Fire, Grazing, and Bird Diversity in Tallgrass Prairie

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Introduction

Tallgrass prairies, once sprawling across North America, historically covered between 30 to 40% of the Earth's terrestrial surface. However, over 70% of America's prairies have been converted to agriculture and development (Jaynes 2024). Characterized by low and highly variable annual rainfall, grasslands receive enough moisture to prevent desert conditions but not enough to support forests (Anadón 2017; Jaynes 2024). Today, grasslands store 20-35% of the carbon sequestered worldwide while accounting for around 33% of the global diversity hotspots (Chalmers 2026). The deep, extensive root systems of native grasses play a crucial role in carbon sequestration, soil stabilization, and erosion control, helping to mitigate droughts and floods (Keen 2022; Jaynes 2024). Grassland ecosystems provide critical habitats for native species, mitigate droughts and floods, aid seed dispersal, improve water and air quality, prevent erosion, and help mitigate climate change.

Management of tallgrass prairie ecosystems across the Great Plains focuses on maintaining the disturbance processes that historically shape these landscapes. Fire and grazing practices are key factors in maintaining grassland-dominated systems and preventing the expansion of woody plants. Reduced fire frequency, altered grazing regimes, and land-use change have allowed shrubs and trees to spread throughout the prairie ecosystem, according to research. Prescribed burning can slow woody encroachment, while grazing can maintain plant diversity by limiting grass dominance. These strategies are often most effective when used together. Because encroaching woody species show diverse growth patterns and varied responses to disturbance, prairie management often requires more integrated approaches. These approaches may look like a combination of fire, grazing, and restoration to maintain biodiversity and healthy ecosystem function (Blair 2002; Veach 2014; Nippert 2021).

In addition to maintaining diversity and function, management decisions regarding fire and grazing strongly influence vegetation structure across tallgrass prairie landscapes. Differences in burn frequency can influence the amount of woody vegetation present, as longer intervals between fires allow shrubs and small trees more time to establish and grow. Grazing can further shape these patterns by affecting plant competition and the distribution of vegetation across the landscape. As a result, different combinations of burning and grazing create variation in prairie structure, ranging from open grassland-dominated areas to patches with greater woody cover.

Woody encroachment has been recognized as a major driver of ecological change in grassland ecosystems. As woody plant density increases, studies have shown grassland-obligate species decline and are progressively replaced by species adapted to shrubland or woodland habitats (Archer et al. 2017:57). This shift alters plant composition and reduces overall biodiversity by outcompeting herbaceous species for light, water, and nutrients, thereby impacting ecosystem structure and habitat quality (Ratajczak 2012). Woody encroachment has been identified as one of several factors exacerbating grassland degradation alongside conversion to cropland, drought, overgrazing, and climate change, which collectively affect rainfall patterns, gas exchange, transpiration rates, and habitat quality (Jaynes 2024). Studies have consistently shown that fire, grazing, and climate variability are essential for maintaining grassland structure, biodiversity, and ecosystem function. The negative effects of woody encroachment on species richness are more pronounced in biomes with higher precipitation, highlighting a trade-off between ecosystem productivity and biodiversity (Ratajczak 2012). While populations of herbaceous species may slightly increase with woody species, their overall cover declines, reducing the diversity and abundance of grasses critical for herbivores (Kimaro 2024). For example, long-term research at Konza Prairie has demonstrated how fire frequency influences plant composition and productivity, while grazing studies have shown how bison create variation across the landscape and increase plant diversity. Research on woody encroachment has clearly shown that reduced disturbance leads to the spread of shrubs and trees. These structural changes can influence habitat availability for many species, particularly grassland-obligate birds.

The tallgrass prairie is home to many grassland-obligate bird species. Birds play an important role in ecological systems, providing ecological services such as seed dispersal, and are also excellent indicators of environmental health and ecosystem integrity (Rosenberg et al. 2019). Grassland bird populations have experienced a 74% decline since 1970 primarily due to loss of habitat (Bernath-Plaisted et al. 2023). Many of these species rely on large, intact areas of tallgrass prairie for breeding, food, and nesting. Woody encroachment fragments these prairies and alters habitat structure, which can affect bird species differently depending on their ecological requirements. Species adapted to open grasslands often decline as shrubs and trees increase, while woodland or edge-associated species may become more common (de Zwaan et al. 2024). Bird community composition can therefore serve as an important indicator of how woody encroachment is reshaping grassland ecosystems.

Grassland bird populations are influenced by a combination of habitat structure, climatic variability, and land management practices. Habitat fragmentation and woody encroachment are major factors affecting grassland bird habitat quality. In addition, drought and precipitation variability can significantly influence reproductive success and breeding behavior. Understanding these factors is critical for developing effective conservation strategies aimed at slowing the population decline of grassland songbird species. Management practices such as removing trees from grasslands may help reduce woody encroachment and fragmentation, improving habitat conditions for grassland birds. Continued research is needed to better understand how changing climate conditions and landscape management practices may influence long-term grassland songbird population dynamics.

One of the best examples of these disturbance processes in action is found in the Flint Hills tallgrass prairie, one of the two most intact grasslands in the United States. Within this region, the Konza Prairie Biological Station (KPBS) represents one of the largest remaining areas of unplowed prairie, largely due to the shallow, rocky, limestone soils and steep topography (KPBS 2025; Jaynes 2024). Konza supports high floristic diversity, including native woody shrubs, forbs, and C4 grasses, making it a critical site for ecological research and conservation. At Konza Prairie Biological Station, long-term studies have shown that bison grazing interacts with fire to create a patchy landscape, where some areas are heavily grazed and others remain lightly grazed (Vinton et al. 1993). This heterogeneity reduces the dominance of certain grasses and promotes plant diversity (Hartnett et al. 1996). However, reduced fire frequency allows woody plants to establish and spread, which can negatively impact grassland species such as Grasshopper Sparrows (*Ammodramus savannarum*) and Meadowlarks (*Sturnella*) that depend on open habitats (Silber et al. 2024; Silber 2023).

Key woody species include: *Quercus macrocarpa* (Bur Oak), *Q. muehlenbergii* (Chinquapin Oak), *Juniperus virginiana* (Eastern Red Cedar), and *Cornus drummondii* (Rough-leaved Dogwood) (R. Keen 2022). Additionally, woody encroachment negatively impacts livestock production, with animal species responses closely linked to vegetation changes (Anadón 2014; Archer 2017). One major challenge is understanding how multiple disturbances interact under variable environmental conditions. Fire suppression is a critical driver of woody encroachment, accelerating the conversion of grasslands to shrublands or woodlands. While many studies examine fire, grazing, or climate separately, fewer studies focus on how these disturbances work together over long periods of time. More specifically, there is a limited understanding of how different management strategies interact with woody encroachment and how these changes affect bird species richness. Birds serve as important indicators of ecosystem health and shifts in woody cover could disrupt grassland-obligate bird populations, threatening biodiversity and ecological balance. Climate change introduces a level of uncertainty as it may alter precipitation patterns, increase drought frequency, and affect how disturbances operate. Challenges in addressing this gap include variability in woody encroachment across landscapes, the timing and frequency of burns, and complex weather interactions influencing bird communities. Recent research has also examined disturbance frequency, long-term resilience, and species recovery following woody encroachment.

This knowledge gap interests us because managing woody encroachment through fire and grazing could be a key lever to restore and maintain healthy prairie ecosystems, preserving their ecological functions and biodiversity. Our project aims to fill these gaps by investigating how woody cover changes across bison-grazed watersheds with different burn intervals and how these changes relate to bird species richness. To this end, we assessed where woody cover has increased between bison-grazed watersheds and quantified the species richness of birds observed at each location. We hypothesize that: (1) longer intervals between burns will increase woody cover; (2) increased woody cover will decrease bird species richness; and (3) longer burn intervals will reduce bird species richness. This research offers valuable insights for prairie conservation and management by linking fire and grazing treatments to biodiversity outcomes.

By improving understanding of how management practices affect woody encroachment and bird communities, our findings can guide future efforts to restore and sustain resilient prairie ecosystems. Such knowledge is essential to safeguarding grassland biodiversity, ecosystem services, and the cultural and economic benefits these landscapes provide.

Method and Materials

Study Site

The study was conducted at Konza Prairie Biological Station, a 3,487-hectare native tallgrass prairie divided into 50 watershed units, each about 66 hectares. The watersheds are labeled based on different grazing and burning treatments. Grazing treatments include year-round bison grazing (N), ungrazed areas (K), cattle grazing (C), low and agricultural land (AL), and leased cattle grazing (WP). Burning treatments are identified by the number of years between burns (1, 2, 4, or 20) and by replicate labels (A-D). Seasonal burns are marked as winter (W), summer every other year (Su), fall (F), or spring (Sp). Some watersheds undergo reversal treatments, indicated by R1 (changing from 20-year to annual burns) or R20 (from annual to 20-year burns). Sampling for this study occurred in four bison-grazed watersheds with different burn frequencies: N1A (annual burn), N2B (burn every two years), N4A (burn every four years) and N20A (switched from burning every 20 years to annually after 2021).

The Flint Hills have a temperate continental climate, characterized by hot summers and cold winters. In the summer the highs are usually between 80 and 100 degrees, with July being the hottest month. In the winter, average temperatures are between 30and 50 degrees ,with January being the coldest. This region has large seasonal temperature swings since the region is far from oceans that would moderate the climate. The region receives approximately 30–35 inches of precipitation annually, most of which occurs during the growing season (April–September), with peak rainfall in late spring and early summer.

Vegetation is dominated by native warm-season grasses, including *Andropogon gerardii* (Big Bluestem), *Sorghastrum nutans* (Indian Grass), *Schizachyrium scoparium* (Little Bluestem), and *Panicum virgatum* (Switchgrass), along with a variety of forbs. Common forbs include *Echinacea purpurea* (Purple Coneflower), *Amorpha canescens* (Leadplant), *Dalea purpurea* (Prairie Clover), *Rudbeckia hirta* (Black-eyed Susan), and *Silphium laciniatum* (Compass Plant). Woody plant abundance has increased over the last 50 years with species such as the *Baptisia australis* (Blue False Indigo), *Cornus drummondii* (Rough-leaf Dogwood), *Cornus amomum* (Pale Dogwood), *Prunus americana* (American Plum), *Prunus angustifolia* (Chickasaw Plum), *Rhus aromatica* (Aromatic Sumac), *Rhus glabra* (Smooth Sumac), *Juniperus virginiana* (Eastern Red Cedar), and *Zanthoxylum americanum* (Prickly Ash).

Experimental Design

The increase in woody plant abundance is driven by several interacting factors, including increased seed dispersal from nearby woody plants and ornamental trees, changes in fire regimes and grazing patterns, and rising atmospheric CO_2 levels (Helzer 2014). This study focused on four bison-grazed watersheds that differed in burn frequency (annual, 2-year, 4-year, and 20-year to annual reversal). By holding grazing regime constant and varying only fire frequency, this design allowed us to isolate the effects of burn frequency on bird communities and woody vegetation.

Data Collection

We conducted point-count bird surveys during March 23rd to April 5th, 2026. During each survey, observers recorded all avian species detected visually or aurally within a 200-meter radius. Within treatment areas, we generated random survey locations using the random point generation tool in ArcGIS Pro (v. 3.5.2). Each point was surveyed for 5 minutes, with a total of $n = 15$ survey locations.

To determine the percent of woody cover of the entire treatment area, we used land cover data from Kansas Mapping Ecosystems in ArcGIS Pro (v. 3.5.2) to calculate the proportion of woody vegetation within survey buffers and at the watershed scale.

Statistical Analysis

We fit 5 generalized linear models (GLMs) using Poisson error distribution and log link function to examine the relationship between bird species richness and environmental variables. Species richness was modeled as a function of percent woody cover and times since burn (TSB) with an additive framework. We used AICc (Akaike's Information Criterion for small sample sizes) for model comparison.

ResultsW

Point Scale

Species richness and time since burn

Species richness varies among watersheds and burn treatments. Model results indicated that time since burn (TSB) had the strongest relationship with bird species richness. Figure 1 shows the relationship between burn interval and species richness. A significant negative trend was observed (β = -0.22, SE = 0.08, z = -2.76, p = 0.006), with sites experiencing longer intervals since burning supporting fewer bird species. For each increase in TSB, species richness decreased by approximately 22%.

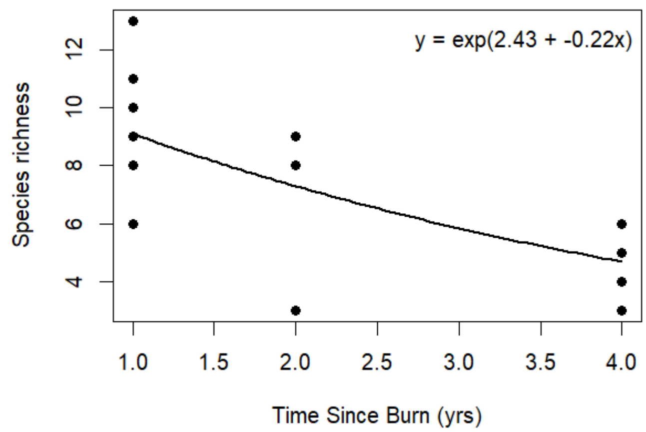

Figure 1

Species richness and grassland cover

Figure 2 shows the relationship between the proportion of grassland cover and bird species richness at survey points. A negative trend was observed with species richness declining as grassland cover increased; however, this relationship was not statistically significant (*β* = -0.97, SE = 0.55, z = -1.78, *p* = 0.075).

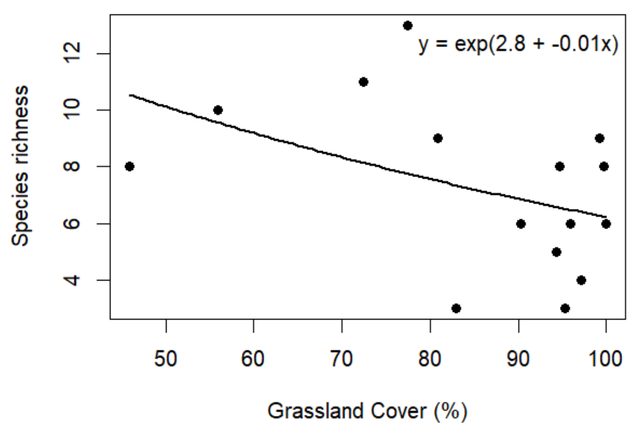

Figure 2

Species richness and woody cover

Figure 3 shows the relationship between total woody cover and bird species richness across tallgrass prairie survey points. A slight positive trend was observed, with species richness increasing as woody cover increased; however, this relationship was not statistically significant

(β = 0.96, SE = 0.55, z = 1.73, p = 0.084). Overdispersion was checked (dispersion parameter = 1.09) and fell within an acceptable range, so the Poisson distribution was retained.

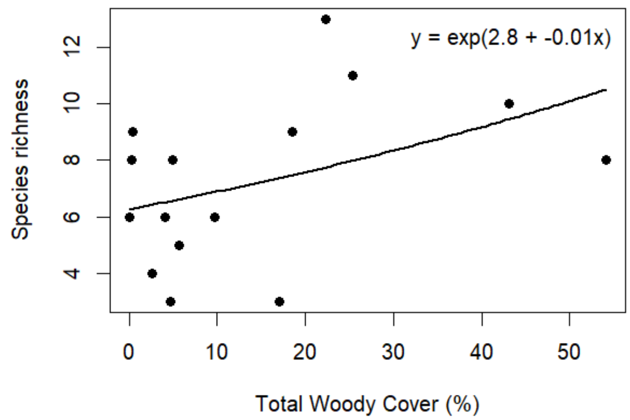

Figure 3

Species richness and native trees

Figure 4 examines the relationship between the proportion of native tree cover and bird species richness. A slight positive trend was observed but the relationship was not statistically significant (β = 1.70, SE = 0.96, z = 1.24, p = 0.216).

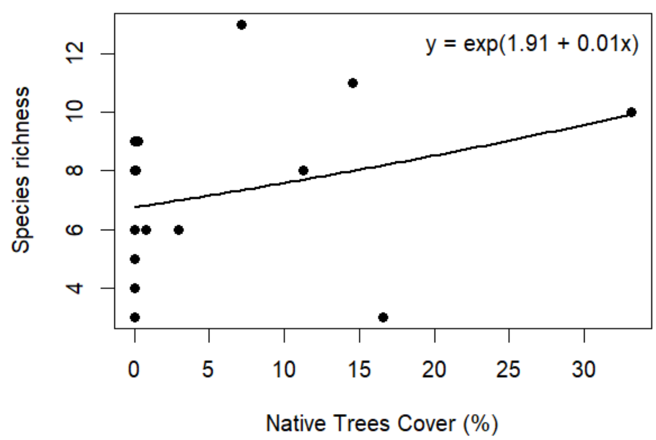

Figure 4

Species richness and Dogwood/Eastern Red Cedar

Figure 5 shows the relationship between woody encroachment by Dogwood and Eastern Red Cedar and bird species richness. A slight positive trend was observed but the relationship was not statistically significant ($\beta = 2.17$, SE = 1.89, z = 1.16, $p = 0.246$).

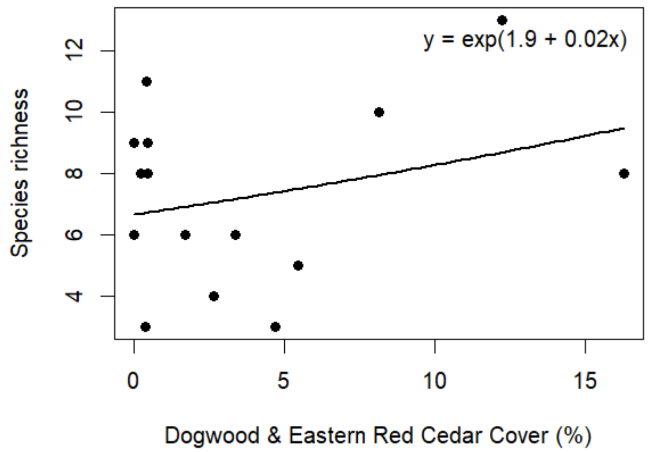

Figure 5

Watershed Scale

Vegetation Composition by Watershed

Figure 6 shows the vegetation composition of each of the four study watersheds. Each color represents a different vegetation type: Dogwood/Eastern Red Cedar, grassland, native trees, other, urban, and woody cover. Vegetation composition varied across watersheds, with grassland making up a majority of the watershed vegetation.

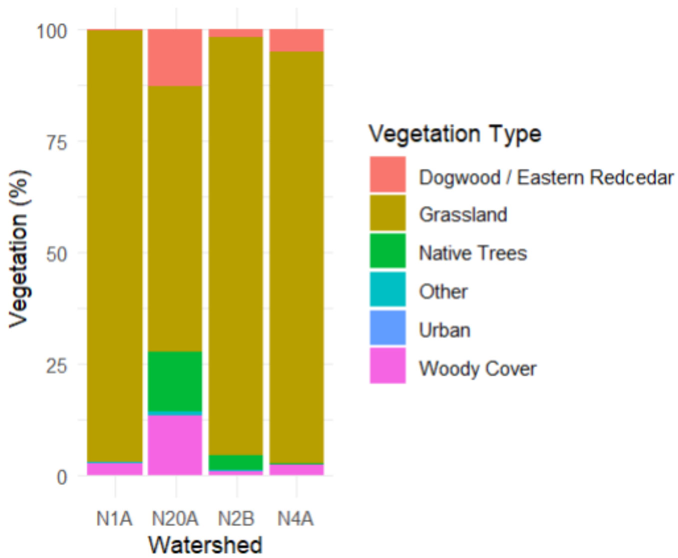

Figure 6

Bird Species by Watershed

Figure 7 shows the total bird species richness recorded across the four study watersheds. Species richness varied among watersheds, with N20A supporting the highest richness (21), followed by N1A (17), N2B (14), and N4A (12). Watershed-level richness was modeled using Poisson general linear models (GLMs) to evaluate the influence of landscape variables on observed differences.

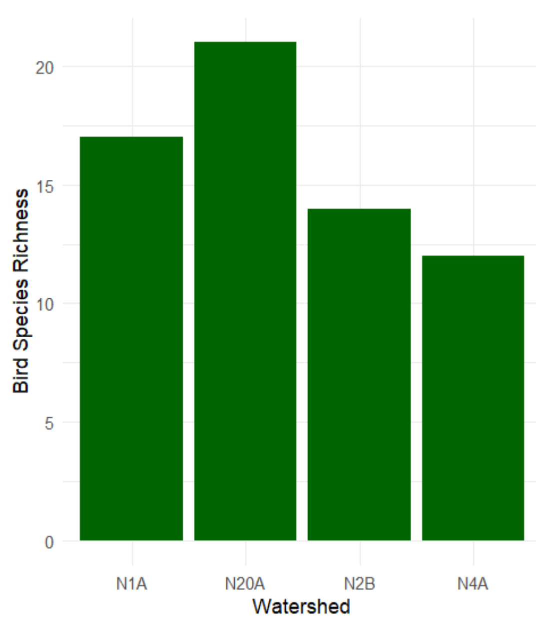

Figure 7

Model selection using AIC (Table 1) indicated that the woody vegetation model on the watershed scale was the most competitive model (AIC = 24.54, ΔAIC = 0), suggesting it is the most important driver of bird species richness. Urban and grassland models also received substantial support (ΔAIC < 2), indicating these factors may also influence the observed patterns, though to a lesser degree. Models representing other land cover types showed weaker support, suggesting they are less influential in explaining variation in the data.

Model	**Title**	**K**	**Deviance**	**AIC**	**ΔAIC**
m_woody	woody	2	0.1104270	24.53538	0.0000000
m_urban	urban	2	0.3938444	24.81879	0.2834174
ws_m_grasslands	grasslands	2	0.4545768	24.87953	0.3441498
m_other	other	2	0.5185256	24.94347	0.4080986
ws_m_dogwooderc	dogwooderc	2	0.7970184	25.22197	0.6865914
ws_m_native	native	2	1.5343950	25.95934	1.4239680

Table 1

Discussion

Our results support the hypothesis that fire frequency has a major influence in shaping woody vegetation dynamics, this in turn influences grassland bird communities in tall grass prairie ecosystems. Consistent with our first prediction, watersheds with longer intervals between burns exhibited greater woody plant cover. This aligns with long-term findings from Konza Prairie Biological Station and other grassland systems showing that reduced fire frequency allows shrubs and trees to establish, grow, and eventually dominate portions of landscapes. Fires are a key disturbance in prairie ecosystems that suppress woody encroachment. Without frequent burns, these systems begin to transition toward shrubland or woodland states.

Increased woody cover was associated with a decline in bird species richness, supporting our second hypothesis. Previous research demonstrates that grassland-obligate bird species depend on open habitats and are negatively impacted by increases in woody vegetation. As woody plants expand and dominate, they alter vegetation structure, reduce the extent of contiguous grassland habitat, and introduce perching and nesting sites for predators and competitor species. These changes disproportionately affect native species like meadowlarks, which require and prefer large uninterrupted grassland areas for breeding and foraging. While some shrub associated or generalist species may increase with woody encroachment, this shift represents a much greater loss of grassland biodiversity rather than a neutral community change.

Our third hypothesis, that longer burn intervals would reduce species richness, was also supported by the observed relationships between time since burn, woody cover, and species richness. Burn frequency appears to influence bird communities both directly and indirectly. Directly, recent burns can create more favorable habitat structure for native grassland birds. Indirectly, frequent burning limits woody encroachment, which maintains the structural conditions necessary for these species. Another important aspect to consider is the interaction between fire and grazing. While grazing was held constant in this study, bison grazing contributes to habitat heterogeneity by creating a mosaic of heavily and lightly grazed patches. This heterogeneity can create a wide range of plant diversity, but without frequent fire, though it may not be sufficient to prevent woody expansion.

These findings highlight the importance of integrated disturbance regimes in maintaining prairie ecosystem function. Fire and grazing are not independent processes; rather, they interact to shape vegetation structure and biodiversity. Our results reinforce the idea that frequent prescribed burning is essential for conserving grassland bird communities in tallgrass prairie systems. Management strategies that reduce burn frequency, even in the presence of grazing, may inadvertently promote woody encroachment and lead to declines in grassland-dependent species.

Future research could build on this study in multiple ways. Increasing the number of survey locations and expanding sampling across additional watersheds would improve the sturdiness of the results and allow for a stronger foundation of statistical inference. Extending bird surveys across multiple seasons and years would provide a more comprehensive understanding of how bird communities respond to changes in habitat structure over time, including breeding success rates and migratory patterns. More complex modeling approaches that look at interactions between variables such as woody cover, time since burn, and grazing intensity could also be a good addition to future research. Addressing these areas, future studies can deepen our understanding of disturbance ecology and improve management practices aimed at preserving the structure, function, and biodiversity of tall grass prairie ecosystems.

Conclusion

This project investigated how woody cover changes across bison-grazed watersheds with different burn intervals and how these changes relate to bird species richness. We assessed where woody cover has increased between bison-grazed watersheds and quantified the birds observed at each location. We hypothesized that: (1) longer intervals between burns will increase woody cover; (2) increased woody cover will decrease bird species richness; and (3) longer burn intervals will reduce bird species richness.

Overall, our results largely support the proposed hypotheses, particularly regarding the influence of fire frequency on bird species richness. Time since burn showed a significant negative relationship with bird species richness, with longer burn intervals associated with lower richness. Relationships between woody cover and species richness were weak and not statistically significant, with slight positive trends observed for total woody cover, native trees, and woody encroachment by Dogwood and Eastern Red Cedar. These results are important because they highlight the importance of fire frequency as a key driver of bird species richness in tallgrass prairie ecosystems, even when vegetation structure alone does not strongly predict patterns of diversity. This suggests that factors associated with recent burning may play a more important role than overall woody cover in shaping bird communities.

Future research should integrate species-level knowledge with broader landscape-scale patterns to better understand how variation in burn frequency and woody encroachment influences both individual grassland bird species and overall community composition. Incorporating seasonal or behavioral data could also provide a more complete understanding of how fire and grazing interact to structure grassland ecosystems. Ultimately, maintaining appropriate fire regimes within bison-grazed landscapes may be critical for supporting diverse bird communities and sustaining the ecological integrity of tallgrass prairie ecosystems.

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