Response of vegetation and soil nitrogen to haying in a restored prairie

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Introduction

Prairie ecosystems are adapted to frequent disturbances, such as fire, grazing, or drought, which help remove thatch buildup and undesirable vegetation (e.g., woody species or non-native invasive forbs and legumes) and promote high-diversity plant communities. These high-diversity plant communities can in turn support a high diversity of fauna, especially pollinators. Increasingly, however, as Minnesota's original prairie landscape continues to be fragmented with housing developments and agriculture, employing necessary disturbance regimes such as prescribed fire or grazing can become impractical.

Haying has been proposed as a novel disturbance regime in prairies, as it can remove periodic thatch buildup and has potential to remove excess soil nutrients, which can otherwise promote weedy and undesirable vegetation. Our study sought to evaluate the response of vegetation and soil nitrogen to haying in a restored prairie in the east metropolitan area of Minnesota. Specifically, we assessed changes in vegetation cover (percent coverage of forbs, legumes, graminoids, litter, bare ground, woody species, and blooms of forbs and legumes), forb species richness, and soil nitrogen after two years of repeated haying in comparison to control units without haying.

Since floral variables alone give an incomplete assessment of the effectiveness of prescribed haying as a prairie management technique, another component of this study, led by Xerces, examined pollinator abundance, diversity, and floral interactions in hayed and control plots. Anticipated benefits of haying to pollinators include higher diversity and abundance of forbs during the spring season when nectar and pollen is most limited; lower abundance of nitrophilic forb species; higher forb-to-grass ratio; and reduced thatch/easier access to soil for ground nesting bees.

Methods

Site Description and Study Design—South Washington Conservation Corridor is an 84-acre restored prairie located in Washington County, Minnesota. The physical conditions of the site consist of rolling topography formed by ice block deposits from the last glaciation and underlain by sand and gravel outwash deposits (EOR 2002). Soils consist primarily of moderately well to well-drained silt loam. Prior to the study, all plots had been seeded with 128 prairie-adapted species native to Minnesota, including 38 graminoid and 90 forb species. Study units ranging from 2.5 to 5 acres were assigned to alternating control and hay treatments (Figure 1).

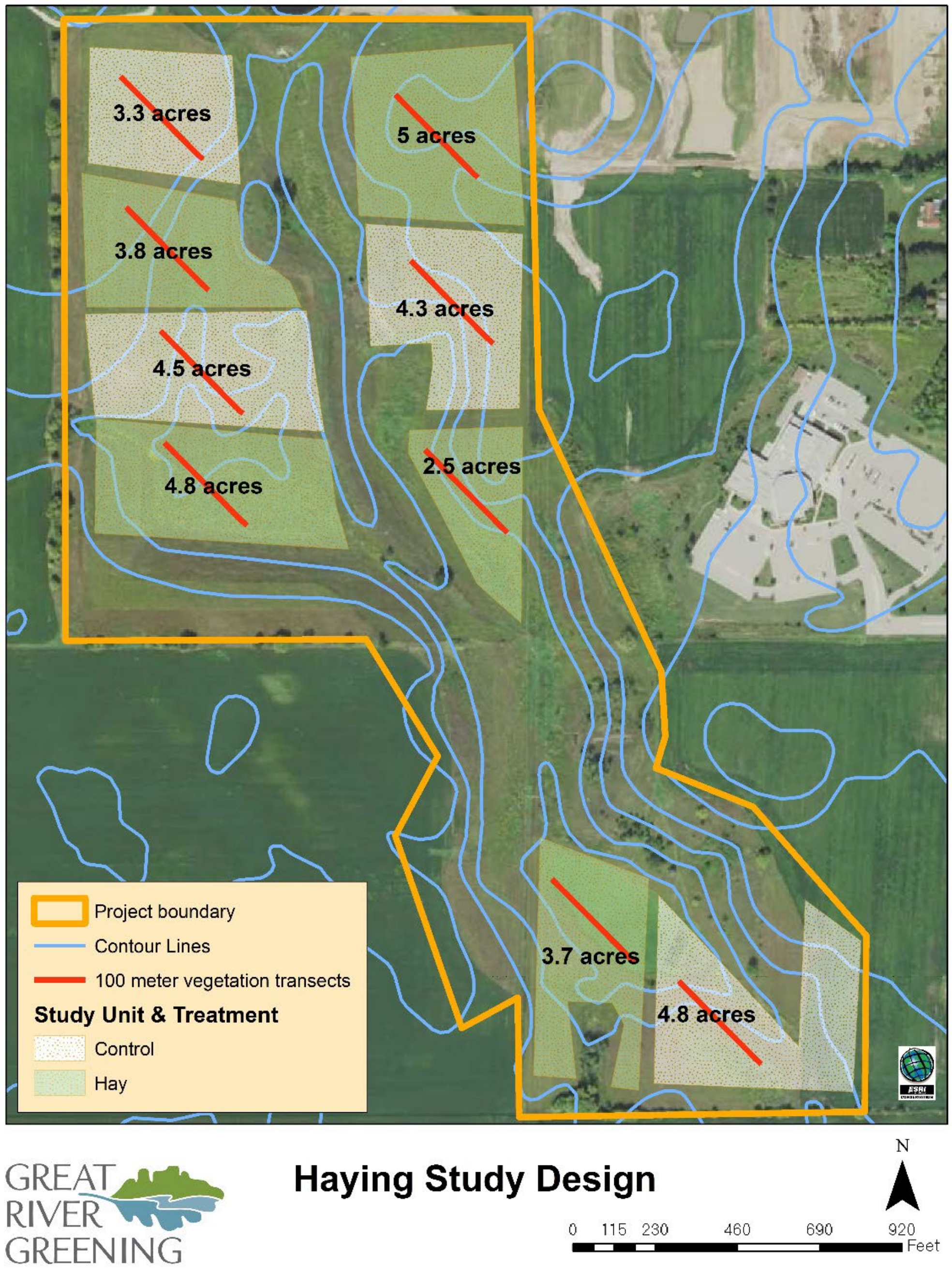

Figure 1 Haying Study Layout and Design

Haying—Hayed units were hayed by Strohfus Stock Farm, LLC in October 10, 2015, early November 2016, and October 18, 2017. Vegetation was cut to a height of 11 cm (4.25 in).

Vegetation and Soil Surveys—Using GIS software (ArcMap 10.5.1, ESRI 2017), a 100 m transect was mapped out along the longest part of each study unit (Figure 1). All transects were located at least 10 meters from the edge of the unit to avoid edge effects. A 20 x 50 cm quadrat was systematically placed along the transects at 0 m, 20 m, 40 m, 60 m, 80 m, and 100 m. In each quadrat, vegetation coverage was estimated based on the following categories: percent cover of graminoids, woody species, forbs (vegetative and blooms), legumes, bare ground, and litter. Vegetation cover was recorded using an 8-point scale (0%, 1%, 3%, 16%, 38%, 63%, 85%, and 96%) per Daubenmire (1959). Additionally, all forbs and legumes (blooming and non-blooming) were recorded to species in each quadrat.

In addition to recording vegetation cover, soil subsamples were collected from the center of each quadrat. Subsamples were collected to a depth of 15 cm (6 in) and composited by transect. Vegetation and soil samples were collected during June, July, and September of 2017, with additional soil samples collected in December of 2016.

Soil Total Nitrogen Analyses—Soil samples were submitted to the University of Minnesota Soil Testing Lab for Total Nitrogen analyses, described by the UMN as follows (UMN 2018):

> This technique uses a LECO FP-528 Nitrogen Analyzer to determine total N in soil materials. A 250-300 mg sample is weighed into a capsule and dropped into an 850°C furnace purged with O_2 gas. The combustion products of CO_2, H_2O and NO_x are filtered, cooled by a thermoelectric cooler to condense most of the water, and collected in a large ballast. A 3 cc aliquot of the ballast combustion products is integrated into a He carrier stream and passed through: 1.) a hot copper column where the O_2 is removed and the NO_x gasses are converted to N_2 and 2.) a reagent tube which scrubs the $CO_2$and remaining H_2O from the stream. The N_2 content is then measured by a thermal conductivity cell against a He background and the result displayed as weight percentage of nitrogen.

Statistical Analyses—Linear mixed effects models were used to examine the effects of treatment (haying vs. no haying) and survey month on soil total nitrogen and forb bloom coverage. Haying treatment and month were included as fixed effects and tested for significance and interaction via Wald's Chi-square test; plot number was included as a random effect. Similar models were used to determine the effects of treatment on functional group canopy coverage (e.g. forbs and graminoids), except survey month was considered a repeated measure and therefore included as a random effect. For all models, where main effects were significant at the 0.05 level, Tukey's honestly significant difference (HSD) for multiple comparisons was used to test for differences among means at a 0.05 significance level. All statistical analyses were performed in R (R Development Core Team 2008).

Results and Discussion

Bloom coverage—We found no significant effect of haying on bloom coverage, nor a significant interaction between haying and month. However, month significantly affected bloom coverage ($p < 0.001$, Figure 1), with September having a significantly higher bloom coverage than June and July; June and July were not significantly different. While significant, the difference in bloom coverage between September and the other two months was minimal, with September, on average, showing a difference in bloom coverage by 2.57% and 3% over June and July, respectively. Nonetheless, the higher bloom coverage observed in September may be due to the presence of a variety of later-blooming forbs, such as species in the goldenrod (*Solidago*) and *Symphyotrichum* genera [e.g., New-England Aster (*Symphyotrichum novae-angliae*)], on the site.

While no differences were observed between haying treatments, future, earlier surveys may show higher bloom coverages in hayed plots. Observationally, certain hayed plots during May 2018 appeared to have higher coverage of lupine (*Lupinus perrenis*) blooms compared to control plots (Figure 2).

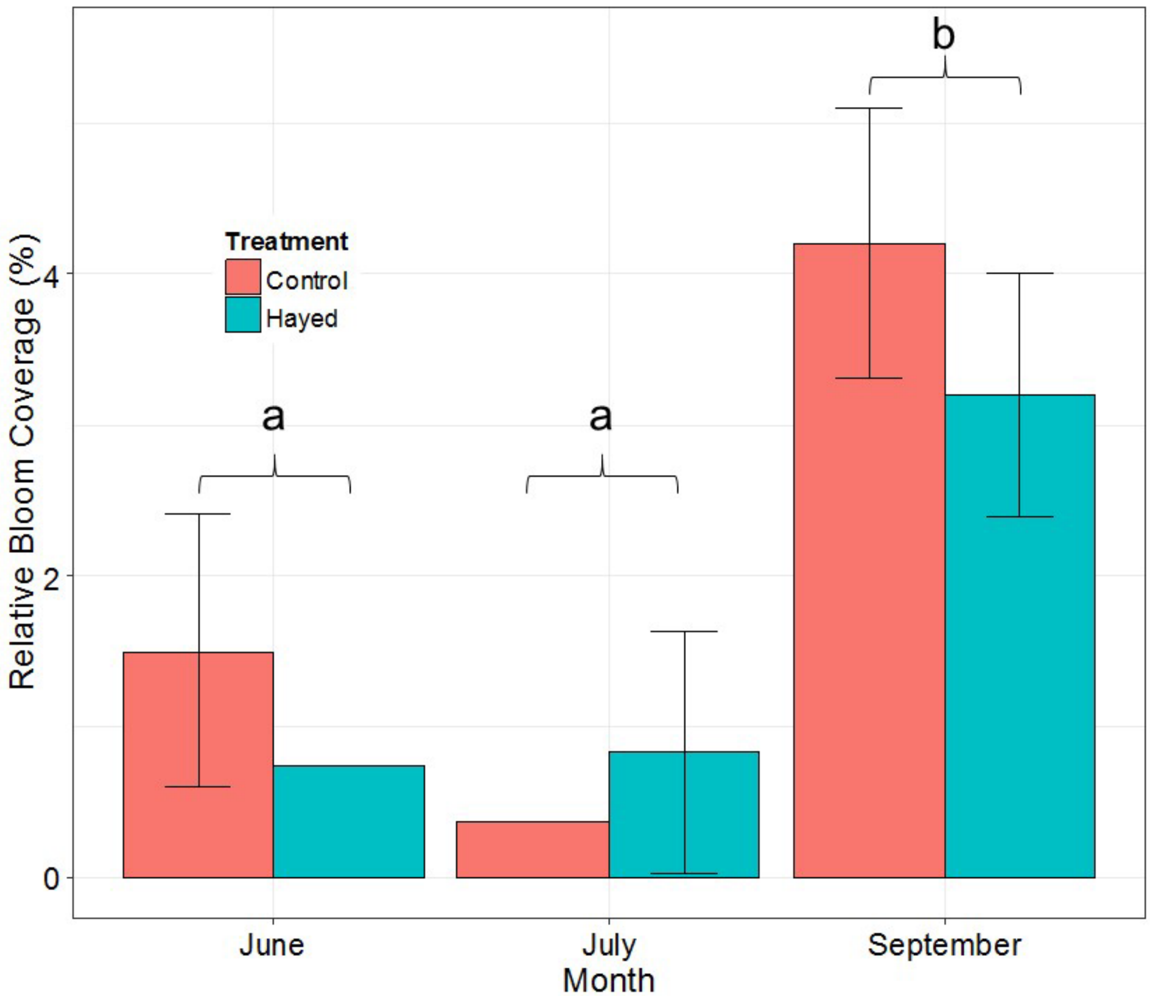

Figure 2 Mean bloom coverage by haying treatment and month. Error bars denote standard error. Different letters above error bars denote significant differences among month as determined by Tukey's HSD test.

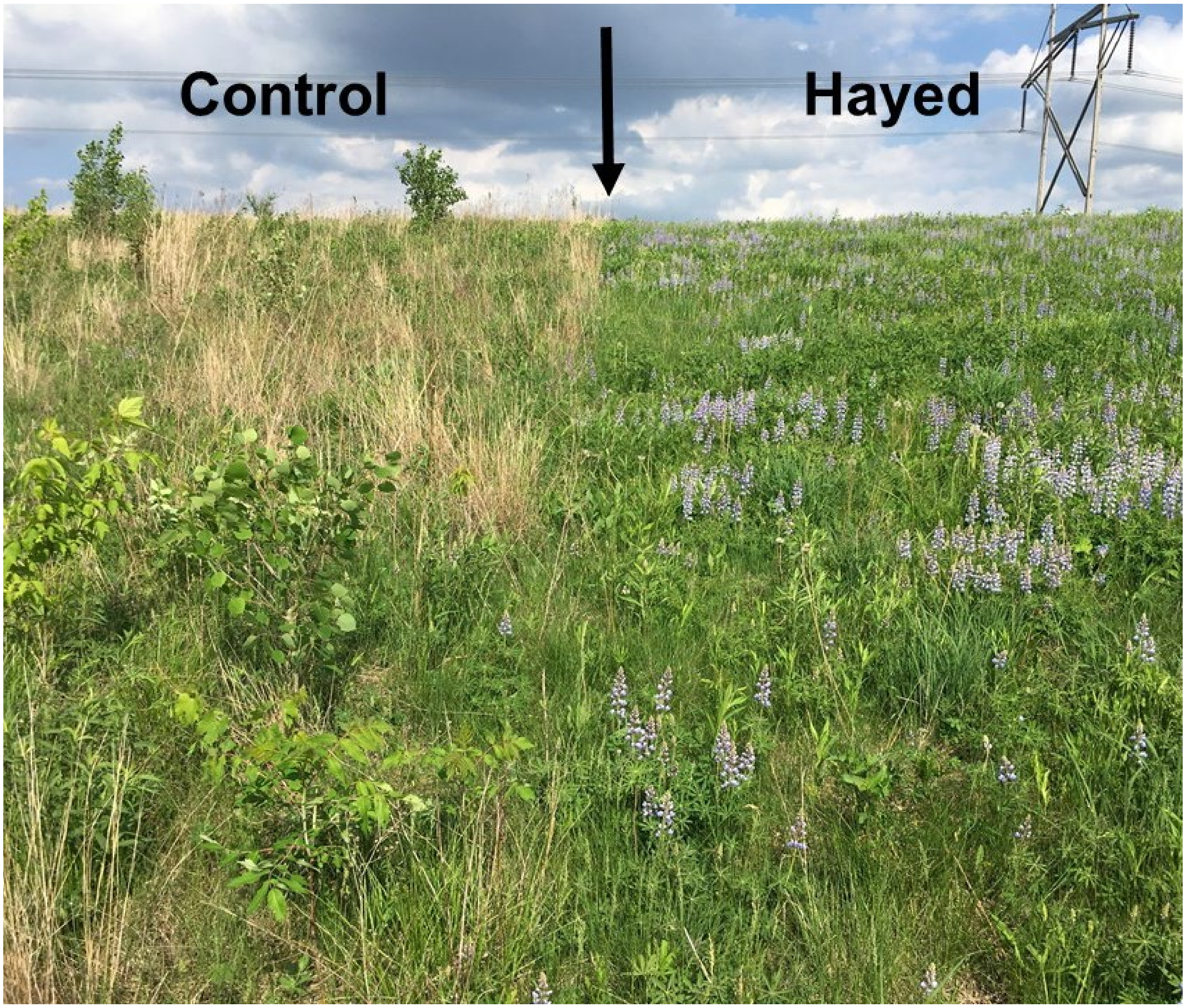

*Figure 3 Lupine (*Lupinus perennis*) blooms in control vs. hayed plots in May 2018.*

Forb and legume species richness

Treatment had a significant effect on forb and legume species richness (P = 0.004998). However, the difference between treatments was slight, with hayed units having, on average, one more species than unhayed units. Furthermore, when native vs. non-native species were considered separately, no significant difference between native species in hayed and unhayed units was identified. This is mainly due to slightly more non-native red and white clover (*Trifolium pretense* and *T. repens*, respectively) being recorded in hayed units.

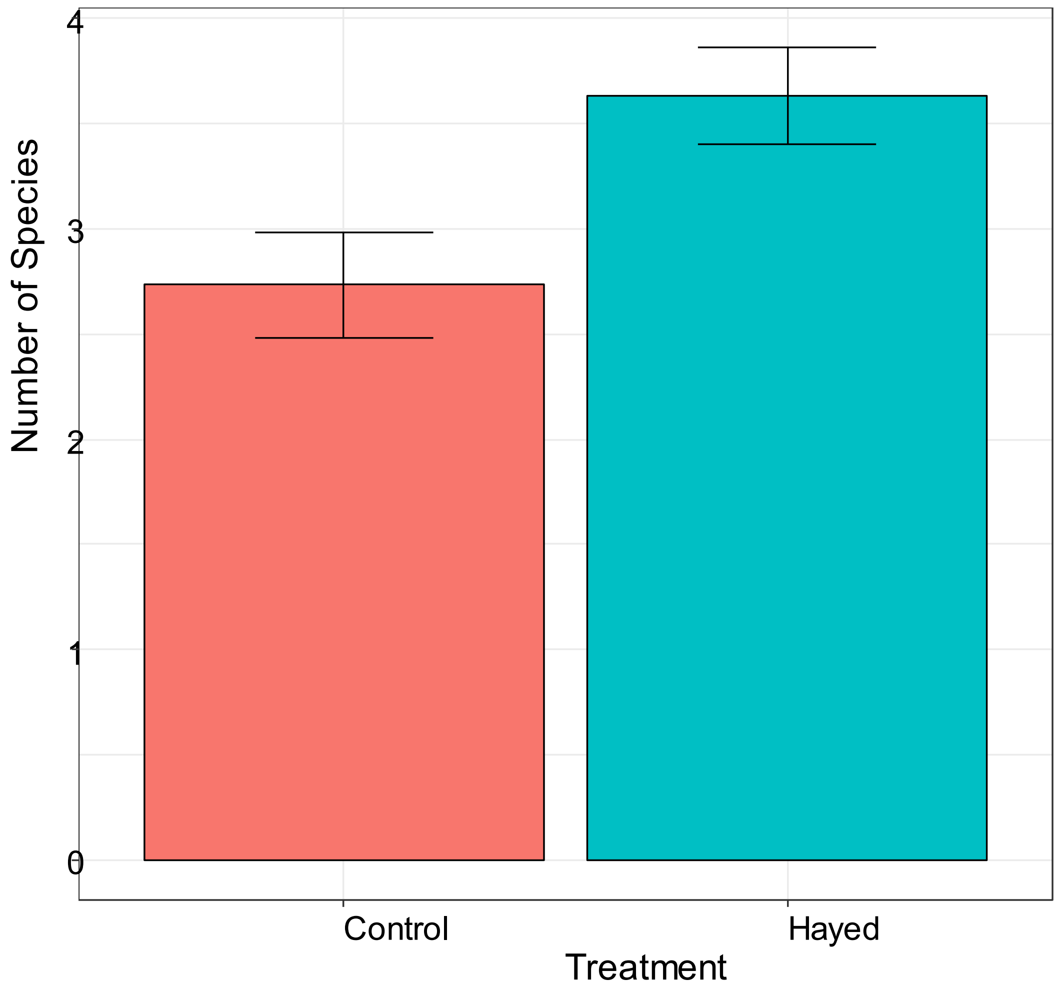

Figure 4 Mean number of species in control and hayed units. Error bars denote standard error.

Functional group coverage

We found no significant difference in canopy coverage between treatments for litter, graminoids, legumes, or bare ground (Figure 4). Although not depicted in Figure 4, bare ground coverage averaged 0.25% and 0.52% for control and hayed units, respectively. Forb coverage was significantly different between control and hayed units ($P = 0.0012$), with hayed units on average having 17.5% greater coverage than control units. The ratios of forb coverage to grass coverage in control and hayed units were also compared (Figure 6). Ratios were significantly different between treatments ($P = 0.041$), wherein hayed units on average had a 5.3-fold greater ratio of forbs to grasses than control units.

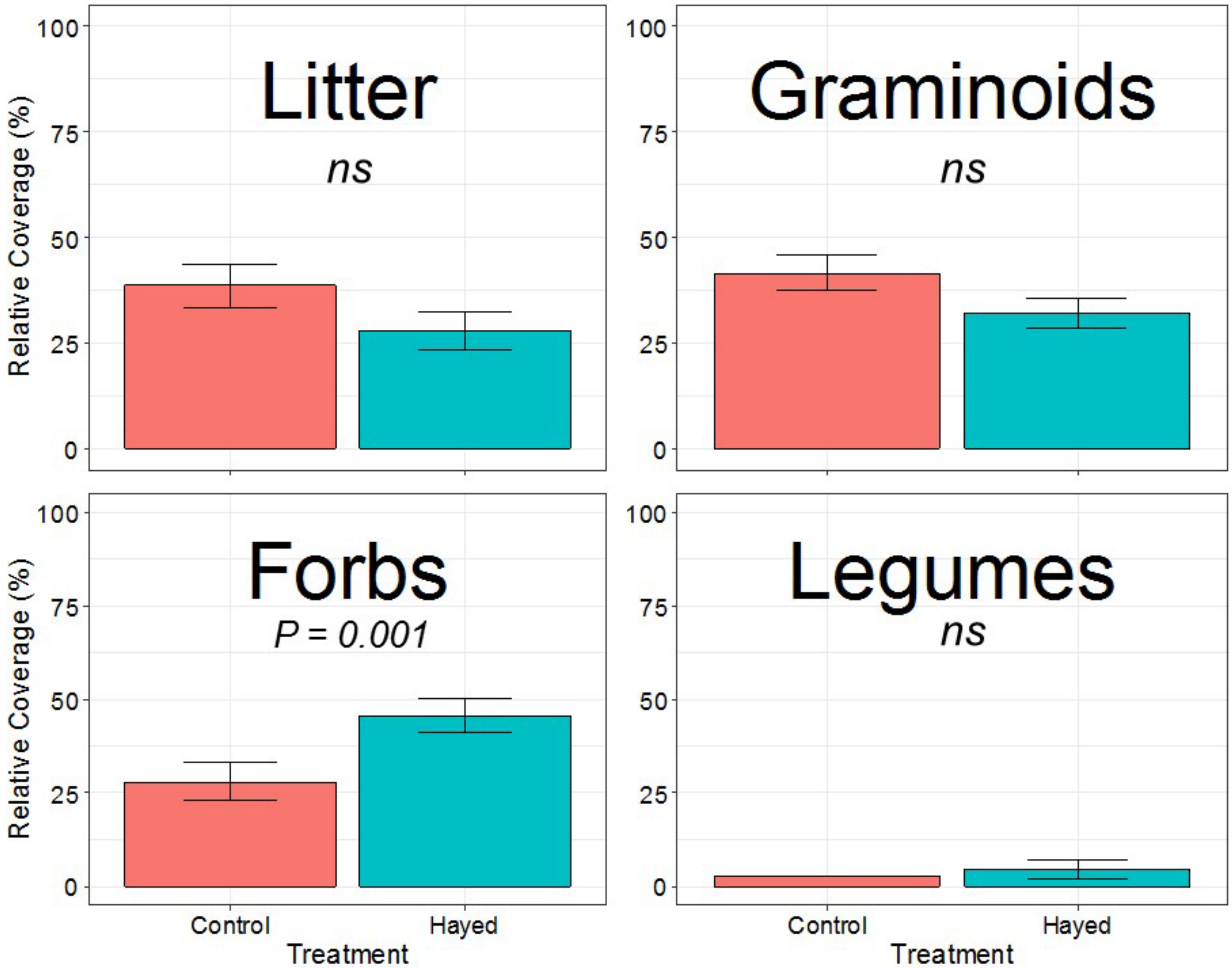

Figure 5 Mean canopy coverage of litter, graminoids, forbs, and legumes. Error bars denote standard error. 'ns' signifies no significant difference between treatments at the 0.05 significance level under the Wald's Chi-Square test. Where significant, the P-value is shown.

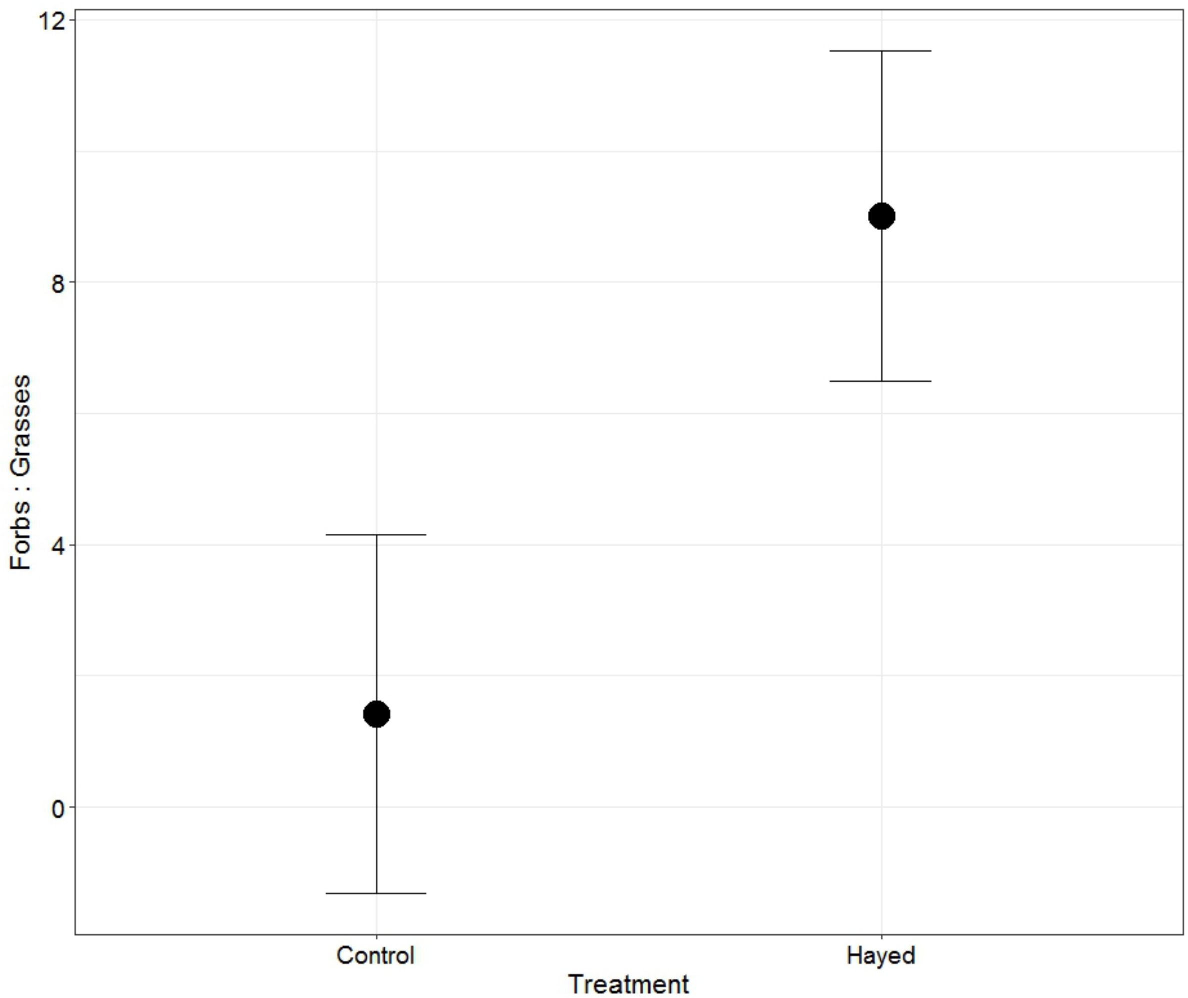

Figure 6 Mean ratio of forb to grass coverage in control and hayed units. Error bars show standard error. Treatment was significantly different at P = 0.0401.

Soil Nitrogen

Haying treatments had no significant effect on total nitrogen at the 0.05 significance level (P = 0.0511); however, month significantly affected total nitrogen (P = 0.0183) when control and hayed treatments were considered together (Figure 5). In this case, the only months that differed significantly in soil N levels were July and September 2017 (P = 0.0451), wherein July was greater than September by 0.014%. It is possible additional years of haying are needed before changes in soil nitrogen can be observed.

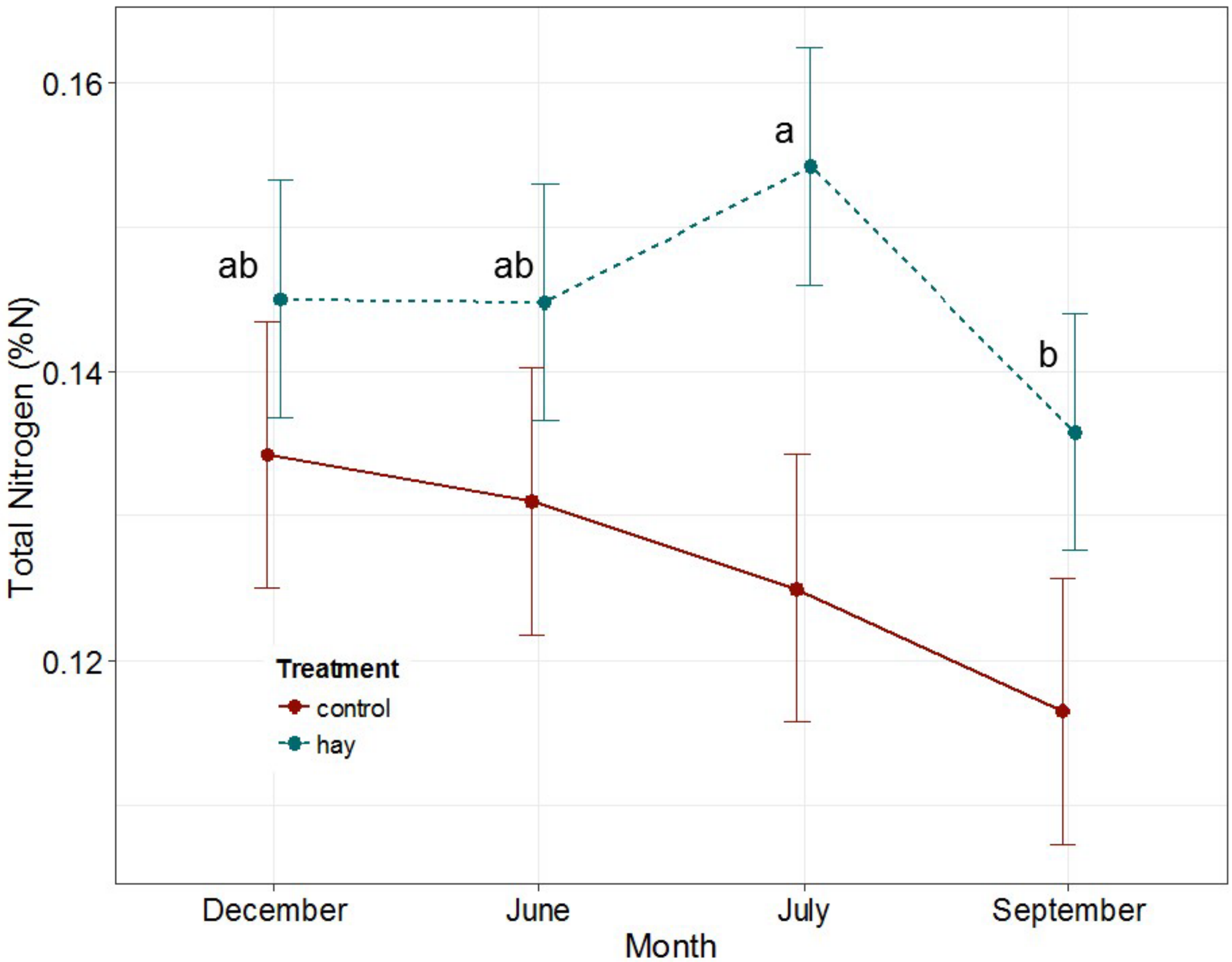

Figure 7 Mean soil total nitrogen by treatment and month. Error bars denote standard error. Letters denote Tukey's test significant differences among month when control and hayed treatments are considered together. Months that share letters are not significantly different. Months with different letters are significantly different at the 0.05 level.

Conclusion and Management Implications:

The goal of this study was to document any changes in soil nitrogen and vegetation, especially as it relates to forb and bloom coverage, in response to haying. Few differences were noted in soil nitrogen and vegetation after three years of consistent haying. Notably, forb coverage was significantly different between control and hayed units, with hayed units on average having 17.5% greater coverage than control units. Additionally, the ratio of forbs to grasses significantly increased by 5.3-fold in hayed units compared to control units. However, this did not seem to drive an increase in overall bloom coverage, which did not significantly differ between control and hayed units. That there was no difference in bloom coverage between the treatments may be reflected by the results of a paired pollinator study, which did not find significant differences in pollinator diversity and abundance between treatments (Foltz Jordan & Herou 2018). The exception to this was for the month of May, which found higher bee diversity and abundance in hayed treatments. Our vegetation survey did not occur during May, which will be an important month for future haying studies, as early forbs and forb blooms are likely more visible then due to a reduction in thatch from the previous year's haying. Since hayed units showed a shift to higher forb:grass ratios, this could suggest a higher number of early-season blooms over control units.

Overall, given some of the observed desirable changes in vegetation, haying appears to be a viable method for periodic thatch removal, as is often required in prairies, and may be an appropriate alternative to prescribed burns. More research is needed regarding the timing of haying, as it relates to promoting pollinator habitat and nutrient removal, and comparing responses of vegetation and pollinator habitat to different disturbance regimes, such as haying and prescribed burns. Additionally, longer-term data are needed to determine the effects, if any, of haying on soil nutrient levels.

References

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