RESEARCH ARTICLE

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Effects of Burning on Snakes in Kansas, USA, Tallgrass Prairie

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Natural Areas Journal 23:315–319

ABSTRACT: We trapped snakes in two annually burned and two long-term unburned watersheds at the Konza Prairie Biological Station in the Flint Hills of Kansas, USA, to examine the impact of burning on tallgrass prairie snakes. Two species, *Coluber constrictor* L. and *Thamnophis sirtalis*, L. were captured in numbers sufficient for statistical analyses. Both species were more frequently captured on long-term unburned prairie than on recently burned prairie in late spring. This difference did not persist, however, during the fall. The distribution of *T. sirtalis* capture dates was biased toward later captures in burned prairie in comparison to unburned. We did not detect a similar pattern in *C. constrictor*. Our data suggest some tallgrass prairie snakes avoid freshly burned tallgrass prairie but can recolonize burned areas within a single growing season. We recommend that unburned areas be maintained adjacent to prescribed burns in managed tallgrass prairies to serve as snake refugia.

Efectos de la Quema en las Serpientes en Praderas de Pastos Altos en Kansas, USA

RESUMEN: Capturamos serpientes en dos cuencas que se queman anualmente y en dos que no fueron quemadas durante largo período de tiempo en la Estación Biológica de Konza Praire, en Flint Hills en Kansas para examinar el impacto de la quema en las serpientes de la pradera de pastos altos. Dos especies, *Coluber constrictor* L. y *Thamnophis sirtalis*, L. fueron capturadas en número suficiente para realizar análisis estadísticos. Ambas especies fueron más frecuentemente capturadas en praderas sin quema durante prolongados períodos de tiempo que en los lugares recientemente quemados en la pasada primavera. Esta diferencia, no obstante, no perduró durante el otoño. La distribución de capturas de *T. sirtalis* en el tiempo estuvo sesgada a capturas más tardías en las praderas quemadas comparando con las no quemadas. No detectamos el mismo patrón en *C. constrictor*. Nuestros datos sugieren que ciertas serpientes de praderas de pastos altos evitan lugares recientemente quemados, pero pueden recolonizar las áreas en la misma estación de crecimiento. Recomendamos mantener áreas sin quema adyacentes a las de quema en praderas de pastos altos para servir de refugio para las serpientes.

Index terms: prairie burning, prescribed fire, snakes, tallgrass prairie

INTRODUCTION

Fire is essential to the development and maintenance of tallgrass prairie in North America (Axelrod 1985). Within the Flint Hills of Kansas, USA, ranchers employ spring burns to encourage growth of warm season grasses, and to halt the encroachment of woody plants (Briggs et al. 1998). Prescribed spring burns are also commonly used to manage isolated prairie preserves (Anderson 1997). Despite widespread use of prescribed burning, the influence of fire on tallgrass prairie snakes is poorly understood. In the absence of fire or a similar disturbance, succession to woodland eliminates many members of the tallgrass prairie snake community (Fitch 1999). However, prescribed burns in tallgrass prairie remnants occur at temporal and spatial scales that differ from historical fire regimes (Anderson 1990). Recent studies of arthropods have questioned assumptions that prescribed burning benefits native prairie species (Harper et al. 2000), and highlight the need to further investigate the effects of fire on other tallgrass prairie fauna.

Periodic fire in tallgrass prairie systems has direct and indirect impacts on snake communities. Observed direct effects of fire on tallgrass prairie snakes include injuries and mortality (Heinrich and Kaufman 1985, Fitch 1999, Cavitt 2000). Fire can indirectly affect snakes by drastically altering the physical environment, and by altering the abundance and behavior of potential predators and prey. Raptors preferentially forage in newly burned prairie (Reichman 1987). Short-term effects of fire in tallgrass prairie include a decrease in abundance of most arthropods (Evans 1984, Warren et al. 1987, Evans 1988), an increase in abundance of small mammals (Kaufman et al. 1990), and altered species composition of arthropod and small mammal communities (Evans 1984, Warren et al. 1987, Evans 1988, Kaufman et al. 1990). Fire in tallgrass prairie alters plant community composition (Collins and Gibson 1990) and reduces the litter layer (Hulbert 1969, Hulbert 1988). The reduction in litter layer decreases available cover, and alters soil temperature (Hulbert 1969, Rice and Parenti 1978) and soil moisture (Anderson 1965, Hulbert 1969). These fire-induced modifications may affect the ability of snakes to utilize burned tallgrass prairie.

Studies in other fire-prone ecosystems demonstrate that periodic burning can affect reptile behavior (Lillywhite and North 1974), population structure (Mushinsky 1992), and community dynamics (Mushinsky 1985, Pianka 1996). Within tallgrass prairie, snake abundance and diversity vary between burned and unburned prairie (Cavitt 2000). We initiated this study to further examine the effects of fire on snake abundance, and to explore the duration of these effects on tallgrass prairie snakes. Specifically, we tested to see if snake abundance differs between spring-burned tallgrass prairie and long-term-unburned prairie during late spring, and if any differences persist into the fall. We also examined the distribution of capture dates in burned and unburned prairie to determine whether snakes were captured at different times of the year in each treatment.

METHODS

Study Area

This study was conducted on the Konza Prairie Biological Station (KPBS) located in Riley and Geary Counties of Kansas. Konza Prairie is a 3487-ha ecological preserve owned by The Nature Conservancy and managed by the Division of Biology of Kansas State University. The management design for KPBS is based on watershed-sized treatments subjected to different fire frequencies (from annually to every 20 y) and grazing treatments (*Bos taurus* L., *B. bison* L., or ungrazed). Konza Prairie lies within the Flint Hills physiographic province, the largest remaining tract of unplowed tallgrass prairie in North America.

The Flint Hills province is characterized by steep-sided hills exposing alternating layers of limestone and shale. Vegetation of the region is dominated by warm season grasses with scattered shrubs and trees (Reichman 1987). Detailed descriptions of the climate, geology, vegetation, and faunal communities of KPBS are given by Knapp et al. (1998). Areas of KPBS used in this study are topographically similar, but long-term unburned sites contain more woody vegetation than annually burned sites.

Field Procedures

We selected study sites on KPBS by choosing four ungrazed watersheds of similar size and topography that were not heavily utilized in other research projects. Watersheds A (35.2 ha) and B (26.8 ha) have been burned annually since 1972 and are situated within 1 km of each other. A small portion of watershed C (~ 6 ha out of 36.1 ha) was burned annually during the following periods: from 1972 to 1980, from 1984 to 1986, and in 1990. Wildfires burned other portions of watershed C in 1973, 1980, and 1991 (burning, respectively, ~ 19 ha, ~ 7 ha, and all of site C). All of watershed D (35.6 ha) burned in a wildfire in 1980 and in a prescribed burn in 1991. Watersheds C and D are separated from each other by less than 1 km, and are located approximately 5 km east of watersheds A and B. All four watersheds abut the southern border of KPBS. In 1997, watershed A was burned 35 days before we initiated trapping. Watershed B was burned 24 days before we initiated trapping.

We trapped snakes using four randomly oriented, 30-m, linear drift fence arrays in each watershed. Each fence consisted of five double-ended funnel traps spaced 5 m apart. Segments of fencing spanned intervals between traps and extended past each terminal trap. Drift fences were constructed of hardware cloth (30 cm high, 0.635 cm^2 mesh) and were connected to funnel traps constructed of the same material (1 m long, 38 cm high) (Imler 1945). We randomly placed drift fence arrays within suitable areas (i.e., array location was constrained by areas of sufficient soil depth). Thus, most arrays were located along slopes and in lowland areas near ephemeral streams. We sampled similar proportions of lowland and upland prairie in each watershed. Likewise, all watersheds contained rocky areas suitable as snake hibernacula. We installed drift fence arrays in watersheds A and B during April and May of 1997. Drift fence arrays in watersheds C and D had been installed in 1995 for a previous study conducted from 1995 to 1996 (Cavitt 2000). Snakes captured during previous studies were released at the point of capture.

We trapped in each watershed during late spring (May 22–June 30) and fall (August 20–October 21) of 1997. We terminated trapping between these periods due to reduced snake activity. We inspected traps every other day during cool weather, and daily during periods of hot weather. We included two snakes hand-captured in the immediate vicinity of our drift fence arrays in our analyses. Captured snakes were identified, sexed, and measured. We individually marked all snakes by clipping a unique combination of ventral scales (Brown and Parker 1976). We released all animals at the point of capture.

Data Analyses

Only two species, *Coluber constrictor* L. and *Thamnophis sirtalis* L., were captured in numbers sufficient for meaningful statistical comparisons between burn treatments. We evaluated these species individually. We also examined the effect of burning on other snakes by pooling captures of all other species. We did not recapture any *C. constrictor* or *T. sirtalis* during the course of our study. However, we included recaptured individuals of other species in our analyses.

We used chi-square goodness of fit tests to compare the number of captures of *C. constrictor*, *T. sirtalis*, and all other snakes on recently burned and long-term-unburned prairie to an expected 1:1 ratio. Because some comparisons involved small numbers of expected captures, we calculated *P*-values using exact rather than asymptotic statistics (Sokal and Rohlf 1969). We evaluated spring and fall captures separately. Additionally, we explicitly examined the effect of burn treatment on capture date by comparing the distributions of capture dates with two-sample Kolmogorov-Smirnov tests. We performed all statistical analyses using SAS release 8.02 (2001, SAS Institute Inc., Cary, N.C.).

RESULTS

We captured 92 individuals of six species (Table 1). A single *Lampropeltis getula* L., captured on three occasions, was the only individual recaptured during the study period. Species richness differed little between burned (six species) and unburned (five species) prairie. We captured fewer snakes on recently burned prairie (n = 32) than on unburned prairie (n = 60). This difference was due to fewer snakes captured on burned prairie (n = 12) compared to unburned prairie (n = 42) in the spring. During the fall, similar numbers of snakes were captured in each treatment (burned, n = 20; unburned, n = 18). *Coluber constrictor* and *T. sirtalis* comprised 32% and 47%, respectively, of all individuals captured.

Coluber constrictor and *T. sirtalis* were captured more frequently in unburned than in recently burned prairie during the spring (Table 2). This difference was not apparent during the fall. We detected no differences in number of captures of other species in either season. The distribution of capture dates for *T. sirtalis* ($P = 0.0025$; D = 0.59; N = 15 burned, 28 unburned) was significantly biased toward later capture dates in burned prairie (Figure 1). We did not detect similar biases in the distributions of *C. constrictor* ($P = 0.2226$; D = 0.45; N = 7 burned, 22 unburned) or other snake captures ($p = 0.6447$; D = 0.32; N = 12 burned, 10 unburned) (Figure 1).

Table 1. Number of snakes captured by watershed[a] during entire study at Konza Prairie, Kansas.

	A	B	C	D	Total
Coluber constrictor	4	3	13	9	29
Pantherophis emoryi	—	1	—	—	1
Lampropeltis getula[b]	4	—	—	5	9
Lampropeltis triangulum	2	1	—	1	4
Pituophis catenifer	1	1	3	1	6
Thamnophis sirtalis	8	7	17	11	43
Total number	19	13	33	27	92
Total species	5	5	3	5	6

[a]Watersheds A and B are annually burned, watersheds C and D were last burned in 1991.

[b]A single female *Lampropeltis getula* from watershed A was recaptured twice, yielding 11 captures of nine individuals. No other snakes were recaptured during the course of the study.

Table 2. Number of captures of *Coluber constrictor*, *Thamnophis sirtalis*, and all other snakes in burned and unburned tallgrass prairie by season. Chi-square goodness of fit tests compare number of snake captures on burned and unburned tallgrass prairie to an expected 1:1 ratio. All chi- square tests were calculated with exact statistics.

	Season	Burned	Unburned	Chi-square tests
Coluber constrictor	spring	4	17	$\chi^2 = 8.048$, df = 1, $P = 0.0072$
	fall	3	5	$\chi^2 = 0.500$, df = 1, $P = 0.7266$
Thamnophis sirtalis	spring	2	18	$\chi^2 = 12.800$, df = 1, $P = 0.0004$
	fall	13	10	$\chi^2 = 0.391$, df = 1, $P = 0.6776$
other snakes	spring	6	7	$\chi^2 = 0.077$, df = 1, $P = 1.0000$
	fall	6	3	$\chi^2 = 1.000$, df = 1, $P = 0.5078$

DISCUSSION

In Kansas tallgrass prairie, snake activity peaks in late spring, and there is a smaller activity peak in the fall (Fitch 1999; authors, pers. obs.). Our data indicate *T. sirtalis* and *C. constrictor* do not heavily utilize recently burned prairie in the spring. However, following a single season of vegetative regrowth, these species used both burned and unburned prairie during the fall. Reduced snake captures in burned prairie may result from fewer individuals present, or reduced movement of individuals. Although our data do not allow us to distinguish between these two possibilities, additional observations on snakes in the Flint Hills suggest snakes in burned areas may migrate to unburned prairie. Many otherwise frequently encountered snakes are difficult to find in large tracts of recently burned tallgrass prairie, and small, unburned areas within these tracts sometimes harbor large numbers of snakes (authors, pers. obs.).

Fire can cause direct mortality in prairie snakes (Erwin and Stasiak 1979, Heinrich and Kaufman 1985, Fitch 1999, Cavitt 2000). However, direct mortality is an unsatisfactory explanation for low spring capture rates on burned prairie. Spring burns at KPBS are conducted in early spring, when most snakes are probably still in, or near, hibernacula (Fitch 1999) and thus are sheltered from fire. Furthermore, our extremely low recapture rates indicate that few individual snakes were continuously active near our arrays. We consider it likely that the apparently large areas used by individual snakes would obscure effects of fire-induced mortality if snakes were not also avoiding, or reducing activity within, recently burned prairie.

We suggest that the removal of vegetative cover by burning renders tallgrass prairie less suitable for many snakes due to increased risk of predation and increased exposure to temperature and moisture fluctuations. Both *C. constrictor* (Fitch 1963, Fitch and Shirer 1971, Fitch 1999) and *T. sirtalis* (Fitch and Shirer 1971, Charland and Gregory 1995) prefer habitats with tall vegetation and abundant litter, and both avoid closely grazed, burned, or mowed grasslands.

The management design at KPBS creates a landscape of prairie with a mosaic of burn frequencies, and all of our burned watersheds were located adjacent to unburned prairie. Thus, snakes in our study were able to move between burned and unburned prairie. Large areas of native tallgrass prairie with such a mosaic of burn frequencies are uncommon. Most eastern North American tallgrass prairie remnants exist as small, isolated patches (Steinauer and Collins 1996). Within the Flint Hills, large expanses of tallgrass prairie remain as privately owned ranches managed for grazing (Kindscher and Scott 1997). However, widespread annual burning on these ranches results in large expanses of burned prairie with few unburned refugia (authors, pers. obs.).

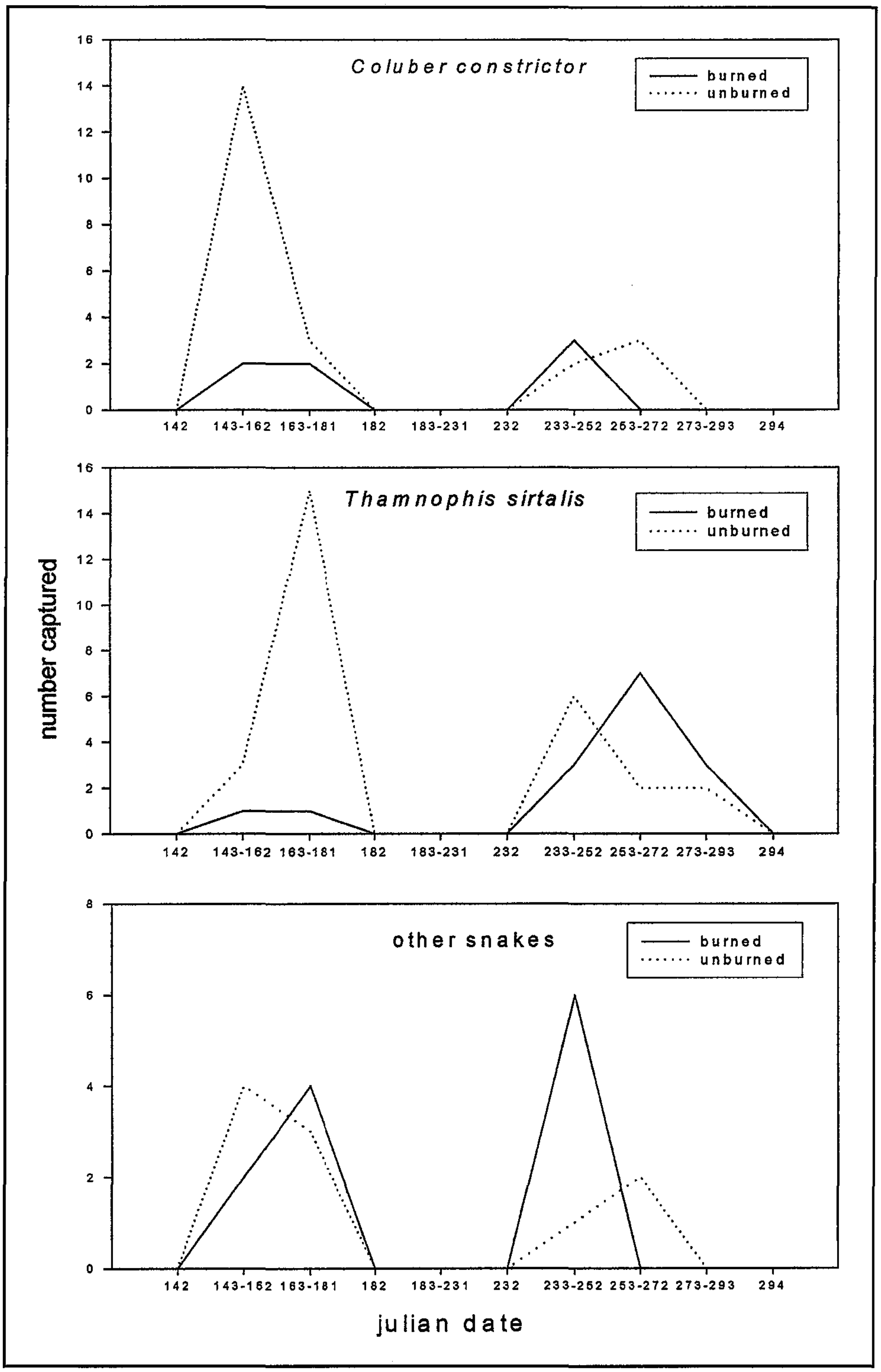

Figure 1. Temporal patterns of captures of *Coluber constrictor, Thamnophis sirtalis,* and other snakes in burned and unburned tallgrass prairie at the Konza Prairie Biological Station, Kansas. Trap arrays were closed from Julian date 182 through Julian date 231.

Concerns about the effects of fire in isolated tallgrass prairie preserves have led to studies on the effect of prescribed burns on arthropods (Harper et al. 2000). Resulting management recommendations highlight the importance of leaving unburned refugia adjacent to burned areas to facilitate recolonization of burned prairie. Harty et al. (1991) investigated the reappearance of small mammals following a prescribed burn, and also noted the importance of unburned refugia. The response of tallgrass prairie snakes to burning remains largely unknown. Few individual species have been evaluated, and no information exists on mechanisms of snake responses to prairie burning. Nonetheless, available data indicate some snakes exhibit a short-term negative response to spring burning. However, snakes quickly reappear on burned prairie in areas with a surrounding matrix of unburned prairie. Unburned refugia have been recommended as important elements of prescribed burns for prairie arthropods and small mammals. We suggest that unburned refugia will probably also benefit prairie snakes.

ACKNOWLEDGMENTS

We thank Brent Brock, Jesse Meik, Joe Mendelson, the herp group at Utah State University, and two anonymous reviewers for comments on earlier drafts of the manuscript. Data on watershed burn histories were supported by the National Science Foundation Long-Term Ecological Research Program at Konza Prairie Biological Station.

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