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The Purple Plague: Effect Of High Intensity Grazing Post Fire On Purple Threeawn Cover And Reproductive Effort And Prairie Dog Responses

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THE PURPLE PLAGUE: EFFECT OF HIGH INTENSITY GRAZING POST FIRE ON PURPLE THREEAWN COVER AND REPRODUCTIVE EFFORT AND PRAIRIE DOG RESPONSES

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PREFACE

This thesis is written in the format appropriate for publication in Rangeland Ecology and Management. This thesis, once approved will be submitted for publication in the above listed journal.

ABSTRACT

Purple threeawn (*Aristida purpurea* Nutt.*)* is a native warm-season bunchgrass found in western Kansas on The Nature Conservancy's Smoky Valley Ranch and across rangelands of western North America. Upon reaching maturity, grazing/clipping pressure decreases for this bunchgrass due to poor forage quality and extreme unpalatability for cattle (*Bos taurus*) and Black-tailed prairie dogs (*Cynomys ludovicianus*). This decrease in grazing/clipping has led to development of near monocultures which cause negative impacts to the prairie ecosystem including decreases in rangeland quality and suitable habitat for prairie dogs, a keystone species. This decrease in prairie dog habitat directly affects many species on the ranch that rely on prairie dogs for habitat, including the Black-footed ferret (*Mustela nigripes*), North America's most endangered mammal. This study aimed to determine a large-scale management strategy using natural processes such as fire and grazing to decrease purple threeawn cover and reproductive effort. Treatments investigated the effects of high intensity grazing by cattle, at short duration and season long, as well as the effects of clipping by prairie dogs, post burn. Through two grazing seasons, purple threeawn percent cover did not changed. However, reproductive ability decreased in both short and long duration grazing treatments, by means of decreased live purple threeawn crowns and increased dead purple threeawn crowns, as well as decreased purple threeawn seedstalk densities. A larger decline was seen in the short duration grazing treatment from 2017 to 2018 than in the long duration grazing treatment. With this decrease in purple threeawn reproductive ability, prairie dog densities increased within both short and long duration grazing treatment plots, with the greatest increase in

the short duration treatment. These results will help inform management of purple threeawn to increase forage and associated economic benefits, while creating better quality habitat for prairie dogs and the organisms that rely on them.

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Thank you, Lord, for this opportunity to further my education and begin a career in a field dedicated to conserving your amazing creation.

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INTRODUCTION

The Great Plains grasslands of North America once spanned 162 million ha from Canada to Mexico, and from the foothills of the Rocky Mountains east to Indiana and Wisconsin (Samson and Knopf, 1994). Today, up to 70% of the Great Plains grasslands have been lost for a variety of reasons, including conversion to agriculture, recreational uses (i.e., 4x4 and snowmobile trails), and urban developments (Samson et al., 2004). Other factors that continues to affect the Great Plains is the change in ecological drivers. The Great Plains ecosystem evolved and was maintained through natural processes such as fire and grazing (Anderson, 1990; Debano et al., 1998; Wright and Bailey, 1982). Changes in the ecological drivers have occurred due to poor grazing management (e.g., overstocking, poor spatial distribution, etc.) and fire suppression (Samson et al., 2004). These changes have negatively impacted the fauna and flora of the Great Plains.

Due to these poor management strategies and fire suppression, native prairies have been over-taken by non-native, introduced, or undesired native species (Ramirez-Yanez et al., 2007). Invasive and encroaching plants have many negative effects on the ecosystem, including reduced quality of wildlife habitat, reduced rangeland economic value, altered ecosystem processes, and displacement of desirable plant and animal species (DiTomaso, 2000; Masters and Sheley, 2001). The impact of invasive and encroaching species in rangelands costs an estimated 35 billion dollars annually for control and loss of product (Pimentel et al., 2005).

One species of concern across the western Great Plains is purple threeawn (*Aristida purpurea* Nutt.). Purple threeawn is a native, warm-season, perennial bunchgrass with densely tufted culms and very narrow basal leaves (Cronquist et al., 1977). The inflorescence is a panicle with reddish-purple spikelets. Each floret bears a twisted column split into three long awns on one end and a sharp, hairy callus on the other. Purple threeawn is not of concern on rangelands with minimal disturbance (Hyder et al., 1975; Smeins et al., 1976), but on rangelands with frequent disturbance (e.g., overgrazing by cattle or clipping by prairie dogs), purple threeawn readily takes over bare ground, creating monocultures, and causes numerous ecological and economic problems (Evans and Tisdale, 1972). Livestock avoid purple threeawn most of the year due to its poor forage quality (Meyer and Brown, 1985) and its production of sharp awns at maturity causes discomfort and abscesses to the mouth/gums of grazers. However, there is a short time in the spring and fall when livestock might utilize purple threeawn. Fire can increase purple threeawn palatability and forage quality (Richarte-Delgado, 2012), creating conditions where livestock might graze purple threeawn more readily and for longer periods of time.

Understanding the impact prescribed burning has on purple threeawn is necessary for proper management of purple threeawn infested rangelands. Numerous studies have found that purple threeawn is negatively impacted by fire (Owens et al., 2002; Parmenter, 2008; Sorenson, 2010; Wright, 1974), with further evidence indicating that prescribed burns in late summer to fall are most effective at reducing purple threeawn in the next growing season (Russell et al., 2013; Strong et al., 2013a, 2013b). Summer or fall burning increases the palatability of purple threeawn and allow cattle to preferentially graze it. During this time of increased palatability, it might be advantageous to use a specialized stocking system to maximize the benefits caused by fire.

Smith and Owensby (1978) developed Intensive Early Stocking (IES) where stocking rates were doubled, for a short duration, on the rangeland to increase consumption of young, palatable grasses during periods of higher forage quality. Later studies by Owensby and Auen (2013) followed the same IES system but then continued grazing the rest of the growing season, at a normal stocking rate, in an attempt to graze regrowth during times of high productivity. Both of these studies focused on cattle mass gains, but a similar strategy could potentially be used to manipulate purple threeawn and reduce reproductive ability through high intensity early grazing practices.

Purple threeawn is quickly gaining attention on Smoky Valley Ranch (SVR) in Logan County, Kansas, operated by The Nature Conservancy (TNC). The mission of TNC "is to conserve the lands and waters on which all life depends." For SVR, this means protecting a combination of native shortgrass and mixed-grass prairie, and prairie wildlife through natural disturbance regimes such as fire and grazing. Before being purchased by TNC, historical overgrazing on this property led to large monocultures of purple threeawn that have decreased rangeland productivity and negatively impacted the prairie ecosystem. Smoky Valley Ranch's operation is funded and management goals are carried out through grazing leases. Therefore, maintaining a productive rangeland is vital for achieving management goals and continued operation of the ranch. Smoky Valley Ranch actively manages for black-tailed prairie dogs (*Cynomys ludovicianus*). In this ecosystem prairie dogs are a keystone species (Stapp, 1998). Prairie dogs have significant effects on plant productivity, plant community dynamics, and nutrient cycling (Whicker and Detling, 1988). However, prairie dog populations on SVR have declined, partly due to development of purple threeawn monocultures. The decrease in the prairie dog population affects many species on the ranch that rely on them for their habitat. One of these species is the black-footed ferret (*Mustela nigripes*), the most endangered mammal in North America (Sampson and Knopf, 1994), which was reintroduced on the property in 2007. Other wildlife species that are negatively affected by prairie dog decline include Burrowing owls (*Athene cunicularia*), Mountain plovers (*Charadrius montanus*), swift fox (*Vulpes velox*), and ferruginous hawks (*Buteo regalis*) (Sampson and Knopf, 1994; Stapp, 1998).

Controlling purple threeawn is a high priority of SVR (The Nature Conservancy, Unpublished). The first objective of this study was to determine the impact of post fire high intensity grazing of two different durations on purple threeawn percent cover, live and dead crown density, and seedstalk production. I hypothesized that post fire high intensity grazing will decrease the percent cover and reproductive effort of purple threeawn, with greater decreases in short duration grazing than long duration grazing. The second objective was to determine if prairie dog densities increased in response to these high intensity grazing treatments. I hypothesized that prairie dog densities would increase for both short and long duration grazing treatments with greater increases in the short duration treatment. Results from this study were expected to help inform management of purple threeawn, increase forage quality and palatability for cattle, and maintain habitat for prairie dogs and the organisms that rely on them.

METHODS

Study Site

This study was conducted in the summer and fall of 2017 and 2018 at The Nature Conservancy's (TNC) Smoky Valley Ranch (SVR) in Logan County, Kansas. Smoky Valley Ranch is a 7,090 hectare (17,520 ac) preserve and working cattle ranch approximately 19 miles southwest of Oakley, Kansas along the Smoky Hill River (Fig. 1). Average annual precipitation for this area is 474 mm, occurring primarily from April to October. The average temperature is 12.1˚C, with the maximum temperature reaching 44.4˚C in the summer and minimum temperature reaching -31.1˚C in the winter. The frost-free growing season ranges from 135 to 150 days (High Plains Regional Climate Center, 2018). Soils in the study area are dominated by Ulysses silt loam, 1 to 3 percent slopes and Ulysses silt loam, 0 to 1 percent slopes. The Ulysses series is defined as fine-silty, mixed, superactive, mesic Torriorthentic Haplustolls (USDA-NRCS, 2018a).

The study area within SVR was approximately 79 ha (180 acres) of upland shortgrass prairie dominated by sod-forming grass, such as buffalograss (*Bouteloua dactyloides* [Nutt.] J.T. Columbus) and blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), and purple threeawn (*Aristida purpurea* Nutt.). Other vegetation consisted of mixed and shortgrass species including; sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), sand dropseed *(Sporobolus cryptandrus* [Torr.] A. Gray), little barley (*Hordeum pusillum* Nutt.), six weeks fescue (*Vulpia octoflora* [Walter] Rydb.), western wheatgrass (*Pascopyrum smithii* [Rydb.] Á. Löve), and tumble grass (*Schedonnardus paniculatus* [Nutt.] Trel.). Common forb species present were scarlet globe mallow (*Sphaeralcea coccinea* [Nutt.] Rydb.), upright prairie coneflower (*Ratibida columnifera* [Nutt.] Wooton & Standl.), ragweed spp. (*Ambrosia* spp L.), prickly Russian thistle (*Salsola tragus* L.), cut-leaf ironplant (*Machaeranthera pinnatifida* [Hook.] Shinners), white heath aster (*Symphyotrichum ericoides* [L.] G.L. Nesom), and numerous annual forbs. Plant nomenclature followed the USDA PLANTS database (USDA-NRCS, 2018b).

A prescribed burn was applied to the study area on August 9, 2016 as part of management practices at SVR. The objectives of this burn were to decrease purple threeawn cover (Strong et al., 2013a, 2013b) and increase forage quality and palatability for the spring (Richarte-Delgado, 2012). Prior to the burn, this study area was managed through yearly rotational grazing with cow-calf pairs at a moderate stocking rate for SVR. A black-tailed prairie dog colony was present across the entire study area.

Experimental Design

Experimental plots were built using wood corner posts, electrified single strand smooth wire, t-posts, and chicken wire. Each plot totaled 5.67 ha (14 ac) and was replicated six times. Each plot was split into four subplots where treatments were applied (Fig. 2). Three of the subplots were 0.8 ha (2 ac), which included the control (no grazing or clipping), clipping by prairie dogs only, and a short duration (1.5 months) grazing by cattle (*Bos taurus*) and clipping by prairie dogs. The fourth subplot was 3.2 ha (8 ac) with a long duration (6 months) cattle grazing treatment (Fig. 2). The grazing treatments were stocked with one dry cow at 453 kg (~1,000 lbs) with the intent of “100% utilization.” This dictated the size of plots based on the grazing duration. Grazing for 1.5 mo (short duration) at 100% utilization required a 0.8 ha plots. Grazing for 6 mo (long duration) at 100% utilization required a 3.2 ha plot. Plot size was determined using available forage data from a 2010 NRCS inventory conducted for the SVR management plan developed in 2016. An electric fence charger was used to deter outside grazers from entering the study plots, as well as keep cattle within the grazing treatments. Since this site is an active prairie dog town, prairie dogs occurring within the control treatment were removed. Chicken wire was then stretched around the control plot and stapled to the ground to deter prairie dogs from re-entering. Efforts were made to continue removing prairie dogs that entered the control plot after establishment. Eradication and removal procedures were conducted following the guidelines set forth by the Animal Care and Use Committee of the American Society of Mammalogist (Sikes et al., 2016), under the Fort Hays State University Animal Care and Use Protocol #17-0014 and followed the recommendations of AVMA Guidelines for the Euthanasia of Animals (2013).

The six experimental plot locations were determined randomly within the 79 ha (180 ac) study area. Using ArcGIS (ESRI, 2017), a numbered grid was overlaid on the study area with each grid large enough to encompass one full 8 ha plot (~ 20 ac) and its buffer. The grids were then selected using randomly generated numbers, and GPS points were extracted from the center of each selected grid to correspond with the center of each plot. The plots were then randomly oriented so not all faced north. A minimum of a 10 m buffer was applied around each plot to prevent influence on one another and maintain independence between replicates. Grazing was initiated on May 8, 2017 for both short and long duration treatments. Cows were removed from short-duration on June 17 (41 days) and long-duration on October 31 (177 days). Grazing was initiated on May 16, 2018 for both short and long duration treatments. Cows were removed from short duration on July 2 (48 days) and long duration on October 30 (168 days).

Vegetation Measurements

Permanent 100 m transects were established in each subplot, extending from the center post where all four subplots meet, with a 15 m buffer from the post before transects began (Fig. 2). Four transects were initially placed within the long duration grazing subplot, each extending from a corner post towards the center of the subplot. However, after an analysis of the 2017 grazing season found no difference between the transects for all measurements, only the transect extending from the center post was used for data collection and analysis. Purple threeawn response to the treatments was then measured in 2017 and 2018 looking at plant composition (purple threeawn percent cover), live and dead crown density (m^{-2}), and seedstalk density (m^{-2}). Baseline vegetation measurements were collected in early May of 2017 (pre-grazing), which included plant composition and live vs. dead crown density. Plant composition and Live and dead crown density were assessed again in early May of 2018 (pre grazing). In late June, after cattle were removed from short duration treatments, plant composition and seedstalk density were collected for short duration plots only (data not reported). To understand the treatment impacts at the end of the season, after cattle were removed from long duration treatments at the end of October, plant composition and seedstalk density were collected for all four treatments.

Plant composition was assessed using the line point-intercept method (Herrick et al., 2017) along each transect at 1 m intervals (1–100 m). To account for the large amount of bare ground and litter in a shortgrass prairie, a modification was made to the line point-intercept method by recording the nearest live plant species whenever bare ground or litter was hit at the basal level. Live and dead crown density and seedstalk density were assessed using a 0.125 m^2 frame along each transect at 5 m intervals (1–100 m). Live and dead crowns were determined by the presence (live) or absence (dead) of green growth coming from the crowns of purple threeawn. Given the large number of seedstalks purple threeawn can produce, an index was created to assess seedstalk density by a visually estimated percent. This index was created by clipping and bagging all aboveground biomass within a 0.125 m^2 frame that contained “100% basal cover” of purple threeawn. Then, the seedstalks from each bag (N=5) were sorted and counted to achieve an average (1,409 seedstalks = 100%). I then visually estimated the percent basal cover of purple threeawn, along each transect, using a 0.125 m^2 frame. Lastly, from the average, visually estimated percentages were converted to seedstalk density (m^{-2}) for analysis. The results reported for plant composition investigated only percent composition of purple threeawn (% cover) collected for all treatments post cattle removal in October for both the 2017 and 2018 seasons. Also, results reported for seedstalk density used data collected for all treatments post cattle removal in October for both the 2017 and 2018 seasons. All other results used data collected as stated previously.

Prairie Dog Density Counts

Prairie dog density counts were performed each year to assess whether treatment applications had an effect on black-tailed prairie dog populations. Methods to estimate black-tailed prairie dog population densities ($no \cdot ha^{-1}$), developed by Menkens and Anderson (1993) and Severson and Plumb (1998), were used for this study with some modifications. Visual counts were conducted late June to early July from the center post of the plots, so each treatment could be counted from the same vantage point (Fig. 2). Counts were conducted from an elevated seat in the bed of a UTV (~2 m above ground). Visual counts were conducted three consecutive days during the morning (0700 to 1100) and evening (1630 to 2030). Upon arriving at the plot, the prairie dogs were given 15 minutes to acclimate to the presence of the observer. Each treatment was then counted 3 times every 5 minutes for 15 minutes. Scanning from corner post to corner post using binoculars (8 x 42), the number of prairie dogs counted on each pass was recorded for a total of 9 readings per treatment per day. Each plot was counted in the morning and evening at least once (Powell et al., 1994) to ensure an accurate representation across time. Since the plot sizes for this study (3.2 ha and 0.8 ha) are below the recommended size (4 ha) suggested by Severson and Plumb (1998), some maximum visual counts were below a detectable level when using the linear formula to estimate total population size. Therefore, the linear formula was not used in this study and the maximum count for each treatment was used for further analysis.

Statistical Analysis

All statistical procedures were conducted using program R (R core team, 2017). A multivariate analysis of variance (MANOVA) using Pillai's Trace test statistic was used to examine the response to post fire grazing on the vegetation data (purple threeawn percent cover, live and dead crown density, and seedstalk density of purple threeawn). A separate univariate analysis of variance (ANOVA) was used to measure the response of prairie dogs to the post fire grazing treatments. Both the MANOVA and ANOVA allowed comparisons between treatments for the 2017 season and the 2018 season separately, as well as among the same treatment between years. Normality of data was tested using Shapiro-Wilk tests. Multivariate homogeneity of variances was assessed with Mahalanobis D and then further assessed with hov plots using the HH package (Heiberger, 2018) for univariate homogeneity of variances. Initial exploratory analysis indicated that the data violated the assumption of normality but not homogeneity of variances. To obtain a normal distribution, Log10 transformations were applied to dead crown and prairie dog densities, and a square-root transformation was applied to seedstalk density. After transformations of the data, normality was obtained. Outliers were identified using the MVOUTLIER package (Filzmoser and Gschwandtner, 2018). The presence or absence of these outliers did not influence the results, and careful investigation of each outlier led to their retention in the dataset. Also, the MANOVA and Pillai's Trace are robust (capable of handling outliers). A significant result from the MANOVA would result in a univariate analysis of variance (ANOVA) to investigate significance for the individual dependent variables. A significant ANOVA for a dependent variable were further analyzed with a post hoc Tukey's Honest Significant Difference test (Tukey's HSD) to determine differences between treatments. Statistical significance for all tests was set at alpha = 0.05.

RESULTS

Treatments differed in the measured plant response variables (MANOVA, Pillai's trace = 1.195, $F = 2.435$, df = 28,160, $p < 0.001$). Differences among the treatments were due to dead crown density (ANOVA, $F = 2.987$, df = 7, 40, $p < 0.0128$), with marginal significance for live crown density (ANOVA, $F = 2.136$, df = 7, 40, $p = 0.062$). Treatments did not differ statistically in purple threeawn percent cover ($F = 0.176$, df = 7, 40, $p = 0.988$) or seedstalk density ($F = 1.806$, df = 7, 40, $p = 0.113$). There was no significant difference between treatments on prairie dog density (ANOVA, $F = 1.879$, df = 5, 30, $p = 0.128$). Post hoc Tukey's HSD tests were performed on significant response variables to determine which treatments effected purple threeawn.

Dead crown density (m^{-2}) was the only response variable that differed among treatments (ANOVA, $p = 0.013$). The post hoc Tukey's HSD test did not find differences between treatments (Tables 1 & 2). However, control, prairie dog, and long duration treatments all saw declines in the dead crown density from 2017 to 2018, but the dead crown density for the short duration treatment stayed constant from 2017 to 2018 seasons (Fig. 3).

Live crown density (m^{-2}) of purple threeawn showed marginal significance (ANOVA, $p = 0.062$) among treatments. The post hoc Tukey's HSD test determined the short duration grazing treatments between 2017 and 2018 were the only treatment comparison approaching significance ($p = 0.096$)(Tables 1 & 2). Short duration treatments saw a 49% decrease in live crown density from 2017 to 2018 while the control, prairie dog, and long duration treatments saw 17%, 25%, and 33% decreases respectively from 2017 to 2018 (Fig. 4).

Grazing and/or clipping treatments had no effect on the percent cover of purple threeawn (ANOVA, $p = 0.988$), Seedstalk Density (m^{-2})(ANOVA, $p = 0.113$), and prairie dog density ($no \cdot ha^{-1}$)(ANOVA, $p = 0.128$). Purple threeawn percent cover was not different among or between treatments for 2017 or 2018 (Fig. 5)(Tables 1 & 2). Seedstalk density had a greater response to treatments applied in 2017 (Fig. 6A) than in 2018 (Fig. 6B)(Tables 1 & 2). A separate univariate ANOVA was performed for prairie dog density because the control treatments were removed from the analysis due to the eradication of prairie dogs within the control. Prairie dog densities seem to be responding to the grazing/clipping treatments (short and long duration) more than clipping treatments (prairie dog) alone (Fig. 7)(Tables 1 & 2).

DISCUSSION

Post fire, high intensity grazing by cattle (short and long duration) and clipping by prairie dogs was examined for two grazing seasons (2017 & 2018) to determine the impact on purple threeawn. Measurements included purple threeawn percent cover, live and dead crown density, seedstalk density, and prairie dog density. After two grazing seasons, purple threeawn live and dead crown densities are the only variables influenced by the high intensity grazing post fire. Purple threeawn percent cover, Seedstalk density, and prairie dog density were not influenced by high intensity grazing post fire. A small sample size and high variation might have decreased the detectability of differences between treatments.

Purple threeawn live and dead crown densities were both influenced by the addition of high intensity grazing post fire. The densities collected in 2017 (pre-grazing) were used as our baseline and were a result of the prescribed burn performed on August 9, 2016 before treatments began. Densities collected in 2018 resulted from the addition of the high intensity grazing treatments during 2017 after the fire. In this study, I did not measure the impact of fire on purple threeawn. Therefore, all measured changes from high intensity grazing are in addition to fire impacts. Effects of fire on purple threeawn are well documented, resulting in increased mortality following a summer burn (Russell et al., 2013; Strong et al., 2013a, 2013b). However, our objective was to see if high intensity grazing could continue the trend of purple threeawn mortality beyond fire alone. Short duration grazing showed the best results: lowest density of live crowns and the highest density of dead crowns in 2018 (one season of grazing), with the long duration grazing being next most effective.

These effects of high intensity grazing on purple threeawn crowns can be explained by the plant's response to fire and grazing. Richarte-Delgado (2012) found that burning purple threeawn in the summer or fall produced the highest forage quality, for a short time (≤4 mo), the following spring. Also, palatability of purple threeawn is increased by removing old growth within the crown by fire (Strong et al., 2013b). With increased forage quality and palatability, cattle will readily graze the new growth and propagules of purple threeawn, resulting in a decrease of new and live crowns. In addition, Russell and Vermeire (2014) found fire alone decreased the number of axillary buds of purple threeawn. Russell et al. (2013) showed that purple threeawn production and number of tillers can be reduced following a severe grazing event. With the initial treatment of fire in summer of 2016, and two seasons of high intensity grazing post fire, we anticipate seeing a continued decline in the number of live crowns in future data collection.

The greater amount of dead crowns in the short and long duration grazing treatments could be due to lack of available nutrients from being outcompeted by more desirable species such as blue grama and buffalograss. Fire and grazing resistance and resiliency has been well documented in blue grama and buffalograss (Castellano and Ansley, 2007; Vermeire et al., 2011) and might give them a competitive advantage over purple threeawn. Furthermore, Russell et al. (2013) observed reductions in purple threeawn biomass and increased production of more palatable species (e.g., blue grama) after undergoing moderate grazing. In addition, the more palatable species (blue grama/buffalograss) saw increased production. In my study area, other than purple threeawn, blue grama and buffalograss are the dominant grasses. Initial grazing disturbance of these species might have prompted the capture of belowground resources such as nutrients and root space before purple threeawn (Briske and Hendrickson, 1998). Furthermore, defoliation of purple threeawn causes carbon allocation to shift from shoots to roots (Briske et al., 1996; Busso et al., 2001). Thus, since a majority of the belowground resources might have been captured by more desirable and fire- and grazing-adapted species, purple threeawn might be vulnerable to winter mortality. This process might have been intensified by continued shoot removal by grazers in our 100% utilization plots, explaining the higher amount of dead crowns measured in the short and long duration grazing treatments.

Purple threeawn percent cover, seedstalk density, and prairie dog density were not significantly influenced by post fire high intensity grazing or clipping by prairie dogs. However, this could be due to a small sample size and high variation within the results which prevented detecting even the smallest differences. With more years of data collection scheduled, I hope to detect differences between treatments for all response variables. Using other research, I can begin to speculate what might be occurring and what is to be expected through continued treatments.

Purple threeawn percent cover was not affected by either of the post fire high intensity grazing treatments or clipping by prairie dogs only. Multiple studies (Launchbaugh, 1957; Olson et al., 1993; Vanzant et al., 1994) reported changes in plant composition, within the shortgrass prairie, took up to 4 years after high intensity grazing applications. However, Harmoney and Jaeger (2011) found minor changes in plant composition, within the shortgrass prairie, following a 7-year study with similar grazing strategies, but attributed minor changes to several seasons of drought. Based on the trends of the other measured purple threeawn variables, I anticipate a decreases of purple threeawn percent cover within the next few grazing seasons assuming a drought does not occur. Due to the intensity of the grazing treatments, bare ground increased within the study plots, more-so within the short duration grazing treatments. This might have led to an overestimation of purple threeawn percent cover through the modification of the line-point intercept where "nearest species" was collected when bare ground was hit. Further research is needed to confirm this hypothesis.

Seedstalk density was reduced following both seasons for short duration and long duration grazing treatments. Given increased palatability (Strong et al., 2013b) and forage quality (Richarte-Delgado, 2012), cattle likely grazed post-burn purple threeawn continually, leading to the decrease in reproductive ability and the crown death observed. The short duration treatment produced the largest reduction on purple threeawn seedstalk likely due to the higher density of grazer per ha (0.5 $cows \cdot ha^{-1}$). I suspect this stock density allowed the grazer to "stay ahead" of purple threeawn growth, compared to the long duration treatment (0.12 $cows \cdot ha^{-1}$), where the area was too large to graze all purple threeawn growth as it occurred. In addition, short duration grazing had the greatest reduction of seedstalk density the first grazing season post fire (2017). I believe this initial decrease in seedstalks is vital for long-term control of purple threeawn by decreasing the number of propagules that might have developed through those seeds. Short duration grazing also showed an impact in the second grazing season (2018), as it was the only treatment to decrease seedstalk density compared to the control. Short duration grazing was the only treatment showing decreased seedstalk density in both years. This demonstrates the importance of continual removal of purple threeawn growth in year one, as palatability and forage quality decreases with increasing time since fire (Richarte-Delgado, 2012).

In most grassland ecosystems, vegetative reproduction is the most common form of propagation for native grasses (Benson et al., 2004). However, purple threeawn produces relatively large numbers of seeds (Evans and Tisdale, 1972) that play an important role in purple threeawn propagation (Fowler, 1986). As seedstalk density declines, we anticipate purple threeawn cover to decline. In combination with the live and dead crown results observed, fewer live crowns and more dead crowns are likely reducing seedstalk density on high intensity grazing treatments.

Deferment of grazing post fire might have potential to control purple threeawn as well. My study suggests that one year post fire, the control treatment had the largest density of seedstalks but by the end of the second year post fire, the control treatment had the second lowest seedstalk density. These results need to be taken with caution because there is much variability within this study and in studies investigating the effect of fire without grazing in the shortgrass prairie. Vermeire et al. (2011) reported no reduction of C_4 perennial grasses one year past a summer fire while Scheintaub et al. (2009) reviewed research on the effects of fire in the shortgrass prairie and found more than half the studies reported reductions in biomass production of C_4 perennial grasses. However, Vermeire et al. (2011) attributed the variability of plant responses to post-fire precipitation and not necessarily fire alone. The impacts of deferment of grazing post-fire on purple threeawn needs further investigation, but might have potential as a control method within the shortgrass prairie.

Prairie dog densities were not statistically different, which could be attributed to low sample size and high variation within the system. With more data, I anticipate detecting the prairie dogs responses to the treatments similar to other research. In my study prairie dogs appeared to be increasing within the short and long duration grazing treatments. This increase of prairie dogs in heavily grazed areas is most likely a response to decreased visual obstruction and enhanced predator avoidance (King, 1955). Uresk (1993) stated that prairie dogs are likely to expand where warm season grasses dominate and grazing by cattle is intense. Uresk (1993) also stated that resting pastures can reduce prairie dog expansion, which might explain the decline within the prairie dog clipping treatment as cattle were excluded from those plots.

Prairie dogs have a major impact on the structure and composition of the prairie ecosystem and this impact can be beneficial for cattle and other ungulates (Archer et al., 1987). Plant diversity is shown to increase in prairie dog colonies, and many ungulates (cattle, pronghorn [*Antilocapra americana*], bison [*Bison bison*], and elk [*Cervus canadensis*]) preferentially graze within prairie dog colonies due to a nutritional advantage (Whicker and Detling, 1993). Even after 6 or more years of prairie dog colonization, Archer et al. (1987) found buffalograss and blue grama as the dominant plant species which offer excellent forage quality for cattle and supports the development of a management plan for purple threeawn using prescribed fire (with proper timing and intensity), grazing by cattle, and prairie dogs in combination.

More time and data are needed to determine whether post fire high intensity grazing, decreases purple threeawn cover and reproductive effort. However, both short duration and long duration grazing treatments show promise for control of purple threeawn post fire and the persistence of prairie dog colonies. I anticipate a greater reduction in purple threeawn within the next few years through the continuation of these treatments.

IMPLICATIONS

At the end of two grazing seasons post fire, purple threeawn continues to show its resilience. All previous research of purple threeawn was either greenhouse studies or investigated individual response to fire with mimicked grazing. The take-away from this study is cattle will graze purple threeawn, and graze it well when a combination of management recommendations is followed. A management plan developed using the current results should focus prescribed burns in late summer (early August) with high intensity, short duration grazing in the spring.

Beyond a small sample size, much of the variation within this study could be due to individual cattle grazing habits. I recommend avoiding the use of a single grazer in future studies. Attempt to use “mob” grazing techniques or herd grazing with multiple grazers. Also, when measuring seedstalks in a similar manner to this study, create a new visual assessment index each year to control climatic variation influence on the seedstalk production each year. Future research should focus on manipulating grazing duration and intensity post fire. I recommend investigating durations between the 45 days and 180 days used for this study with decreasing intensity to determine if a threshold exists where grazing no longer impacts purple threeawn. Following that, research should investigate the impact on purple threeawn using one season of post fire high intensity grazing (using the best duration and intensity of the prior) followed by deferment.

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Table 1: Means and standard errors of response variables for each grazing and clipping treatment 1 year (2017) post fire collected at Smoky Valley Ranch.

2017	**PTA Percent Comp. (%)**		**Live Crown Density (m^2)**		**Dead Crown Density (m^2)**		**Seedstalk Density (m^2)**		**Prairie Dog Density ($no \cdot ha^{-1}$)**	
Treatment[a]	**Mean**	**SE[b]**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Control	26.3	±4.74	12.1	±1.96	5.6	±1.18	395.5	±160.48	0.0	±0.00
Pdog	25.3	±5.12	13.5	±2.70	5.3	±2.24	281.8	±95.15	9.5	±1.82
SD	24.5	±3.56	18.0	±2.52	5.7	±1.11	113.7	±46.00	14.8	±5.89
LD	27.5	±2.97	15.9	±2.01	5.5	±1.07	261.1	±49.02	6.2	±1.45

[a]Pdog = prairie dog clipping treatment, SD = short duration grazing treatment, LD = long duration grazing treatment
[b]SE = standard error (95% confidence interval)

Table 2: Means and standard errors of response variables for each grazing and clipping treatment 2 years (2018) post fire collected at Smoky Valley Ranch.

2018	**PTA Percent Comp. (%)**		**Live Crown Density (m^2)**		**Dead Crown Density (m^2)**		**Seedstalk Density (m^2)**		**Prairie Dog Density ($\#\cdot ha^{-1}$)**	
Treatment[a]	**Mean**	**SE[b]**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Control	23	±3.73	10.0	±2.36	1.6	±0.31	141.3	±18.35	0.0	±0.00
Pdog	23.8	±4.87	10.1	±2.33	1.6	±0.64	176.6	±31.67	8.2	±1.48
SD	26.7	±2.47	9.1	±1.62	5.8	±2.25	115.5	±17.44	20.8	±6.31
LD	27.2	±2.95	10.7	±1.54	2.5	±0.60	164.4	±26.09	11.9	±3.31

[a]Pdog = prairie dog clipping treatment, SD = short duration grazing treatment, LD = long duration grazing treatment
[b]SE = standard error (95% confidence interval)

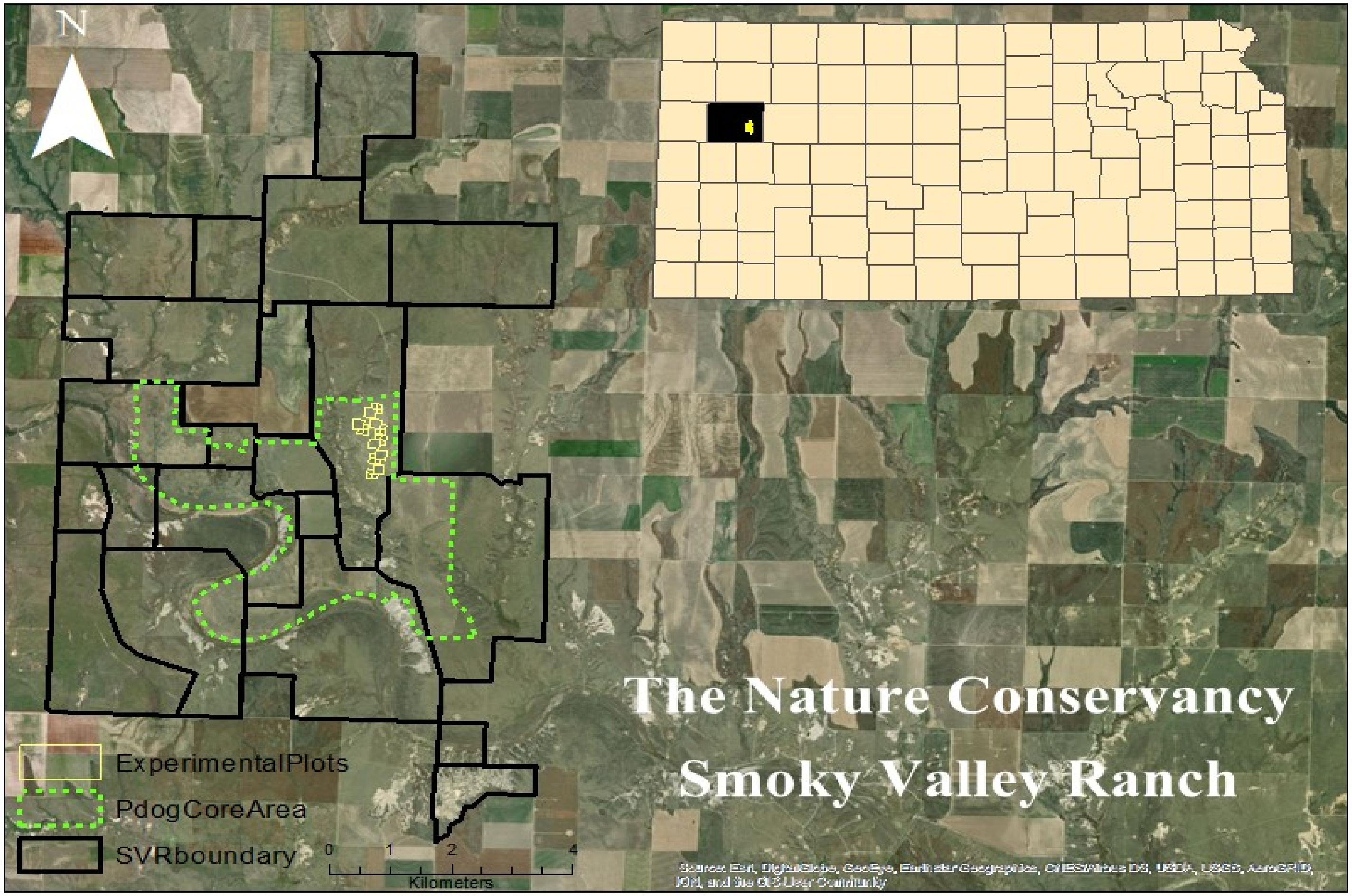

Figure 1: Map depicting the study area used in 2017-2018, located at The Nature Conservancy Smoky Valley Ranch in Logan County, Kansas with the six replicated experimental plots located within the prairie dog core management area in the center of the property.

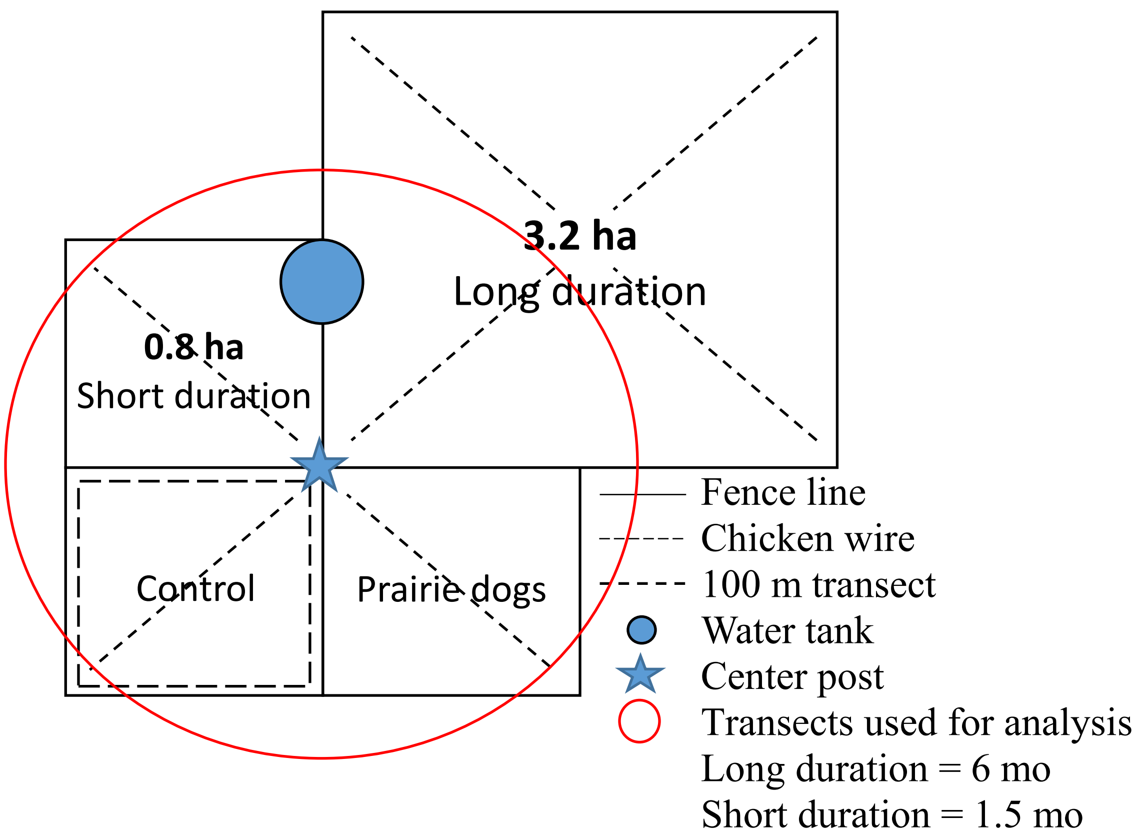

Figure 2: Depicts the experimental plot design used in 2017 and 2018 with one cow (~450 kg) placed in short duration and long duration grazing treatments. Control and prairie dog plot size matched the short duration plot (0.8 ha). Star marks the point of origin for all permanent vegetation transects and location where prairie dog counts were conducted.

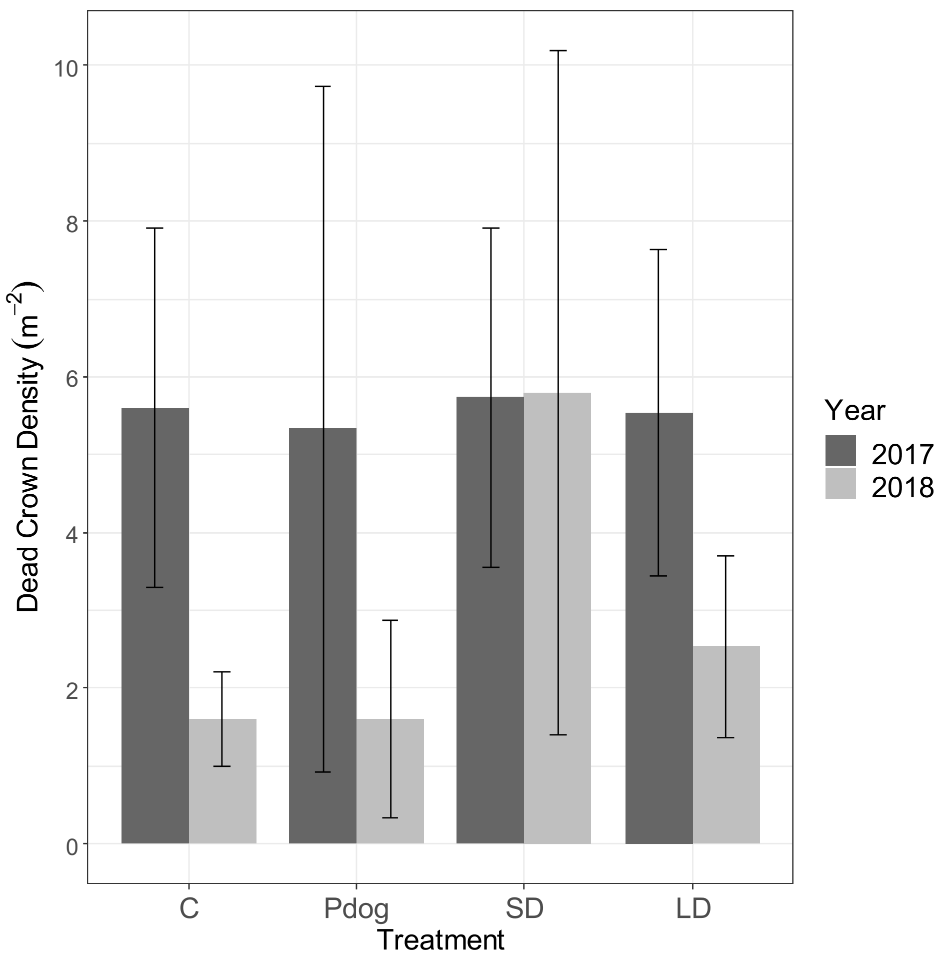

Figure 3: Mean dead crown density (m^{-2}) of purple threeawn for treatments in 2017 and 2018. Treatments consisted of C = control (no grazing by cattle or clipping by prairie dogs), Pdog = only prairie dog clipping, SD = short duration grazing by cattle (1.5 mo), LD = long duration grazing by cattle (6 mo). 2017 dead crown densities were collected before treatments were applied. Error Bars represent a 95% confidence interval.

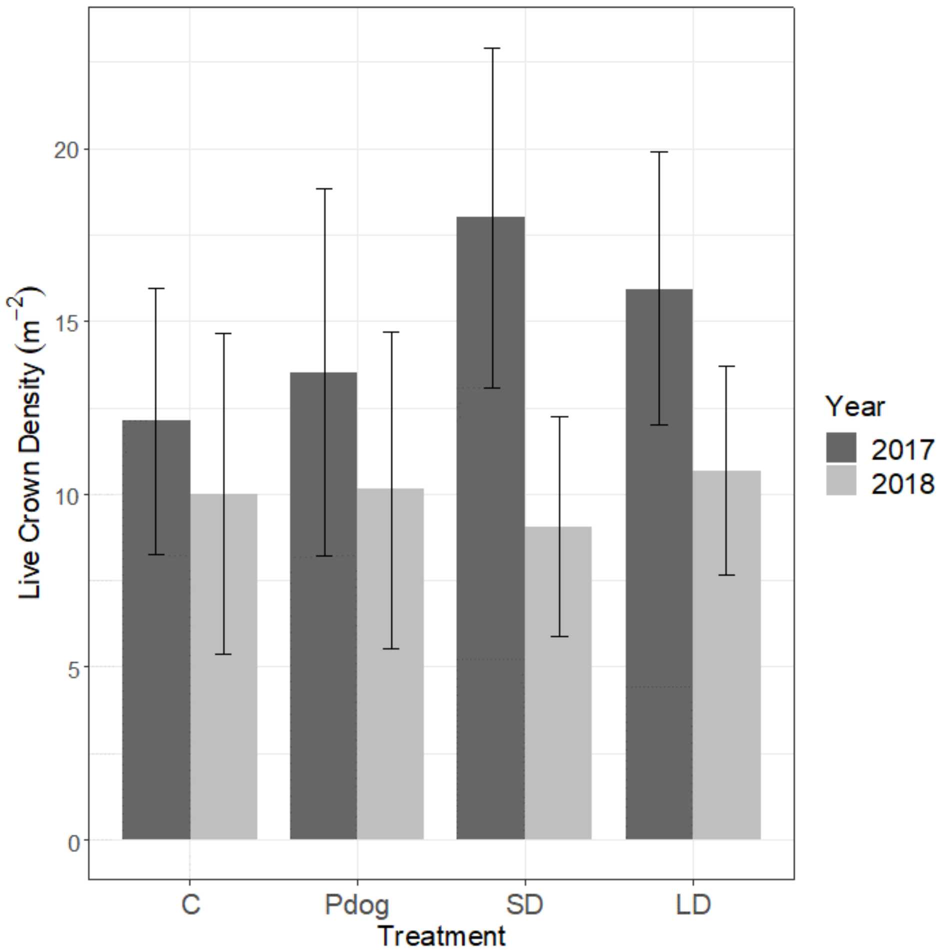

Figure 4: Mean live crown density (m^{-2}) of purple threeawn for treatments in 2017 and 2018. Treatments consisted of C = control (no grazing by cattle or clipping by prairie dogs), Pdog = only prairie dog clipping, SD = short duration grazing by cattle (1.5 mo), LD = long duration grazing by cattle (6 mo). 2017 live crown densities were collected before treatments were applied. Error bars represent a 95% confidence interval.

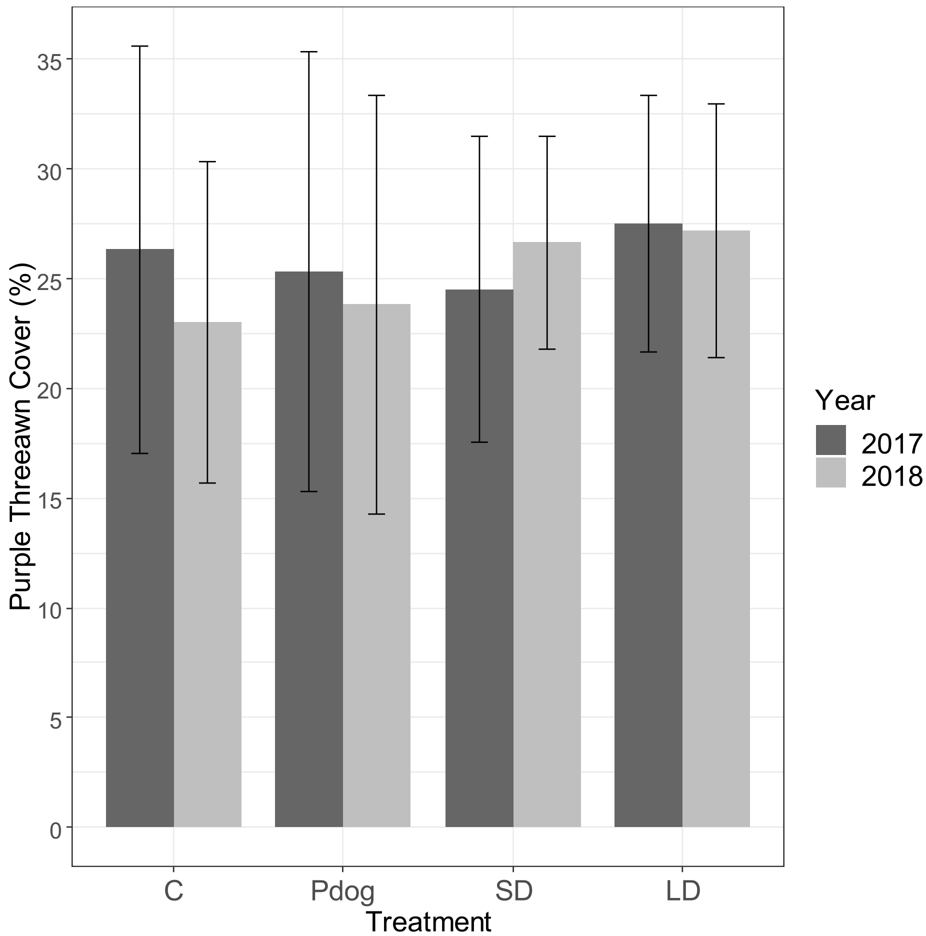

Figure 5: Mean purple threeawn percent cover for treatments in 2017 and 2018. Treatments consisted of C = control (no grazing by cattle or clipping by prairie dogs), Pdog = only prairie dog clipping, SD = short duration grazing by cattle (1.5 mo), LD = long duration grazing by cattle (6 mo). Error bars represent a 95% confidence interval.

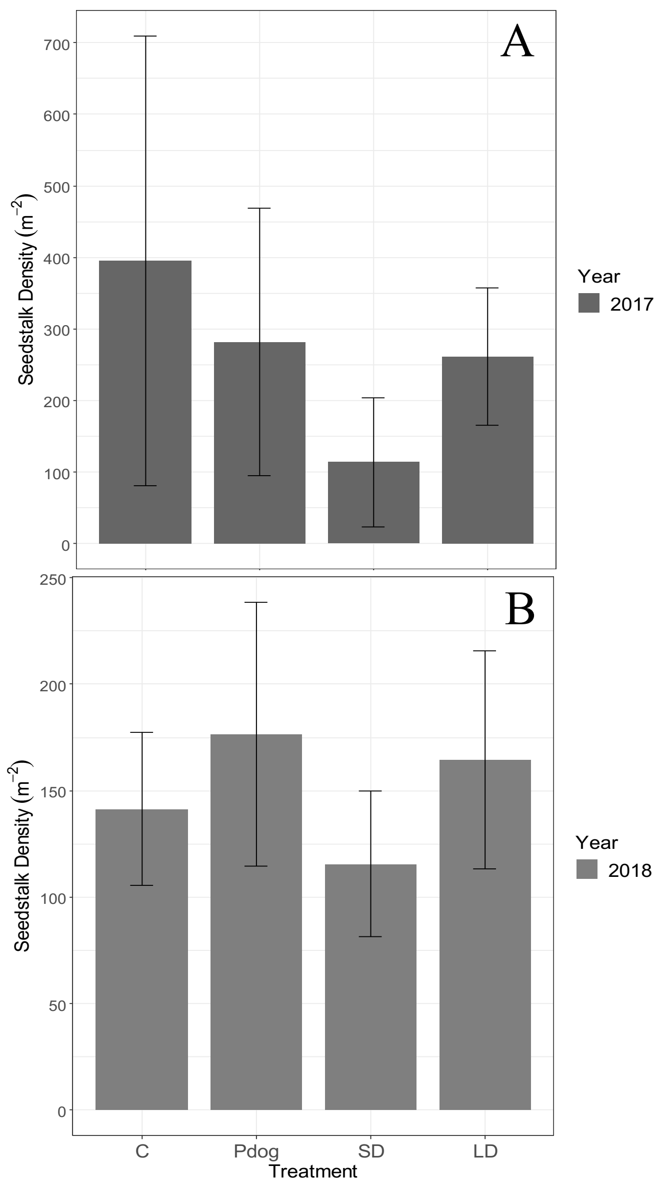

Figure 6: Mean seedstalk density (m^{-2}) of purple threeawn for treatments in 2017 (A) and 2018 (B). Treatments consisted of C = control (no grazing by cattle or clipping by prairie dogs), Pdog = only prairie dog clipping, SD = short duration grazing by cattle (1.5 mo), LD = long duration grazing by cattle (6 mo). Error bars represent a 95% confidence interval. Note Y axes are on different scales between the years.

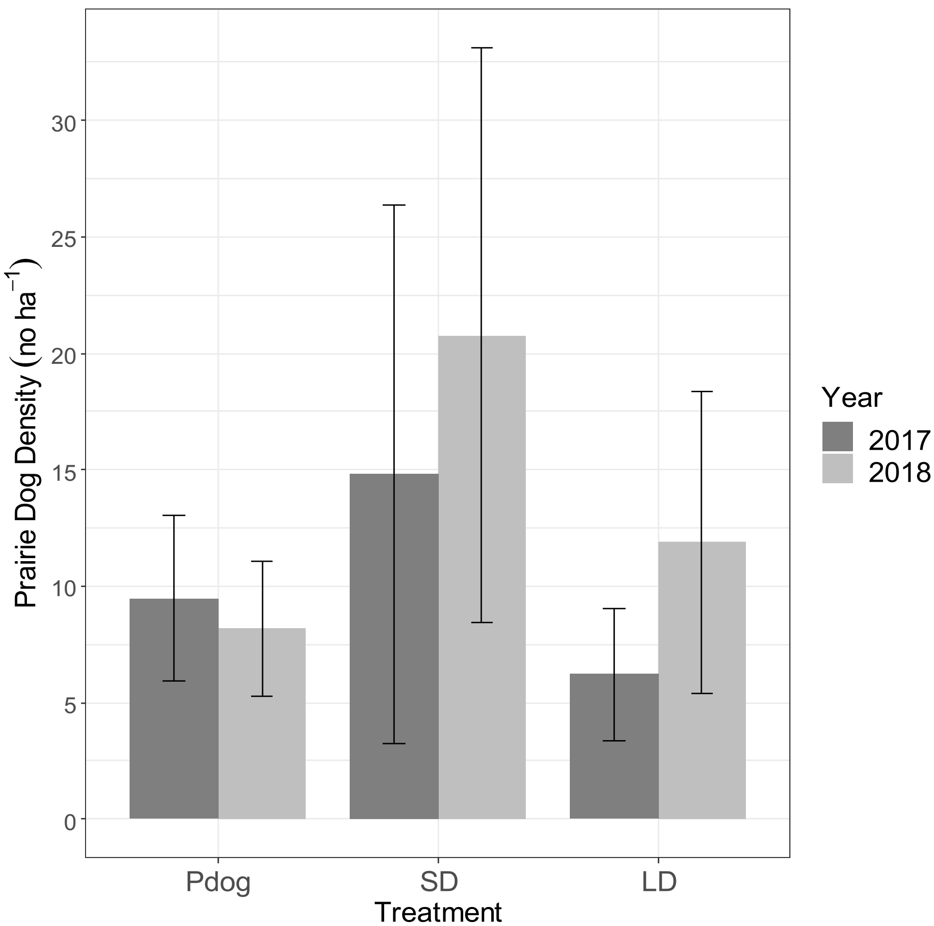

Figure 7: Mean prairie dog density counted in each treatment for 2017 and 2018. Treatments consisted of Pdog = only prairie dog clipping, SD = short duration grazing by cattle (1.5 mo), LD = long duration grazing by cattle (6 mo). Error bars represent a 95% confidence interval.

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