Mortalities of Grassland Herpetofauna in Warm Season Prescribed Fires

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Abstract – Prescribed fire is an effective tool for the management of Great Plains grasslands, but this tool has potential drawbacks. For some vertebrate taxa, fire-caused mortalities can be high in prescribed fires. Herein we documented wildlife mortalities from 3 warm season prescribed fires in the Great Plains. After fires, we documented 187 individuals dead and alive of 21 vertebrate species, with 142 representing 16 species of herpetofauna. Of herpetofauna, 75 individuals of 14 species were killed by fires. *Ophisaurus attenuatus* Cope (Slender Glass Lizards) had the highest mortality with 45 individuals. Despite our observed mortalities, prescribed fire is a valuable tool to maintain prairie functions, but conducting them when above-ground abundances of herpetofauna are high appears to increase mortalities, such as during their breeding season.

Introduction

Wildfires have been an integral part of Great Plains ecosystems of North America for centuries (Frost 1998). Prior to European settlement, fires occurred naturally on average from every 1 to up to 12 years throughout the Great Plains, which promoted new growth of fire-adaptive, native prairie species while suppressing invading woody species (Frost 1998, Stambaugh et al. 2014). Variation in fire frequency was likely due to yearly variation in precipitation, humidity, and annual vegetative production. As Europeans settled grasslands of the Great Plains, fire suppression became the norm, which drastically decreased frequency and extent of wildfires in the region (Briggs et al. 2002, Briggs et al. 2005, Frost 1998, Knapp et al. 2009, Twidwell et al. 2013). Fire suppression in the region has persisted for decades, but now some advocate for the use of fire to help protect and restore Great Plains grasslands (Twidwell et al. 2013, Wilcox et al. 2022).

In the Great Plains, native plant communities require fire to sustain grassland ecosystems (Axelrod 1985, Ratajczak et al. 2014). Fires incinerate vegetation which recycles inorganic nutrients, while also exposing soils to sunlight and promoting growth from underground root networks of fire-adapted plants (Knapp and Seastedt 1986, Pyne et al. 1996, Schafer and Mack 2010). Although essential for native flora, fire is also useful in managing invasive species that frequently outcompete native vegetation and rapidly overtake landscapes when fire is absent (Bragg and Hulbert 1976, Briggs et al. 2002, Gibson and Hulbert 1987, Ratajczak et al. 2014, Stambaugh et al. 2014). Without fire, woody species and invasive grasses successfully outcompete native grassland plants as seedlings and become established during the recruitment state of encroachment (Briggs et al. 2005, Twidwell et al. 2021). Prescribed fire is an attempt to mimic natural fires regimes to restore and maintain certain character-

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istics of native plant assemblages. This has become an effective tool to combat invasive species recruitment and encroachment, as many trees, shrubs, and cool season grasses are fire-sensitive and non-resprouting after prescribed fires (Bragg and Hulbert 1976, Gibson and Hulbert 1987).

While prescribed fires improve prairie habitats, fires also cause wildlife mortalities. Fire-caused mortalities have been recorded in birds, mammals, reptiles, and amphibians (Erwin and Stasiak 1979, Jolly et al. 2022, Lyon et al. 1978, Russell et al. 1999). Mortalities can occasionally be especially frequent among herpetofauna compared to other groups (Babbitt and Babbitt 1951, Geluso et al. 1986, Russell et al. 1999). Herpetofauna are more likely to have higher mortalities compared to other vertebrates because many amphibians and small reptiles have limited locomotion and movement capabilities (Sinsch 1990). However, some suggest that in historically fire-adapted environments, herpetofauna should be at least behaviorally adapted to escape fire, with fires generally having little long-term effects on most reptile and amphibian populations (Means and Campbell 1981).

Herein, we opportunistically documented wildlife mortalities from 3 warm season prescribed fires in prairies of northern Oklahoma and southern Kansas. We focused this study on herpetofauna, as this group dominated mortalities. We present these data to assist with a broader understanding of the importance in the timing of prescribed fires for resource managers to reduce mortalities when managing grasslands with fire. We acknowledge that data reported herein are anecdotal, as are most other papers on direct mortalities of herpetofauna following fires (Russell et al. 1999). We find that our data represented a unique opportunity to examine mortalities following fires where heavy rains increased visibility immediately after all 3 prescribed fires.

Materials and Methods

This study was conducted in mixed-grass prairies of Woods County, Oklahoma, and Barber County, Kansas. The region is situated in a geomorphic area known as the Cimmaron Gypsum Hills of southern Kansas and northwestern Oklahoma, defined by numerous red rock buttes and valleys capped with a layer of gypsum from the Permian Blaine Formation. The ranch was purchased in 2000, and to the ranch manager's knowledge, there were no intentional fires on the ranch by the previous owner. The current management on the ranch attempts to burn all pastures once every 10 years, thus burning about 10% of the ranch each year. Current management uses both spring and summer prescribed fires with patches burned varying in size considerably.

For the purposes of this study, we report on 2 prescribed fires conducted in 2023 and 1 in 2024 to reduce encroachment of cool season grasses (e.g., *Poa pratensis* L. [Kentucky Bluegrass]), small trees, and shrubs on various ranch pastures, according to the ranch manager. Both fires in 2023 were of similar small size (Sites 1 and 2), separated by a two-track dirt road. The 2024 fire covered a larger area than both 2023 fires combined. In 2023, both sites were re-established grasslands from once agricultural fields in the 1980s, with the east side of the road (Site 2) having several contours/terraces present on the landscape that yielded temporary pools of water on the upward side of contours after abundant rains in 2023. These two sites were relatively flat. The larger prescribed fire in 2024 consisted of mainly native grasslands during a time with less precipitation as compared to 2023. This site had some moderate slopes in burned areas but most consisted of gentle slopes. All prescribed fires were within 10 km of each other on the ranch.

The first prescribed fire (Site 1; 36.9977°, -98.9949°) burned 9.4 ha and occurred on 30 May 2023. A heavy rainfall occurred the night after the fire, and we walked the area starting at about 10:00 on 1 June 2023. The second prescribed fire (Site 2; 36.9979°, -98.9928°) burned 9.5 ha and occurred on 15 June 2023 at 13:15 and ended at 14:15. Heavy rains occurred the night after the burn, and we walked the area starting at 07:15 on 16 June 2023. The third prescribed fire (Site 3; 37.0425°, -98.9010°) burned 93.1 ha and occurred on 13 June 2024 at 10:30 and ended mid-afternoon. Rainfall once again occurred the night after the burn, and we walked the area starting at 06:30 on 14 June 2024. The prescribed fires were flank fires that were "pushed some by the wind," according to the ranch manager. We were not present for any of the prescribed fires when ranch personnel burned the prairies.

To examine each site for vertebrate mortalities, 3 of us generally walked east-west transects from north to south across burned areas at the 2023 sites (Sites 1 and 2) and walked clockwise rotational transects beginning on the west side around the outer part of the 2024 fire (Site 3). We generally walked abreast one another about 15-20 m apart. Smaller species generally were detected in a narrower 2-3 m swath around us, whereas larger species sometimes could easily be detected at farther distances. We estimated that we walked 3 km of transects on Site 1 and then about 3 km again on Site 2 for the 2023 fires and 7.5 km on the 2024 prescribed fire. We recorded each species observed dead and alive in all cases. Several deceased organisms were kept as voucher specimens and deposited in natural history collections at the Sternberg Museum of Natural History, Fort Hays State University, Hays, Kansas.

Results

We documented a total of 187 individuals of 21 vertebrate species, including 5 classes of vertebrates (Amphibia, Aves, Chelonia, Mammalia, and Squamata), after 3 prescribed fires in northern Oklahoma and southern Kansas in May and June 2023 and June 2024 (Table 1). Most observations (n = 142) were reptiles, turtles, and amphibians of 16 species (Table 1). Of these herpetofauna, 75 individuals of 14 species were killed by fire, which was dominated by 45 mortalities of *Ophisaurus attenuatus* Cope (Slender Glass Lizards; Fig.1). We only observed a few (n = 4) mammalian mortalities including *Sylvilagus floridanus* (Allen) (Eastern Cottontail), *Microtus ochrogaster* (Wagner) (Prairie Vole), and a young *Sigmodon hispidus* Say & Ord (Hispid Cotton Rat; Table 1). We observed avian mortalities dominated by eggs (n = 38) in 4 nests of *Colinus virginianus* (Linnaeus) (Northern Bobwhite; Table 1).

For mortalities of herpetofauna, we documented 5.3 dead individuals per km at Site 1 in 2023, 16.7 dead individuals per km at Site 2 in 2023, and 1.2 dead individuals per km at Site 3 in 2024. The 4 weeks prior to each of the 3 fires, we calculated the amount of rainfall at a nearby weather station located 2 km southwest of Sites 1 and 2 (Freedom 16 NNE in Woods County, Oklahoma [36.9871, -99.0111]; accessed from High Plains Regional Climate Center; http://climod.unl.edu/). In 2023, Site 1 had 111.6 mm of rainfall with 10 days of measurable precipitation and Site 2 had 179.2 mm of rainfall with 15 days of precipitation for the 4 weeks prior to fires, whereas in 2024, Site 3 had 59.0 mm of rainfall with only 6 days of precipitation the 4 weeks prior. The 4 weeks prior to each of the 3 fires, we also calculated the average daily high and daily low temperatures for the same nearby weather station. In 2023, the 4 weeks prior to the first fire at Site 1 had an average daily high temperature of 26.4 °C and average daily low temperature of 14.1 °C and prior to the second fire at Site 2 had an average daily high temperature of 26.4 °C and average daily low temperature of 15.1 °C. In 2024, prior to the third fire at Site 3, the average daily high temperature was 29.4 °C and daily low temperature was 15.8 °C.

Table 1. Fire-induced wildlife mortalities and living organisms observed after 3 prescribed fires in grasslands of Woods County, Oklahoma (2023), and Barber County, Kansas (2024). Prescribed burns were conducted in late May and mid-June 2023, after an unusually rainy period in the region, and in mid-June 2024 during a drier period.

		2023 Site 1		2023 Site 2		2024 Site 3		Grand
Class (Common Name)	Species	Alive/Dead	Total	Alive/Dead	Total	Alive/Dead	Total	Total
REPTILIA								
Slender Glass Lizard	*Ophisaurus attenuatus*	0/7	7	3/33	36	5/5	10	53
Little Brown Skink	*Scincella lateralis*	0/1	1	1/0	1	45/1	46	48
Lined Snake	*Tropidoclonion lineatum*	0	0	1/7	8	0	0	8
Ring-necked Snake	*Diadophis punctatus*	1/2	3	2/2	4	0	0	7
Common Gartersnake	*Thamnophis sirtalis*	0	0	1/0	1	1/0	1	2
Dekay's Brownsnake	*Storeria dekayi*	0	0	0/2	2	0	0	2
Prairie Rattlesnake	*Crotalus viridis*	0	0	0/2	2	0	0	2
Southern Prairie Skink	*Plestiodon septentrionalis*	0	0	1/1	2	0	0	2
Speckled Kingsnake	*Lampropeltis holbrooki*	0	0	2/0	2	0	0	2
Unidentifiable Snakes	N/A	0/2	2	0	0	0	0	2
Western Massasauga	*Sistrurus tergeminus*	0/1	1	0/1	1	0	0	2
Coachwhip	*Masticophis flagellum*	0	0	0/1	1	0	0	1
Great Plains Ratsnake	*Pantherophis emoryi*	0	0	0/1	1	0	0	1
North American Racer	*Coluber constrictor*	0	0	0	0	0/1	1	1
CHELONIA								
Ornate Box Turtle	*Terrapene ornata*	0	0	0	0	3/2	5	5
Yellow Mud Turtle	*Kinosternon flavescens*	0/2	2	1/0	1	0	0	3

Table 1 continued. Fire-induced wildlife mortalities and living organisms observed after 3 prescribed fires in grasslands of Woods County, Oklahoma (2023), and Barber County, Kansas (2024). Prescribed burns were conducted in late May and mid-June 2023, after an unusually rainy period in the region, and in mid-June 2024 during a drier period.

		2023 Site 1		2023 Site 2		2024 Site 3		Grand
Class (Common Name)	Species	Alive/Dead	Total	Alive/Dead	Total	Alive/Dead	Total	Total
AMPHIBIA								
Plains Leopard Frog	*Lithobates blairi*	0/1	1	0	0	0	0	1
AVES								
Northern Bobwhite (eggs)	*Colinus virginianus*	0	0	0/16	16	0/22	22	38
Unidentified blue eggs		0	0	0	0	0/2	2	2
Red-winged Blackbird	*Agelaius phoeniceus*	0	0	0/1	1	0	0	1
MAMMALIA								
Prairie Vole	*Microtus ochrogaster*	0	0	0/2	2	0	0	2
Eastern Cottontail	*Sylvilagus floridanus*	0	0	0	0	0/1	1	1
Hispid Cotton Rat	*Sigmodon hispidus*	0	0	0	0	0/1	1	1
GRAND TOTAL		1/16	17	12/69	81	54/35	89	187

Discussion

To our knowledge, our observations represented the first published documentation of fire-caused mortality for Slender Glass Lizards (see Russell et al. 1999). However, other studies have observed that *Ophisaurus ventralis* (Linnaeus) (Eastern Glass Lizards) similarly incur significantly high amounts of fire-caused mortality in fires. In Dade County, Florida, 24 Eastern Glass Lizards were observed dead after a 30 m stretch of highway roadside was burned (Babbitt and Babbitt 1951). In Franklin County, Florida, 15 Eastern Glass Lizards were observed dead after the limited area (0.026 h) of prescribed burns, with 4 individuals also observed alive (Means and Campbell 1981). Both observations associated with Eastern Glass Lizards demonstrated many mortalities for small areas, similar to our findings for Slender Glass Lizards. Negative results for both species of glass lizards likely are related to their diurnal activity patterns (Blair 1961, Fitch 1989), as burns occurred during daylight hours. Additionally, seasonal activity and reproduction for Slender Glass Lizards also peak in early summer, specifically May and June, and all prescribed burns in this study occurred during these peak months (Blair 1961, Fitch 1989). These limited data suggested that glass lizards are prone to higher mortality in warm season fires than other groups of herpetofauna.

Most research reporting fire-caused mortality for herpetofauna generally does not report such high mortalities and numbers of species affected (Bigham et al. 1964, Caven et al.

Figure 1. Deceased *Masticophis flagellum* (Shaw) (Coachwhip; top left), *Plestiodon septentrionalis obtusirostris* (Bocourt) (Southern Prairie Skink; top right), *Crotalus viridis* (Rafinesque) (Prairie Rattlesnake; bottom left), and *Ophisaurus attenuatus* Cope (Slender Glass Lizard; bottom right) after the second prescribed fire in Woods County, Oklahoma in June 2023.

2017, Erwin and Stasiak 1979, Means and Campbell 1981, O'Connor et al. 2016, Russell et al. 1999, Simons 1989; this study 2024 fire). In a 22.8 ha burn on a reestablished prairie surrounded by row-crop agricultural lands in Nebraska, only 3 snakes of 3 species, *Pituophis catenifer sayi* (Schlegel) (Bullsnake), *Thamnophis radix* (Baird and Girard) (Plains Gartersnake), and *Thamnophis sirtalis* (Linnaeus) (Common Gartersnake), were observed dead (Erwin and Stasiak 1979), and in Florida after a 600 ha burn, only 2 *Crotalus adamanteus* Palisot de Beauvois (Eastern Diamond-backed Rattlesnake) were observed deceased (Means and Campbell 1981). Thus, our observations in 2023 with many mortalities of many species were unusual according to the published literature. We attribute this, in part, to fortuitous heavy rainfall events occurring during all nights after burns, greatly reducing the layer of ash which greatly increased detectability of deceased organisms. Our observations suggested that although many other studies only report few mortalities (see references above), those data might be an underrepresentation of actual mortalities, especially for smaller species covered by ash immediately after fires. One of the only other reports showing a high number of mortalities also had rain on the night after the fire "making it exceptionally easy to spot dead animals" the next day (Geluso et al. 1986). One study even reported that researchers raked and probed areas with accumulated ash to increase detections (Erwin and Stasiak 1979). Such methodologies might be effective in small, burned areas, but inhibitive in larger areas. Overall, we were fortunate to have rain after all 3 of our prescribed fires allowing for equal visibility among fires, although there were differences in the numbers of mortalities in prescribed fires between 2023 and 2024.

High numbers of mortalities in 2023 per km walked likely were associated, in part, with increased seasonal activity during the general breeding period for many herpetofaunal species (Cavitt 2000, Collins et al. 2010, Fitch 1999, Setser and Cavitt 2003) during a period with more rainfall than in 2024. Interestingly, late spring also corresponds to a time when natural wildfires generally do not occur in the region, as natural wildfires reportedly occurred more often during summer months in the Great Plains when risk from lightning increases with more thunderstorms (Bragg 1982, Frost 1998, Higgins 1984). During hot and dry seasons, herpetofauna commonly reside underground or are less active above ground especially during daytime hours and resort to crepuscular or nocturnal activities, whereas during wetter periods or years, when wildfires are likely harder to ignite, herpetofauna are more active above ground during the daytime (Cavitt 2000, Lowe and Holm 1991, Schlesinger et al. 2010).

Frequent rainfall in weeks prior to our prescribed fires in 2023 likely promoted herpetofaunal activity, as our prescribed fire during a drier period in 2024 had fewer mortalities for herpetofauna even with a greater distance walked after the fire. In northern Oklahoma, maximum precipitation occurs from mid-March through mid-June (Illston et al. 2004), and precipitation amounts in 2023 were notably higher than prior years (total precipitation 175.5 mm in June 2023, whereas 87.9 mm in June 2022, and 83.1 mm in June 2021; Alva, Oklahoma; ~40 km from study site; NOAA Online Weather Data). Increased activity associated with both seasonality and precipitation (Cavitt 2000, Reynolds 1982, Schlesinger et al. 2010) likely increased diurnal activity also leading to higher-than-normal mortalities in our 2023 prescribed fires, whereas a drier and warmer period leading up to the prescribed fire in 2024 likely led to lower mortalities of herpetofauna. We find this to be the most parsimonious explanation for such a difference in mortalities for the prescribed fires between the 2 years, although there are other possible explanations. This also was supported by our general observation of increased abundances of herpetofauna on the ranch roadways and under rocks during herpetofaunal surveys from late May to mid-June 2023 compared to fewer individuals during road and visual encounter surveys during the drier conditions in June 2024 on the same ranch.

Many prescribed fires in the Great Plains emphasize early spring burning, thus such fires occur at a different time of the year than pre-settlement fires that occurred during summer months (Bragg 1982). Prescribed fires generally are ignited early in the year before vegetation has greened and accumulated moisture (February/March) or late in the year after vegetation has dried (November/December; Knapp et al. 2009; Ryan et al. 2013). Prescribed fires early in the year (January to March) tend to have little effect on herpetofauna because these poikilothermic organisms are underground in hibernacula (Cavitt 2000, O'Connor et al. 2016, Setser and Cavitt 2003), but in late spring and summer when temperatures are warm, fires can potentially have negative implications on these organisms when individuals are more active and aboveground. Other papers have suggested that susceptibility to fires could differ based on times of the year, or even different times of day, due to seasonal, circadian, and temperature-related periods of activity for herpetofauna (Cavitt 2000, Erwin and Stasiak 1979, Gaetani et al. 2010, Griffiths and Christian 1996, O'Connor et al. 2016, Pilliod et al. 2003, Russell et al. 1999). Increased rainfall during a period of normally high activity was likely associated with higher mortalities of herpetofauna in our warm season prescribed fires. More data are needed to demonstrate that conducting prescribed fires during dry and hot periods can reduce mortalities of herpetofauna. Fire is still an essential tool for prairie management, but timing of prescribed fires appears important to consider to minimize vertebrate mortalities and still support prairie conservation efforts.

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