0.66 | — | — | — | — | — | |

slopes and lowland sites. Thus, species commonly found on rocky upland sites (e.g., *Crotaphytus collaris* and *Phrynosoma cornutum*; Heinrich and Kaufman, 1985) were not monitored in this study.

In 1994, the study consisted of sampling one ungrazed site (A) with four drift fence arrays. Five additional arrays were installed in 1995 for a total of nine. Arrays were also added in equal densities to three ungrazed study areas in 1995; nine arrays were installed to a portion of B, four arrays in C and four arrays in D (Fig. 1). Area and fire histories were: A—90 ha, burned in 1980, 1985, and 1991; B—80 ha, burned in 1980, 1986, 1991, 1994 and 1996; C—36 ha, burned annually from 1972–1977 and then in 1980 and 1991; D—36 ha, burned in 1980 and 1991.

Snakes captured in both A and B were removed as part of another study (Cavitt, 1998) and released in similar habitat at least 15 km from Konza Prairie. Snakes captured were only identified and removed in 1994. From 1995–1996 all snakes were identified and sexed by tail shape and by probing for the presence of hemipenes (Schaefer, 1934). Juveniles and small species usually were not sexed. Lizards captured in both removal and release sites were not sexed or removed, but were identified and then released at the point of capture. Reptiles captured in both C and D were not removed but were marked individually by clipping ventral scales (Brown and Parker, 1976) and then released at the point of capture. Traps located on all sites were opened in mid to late April and checked daily until they were closed in mid to late August.

On February 25, 1996 a wildfire burned the B study site. All other sites utilized for this study remained unburned. This unique opportunity allowed me to examine the effects of fire on species composition and relative abundance by comparing snakes captured on the B site in 1996 to the same unburned site in 1995, and unburned A in 1996. Both A and B are similar in soil type, vegetation, and proximity to the Konza gallery forest (Fig. 1).

*Data Analyses.*—All statistical analyses were performed on SAS-PC software (SAS, 1996). Nonparametric statistics were used for analyses when assumptions of normality and homoge-

TABLE 2. Effects of snake removal on the relative abundance (number captured/100 trap array days) of each focal species.

| Species | 1995 Removal–release sites median (upper, lower quartiles) | 1995 Wilcoxon 2-sample test $Z$, $P$ | 1996 Removal–release sites median (upper, lower quartiles) | 1996 Wilcoxon 2-sample test $Z$, $P$ |
|---|---|---|---|---|
| *Coluber constrictor* | 7.62 (7.67, 7.56)–4.82 (7.81, 1.82) | 0.0, 1.00 | 4.60 (6.64, 2.55)–7.38 (7.75, 7.0) | −1.16, 0.25 |
| *Thamnophis sirtalis* | 1.79 (1.98, 1.59)–11.55 (13.54, 9.55) | −1.16, 0.25 | 1.22 (1.28, 1.15)–2.13 (2.5, 1.75) | −1.16, 0.25 |
| *Ophisaurus attenuatus* | 3.44 (3.97, 2.91)–0.46 (0.91, 0) | 1.16, 0.25 | 1.28 (1.28, 1.28)–0.0 | 1.30, 0.19 |

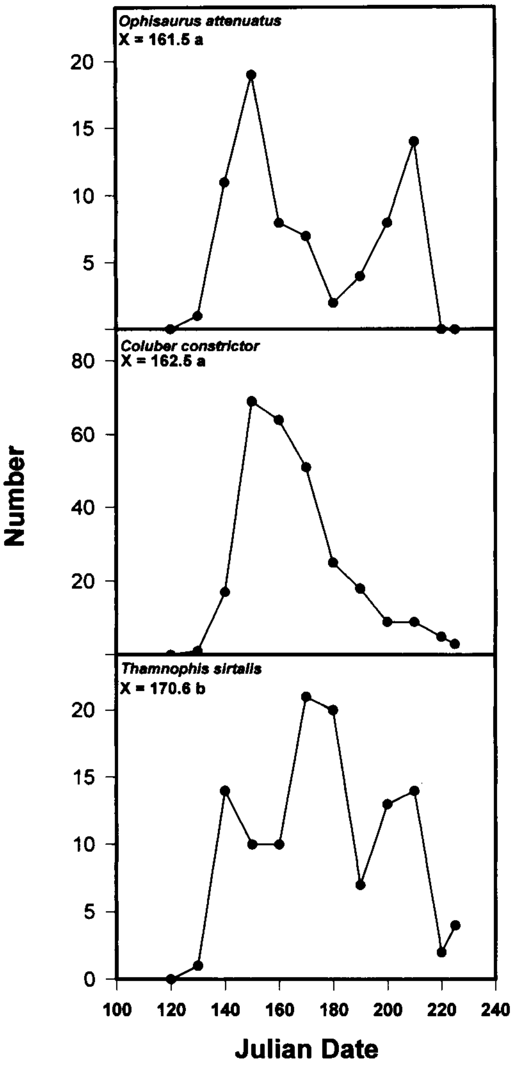


FIG. 2. Seasonal activity patterns (number per 10 day trapping period) of each species. Least square adjusted mean capture date for each species are given in each panel (means with the same letter are not significantly different $P > 0.05$).

nous variances could not be met. Meteorological data were obtained from a weather station located at the Konza headquarters. Taxonomy follows J. Collins (1993).

Only three species, *Coluber constrictor, Thamnophis sirtalis,* and *Ophisaurus attenuatus* were captured in sufficient numbers for meaningful statistical comparisons. The relative abundance (number trapped/100 trap array days) of these species was computed for each year and site. The relative abundance measure was used to examine yearly variation in populations and to determine if removal affected *C. constrictor* or *T.*

TABLE 3. Results of Goodness of fit G-tests (relative to an expected 1:1 ratio) for the null hypotheses that 1) there are no differences in the number of reptiles captured between unburned B and unburned A in 1995, 2) the number of reptiles captured in burned B and unburned A in 1996 are equal and 3) the number of reptiles captured in unburned B in 1995 is equal to the number captured in burned B in 1996 (* = $P < 0.05$).

| | $G_{adj}$ | | |
|---|---|---|---|
| Species | 1 Unburned B 1995 vs. Unburned A 1995 (Prior to wildfire) | 2 Burned B 1996 vs. Unburned A 1996 | 3 Unburned B 1995 vs. Burned B 1996 |
| *Coluber constrictor* | 0.959 | 7.481* | 7.1** |
| *Thamnophis sirtalis* | 0.163 | 0.025 | 0.49 |
| *Ophisaurus attenuatus* | 0.610 | 0 | 5.30* |

*sirtalis* populations. Comparison of relative abundances between species was not performed because species differ in their activity and thus, trappability. Nonparametric equivalents of the two-way ANOVA were performed by first ranking the observations and then performing a two-way ANOVA on the ranks. This analysis was performed for the effects of year and species on Julian date of capture.

The effect of fire on reptile abundance was examined by performing goodness of fit G-tests with William's corrections (Sokal and Rohlf, 1981). Tests examined the effects of fire in three ways: (1) comparing the number of each species trapped in 1995 on unburned A and unburned B relative to an expected 1:1 ratio (pre-fire comparison), (2) by comparing the number of each species trapped in 1996 on burned B to unburned A relative to an expected 1:1 ratio, and (3) by comparing the number of each species trapped on unburned B in 1995 to burned B in 1996 relative to an expected 1:1 ratio.

Wilcoxon two-sample tests (Sokal and Rohlf, 1981) were used to determine if Julian date of capture differed annually and to determine if date of capture differed between sexes. In addition, the effects of fire on seasonal activity in 1996 (year of the wildfire) were examined by performing Wilcoxon two-sample tests to determine if differences existed in the Julian date of capture between burned and unburned sites. Goodness of fit G-tests with William's corrections (Sokal and Rohlf, 1981), were performed to determine if observed sex ratios deviated from parity.

## RESULTS

A total of 550 individuals representing 10 species of snakes and 108 individuals representing three species of lizards were captured from 1994–1996 (Table 1). *Coluber constrictor, Elaphe emoryi, Lampropeltis getula,* and *T. sirtalis* were trapped in each site every year, whereas *Pituophis catenifer* and *L. triangulum* were found in every site but not every year. Both *O. attenuatus* and *E. obsoleta* were primarily trapped in sites with greater coverage of woody vegetation and nearest the gallery forest (A and B).

*Relative Abundance.*—Few marked individuals were subsequently recaptured. Therefore, population size estimates could not be calculated. Alternatively, the number captured per 100 trap array days was computed as a measure of relative abundance for the three focal species (Table 1).

Continual removal of snakes did not affect the relative abundance of either *C. constrictor* or *T. sirtalis* (Table 2). It is also possible that snake removal may influence the abundance of lizard populations but I found no affect on the relative abundance of *O. attenuatus* (Table 2). Relative abundance also did not vary significantly between years for *C. constrictor* ($Z = 0.433$, $P = 0.665$), *T. sirtalis* ($Z = 1.30$, $P = 0.194$), or *O. attenuatus* ($Z = 0.744$, $P = 0.457$).

Site A and B were similar in the relative abundance of species prior to the wildfire (Table 3). However, following the wildfire in 1996, the number of *C. constrictor* trapped on site B was significantly lower than unburned A in 1996 and unburned B in 1995 (Table 3). The number of *O. attenuatus* was also lower on burned B compared to the same unburned site in 1995. There were no other significant differences found in the number of reptiles captured between the burned and unburned study sites (Table 3).

*Seasonal Activity Patterns.*—The median Julian date of capture varied significantly between years ($F = 49.40$, df = 1,419, $P = 0.0001$) and species ($F = 5.68$, df = 2,419, $P = 0.003$), but there were no significant year by species interactions ($F = 2.0$, df = 2,419, $P = 0.137$). The date of capture for *C. constrictor, T. sirtalis,* and *O. attenuatus* was 15 d earlier in 1996 than in 1995 (Fig. 2). The significant species difference is accounted for by significantly later captures of *T. sirtalis* relative to either *C. constrictor* or *O. attenuatus* (Fig. 2). The wildfire in 1996 did not sig-

TABLE 4. Effects of the 1996 wildfire on the average Julian date of capture of each species (comparisons are between burned site with unburned sites in 1996).

| Species | Wilcoxon 2-sample test $Z$, $P$ | Median (upper, lower quartile) Julian date of capture burned–unburned |
|---|---|---|
| *Coluber constrictor* | −1.32, 0.188 | 148 (163, 140)–155 (169, 144) |
| *Thamnophis sirtalis* | −1.28, 0.201 | 147 (173, 137)–166 (178, 142) |
| *Ophisaurus attenuatus* | −1.87, 0.062 | 139 (143, 131)–151 (176, 139) |

nificantly affect the Julian date of capture of the three focal species (Table 4).

Median capture date of *C. constrictor* females was significantly earlier than males in 1995 but significantly later than males in 1996 (Table 5). Median capture date did not differ significantly between sexes in the remaining species (Table 5). The sex ratio (males:females) of captured *C. constrictor* was significantly greater than parity (137:61, Gadj = 15.20, df = 1, $P = 0.001$). However, there were no significant deviations in the sex ratios of *T. sirtalis* (Gadj = 3.265, df = 1, $P = 0.071$). Furthermore, the sex ratios of *C. constrictor* or *T. sirtalis* did not differ for those captured on burned versus unburned sites in 1996 (*C. constrictor*-Gadj = 2.41, df = 1, $P > 0.05$; *T. sirtalis*-Gadj = 2.11, df = 1, $P > 0.05$).

## DISCUSSION

Fire, grazing and a variable climate are three factors responsible for the evolution and maintenance of tallgrass prairie (Knapp and Seastedt, 1998). The direct and indirect effects of fire on the tallgrass prairie plant community has been the focus of research for decades (e.g., Hulbert, 1969). It is well known that fire acts to suppress woody vegetation (e.g., Bragg and Hulbert, 1976), removes the litter layer, alters vegetation composition (Gibson and Hulbert, 1987), and productivity (Collins and Gibson, 1990). The influence of fire on the tallgrass prairie reptile community, however, is largely unknown. Because reptiles may be closely associated with specific features of their habitat, including the vegetation (Weatherhead and Charland, 1985; Plummer and Congdon, 1994; Charland and Gregory, 1995), fire has the potential to shape the structure and composition of reptile communities.

Unfortunately, the sites utilized in this study did not enable me to replicate the effects of fire which constrained the type of analyses that could be conducted. Furthermore, reptile populations are known to have considerable temporal variation (Fitch, 1963; Parker and Plummer, 1987; James, 1994). This potential variation is problematic for interpreting the results of a short-term study. Together, these limitations hinder the ability to make firm conclusions regarding the response of tallgrass prairie reptiles to recent fire. However, some of the patterns observed in this study are consistent with what is known about the natural history of the species in other parts of their range. Because so little is known about the effects of fire on tallgrass prairie reptiles, this study can serve as a basis for future work.

Both the direct and indirect effects of fire have the potential to influence reptile abundance (Patterson, 1984; Lunney et al., 1991; Friend, 1993; Greenberg et al., 1994; Trainor and Woinarski, 1994; Masters, 1996). Because fire removes dead vegetation, and all three of the focal species have been found to prefer sites with a developed litter layer (Fitch, 1963, 1989; Fitch and Shirer, 1971; Charland and Gregory, 1995), I expected these species to respond negatively

TABLE 5. Difference in median Julian capture date between sexes (median–upper and lower quartile shown only for significant differences).

| Species | Year | Sex | Wilcoxon 2-sample test $Z$, $P$ | Median Julian date of capture (upper, lower quartiles) |
|---|---|---|---|---|
| *Coluber constrictor* | 1995 | M | −2.69, 0.007 | 165 (170, 157) |
| | | F | | 157 (164, 152) |
| | 1996 | M | 2.21, 0.03 | 145 (161, 143) |
| | | F | | 158 (177, 144) |
| *Thamnophis sirtalis* | 1995 | M | −1.50, 0.14 | |
| | | F | | |
| | 1996 | M | −0.53, 0.60 | |
| | | F | | |

to fire. The results of this study do provide some support for this hypothesis. Of the three focal species, the data suggests that *C. constrictor* may respond negatively to fire. The number of *C. constrictor* trapped on unburned B was no different from that trapped on unburned A the year before the fire. Yet, following the 1996 fire, the number captured was significantly lower relative to the same unburned site in 1995 (Table 3). In addition, fewer *C. constrictor* were trapped on burned B relative to the unburned A site during the same year. There were no significant differences in the number of *O. attenuatus* trapped between the burned B site and unburned A site in 1996, but significantly fewer were captured on site B in 1996 relative to the same site in 1995. It is possible that the variation in abundance observed between burned and unburned sites may be the result of differences in activity levels, perhaps as a result of variation in precipitation (Table 6; 1995—wet; 1996—dry). However, by comparing abundances between the burned B and unburned A within a single year, the effects of climatic variation can be eliminated. Thus, the differences observed in *C. constrictor* abundance are not likely a response to variation in climate, but this possibility can not be ruled out for the differences observed of *O. attenuatus.*

Spring fires have caused direct mortality of reptiles on Konza (Heinrich and Kaufman, 1985) and snakes have been captured with obvious burn scars (Cavitt, unpubl. data). However, the fire in this study occurred in late February when snakes were likely within hiberbnacula. Hibernacula most likely provide protection from prairie fires because below surface soil temperatures do not reach lethal levels during grass fires (Wright and Bailey, 1980). Therefore, the decline in *C. constrictor* mean relative abundance on burned B, coupled with the observation that this species avoids crossing open areas (Fitch, 1963; Fitch and Shirer, 1971) suggests that the removal of litter by burning may render sites temporarily unsuitable for these species. Removal of the litter layer may increase the risk of predation, increase exposure to temperature fluctuations (Hulbert, 1969; Rice and Parenti, 1978) and alter insect abundance (Nagel, 1973; Evans, 1984; 1988; Warren et al., 1987). Additional work on this *C. constrictor* population has demonstrated a seasonal shift in the use of burned and unburned prairie (Setser and Cavitt, unpubl. data). During late spring and early summer *C. constrictor* is more abundant on unburned sites. However, as the vegetation recovers from spring fires, *C. constrictor* becomes more abundant on burned sites during late summer and early fall (Setser and Cavitt, unpubl. data).

Fire did not appear to influence the distribu-

TABLE 6. Climatic differences for the month of May 1995 and 1996.

| | 1995 | 1996 | Statistic |
|---|---|---|---|
| Mean Daily Average Temperature (°C) ± SE | 14.99 ± 0.563 | 18.72 ± 0.94 | $F = 11.62$, $df_{model, error} = 1,60$, $P = 0.001$ |
| Median Total Daily Precipitation (mm) (Upper, Lower Quartiles) | 1.30 (13.6, 0) | 0 (2.20, 0) | $Z = 1.86$, $P = 0.06$ |
| Median Total Daily Solar Radiation (ly) (Upper, Lower Quartiles) | 330.84 (489.49, 156.32) | 390.72 (586.67, 254.98) | $Z = -1.54$, $P = 0.12$ |

tion of males and females captured. A significant overall male bias in the number of *C. constrictor* captured most likely reflects a difference in seasonal activity patterns or behavior rather than unequal sex ratios within the population as a whole (Fitch, 1963; Gibbons and Semlitsch, 1987; Parker and Plummer, 1987; Charland and Gregory, 1995). Biased sex ratios of snakes caught using drift fences and funnel traps are commonly reported in the literature (e.g., Parker and Plummer, 1987; Cink, 1994). On many occasions when a female *C. constrictor* was found in a trap, two or more males were often encountered within the same trap line.

The patterns of activity represented by capture data from this study are consistent with other studies in Kansas (Fitch, 1963; Platt, 1989; Cink, 1994); activity typically peaked in late May to early June of each year and was followed by a decline throughout the remainder of the season. Mean capture date for all reptiles was significantly earlier in 1996 than in 1995. The yearly difference in capture date coincides with significantly lower average daily temperatures during May of 1995 relative to 1996 (see Table 6). In addition, further reductions in thermoregulating abilities would have been experienced because of greater total daily precipitation and lower total daily solar radiation during the spring of 1995 (Table 6). This temporal variation in activity may affect reptile population responses to fire. Fires, such as the one reported in this study, that occur early in the year, when reptiles are likely within hibernacula may have little direct affect. Yet, fires that occur later in the spring may have quite different influences depending on reptile activity.

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