Small Mammal Community Responses to Fire and Grazing in the Northern Mixed-grass Prairie

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Summary

Landscape heterogeneity is essential for ecosystem biodiversity. Historically, the interaction of fire and grazing, known as pyric-herbivory, created heterogeneity in the Great Plains capable of supporting a wide variety of wildlife and diverse small mammal communities.

Disturbances that vary spatially, temporally and in intensity create a wide array of habitat types. Present land management creates homogenous landscapes and habitat due to a lack of disturbances, which has led to a decrease in biodiversity of rangelands.

To determine how small mammal communities would react to reintroducing pyric-herbivory, we evaluated the differences in small mammal communities in a conventional season-long grazing treatment and two burn grazing treatments. Total species abundance was highest in patch-burn grazing treatments.

Deer mice (Peromyscus maniculatus) had the highest abundance of any species across treatments and was highest in patch-burn grazing treatments. Vole species (Microtus spp.) abundance decreased with time in the patch-burn grazing treatments while remaining stable in the season-long grazing treatment.

Using perMANOVA, we established that average pasture community composition was not different between treatments in 2017 ($P < 0.05$) but was different between the patch-burn grazing 40-acre treatment and the season-long grazing treatment in 2020 ($P < 0.05$). Species richness was highest in the patch-burn grazing treatments ($S = 8$) and lowest in the continuous grazing treatment ($S = 5$) during the course of the study.

Higher total species abundance and richness in patch -burn grazing treatments most likely can be attributed to the shifting mosaic landscape produced by the rotation of annual fires and focal grazing creating more variable habitat structure needed for various species. This suggests that patch-burn grazing could be used to create heterogeneous landscapes of variable habitat structure needed to support various small mammal species.

Introduction

Heterogeneity is essential to a biodiverse ecosystem (Ostfeld et al., 1997; Fox and Fox, 2000). The combination of inherent heterogeneity, caused by abiotic factors such as soil, climate, topography and nutrient availability, and disturbance-driven heterogeneity create habitat heterogeneity (Fuhlendorf et al., 2017). Historically in the Great Plains, the interaction between grazing and fire has been the main source of disturbance-driven heterogeneity, otherwise known as pyric-herbivory (Fuhlendorf et al., 2009).

Pyric-herbivory creates a shifting mosaic of plant communities due to the temporal and spatial interactions of fire and grazing (Fuhlendorf et al., 2009). This occurs when large herbivores, such as bison or cattle, preferentially graze recently burned areas because new plant growth is more palatable and nutritious (Fuhlendorf and Engle, 2001; Fuhlendorf et al., 2009; Knapp et al., 1999; Vermeire et al., 2004). This allows patches that had been burned and grazed in previous growing seasons to recover (Fuhlendorf and Engle, 2001; Gates et al., 2017).

These patches begin accumulating plant litter from a lack of grazing, which leads to increased fuel loads and probability of these patches burning again, repeating the cycle of the fire-grazing interaction (Fuhlendorf and Engle, 2001, 2004). This produces varying plant community composition and structure through space and time, which can sustain diverse wildlife communities (Fox, 1990; Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Heterogeneous habitat is crucial for supporting a variety of wildlife species at extreme ends of the habitat structure gradient (Fox and Fox, 2000; Fuhlendorf et al., 2009).

Due to present land management, the interaction between grazing and fire has been removed from the landscape, creating more homogenous ecosystems and habitat types. To counteract this, an effort has been made to develop land management strategies to reintegrate pyric-herbivory on the landscape. One such strategy is patch-burn grazing (Fuhlendorf and Engle, 2001, 2004).

Patch-burn grazing was developed to re-establish the historical fire-grazing relationship on the landscape. This framework creates a shifting mosaic of plant communities by establishing discrete patches of burned and nonburned patches within a pasture.

This cycle occurs every growing season, where previously nonburned patches subsequently are burned, while burned patches from the previous growing season experience a decrease in grazing intensity (Fuhlendorf and Engle, 2001). This interaction between burned and nonburned patches creates a heterogeneous landscape that varies in structure and composition, providing a wide variety of habitat for wildlife, such as small mammals (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016).

Small mammals fill an important niche in grassland ecosystems. They are a major food source for mesocarnivores, such as coyotes (Brillhart and Kaufman, 1995), and many raptor species, where *Microtus pennsylvanicus* (prairie voles) can make up to 41% of an owl's diet (Huebschman et al., 2000).

Researchers also have found that small mammals can influence plant community composition by reducing the number of native plant seedlings in post-disturbance ecosystems (Maron et al., 2012; Reed et al., 2004). *Peromyscus maniculatus* (deer mice), the most abundant small mammal in North America, are a granivore that prefers large-seeded native plants while avoiding small seeded exotics, such as *Bromus inermis* (smooth brome) (Everett et al., 1978; Witmer and Moulton, 2012). This has been found to limit re-establishment of native plant species in some cases (Everett and Monsen, 1990).

In previous studies, patch-burn grazing treatments were found to create spatial and temporal patterns of differing habitat types suitable to supporting diverse small mammal communities (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Because small mammals are an integral part of the grassland ecosystem, we need to study the effects of different grazing management systems on their community structures.

The objective of this study is to determine what effect land management has on small mammal communities using three treatments: two patch-burn grazing treatments that vary in size and season of fire, and a conventional season-long grazing treatment as a control treatment. We hypothesize that the patch-burn grazing treatments will create a shifting mosaic of plant communities that will support a diverse small mammal community, while the season-long grazing treatment will promote even grazing pressure, creating a uniform vegetation structure and decreased small mammal diversity.

Methods

Study Area

This study was conducted at the North Dakota State University Central Grasslands Research Extension Center (CGREC) in south-central North Dakota. The CGREC is in the Missouri Coteau ecoregion in the northern mixed-grass prairie of the Great Plains.

This area is characterized by irregular, rolling plains and depressional wetlands. The climate is characterized as temperate and receives an average of 40.1 centimeters (cm) (15.8 inches) of precipitation a year and has an average temperature of 5 C (41 F) (1991-2020, North Dakota Agricultural Weather Network). The vegetation of this area is typical of a northern mixed-grass prairie invaded by Kentucky bluegrass (Limb et al., 2018).

Treatment Structure

Three treatments are applied to the study area, in which we compare four intervals of time since fire of the patch-burn grazing treatments (PBG), and a season-long grazing treatment (SLG). A total of 12 160-acre (approximately 65-hectare [ha]) pastures were used in this study, with four pastures (replicates) per treatment.

Pastures were split into eight 20-acre (8 ha) subpatches. All pastures are stocked with cow-calf pairs to achieve approximately a 40% to 60% degree of disappearance at a harvest efficiency of 30%.

(a) Patch-burn grazing 40-acre treatment (PB40) is a management technique that is used to mimic a historic disturbance regime of pyric-herbivory (Fuhlendorf and Engle, 2001). Prescribed fire was applied to two sub-patches (40 acres, 16 ha or one-fourth of the pasture) concurrently within each pasture every year for a total of eight subpatches being burned in the spring of each year.

(b) Patch-burn grazing 20-acre treatment (PB20) is similar to the previous patch-burn grazing treatment, in which two subpatches are burned every year. However, we wanted to observe what effect season and size of burn would have on small mammal communities. One 20-acre subpatch (one-eighth of the pasture) was burned in the spring while the other 20-acre subpatch was burned in the summer. Time-since-fire data from the PBG treatments was analyzed by zero-, one-, two- and three-years-since-fire, and by nonburned subpatches.

(c) Season-long grazing treatment (SLG) is intended to replicate a conventional cow-calf grazing management system and serves as a control treatment.

Data Sampling

Sampling of small mammals occurred from late May to late June. Each sampling period consisted of 25 days. Treatments were sampled concurrently to prevent biases associated with weather or time of day.

We established 40- by 40-meter grids of 25 Sherman live-traps (7.6- by 8.9- by 22.9-cm) spaced 10 meters apart per subpatch. In one day, 12 separate subpatches, one subpatch per pasture, were sampled (four subpatches/treatment). Three hundred traps were set per night, for a total of 4,200 traps set per sampling period.

Traps were baited with a combination of peanut butter and rolled oats. Sampled individuals were recorded by species and marked with ear tags – Style 1005-3 from the National Band and Tag Co. – to identify previously captured individuals.

Statistical Analysis

We estimated species abundances by subpatch using closed-capture Huggins models in Program MARK. Using PC ORD 6.0, we constructed PCA (Principal Components Analysis) ordinations based on estimated species abundances of our top six most abundant species to evaluate community composition of treatments from 2017-2020 and times-since-fire intervals using 2020 data. Utilizing permutational multivariate analysis of variance (PerMANOVA), changes in community composition by pasture from 2017-2020 were assessed.

Results

Ten small mammal species were recorded during the duration of this study (Table 1). The most abundant species in this study and in each treatment were deer mice (*Peromyscus maniculatus* - PEMA), which were most abundant in PB40 (Table 1). PB40 had the highest species richness of all treatments, with eight species, while PB20 had seven species and SLG had five species being recorded during the course of the study.

Table 1. Number of small mammal individuals captured by species in each treatment across all years of this study at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017-2020.

Scientific Name	Common Name	Species Code	Treatment		
			PB40	PB20	SLG
Peromyscus maniculatus	deer mouse	PEMA	87	74	46
Microtus ochrogaster	prairie vole	MIOC	9	6	18
Microtus pennsylvanicus	meadow vole	MIPE	4	5	5
Ictidomys tridecemlineatus	thirteen-lined ground squirrel	ICTR	6	10	
Urocitellus richardsonii	Richardson's ground squirrel	URRI	3	6	1
Zapus hudsonius	meadow jumping mouse	ZAHU	2		2
Thomomys talpoides	northern pocket gopher	THTA	2		
Mustela nivalis	least weasel	MUNI		1	
Peromyscus leucopus	white-footed mouse	PELE		1	
Blarina brevicauda	northern short-tailed shrew	BLBR	1		

From 2017 to 2020, relative abundance of deer mice did not change much in the PB40 or PB20 but did decrease in the SLG treatment due to a decrease in deer mouse abundance in 2020 (Figures 1 and 2). The biggest changes we see in the patch-burn grazing treatments (PBG) is the shift in relative abundance of specialist species.

Prairie vole (*Microtus ochrogaster* - MIOC) were not present in the 2020 PB40, as they were the second most abundant species in 2017, while relative abundance decreased slightly in the PB20, and stayed the same in the SLG (Figures 1 and 2). Meadow vole (*Microtus pennsylvanicus* - MIPE) relative abundance decreased in the PB40 but increased in the PB20 and SLG (Figures 1 and 2).

Thirteen-lined ground squirrel (*Ictidomys tridecemlineatus* - ICTR) relative abundance increased in both PBG treatments and were not present in the SLG in both years, while Richardson's ground squirrel (*Urocitellus richardsonii* - URRI) relative abundance increased in the PB40, as they were not present in 2017, stayed the same in the PB20 and no longer were present in the SLG in 2020 (Figures 1 and 2). While meadow jumping mice (*Zapus hudsonius* - ZAHU) were not present in 2017, they did make up about 10% of the population in the PB40 and SLG in 2020 but were not present in the PB20 (Figures 1 and 2).

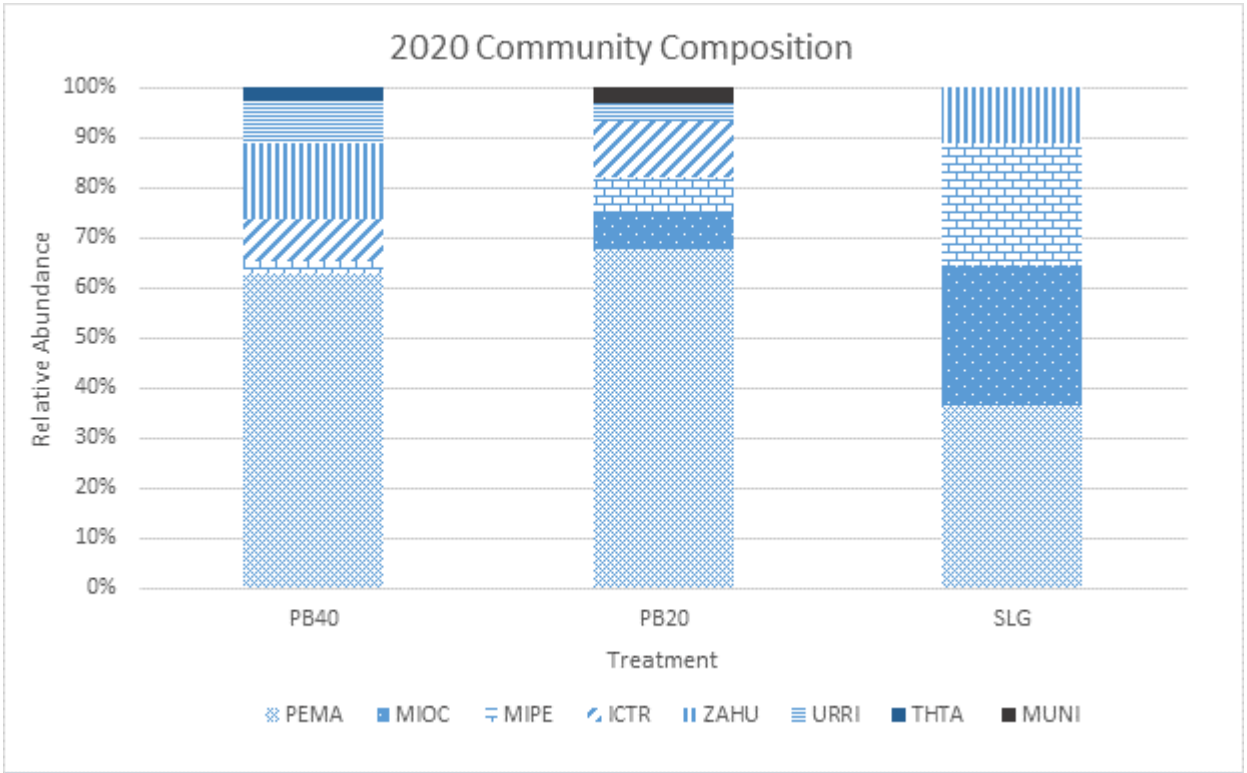

Figure 1. Relative abundance of small mammal communities according to treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2020. Species codes are listed in Table 1.

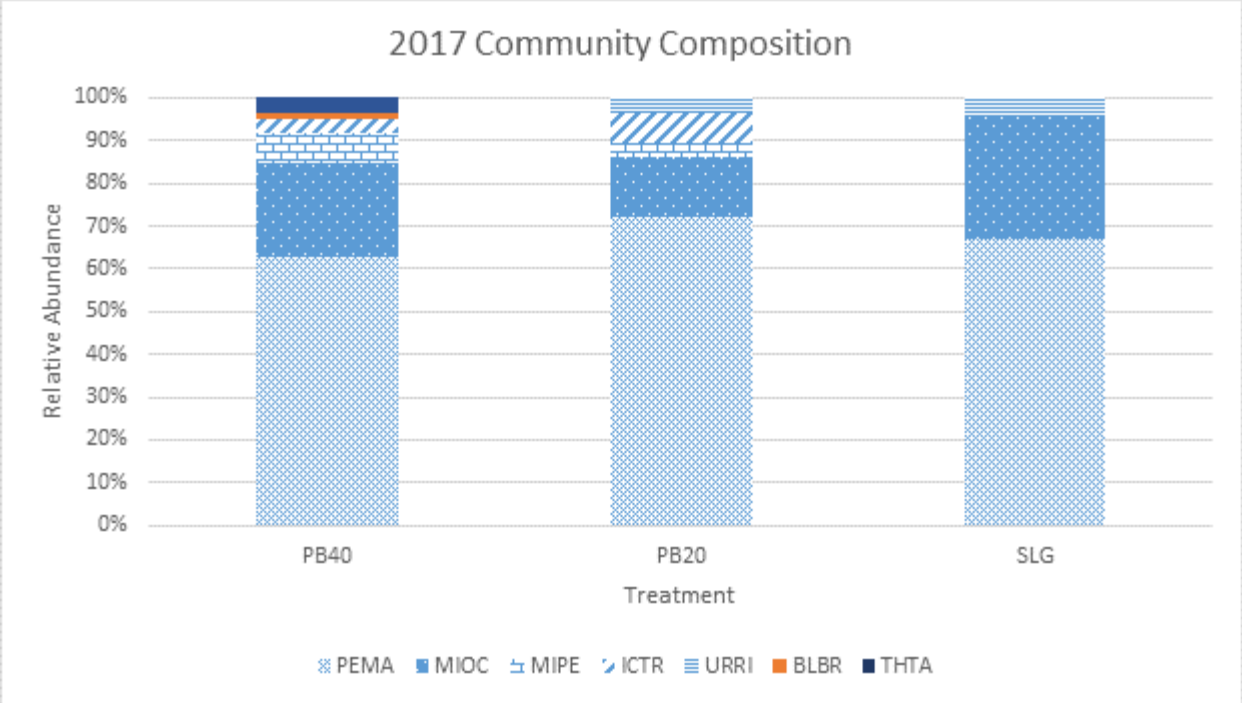

Figure 2. Relative abundance of small mammal communities according to treatment at the Central Grasslands Research Extension Center near Streeter, N.D., in 2017. Species codes are listed in Table 1.

PCA analysis of average pasture community composition indicated that year had a strong effect on community composition, especially in 2018 communities, where drought from the previous year combined with below-average cold temperatures and lack of snowpack in the winter of 2017-2018 likely caused communities in all treatments to contract (Figure 3, next page). After 2018, small mammal communities began to recover, with PBG treatments starting to become dissimilar from the SLG community in 2019 and 2020 (Figure 3). Using perMANOVA analysis, we established 2017 communities were not significantly different from each other, but PB40 and SLG treatments were different in 2020 ($p < 0.05$).

Time-since-fire PCA analysis illustrates the difference in community composition between recently burned subpatches (zero- and one-year-since-fire) and subpatches that had longer time-since-fire intervals (two- and three-years-since-fire), and how these communities are similar or dissimilar to communities in the SLG treatment (Figure 4). Recently burned subpatches were most dissimilar to the SLG communities, with communities having greater composition and being more diverse with time since fire, except in the three-year-since-fire subpatches, where communities were less diverse than the one- and two-year-since-fire communities (Figure 4). Of the different time-since-fire subpatches, one- and two-year-since-fire communities were the most diverse, but with increasing time since fire, communities become more similar to SLG communities (Figure 4).

Specialist species (animals that require unique habitat and resources) had different responses to time since fire. Vole species (*Microtus* spp.) were more associated with the SLG and the greater time-since-fire areas, while thirteen-lined and Richardson's ground squirrels were more associated with the most recently burned areas (Figure 4). In contrast, deer mice, a generalist species (animals that can occupy a wide variety of habitats), were not strongly associated with any of the time-since-fire intervals or the SLG treatment because they were prevalent across all sites (Figure 4).

Discussion

Relative composition of small mammal communities did not change greatly within treatment from 2017 to 2020 because the dominant species (deer mice) did not change in relative abundance except in the SLG treatment, where estimated abundance was 68% lower in 2020 than it was in 2017. Where we did see changes in community composition of treatments was

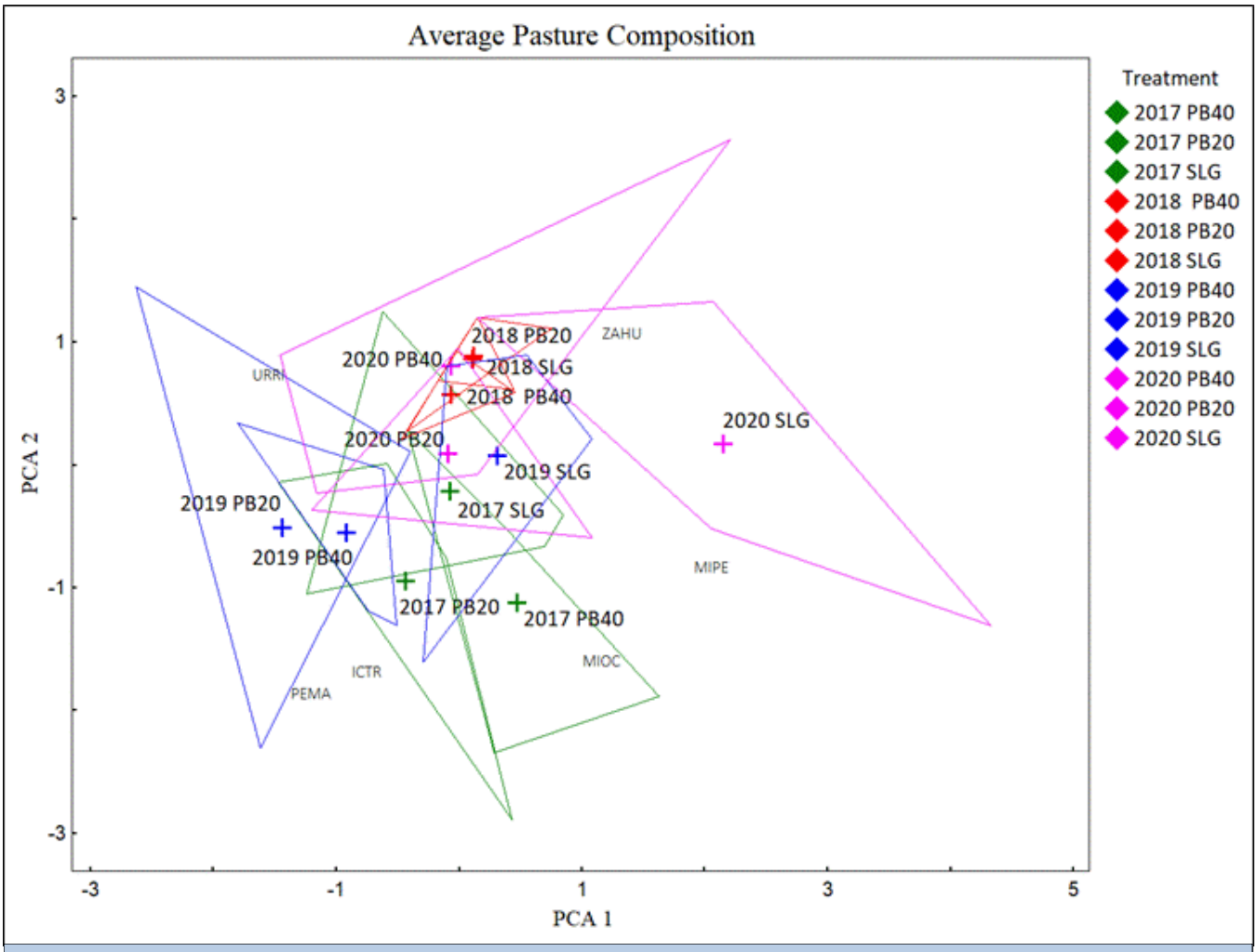

Figure 3. PCA ordination of average pasture small mammal communities at the Central Grasslands Research Extension Center near Streeter, N.D., from 2017 to 2020. Polygons represent average pasture community composition by year of treatment. The four-letter species codes (see Table 1) are presented in the ordination to visualize relationships between species and treatments. Centroids of each polygon are represented by crosses.

in the specialist species, where vole species became less prevalent in the PB40 and to a lesser extent in the PB20.

This likely is due to a loss of habitat associated with high amounts of litter, which is needed by vole species (Ricketts and Sandercock, 2016). Species more associated with bare ground, such as thirteen-lined and Richardson's ground squirrels, increased in relative abundance in PBG treatments, likely in response to the increased bare ground that is associated with post-fire plant communities (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2010).

With time, small mammal communities of the PBG treatments and the SLG treatment began to diverge in composition. Although yearly weather can have a great effect on community composition (See Hamel et al., 2020, report), divergence in small mammal communities likely can be attributed to the differences in habitat created by time since fire in our PBG treatments.

After a full rotation of fire through the PBG pastures in 2020, a mosaic of patches was established with four different time-since-fire intervals and habitat types, which can explain why average pasture community composition in the PBG treatments differed with respect to the SLG treatment (Fuhlendorf et al., 2010).

Although we didn't find that PB20 pasture community composition was significantly different to that of the SLG pasture, this is not entirely surprising. At the time of sampling in June, only half of the 40-acre patches were burned (one 20-acre subpatch burned in spring, one 20-acre subpatch burned in summer), leaving the other half unburned, possibly acting as refugia for

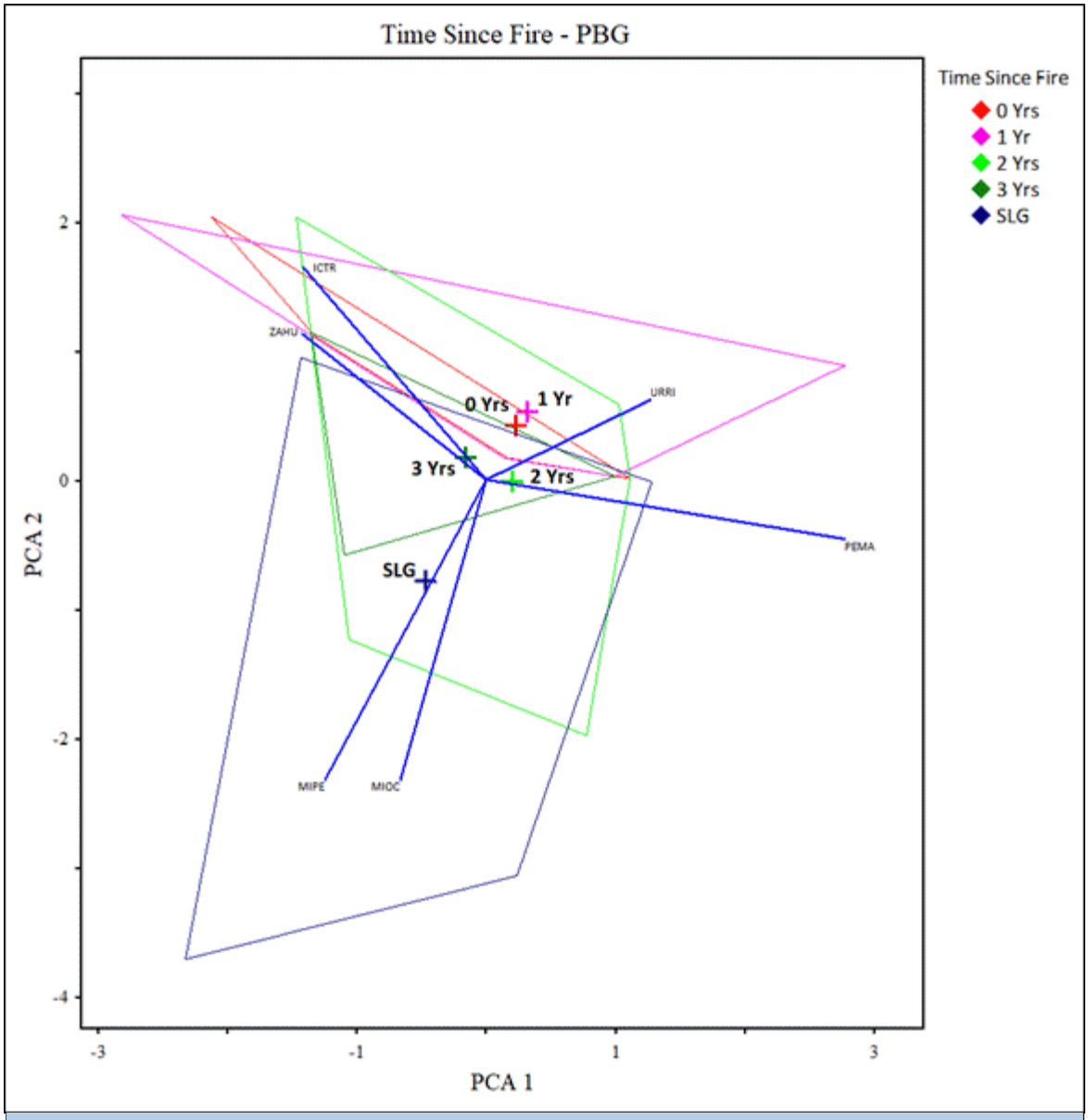

Figure 4. PCA ordination of average small mammal community compositions from PBG treatments arranged by time-since-fire intervals of subpatches compared with SLG community in 2020 at the Central Grasslands Research Extension Center near Streeter, N.D. The four-letter species codes (see Table 1) are presented in the ordination to visualize relationships between species and treatments. Centroids of each polygon are represented by crosses.

species that require more vegetative cover and litter, such as voles (Ricketts and Sandercock, 2016).

As discussed previously, species such as voles and ground squirrels can have specific habitat requirements. This is evident with time since fire as species more associated with bare ground (ground squirrels) were more abundant in recently burned areas, while species that require litter and canopy cover (voles) were more associated with areas that had greater time since fire and the SLG treatment.

Communities that occupied one- and two-year-since-fire subpatches were more diverse than those in the zero- and three-year-since-fire subpatches. This is because habitat within one- and two-year-since-fire subpatches is transitioning from areas with bare ground, needed for some species (ground squirrels), to areas begin accumulating litter and canopy cover, needed for other species (voles), causing more diverse communities (Ricketts and Sandercock, 2016).

Many of the results presented here are consistent with similar studies conducted in the tall grass prairie (Fuhlendorf et al., 2010; Ricketts and Sandercock, 2016). Patch-burn grazing shifted small mammal community composition in ways that season-long grazing couldn't by creating a mosaic of patches of differing habitat and time since fire. But because small mammal community responses to patch burning in the mixed-grass prairie are dynamic and are affected by more than management, further study is needed to better understand what effect this patch-burn grazing has on these communities.

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