National Park Service
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Natural Resource Stewardship and Science

# Evaluating Long-term Trends in Vegetation and Management Intensity

## *Tallgrass Prairie National Preserve 1995–2014*

Natural Resource Report NPS/HTLN/NRR—2018/1582

ON THIS PAGE
Beatle on a milkweed pod at the Tallgrass Prairie National Preserve, August 2017.
Photography by: J. Johnson/NPS Heartland Inventory and Monitoring Network

ON THE COVER
Bison on the tour road at Tallgrass Prairie National Preserve, August 2017.
Photography by: J. Johnson/NPS Heartland Inventory and Monitoring Network

# Evaluating Long-term Trends in Vegetation and Management Intensity

## *Tallgrass Prairie National Preserve: 1995–2014*

Natural Resource Report NPS/HTLN/NRR—2018/1582


Sherry A. Leis,[1] Lloyd W. Morrison[2]

[1]National Park Service
Wilson's Creek National Battlefield
6424 West Farm Road 182
Republic, MO 65738

[2]National Park Service
Missouri State University
901 South National Avenue
Springfield, MO 65897



*Editing and Design by*

Tani Hubbard

National Park Service &
Northern Rockies Conservation Cooperative
12661 E. Broadway Blvd.
Tucson, AZ 85748

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# Abstract

Inventory and Monitoring Networks of the National Park Service are charged with collecting and reporting data related to the status and trends of key natural resources. We have analyzed a suite of grazing data from 1995-2016, fire history data from 1998-2015, and vegetation community data from 2002-2014 to better understand trends as they relate to management strategies at the preserve over time. We found that cattle stocking rates declined and fires became less frequent over the latter half of the record. Similarly, bare ground declined, woody species increased slightly, and the floristic quality index was relatively stable with a decline in 2014. Although it is difficult to directly infer cause and effect from our monitoring design, the data are valuable for helping park managers evaluate their goals and develop future action plans.

# Acknowledgments

We are grateful to the staff at Tallgrass Prairie National Preserve for working with us to collect and archive fire history and grazing data and provide access to the preserve. We acknowledge the time and talent of previous botanical staff and technicians, K. Mlekush and K. James in particular. J. Haack and G. Rowell provided a great deal of support for our databases and geodatabase. Kathie Hansen provided support for spatial fire frequency mapping. This work would not be possible without their contributions.

# Introduction

Tallgrass Prairie National Preserve (hereafter Preserve) is unique in that it is cooperatively owned and managed by the National Park Service and The Nature Conservancy. The 10,894 acre (4,409 ha) Preserve was established to conserve a piece of the tallgrass prairie ecosystem, and to commemorate the ranching legacy of the Flint Hills (Tallgrass Prairie NationalPreserve Act of 1996). Through time the partners have made adjustments to land management strategies that reflect the Preserve's mission.

Shifting from a paradigm of intensive grazing and focus on livestock production to one of ecosystem management and heterogeneity has manifested in changes to cattle stocking rates, fire regimes, and grazing systems. The introduction of bison into Windmill Pasture was a significant achievement towards restoring and conserving the tallgrass prairie ecosystem.

The Heartland Inventory and Monitoring Network has measured the plant community at the Preserve since 1997. Previous reports have documented the status and trends of the plant community and results of prescribed fires (James 2011; James and DeBacker 2007; Leis and Hinman 2015, 2016; Leis and Kopek 2012, 2013). We have developed and maintained grazing and fire history databases in addition to a fire effects monitoring database. One of the ecological goals in the fire management plan (Hase 2016) is to maintain and restore fire adapted ecosystems using appropriate tools and techniques in a manner that will provide sustainable environmental and social benefits. We interpreted this goal to include the fire and grazing regimes at the Preserve as well as bare ground cover, an indicator of disturbance intensity. Additionally, we included floristic quality as a measure of the potential effect of the disturbance regime on the vegetation community. Another fire management goal was to maintain abundance (cover) of woody plants below 5%. Additional understanding of the prairie ecosystems will be helpful for evaluating these goals and in future planning efforts as the Preserve's management partnership matures and the data record lengthens.

We analyzed plant community data from 2002 to 2014 (see Figure 1 for monitoring site locations). Because grazing and fire fundamentally influence prairie vegetation, we first asked

1. Has the grazing regime changed through time?

2. Has fire frequency changed through time?

3. Has woody cover changed through time?

4. Has bare ground cover changed through time?

5. Has floristic quality changed through time and what role did species richness play?

Lastly, we tested whether grazing, fire, and precipitation helped to explain any differences we detected in the plant community (questions 3, 4, and 5 above). It is our hope that a better understanding of plant community trends will inform development of management goals.

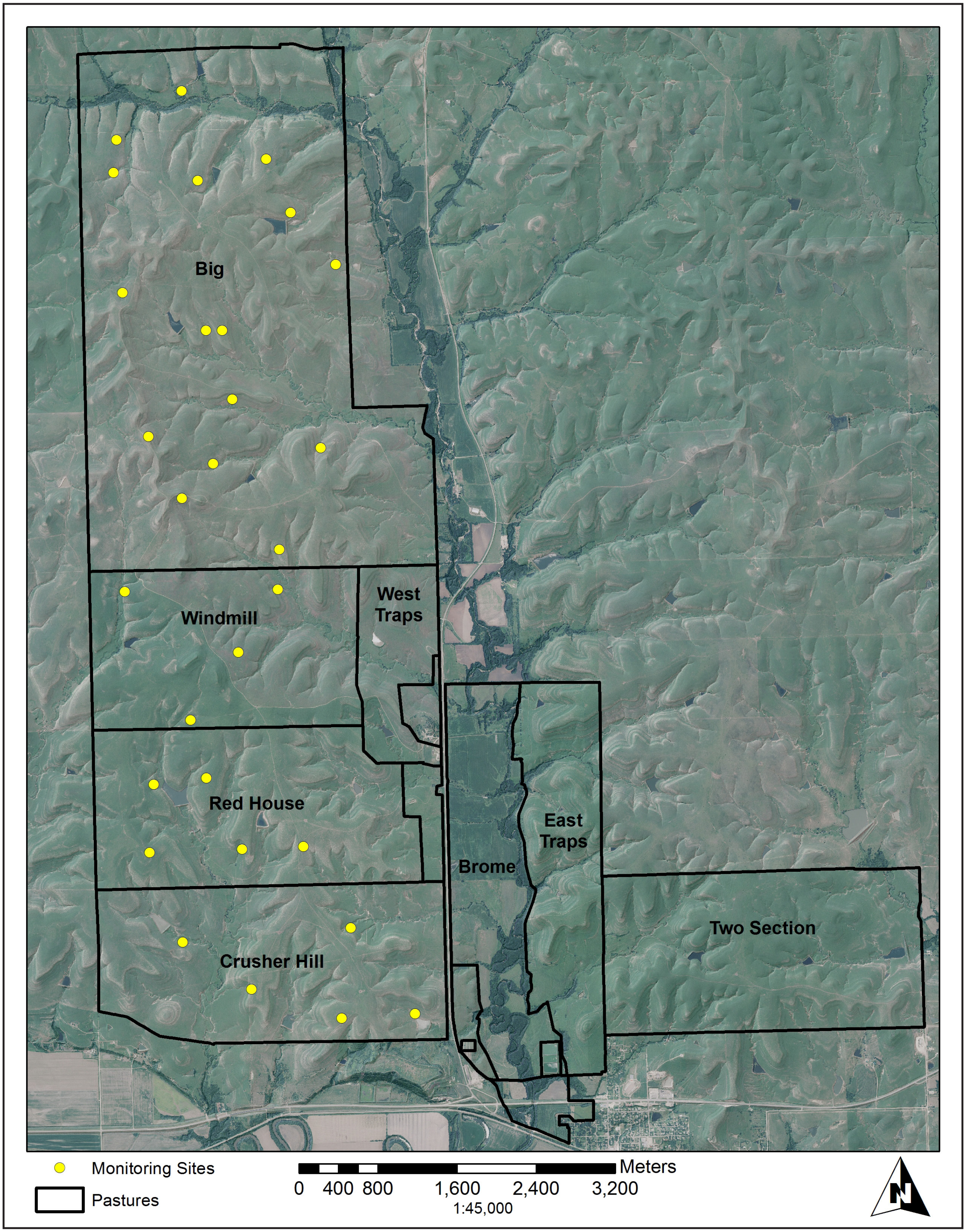


**Figure 1.** Map of Tallgrass Prairie National Preserve including long-term monitoring sites. Major pastures are also labeled.

# Methods

## Site description and data development

The Preserve includes nearly 11,000 acres, although our monitoring and analyses have focused on the western Preserve where long-term monitoring sites were installed (Figure 1). Monitoring sites were primarily tallgrass prairie (Figure 2; Kindscher et al. 2011). Although monitoring was initiated in 1997, the protocol was not consistent until finalized in 2002. As a result, we included vegetation data from 2002–2014 in our analysis. Vegetation data were collected annually from 2002 to 2008, and then in 2010 and 2014 (n=9 years). The revisit design changed through time (DeBacker et. al. 2004; James et.al. 2009) from a two season (mid-May, early October), annual visit rotating panel type with a core of 18 sites to a one season (mid-June), one visit every four-years design with 30 sites. Conversion of the two-season sampling to a single dataset was done by using the maximum cover of the two seasons for each species.

Vegetation monitoring sites are comprised of 10 plots (Figure 3). Data are summarized at the plot level and averaged to the site. Site values were then used to calculate pasture- and preserve-level statistics.

Vegetation and ground cover data were collected using a modified Daubemire cover class system at the 10-m2 plot scale (James et.al 2009). Woody cover included plants listed in the woody guild in USDA Plants database (USDA 2017). This included shrubs and trees. The floristic quality index (FQI) was calculated using coefficient of conservatism (C) values developed for Kansas (Freeman 2017). The index uses a coefficient of conservatism value assigned to native species only. The value considers a species fidelity to a particular ecosystem using a 1-5 scale with 5 being the most conservative. FQI was calculated as in Jog et.al. 2006:

$$FQI = \frac{R}{\sqrt{N}}$$

where R = sum of coefficients of conservatism and N = number of different native species recorded.

In cases where species data were only collected to genus, we averaged the C values for species of that genus known to occur at the Preserve. FQI was calculated at the plot level and averaged to the site, and sites were aggregated at larger scales as described below.

Fire history data were primarily collected with Trimble GPS units by preserve staff (2009–2014). Additional spatial data were collected by digitizing from satellite imagery or based on agency records. The data were compiled into a geodatabase used to calculate time since fire (TSF) in years, regardless of burn month, for each vegetation monitoring plot.

Annual grazing data were collected from the Preserve leasee, stored in a Microsoft Access database and used for stocking rate calculations. Rates were based on a 750-lb (340.2 kg) animal as stocker cattle are typically used for grazing. Grazing systems through time have included pasture-based intensive early stocking (Smith and Owensby 1978), modified intensive early stocking (less than double stocking rates or extended season, based on preserve records), season long stocking (six months; Holechek et.al. 2001) and patch burn grazing (implemented in Big Pasture in 2006; Fuhlendorf and Engle 2001; Leis et al. 2013). Bison are stocked year round in Windmill Pasture. Data for Crusher Hill Pasture in 2006 were not used because stocking rates could not be adequately determined. Bison were stocked in Windmill Pasture in 2010 but weight based calculations were not available, so we did not include stocking data from 2010 forward for that pasture. On a per head basis, Windmill Pasture was lightly stocked with bison from 2010-2014 with ≤ 18 head/acre (7.3 head/ha).

## Statistics

Preliminary statistical tests addressed the issue of whether it was reasonable to compare data from the 30 sites sampled in 2010 and 2014 to the smaller set of the core 18 sites sampled in other years. We tested whether the two sets of samples (the original 18 and the additional 12) come from the same population. Three variables were tested: woody cover, bare ground cover and species richness. For the woody and bare ground cover data, the values did not approximate a normal distribution and there was too much skew for an arcsine square root transformation, so the nonparametric Mann Whitney test was applied. For species richness, the data were approximately normal, so a t-test was used. Tests were conducted for each variable (n=3) for each year (n=2) separately, resulting in six total hypothesis tests. In all cases, P-values did not approach significance (P

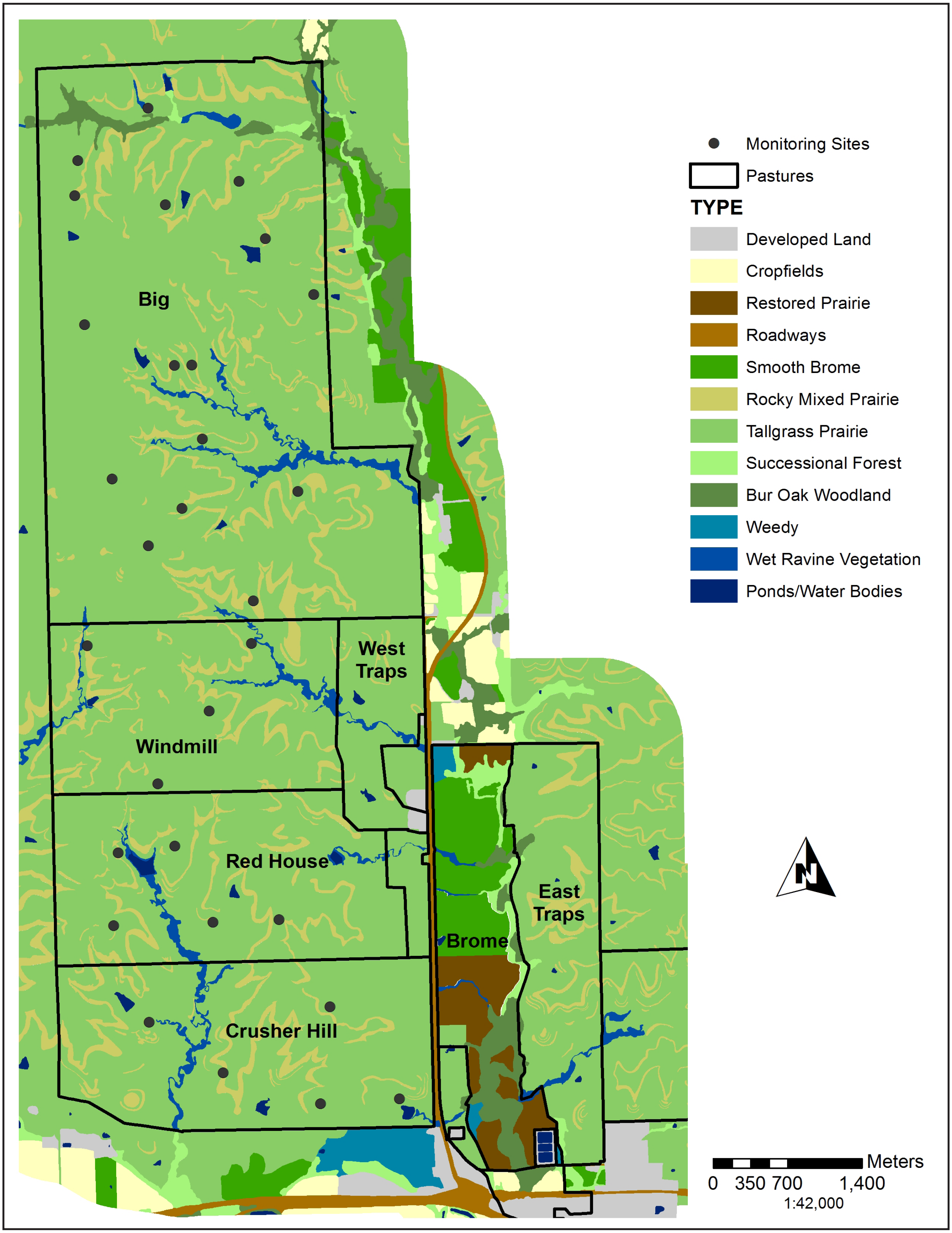


**Figure 2.** Vegetation types with respect to long-term monitoring sites at Tallgrass Prairie National Preserve.

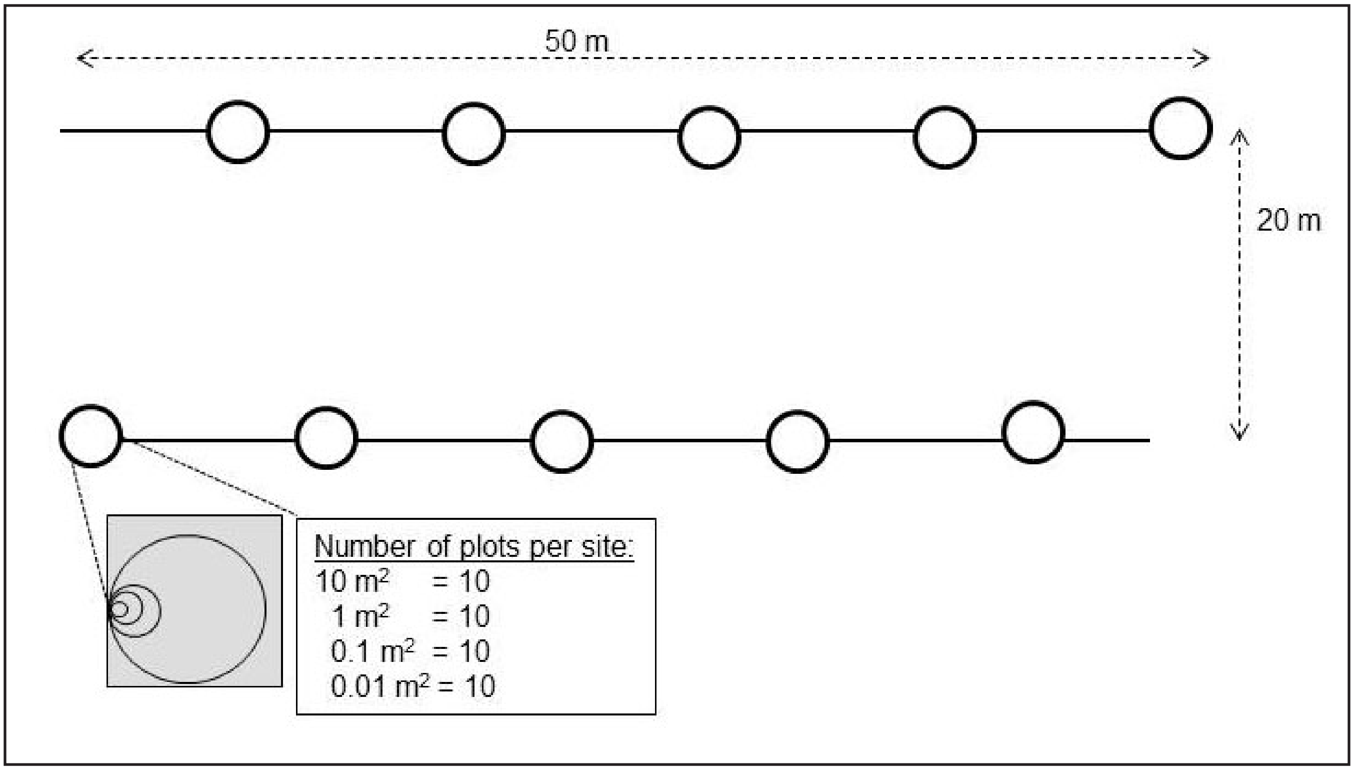


**Figure 3.** Heartland Inventory and Monitoring Network basic long-term vegetation monitoring sampling site design. Each site consists of 10 nested plots.

>> 0.05), so there is no evidence that the samples come from different populations. In other words, it was determined that it was reasonable to use the data from 30 sites for the years that they were available (2010 and 2014), and compare these data to the 18 sites in other years.

As a result, descriptive (graphical) analyses of the woody cover, bare ground cover, and FQI data (questions 3, 4 and 5 below) included all 30 sites (209 total observations) to obtain more precise parameter estimates. Analyses with a repeated measures design (ANOVA or the nonparametric Friedman test; questions 3, 4 and 5 below) included only the core 18 sites for which data were available for all years (18 sites x 9 years = 162 observations). Of these 18 sites, seven were located in Big Pasture, four in Crusher Hill Pasture, 4 in Red House Pasture, and three in Windmill Pasture.

Analysis of the grazing and fire frequency datasets included comparisons between two blocks of time: up to 2005 and 2006 to 2014. This was informative because we recognized that significant changes in management approaches occurred in 2006. The current paradigm of management for ecological heterogeneity was also being defined and implemented in the post-2006 dataset (Hase 2016).

We evaluated our focal questions by calculating statistics at both the preserve and pasture scale, with the exception of grazing history, which was only evaluated at the pasture scale. The pasture scale is the scale at which management typically occurs. We employed parametric tests unless their assumptions (e.g., normality) were violated, and in such cases used nonparametric comparisons. All statistics were calculated in SPSS (IBM 2011). Statistical significance was assessed at the alpha = 0.05 level.

Details on tests used for the specific questions outlined in the introduction are explained in the following paragraphs. Generally, when repeated measures ANOVA was applied, Mauchly's test was used to evaluate the assumption of sphericity. A significant result indicated that the condition of sphericity had not been met. In such cases, a correction factor is necessary. A correction factor was chosen based on the following criteria: if the Greenhouse-Geisser Epsilon was ≥0.75, then the Huynh-Feldt correction applied; if Epsilon was <0.75, then the Greenhouse-Geisser correction was used (Norusis 2008).

### *Question 1: Has the grazing regime changed through time?*

Grazing history was evaluated by comparing annual stocking rates for five different pastures (Big, Crusher Hill, Red House, Windmill and Two Section) in two time periods (1995–2005 [n=11 years] and 2006–2016 [n=11 years]) using Mann-Whitney tests (Daniel 1990). Stocking rate data were available at the level of the pasture only and was not a site-level variable. Bison were present at Windmill after 2009 and not included in these analyses.

### *Question 2: Has fire frequency changed through time?*

Similar to the grazing history, we divided the record into two time periods: 1998–2005 and 2005–2015. We calculated time since fire on a site-by-site basis as well as calculating a spatial fire frequency map. For the spatial analysis we included data from 1998–2015. The frequency map was calculated using burned area polygons. Polygons prior to 2009 may have been drawn based only on the burn units attempted and not necessarily reflect unburned areas within the units. After 2009, polygons were based on GPS data using a 1-acre (0.4 ha) threshold. After applying the *union* function, number of times burned was tallied for the period of interest.

For the monitoring site-based analysis, we calculated time since fire on an annual basis for each monitoring site (30 sites). Knowledge of burned status prior to 2009 was based on the spatial fire data. Post-2009, burned status was assigned based on actual visits to the sites during post-burn monitoring. Site scale time since fire values were averaged to the burn unit scale (17 observations per site for the whole period). The 2001–2005 time period included five observations per site and the 2006–2017 period included 12 observations per site. We report some values at the sub-pasture level, because it is the scale at which fire is applied to the landscape. We did not aggregate the sub-pasture units because trends results will be more useful to managers at the scale that fire management is applied.

### *Question 3: Has woody cover changed through time?*

The core 18 monitoring sites were used to assess woody cover through time. Woody cover data were evaluated using a nonparametric Friedman test (Daniel 1990). We explored bivariate correlations using Kendall's tau between woody cover and stocking rates, and between woody cover and precipitation, both on a pasture-by-pasture basis. We looked at whether the change in woody cover over time was different among pastures; since stocking rate was a pasture-level factor, a Kruskal-Wallis test was used. The potential effect of fire return interval on woody cover was evaluated by taking the difference between woody cover in the last year (2014) and the first year (2002), and evaluating correlations using Kendall's tau with three summary fire return interval metrics: mean time since fire, maximum time since fire, and total number of times burned.

### *Question 4: Has bare ground cover changed through time?*

To assess changes in bare ground cover over time, data were arcsine square root transformed and only sites sampled in all years (n=18) were included in the analysis. A two-way repeated measures ANOVA was applied to test for differences. We explored patterns of the variance of the mean through time. We evaluated bivariate correlations using Kendall's tau between woody cover and stocking rates and between woody cover and precipitation, both on a pasture-by-pasture basis. A two-way ANOVA with time since fire (TSF), pasture, and bare ground cover was conducted for years 2010 and 2014. Significant results were graphed.

### *Question 5: Has floristic quality changed through time and what role did species richness play?*

FQI was analyzed using a repeated measures ANOVA on data from the 18 core sites. We explored bivariate correlations using Spearman's rho between FQI and precipitation on a pasture-by-pasture basis. To understand trends in FQI we visually compared FQI trends to species richness trends.

# Results

## Question 1.

Stocking rates were significantly greater for the first 11 years of our study (1995–2005) than in the last 11 years (2006–2016) in five pastures (Figures 4 and 5, Table 1).

**Table 1.** Difference in stocking rates between two time periods (1995–2005 and 2006–2016) at Tallgrass Prairie National Preserve.

| Pasture | Mann-Whitney U | P |
|---|---|---|
| Big | 0.00 | 0.00 |
| Crusher Hill | 10.00 | <0.01 |
| Red House | 1.00 | 0.00 |
| Two Section | 0.00 | 0.00 |
| Windmill | 3.50 | 0.02 |

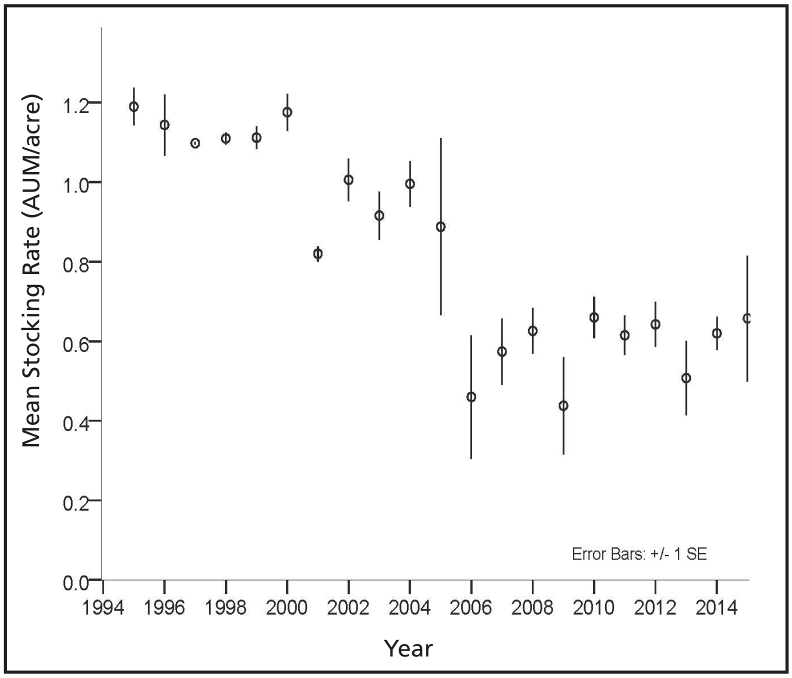


**Figure 4.** Preserve scale mean stocking rates at Tallgrass Prairie National Preserve.

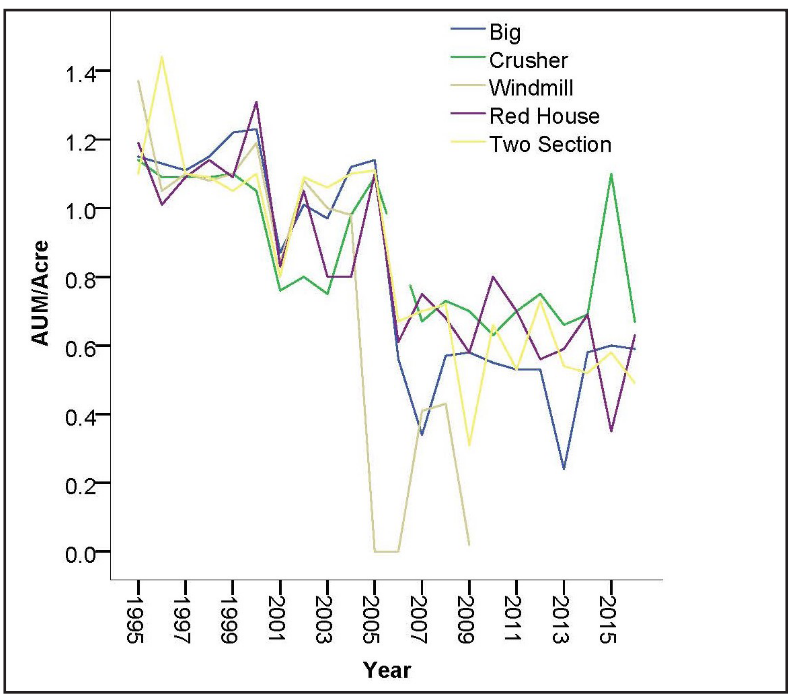


**Figure 5.** Pasture scale stocking rates for five pastures at Tallgrass Prairie National Preserve. All pastures except for Two Section are located on the western Preserve.

## Question 2.

Similar to stocking rates, patterns of fire frequency changed over time on both the preserve scale and pasture scale (Figures 6 and 7). Fires were less frequent on the majority of the preserve during 2006–2015.

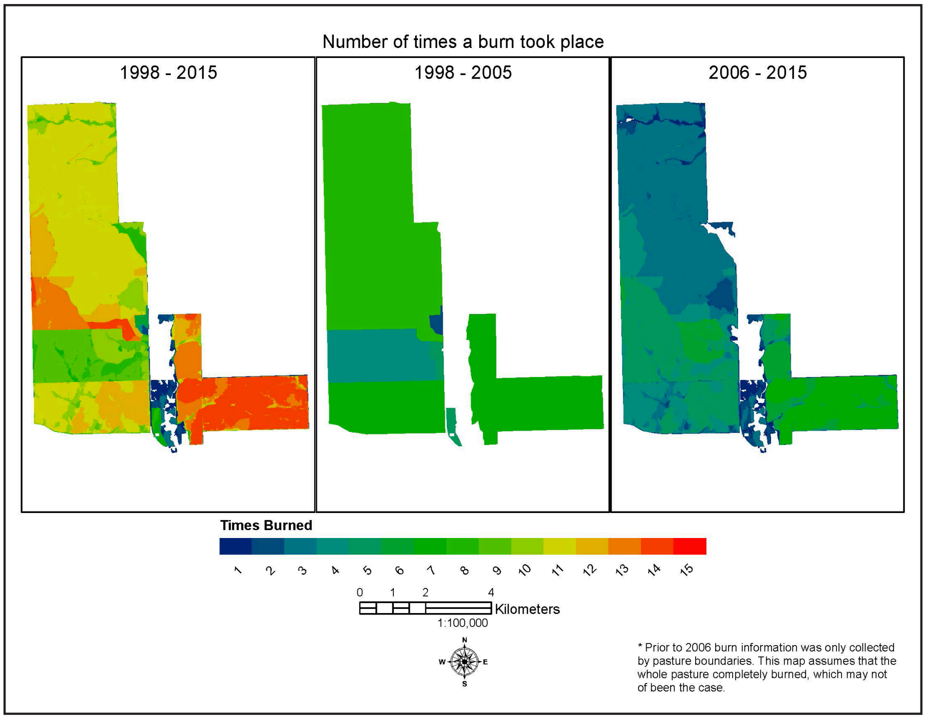


**Figure 6**. Map showing fire frequency for three time periods. Data derived from preserve records, GPS, and satellite data.

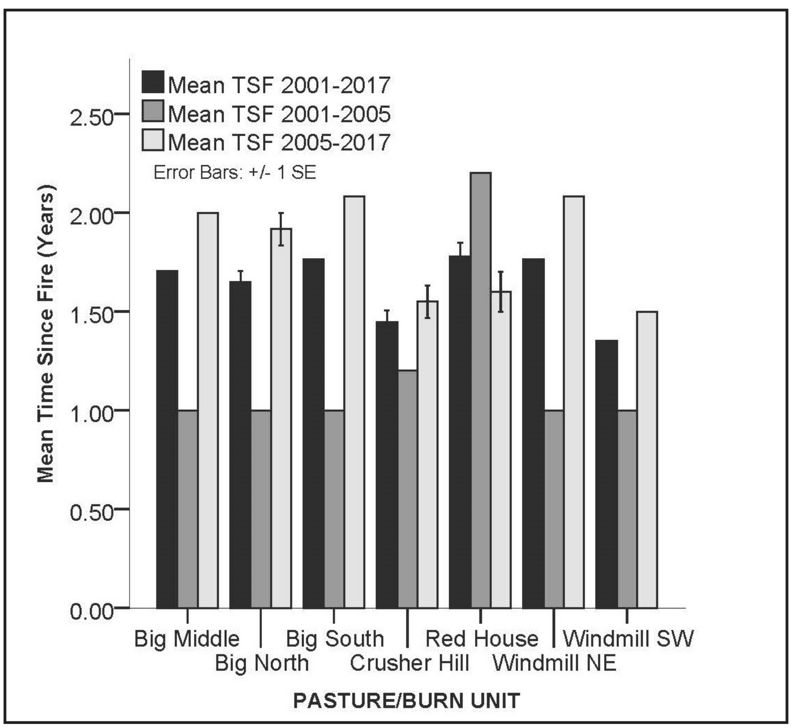


**Figure 7.** Graph of time since burn based on site level data arranged by pasture or burn unit.

## Question 3.

Woody cover increased significantly during the monitoring period. Increases were detected at the preserve scale, but only in Big Pasture at the pasture scale (Figure 8A, B; Table 2). Significant results are shown in graphs below for the preserve scale and Big Pasture. However, woody cover remained below 1%. Big Pasture contained more monitoring sites than other pastures because of its greater area. Therefore, we consider our ability to detect change to be similar across pastures. We did not detect significant relationships between woody cover and precipitation, fire, or grazing (all P >> 0.05).

**Table 2.** Change in woody cover through the 2002–2014 monitoring period at Tallgrass Prairie National Preserve. A nonparametric Friedman test was applied to the data.

| Pasture | N | Chi square | df | P |
|---|---|---|---|---|
| All (Preserve scale) | 18 | 31.40 | 8 | 0.00 |
| Big | 7 | 33.62 | 8 | 0.00 |
| Crusher Hill | 4 | 6.19 | 8 | 0.63 |
| Red House | 4 | 10.35 | 8 | 0.24 |
| Windmill | 3 | 6.72 | 8 | 0.57 |

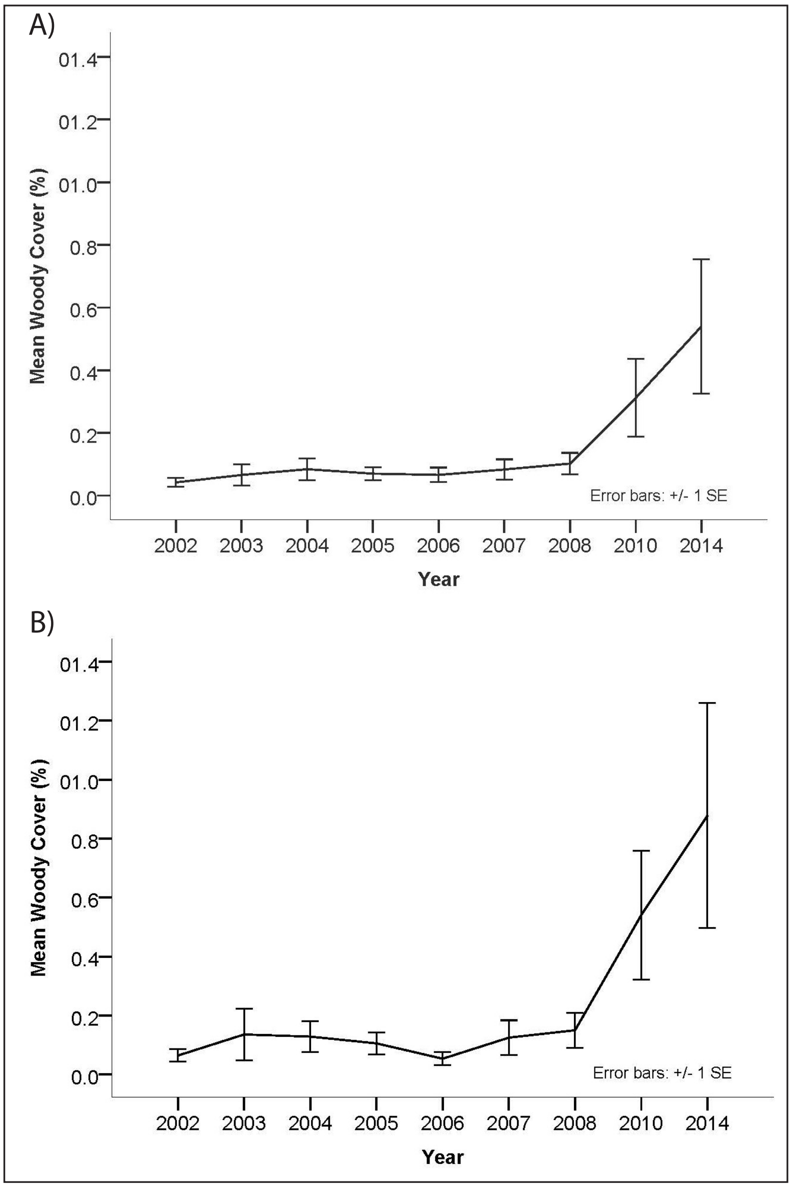


**Figure 8.** Significant results for mean woody cover at Tallgrass Prairie National Preserve, 2002–2014. A. Woody cover results at the preserve scale. B. Woody cover results at Big Pasture management unit. Nonsignificant results at the pasture scales are not shown.

## Question 4.

Bare ground cover declined over the last two to three sampling events in Big and Windmill Pastures as well as at the preserve scale (Figures 9, 10, and 11). The effect of year and the interaction of year with pasture on bare ground cover were significant. The between subjects effect of pasture was marginally significant (P = 0.06; Table 3).

Although the variance in bare ground cover changed greatly over time, there were no significant associations between bare ground cover and stocking rates or precipitation (all P > 0.05).

In a two-way ANOVA with time since fire and pasture as factors and bare ground cover as the response variable, no significant main effects and no significant interaction between the two factors were found in 2010. In 2014, the effect of pasture and the interaction were not significant. Time since fire was significant (F = 44.04, df = 3, P = 0.003), although the relationship of time since fire with bare ground cover was not consistent. For example, at Big Pasture, the mean bare ground cover was the same for two and four years since fire, but much larger for three years since fire (Figure 12). This was an unbalanced design (i.e., not all time since fire categories were represented in all pastures) with relatively small sample sizes.

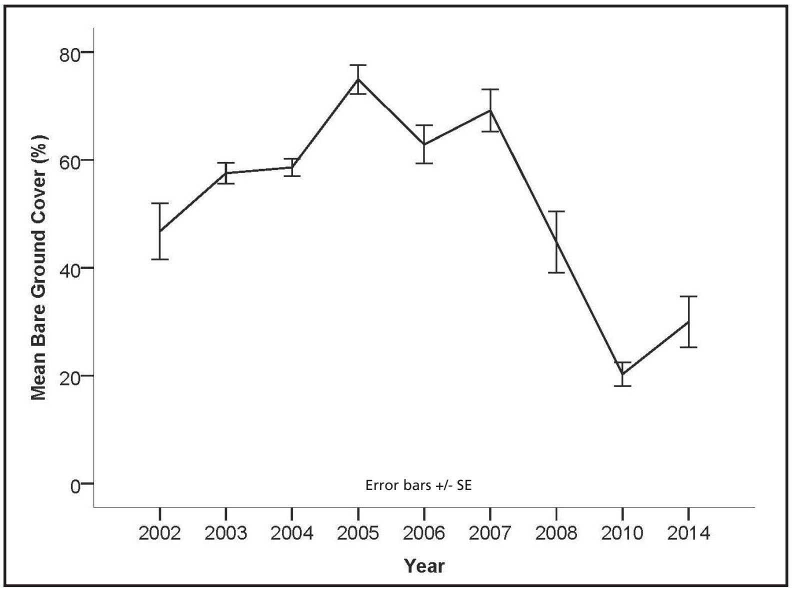


**Figure 9.** Mean bare ground cover at the preserve scale at Tallgrass Prairie National Preserve, 2002–2014.

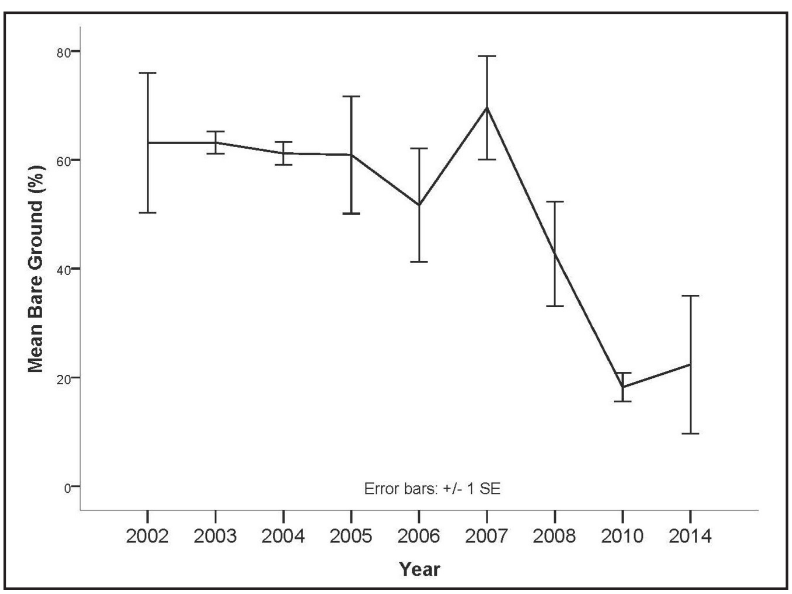


**Figure 10.** Mean bare ground cover at Windmill Pasture (management unit scale) at Tallgrass Prairie National Preserve, 2002–2014.

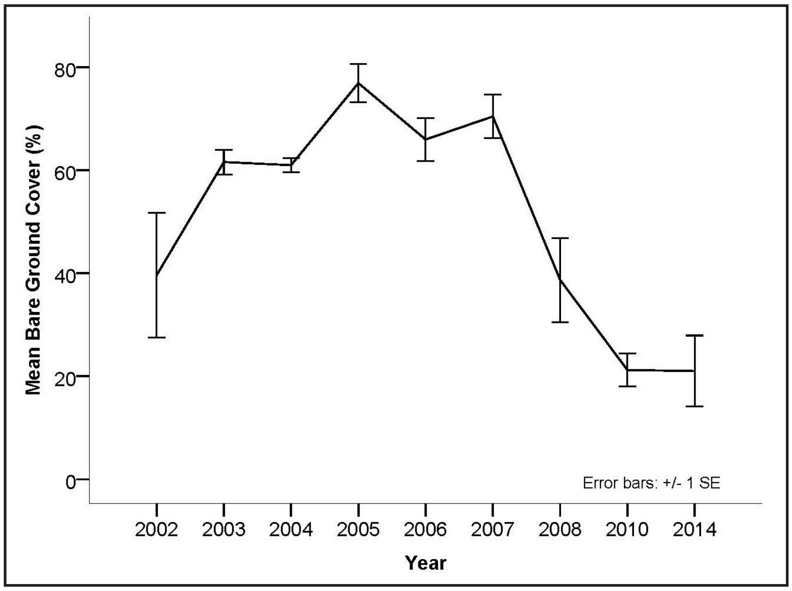


**Figure 11.** Mean bare ground cover at Big Pasture (management unit scale) at Tallgrass Prairie National Preserve, 2002–2014.

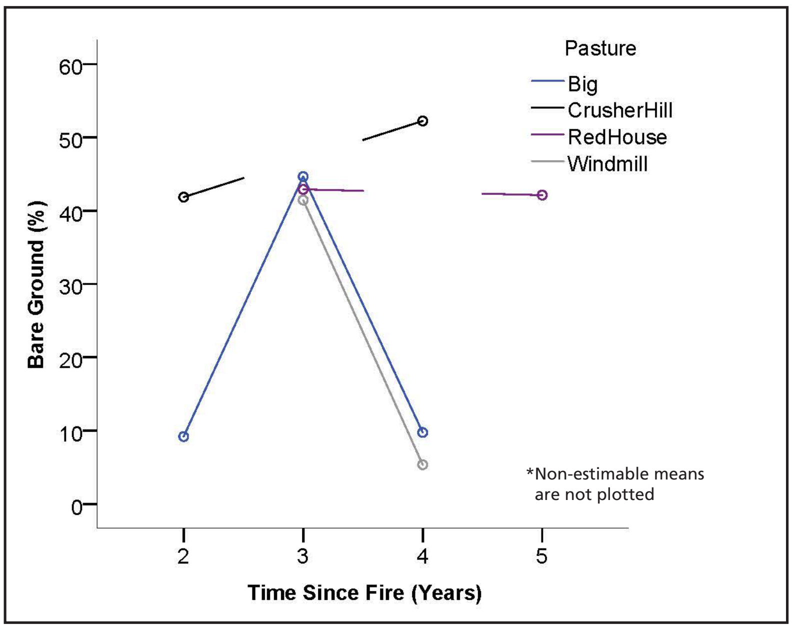


**Figure 12.** Relationship between time since fire and percent bare ground cover by pasture for 2014.

**Table 3.** Results of two-way repeated measures ANOVA on percentage of bare ground through the 2002–2014 monitoring period at Tallgrass Prairie National Preserve. Mauchly's test of sphericity was significant ($P < 0.001$), and Epsilon was 0.374, so the Greenhouse-Geisser correction was applied.

| Effects Test | Source | Sums of Squares | df | Mean Square | F | Significance |
|---|---|---|---|---|---|---|
| Tests of within-subject effects | Year | 19492.07 | 2.99 | 6515.38 | 25.77 | <0.001 |
| | Year x Pasture | 9019.52 | 8.98 | 1004.95 | 3.97 | 0.001 |
| | Error (year) | 10591.28 | 41.88 | 252.88 | – | – |
| Tests of between-subjects effects | Intercept | 307668.54 | 1 | 307668.54 | 4187.47 | <0.001 |
| | Pasture | 696.28 | 3 | 232.09 | 3.16 | 0.058 |
| | Error | 1028.63 | 14 | 73.47 | – | – |

## Question 5.

We found a significant interaction of year and pasture as well as a significant effect of year on FQI (Table 4; Figure 13).

In trying to understand the FQI decline in 2014, we plotted species richness (Figure 14). The 2014 decline in FQI appears to have resulted from a similar decline in its component species richness. The cause of this decline is unclear and may be related to changes to the sampling protocol (change from two visits to one visit per year, *see methods*).

There was a tendency for greater precipitation to be associated with greater FQI values (Figure 15). However, precipitation was only significantly associated with FQI for a single pasture (Crusher Hill; Spearman's rho=0.62, P=0.77, n=9). As a result of multiple potential causes, more years of data will be required to understand the driver(s) behind the 2014 FQI decline.

**Table 4.** Results of repeated measures ANOVA on the floristic quality index through the 2002–2014 monitoring period at Tallgrass Prairie National Preserve. Mauchly's test of sphericity was significant (P < 0.045), and Epsilon was 0.484, so the Greenhouse-Geisser correction was applied.

| Effects Test | Source | Sums of Squares | df | Mean Square | F | Significance |
|---|---|---|---|---|---|---|
| Tests of within-subject effects | Year | 129.15 | 3.87 | 33.34 | 29.90 | <0.001 |
| | Year x Pasture | 33.56 | 11.62 | 2.89 | 2.59 | 0.009 |
| | Error (year) | 60.47 | 54.23 | 1.12 | – | – |
| Tests of between-subjects effects | Intercept | 63542.43 | 1 | 63542.43 | 1770.51 | <0.001 |
| | Pasture | 47.41 | 3 | 15.80 | 0.44 | 0.728 |
| | Error | 502.45 | 14 | 35.89 | – | – |

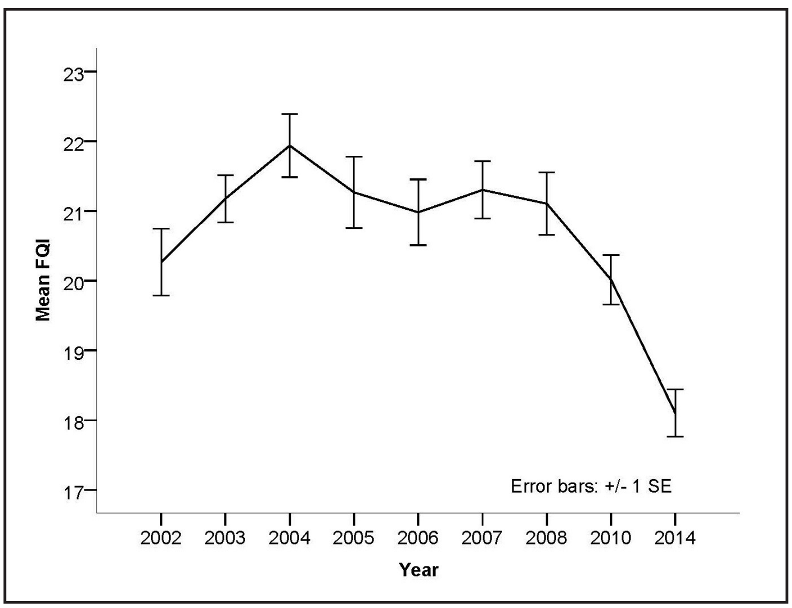


**Figure 13.** Floristic quality index for monitoring sites at the Preserve scale for Tallgrass Prairie National Preserve, 2002–2014.

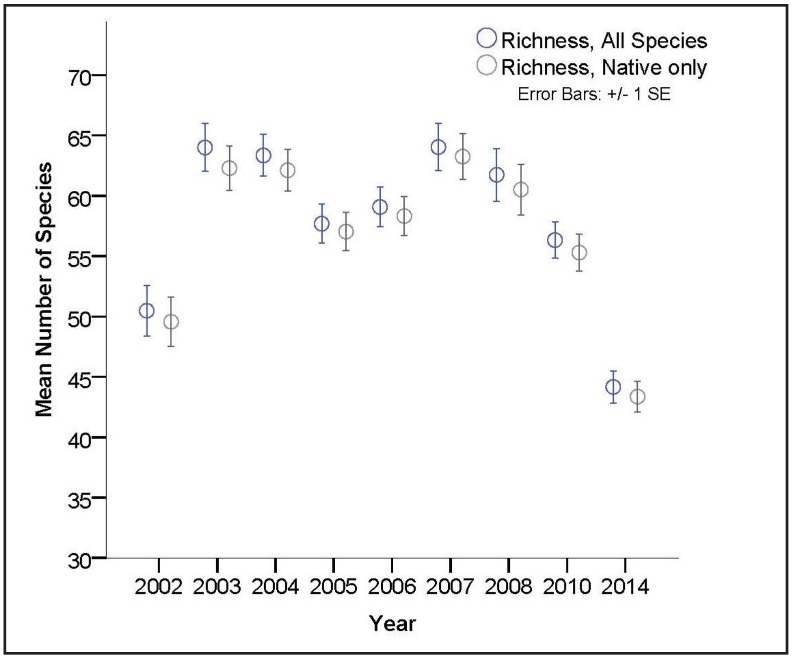


**Figure 14.** Mean total species richness at the preserve scale through the 2002–2014 monitoring record at Tallgrass Prairie National Preserve.

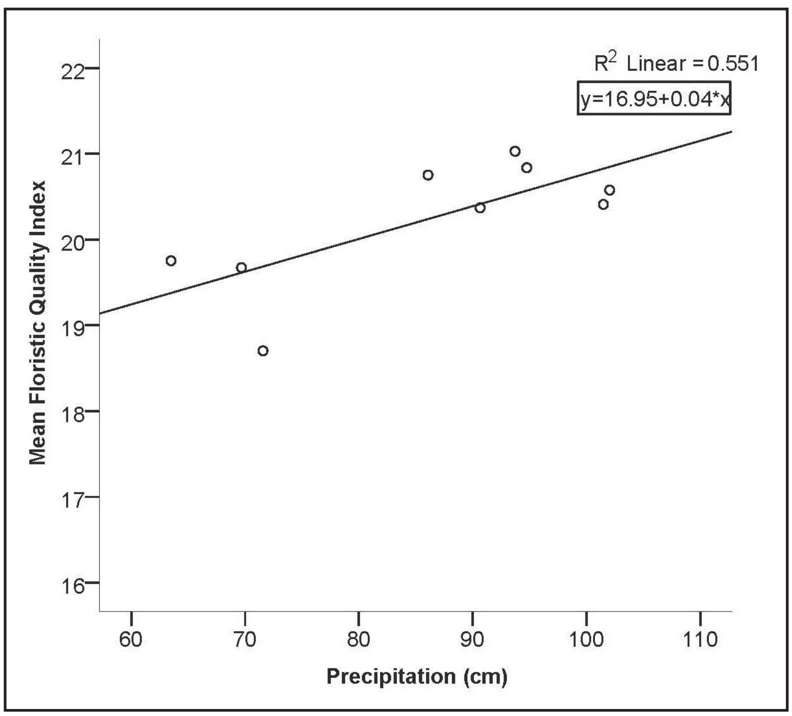


**Figure 15.** Mean floristic quality index as related to precipitation in Crusher Hill Pasture at Tallgrass Prairie National Preserve, 2002-2014.

# Conclusions

Tallgrass Prairie National Preserve's mission is to protect a functioning tallgrass prairie community (Tallgrass Prairie National Preserve Act of 1996). Prairie ecosystems are affected by a variety of disturbances such as grazing, fire, and drought (Gibson 2009). These disturbances, whether human caused or natural, may affect ground cover or species abundances and composition. In this suite of analyses, we sought to learn about the management history of the Preserve and vegetation trends.

## Question 1

The Preserve has a long history of cattle grazing. In the first 11-years of our grazing record, fires were annual and stocking rates were heavy. Qualitatively, the horizontal vegetation structure was closely grazed and homogenous. Stocking rates declined significantly in the latter half of our record (Figure 4).

## Question 2

In the latter half of our record, fire return intervals appeared to be longer from a preserve-wide perspective. However, some pastures continued to be burned frequently, particularly the east side of the Preserve (not studied in detail here).

## Question 3, 4

We recorded a decline in bare ground cover and a small increase in woody cover that corresponded with the declines in grazing and fire. Unfortunately, an experimental design did not exist to allow for direct determination of cause and effect. While the increase in woody cover was significant, we recognize that the mean value is below 1%. This value is below the 5% threshold described in the Fire Management Plan (Hase 2016). Native woody plants (non-tree species in particular) are an important component of grasslands. They provide thermal and escape cover for grassland birds as well as food for many species (Horncastle et.al. 2005; Hovick et.al. 2014). However, this guild of plants can exceed heathy thresholds for prairies (Collins and Gibson 1990; Hoch et.al. 2002). Control of woody plants can be a challenge when they become too abundant. In that regard, this is an important trend to continue to observe.

## Question 5

Our floristic quality index values are similar to values for warm season grass pastures in Kansas (i.e., mean FQI = 21; Jog et. al 2006). These values indicate prairie with substantial diversity. Furthermore, FQI values in our study are greater than those reported in a study of Missouri native remnant prairies which described values ranging from 12 to 18 (Briggler et. al. 2017). FQI values on our study were also substantially greater than less diverse introduced cool season pastures described by Jog et.al. (2006) with mean FQI values of 0.3.

Although we documented changes in the disturbance regime, the FQI pattern appeared to be relatively stable over time, with the exception of 2014. The FQI in our study showed some annual fluctuation but more notably a recent decline. We cannot directly attribute the decline to management or sampling error. For the last monitoring event, however, only a single sample event was collected. In previous years, plots were revisited twice per year. James et.al. (2009) predicted an 8% loss of species richness resulting in the change in sampling schedule. Since our mean C values increased while species richness declined in 2014, it lends credence to sampling error being the culprit. Additional years of data will be needed to better discern whether the drop in FQI is perhaps a precipitation factor, as suggested in Figure 15, or a sampling error factor.

Briggler et.al. (2017) demonstrated that losses in floristic quality with patch burn grazing were temporal and recovered in focal patches the year after burning. Our results at the pasture and preserve scales similarly show stability in the floristic quality index over a longer timeframe with the exception of the 2014 decline.

## Next steps

We were able to document some changes to the prairie and management over the record 2001–2014 despite not having an experimental design including planned treatments. An experimental setting with control over the treatments could provide a much stronger basis for inference of fire or grazing effects than we had with our monitoring approach.

Some vegetation goals are included in the Fire Management Plan (Hase 2016), but the Preserve does not currently have an official vegetation management plan. Efforts are underway to begin that process. The information presented here documenting management changes through time and resulting changes in vegetation will help inform future discussions of management goals, methods, and target conditions.

Together these patterns in stocking rate, fire history, bare ground cover, woody cover, and floristic quality index also set the stage for future analyses of species composition. Our next data collection is planned for summer 2018.

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525