Cheatgrass, Mammals, Birds, Butterflies, and Wildfire: A Study of Ecosystem Interactions

Running Head

Cheatgrass, Wildlife, and Wildfire

Authors and Affiliations:

Anyll Markevich, Undergraduate Student, Prescott College, 5570 Magnolia Drive, Nederland, CO 80466, USA, anyllmarkevich@gmail.com, (303) 800-6342

Stephen R. Jones, Boulder County Nature Association, PO Box 493, Boulder, CO 80306, curlewsj@comcast.net, (303) 494-2468

Christel G. Markevich, Independent Researcher, 5570 Magnolia Drive, Nederland CO, 80466, USA, christelmarkevich@gmail.com, (303) 800-6403

Timothy R. Seastedt, Senior Fellow, Institute of Arctic and Alpine Research, Univ. Colorado, Boulder 80309-0450, timothy.seastedt@colorado.edu

Corresponding Author

Anyll Markevich, anyllmarkevich@gmail.com, (303) 800-6342

Author Contributions

AM, SJ, CM selected plot locations; AM, CM installed cameras and delineated plots; AM, SJ, CM conducted bird and butterfly counts; AM, CM conducted vegetation counts; AM, SJ analyzed images from cameras; AM, SJ, TS conducted analyses; AM, SJ drafted manuscript; AM, SJ, CM, TS reviewed and finalized manuscript.

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Executive Summary

Over two years of research, we used remotely triggering cameras, point counts, and transect counts to measure the number of mammals, birds, and butterflies across eight plots in the Rocky Mountain foothills that varied in cheatgrass cover. We found that mammals and butterflies were less numerous in areas infested with cheatgrass and that such areas sustained fewer bird and butterfly species. Furthermore, butterflies appeared more sensitive to small changes in cheatgrass cover than mammals. Cheatgrass density decreased dramatically on heavily infested plots burned by the Calwood fire (at low intensity), consistent with the findings of other research projects in similar ecoregions and climates. These areas regenerated with native plants and appeared to receive more use from wildlife than before the fire.

Management Implications

- Habitat restoration efforts and critical habitat designations should recognize that areas infested with cheatgrass hold lesser value to mammals and butterflies.
- Minor cheatgrass infestations may be of lesser concern in managing large mammals than butterflies, although major infestations may significantly degrade habitat for both taxa.
- Prescribed fire may be an effective tool for controlling cheatgrass under certain ecological and climactic conditions.
- Cheatgrass control methodologies should strive to restore holistic ecosystem function, including plant community composition and wildlife prevalence, instead of simply prioritizing proxies such as reductions in cheatgrass density or increased abundance of native species.

Abstract

Understanding the impacts of cheatgrass (*Bromus tectorum*), an invasive annual grass, on mammal, bird, and butterfly populations is vital for wildlife habitat conservation, especially as cheatgrass continues to spread across the western United States. The impact of cheatgrass on most wildlife populations and their distributions has not been adequately studied. In this study, we investigate the impacts of cheatgrass on wildlife in the Rocky Mountain foothills in central Colorado during 2020 and 2021. We used a combination of remote-triggering cameras, point counts, and transect counts to quantify numbers of mammals, birds, and butterflies (respectively) on eight 75m radius circular plots varying in cheatgrass cover. Cheatgrass cover was quantified during each research season using a radial point-intercept method. Our findings indicate that both mammals and butterflies avoid areas infested with cheatgrass. The extent of cheatgrass cover did not appear to impact bird numbers or species richness of mammals significantly, but was a negative predictor of bird species richness and butterfly species richness. Our study suggests that cheatgrass infestation can degrade habitats for mammals and butterflies and should be considered when designing wildlife habitat conservation efforts. In late 2020 the Calwood fire burned part of the research area, allowing us to investigate the impact of wildfire on cheatgrass. Our results indicate that fire can significantly reduce cheatgrass cover within this ecosystem, and that prescribed fire may be a potential tool for cheatgrass management under certain environmental conditions.

Keywords: Bromus tectorum, conservation, fire, habitat, infestation, invasive plants, restoration, wildlife, camera traps

Introduction

Cheatgrass (*Bromus tectorum*) spread rapidly through the western United States, drastically altering native plant communities (Knapp 1996) and fire regimes (Bradley et al. 2018). Despite the environmental impacts of cheatgrass, few studies have focused on the role of cheatgrass as an environmental stressor on wildlife populations. Assessments of habitat quality in conservation and restoration projects should account for the prevalence of cheatgrass and its impacts on native species. Furthermore, an improved understanding of cheatgrass-fire interactions is important for developing sustainable approaches to mitigating negative impacts.

This study tested our hypothesis that cheatgrass infestation negatively impacts large mammals, birds, and butterflies. We used remote-triggering cameras, point counts, and transect counts to quantify the presence of these three types of animals on plots containing varying amounts of cheatgrass. During the second research season in 2021, we tested an additional hypothesis that wildfire affects cheatgrass density by comparing our 2020 and 2021 vegetation data across both burned and unburned plots.

Ungulate diets primarily consist of native vegetation, although deer and elk consume cheatgrass in the winter and spring (Kohl et al. 2012) as this winter annual is most nutritious during these seasons, prior to its senescence in the late spring and early summer. The movements of ungulates and other mammals likely reveal habitat suitability more accurately than dietary studies, but we are unaware of studies investigating how cheatgrass impacts large mammal distributions.

Among studies investigating the impact of cheatgrass on small mammals, dietary studies produce results distinct from those of population studies. Even though Richardson et al. (2013) found that cheatgrass seeds constituted the majority of seeds collected in cheek pockets of Great

Basin pocket mice (*Perognathus parvus*), numerous other studies have found significant decreases in mouse populations and diversity in areas infested by cheatgrass. One such study by Ostoja & Schupp (2009) found that total rodent abundance in the Great Basin was 6.1 times greater in sagebrush-dominated areas relative to cheatgrass-dominated areas. Similarly, Freedman et al. (2014) found that the abundance and diversity of small-mammal communities in the Great Basin decreased with an increased abundance of cheatgrass.

These small mammal studies suggest that invasive plants that constitute a portion of animal diets are not necessarily beneficial to local animal populations. Therefore, we hypothesized that large mammal densities would be lower in areas heavily infested by cheatgrass.

Birds appear to follow a similar pattern to mammals: dietary studies show that, although cheatgrass seeds are palatable to some species, birds preferentially feed on native grasses (Goebel & Berry, 1976). Under many of the environmental conditions found in the western U.S., Cheatgrass outcompetes native vegetation, possibly leading to a reduction in preferred food sources for birds. Furthermore, arthropods, which constitute a significant portion of many bird diets (Rotenberry, 1980), are affected by cheatgrass infestation (an interaction we discuss further in the following paragraph). These observations lead us to suspect that cheatgrass infestation impacts bird populations by altering food availability, forming our hypothesis that areas dominated by cheatgrass would sustain decreased bird densities.

Little research has looked specifically at the interactions between cheatgrass and butterflies. However, extensive research on arthropod response to cheatgrass infestation shows a general trend toward increased arthropod numbers in cheatgrass-infested areas, although this trend does not hold for all taxa. Ostoja et al. (2009) and Gardner et al. (2009) found consistent increases in arthropod numbers in cheatgrass-infested areas. However, Thapa-Magar et al. (2020)

found increased numbers of below-ground nesting native bees but reduced numbers of above-ground nesting native bees in areas infested by cheatgrass in the Colorado Front Range. Pei et al. (2023) found that litter accumulation from invasive grasses constrain native bee populations, although they did not specifically investigate the impact of cheatgrass. A study conducted by Looney & Zack (2008) found that beetle populations in cheatgrass-infested areas tended toward herbivorous species.

Young et al. (1987) found that cheatgrass forms monocultures that outcompete other plants, including potential nectar sources. Fleishman et al. (2005) found that butterfly numbers in the Muddy River drainage (Nevada) were not impacted by non-native plants but were instead influenced by nectar availability. Based on these two studies that together suggest cheatgrass may be detrimental to butterflies, we formed our hypothesis that cheatgrass-infested areas would support decreased butterfly numbers and butterfly species diversity.

Cheatgrass infestation generally increases fire risk and frequency (Bradley et al. 2018; Whisenant, 1990), favoring cheatgrass regrowth over native vegetation (Melgoza & Nowak, 1991). Mitigating this positive feedback cycle has become a management priority to protect intact ecosystems (Pilliod et al. 2021), with a particular focus on preserving ecosystems that are maladapted to frequent fire regimes, such as the Great Basin sagebrush steppe. Despite the significant environmental differences between the Great Basin sagebrush steppe and the Rocky Mountain foothills, we hypothesized that we would observe a similar pattern of increased cheatgrass abundance after fire.

Methods

Study Area

The study area lies at elevations between 1684-1790 m at the base of the Colorado Front Range foothills in the United States, where the Great Plains converge with the Southern Rocky Mountains. Annual precipitation averages 45-50 cm/year, with approximately half of this amount falling during the March-June spring growing season (from US Climate Data 2020).

In early May 2020, we established eight circular 75 m radius plots on Boulder County Parks and Open Space properties (Appendix A) near Lyons, Colorado (between 40°09'54.11" N, 105°16'16.54" W and 40°10'57.43" N, 105°15'28.98" W) where the Level IV ecoregion varies from Foothills Shrubland to Front Range Fans (Chapman et al., 2006). During the first research season, we located four plots in areas visually estimated to have high cheatgrass cover (> 20%) and four plots in areas visually estimated to have low cheatgrass cover (< 20%). The visual estimates were later confirmed by vegetation counts. We sampled the same plot locations in 2021.

Vegetation in the study area (scientific names follow Wittmann & Weber 2011, except cheatgrass for which we use the widely accepted name, *Bromus tectorum*) consisted primarily of foothills mixed-grass prairie, foothills shrub, and ponderosa pine woodland (Baker & Galatowitsch 1985; Colorado Natural Areas Program 1998). In relatively flat areas with deep soils, these grasslands tend to be dominated by green needlegrass (*Nassella viridula*) and western wheatgrass (*Pascopyrum smithii*), with numerous other native grass species well represented. Flat-bottomed ravines support dense stands of native shrubs, including skunkbrush (*Rhus trilobata*), wild plum (*Prunus americana*), and mountain mahogany (*Cercocarpus montanus*). Canyon bottoms support scattered hackberry trees (*Celtis reticulata*) and box elders (*Negundo aceroides*) along with small patches of native tallgrasses, including switchgrass (*Panicum *virgatum*) and indiangrass (*Sorghastrum avenaceum*). Ponderosa pines (*Pinus ponderosa*) are scattered throughout the study area, becoming most numerous in rocky uplands. Non-native cheatgrass is most prevalent in rocky or sloped areas.

All but one of the plots contain areas previously treated with the herbicides Esplanade and Glyphosate, sometimes mixed with a combination of Quinstar, Dicamba, and/or Hardball (Appendix A). The treatments occurred between 2017 and early 2020 prior to the first research season. As we were not aware of these treatments until late in the research study, we did not factor the treatments into our experimental design or our choice of plot locations. Mensah et al. (2015) identified glyphosate as a potentially significant toxin for wild mammal populations. However, McComb et al. (2008) found that glyphosate exposure in wild animals remained well below acute toxicity and did not appear to impact behavior. Van Deynze et al. (2022) found that glyphosate application wasn't correlated with declines in butterfly numbers despite evidence for genotoxicity to butterflies (Santovito et al. 2020). Given the limited impact of such treatments on immediate animal behavior and fitness within treated areas, we expect that the prior herbicide applications did not significantly impact our results.

A 4092 ha wildfire (Haverfield, 2021) on October 17th, 2020 (known as the "Calwood fire") burned four of our plots (Appendix B), including two with high cheatgrass cover and two with relatively low cheatgrass cover. In 2021, using the same methodology as in 2020, we re-measured cheatgrass cover within burned and unburned plots and repeated the wildlife counts. Although the Calwood fire burned intensely through much of its range, spectral reflectance analysis conducted by local agencies found that our research area experienced low soil burn severity (*Cal-Wood Fire Rehab: Soil Burn Severity*, 2020). Our on-site observations, using burn severity characteristics modified from Ryan and Noste (1985) by Neary et al. (2005), indicated that the burn severity across the four burned plots was primarily “Light,” apart from areas adjacent to shrubs and trees that often experience “Medium” severity. The burned plots regenerated with native grasses and forbs, including dense patches of big bluestem (*Andropogon gerardii*) in some previously cheatgrass-infested areas. The most intensely burned areas around fuel sources, such as shrubs and bushes, regenerated with invasive thistles (*Carduus* spp.) and mustards (*Brassica* spp. and *Sisymbrium* spp.), likely due to significant soil disturbance and diminishment of the native seed bank.

Vegetation Sampling

We conducted vegetation sampling using an identical methodology across both study years. Within each plot, we established 40 sampling locations arranged in a radial pattern adjusted for the non-linear increase of circle area with increased circle radius (Figure 1). At each sampling location, we used a Point-Intercept with a Grid Quadrant Method similar to that of Caratti (2006), utilizing a 0.7-meter sampling frame with 25 sampling points arranged in a grid pattern. We lowered a sampling pin at each sampling point and identified the vegetation beneath the pin as cheatgrass plants, cheatgrass litter, bare ground and rocks, non-cheatgrass litter, or non-cheatgrass plants.

Mammal Sampling

We mounted Stealth Cam (headquartered in Arlington, Texas, United States) G45NGX remote-triggering cameras 0.9 meters off the ground on T-posts located at the center of each plot, attached such that each camera could be oriented in any cardinal direction. The cameras were set to maximum sensitivity with a 15-second recovery time to avoid missing mammals while keeping false positive detections manageable.

We began observation at 2300 MST on May 13th and ended observation at 2259 MST on August 13th in both 2020 and 2021. At intervals ranging from one to two weeks, we rotated the cameras by 90 degrees, such that they completed two full rotations around their posts over the course of the study.

We identified and counted all mammals in the images from the remote-triggering cameras without relying on previous or subsequent images to detect or identify each mammal. Individual mammals were counted regardless of whether they may have appeared in previous images. We categorized all detected mammals by species, or when not identifiable to the species, as deer, ungulates, or mammals.

Bird Surveys

We counted birds seen or heard perching or foraging within 75m of the center points of the eight monitoring plots for 8 minutes per plot on four mornings between 29 May and 10 July, beginning each survey at sunrise and completing sampling of all eight plots by 0730 MST. We varied the order of the plot counts during each replication to reduce temporal biases that might stem from sampling bird populations at varying times of the early morning. As we entered each plot, we counted any birds flushed from the vegetation. We counted swallows when they were flying below the tops of the tallest trees and shrubs and when their irregular movement patterns suggested that they were foraging. We did not count birds flying over or through the plots without foraging (Ralph et al. 1998).

Butterfly Surveys

We counted butterflies seen along 150 m north/south transects bisecting each monitoring plot during a time interval of 5 minutes per plot on six days in 2020 and four days in 2021 between 31 May and 10 August. We walked slowly (2 km/hr) along each transect, using binoculars and cameras with telephoto lenses to identify all butterflies seen within 30 m. Counts were carried out between 0745-0945 MST on calm (peak wind velocity ≤ 20 km/hr) and clear (mean cloud cover ≤ 30%) mornings when the air temperature exceeded 18° C. We rotated the order of plot sampling during each count replication to reduce temporal biases.

Additional Data Collection

In addition to measuring our primary variables, we quantified other properties of the plots, notably slope, shrub and tree cover, and distance to a highway (effectively the distance to the nearest human development). We also used vegetation sampling data to calculate the bare and rocky ground percentage in each plot.

In 2020 we estimated woody plant (tree and shrub) cover using a custom grid overlay on Google Earth Pro satellite imagery. We could not use the same methodology in 2021, as the Google Earth imagery had not been updated since the Calwood fire. Instead, in 2022 we used a different methodology to estimate woody plant cover, noting for each vegetation sampling square whether it was located below a living tree or shrub or below a burned tree or shrub. Shrubs that were burned to the ground or retained only a few charred stems were ignored.

Data from each of the two years were used to calculate both living and total (including burned) woody plant cover, but shrub and tree density data were not compared across the two years due to inconstancy in the data gathering methodologies.

Data Analysis

We used the vegetation sampling data to produce a cheatgrass cover value, representing the percentage (expressed as a decimal) of each plot covered by either cheatgrass plants or cheatgrass litter. We used cheatgrass cover as the independent variable in all primary calculations and analyses, all of which were performed in the software package R.

We designated a Type 1 error rate of 5% ($p<.05$) as the statistical significance level in all our analyses.

ANCOVA best fit our animal data as it allowed us to determine the relationship between the number of animals and cheatgrass while adjusting for the sampling year. However, only our 2020 data consistently passed normality and homogeneity of variance tests (determined using the Shapiro-Wilk Normality Test and the Fligner-Killeen Test of Homogeneity of Variances, respectively). We used ranked animal data in the two-year animal-related analyses to accommodate the different data normalizations required across the two years. We excluded interactions between year and cheatgrass cover from the ANCOVA models because half the plots were burned in the second year, thus significantly altering their cheatgrass cover relative to unburned plots.

We used R-squared values from Two-Way ANOVA and ANCOVA analyses to determine the best fit models for different animal categories to see if these values provide additional insight into how different species categories respond to cheatgrass infestation. However, as described earlier, we treated this purely as a secondary analysis and consistently used ANCOVA to test our primary hypotheses.

One-Way ANOVA was used for secondary analyses comparing cheatgrass cover across burn conditions. For these analyses, we used percent change in cheatgrass cover, calculated as the change in cover across both years divided by the original cheatgrass cover of the plot. Data assumptions were tested using the aforementioned normality and homogeneity of variance tests. Data that failed these tests were normalized using Tukey Tests.

We additionally used Pearson's Correlation Coefficient Matrices to investigate other variables and interactions that may have influenced the results. We again used Tukey tests on the primary dependent variables to ensure normality. Ranking was not necessary because we could not compare data across the two years using this method. We retained a Type I error rate of 5% due to the limited number of variables.

Results

Vegetation

Cheatgrass cover on low cheatgrass plots varied from 0.031 to 0.135 in 2020, while cheatgrass cover on high cheatgrass plots varied from 0.235 to 0.350 (Figure 2). The mean values of the two groups were statistically significant during the first year, $F(1,6)=44.72$, $p<0.001$, confirming our original cheatgrass cover designations based on visual estimates.

We found a significantly higher percent decrease in cheatgrass cover, $F(1,6)=25.21$, $p=.002$, and cheatgrass litter, $F(1,6)=57.95$, $p<.001$, on burned plots relative to unburned plots. We also observed a greater percent decrease of cheatgrass plants in burned areas, but this effect was not statistically significant, $F(1,6)=2.656$, $p=.15$. However, this effect was significant when including only the four plots identified as high cheatgrass during the first research season, $F(1,2)=334.7$, $p=.003$.

Mammals

During the total of 6 months (across two years) of remote camera observation, we recorded 27,101 images, 752 (2.7%) of which contained at least one mammal. We detected 1091 mammals, 88% of which were ungulates.

ANCOVA analysis showed a significant inverse correlation between the cheatgrass cover of plots and the number of observed mammals, $F(1,13)=7.432$, $p=.02$ (Figure 3). Year was not a significant predictor of mammal detections, $F(1,13)=3.896$, $p=.07$. Mammal species richness was significantly correlated with year, $F(1,13)=6.647$, $p=.02$, but not cheatgrass cover,

$F(1,13)=1.931$, $p=.19$ (Figure 3). We found that mammal numbers and mammal species richness best fit a 2-way ANOVA model.

Birds

During the total of eight bird surveys (across two years), we observed 33 species across the 8 plots. Obligate ground-nesters (Wickersham, 2017), which come into frequent direct contact with grassy vegetation, comprised 40.9% of all birds observed.

ANCOVA analysis showed an insignificant negative relationship between mean birds per plot and cheatgrass cover, $F(1,13)=3.719$, $p=.08$ (Figure 4), but a significant relationship with year, $F(1,13)=11.83$, $p=.004$. We found a significant negative relationship between bird species richness and cheatgrass cover, $F(1,13)=6.8154$, $p=.02$ (Figure 4), along with a significant correlation between bird species richness and year, $F(1,13)=16.39$ $p=.001$. Bird numbers best fit a 2-way ANOVA model, while bird species richness followed an ANCOVA pattern.

Butterflies

During the total of ten butterfly surveys (across two years), we observed 33 butterfly species. Variegated fritillaries, habitat generalists that occasionally invade the Rocky Mountain region in large numbers in response to environmental stresses in the southern United States (Opler 1999), comprised 69% of all butterflies observed.

ANCOVA analysis showed a significant negative relationship between mean butterflies and cheatgrass cover, $F(1,13)=16.81$, $p=.001$ (Figure 5), but no correlation between mean butterflies and year, $F(1,13)=2.274$, $p=.16$. Butterfly species richness was significantly negatively correlated with cheatgrass cover, $F(1,13)=23.53$, $p<.001$ (Figure 5), and significantly correlated with year, $F(1,13)=14.65$, $p=.002$. Both butterfly numbers and butterfly species richness best fit an ANCOVA model.

Additional Factors

Analysis investigating relationships between the primary variables and plot slope, bare ground, shrub and tree cover, and distance to human development generally supported our hypothesis that cheatgrass cover was the primary driving factor influencing wildlife abundance (Table 1; Table 2). However, mammals were negatively correlated with plot distance to human development in 2021. Butterfly numbers in 2020 correlated negatively with plot distance to human development, and butterfly species richness in 2021 correlated negatively with both plot distance to human development and plot slope. We also found positive correlations between living woody plant cover and cheatgrass cover, cheatgrass plants, and cheatgrass litter in 2021.

Discussion

Confirmation of Primary Hypothesis

Our findings support the hypothesis that cheatgrass negatively impacts habitat suitability for native wildlife.

The two-year study indicates that large mammals, particularly ungulates, avoid areas infested by cheatgrass. Given the predominance of ungulates in our dataset, we do not expect the mammal results to represent a general mammal response to cheatgrass accurately. Ungulates are probably sensitive to cheatgrass infestation due to their preference for grazing on grasses and forbs that directly compete with cheatgrass. Other mammal species, particularly predators, are unlikely to be similarly impacted by cheatgrass, which may explain the weak correlation between mammal species richness and cheatgrass cover in our results.

Our study suggests a possible negative impact of cheatgrass infestation on bird numbers. Bird density was generally lower on cheatgrass-infested plots, but this tendency was not statistically significant. However, bird species richness was significantly lower on cheatgrass-infested plots. We examined the possibility that this inconsistency in observed bird response was due to variation in shrub cover across the plots, but our data did not support this hypothesis.

Our study indicates that butterflies are strongly impacted by cheatgrass infestation. Both butterfly abundance and species richness were significantly lower in areas infested by cheatgrass. This is likely due to decreased nectar and host plant availability as cheatgrass displaces native plants.

Varied Species Group Responses to Cheatgrass

The informal comparison of Two-Way ANOVA and ANCOVA models suggests that mammals respond to discrete cheatgrass densities, while any increase in cheatgrass density impacts butterflies. Due to their larger home ranges relative to butterflies, we hypothesize that mammals are relatively unaffected by cheatgrass interspersed among other plants up to a certain threshold level above which foraging in a particular area becomes unattractive. Conversely, butterflies have small home ranges and are dependent on native grasses and forbs as host plants and nectar sources within a small area. Therefore, any reduction in native plant density, even within a relatively small area, may directly drive down butterfly populations. Further research with larger datasets and formal statistical tests could strengthen our tentative conclusion.

Alternative Explanations

Factors other than cheatgrass cover are unlikely to explain our results.

Although mammal numbers, butterfly numbers, and butterfly species showed a weak negative correlation with distance to human development and plot slope, this was likely due to high cheatgrass density plots being located farther away from the highway at higher elevations characterized by steep and rocky slopes.

The correlation between living woody plant cover and cheatgrass is likely due to the parallel die-off of shrubs and reduction of cheatgrass density on burned plots.

Impact of Fire on Cheatgrass

Contrary to our original hypothesis, fire reduced cheatgrass infestation and favored native plant recovery.

In the literature, cheatgrass is generally described as increasing fire risk and fire frequency (Bradley et al. 2018; Whisenant, 1990). However, most cheatgrass studies have been conducted in a limited set of locations (typically in the Great Basin area) that are not representative of all ecoregions (Porensky & Blumenthal, 2016). The literature suggests multiple key factors that could explain the difference between cheatgrass response to fire on our plots from the response frequently observed in the Great Basin area: increased altitude, increased soil moisture, decreased temperature, and remnant native seed bank. Urza et al. (2019) found increased resistance to cheatgrass invasion after fire on higher elevation plots, which were consequently cooler and moister, compared to lower elevation plots. Consistent with these findings, Sherrill & Romme (2012) identified increased altitude, increased fire severity, and increased post-fire soil moisture as factors decreasing cheatgrass return after fire. White and Currie (1983) found that fall burns in Montana were more effective at controlling cheatgrass than spring burns, although these researchers consistently observed decreases in cheatgrass density regardless of burn timing. Lastly, evidence that reseeding of native vegetation after fire is effective at controlling invasive species, including cheatgrass, over both short (Thompson et al. 2006) and long (Ott et al. 2019) time periods suggests that a remnant native seed bank in infested areas would help reduce cheatgrass regrowth post-fire.

Our plots satisfied many of the requirements for increased resistance to cheatgrass infestation after fire, as they were located in a mid-elevation environment characterized by relatively high winter seasonal precipitation (which occurred shortly after the fire) and relatively low temperatures. Our plots also sustained remnant native vegetation in cheatgrass-infested areas, likely indicating the presence of a dormant native seed bank. Furthermore, the Calwood Fire occurred on October 17th, 2020, during the season that White and Currie (1983) identified as a particularly effective season for fire-based cheatgrass control.

Our results, combined with previous studies, suggest that controlled fire may be an effective tool for cheatgrass control in Boulder County and possibly across the Colorado Front Range and beyond. Because the Rocky Mountain foothills ecosystem is highly fire-adapted (Kaufmann et al. 2006), the cheatgrass fire cycle observed in fire-sensitive Great Basin landscapes may not be present in our area.

Further Research

Although our research provides insight into the impact of cheatgrass on large mammals, birds, and butterflies, the impact of cheatgrass on wildlife populations requires further study to inform sustainable management practices.

Our results should be verified and expanded through research covering a larger geographic area utilizing more plots, broader animal sampling, and extending over a longer timescale. Of particular interest would be the inclusion of multiple invertebrate taxa in sampling methodology to understand better their contribution to the impact of cheatgrass on higher trophic levels.

A variety of methods have been used to manage cheatgrass infestation. Future research should investigate the differential impact of such methods on wildlife populations. We recommend that such research compare wildlife populations over appropriately long timescales on untreated plots relatively free of cheatgrass, on untreated plots infested by cheatgrass, and on previously infested treated plots. The standard for treatment success should include restoration to ecosystem conditions similar to those found in untreated, relatively cheatgrass-free areas, not just improvement over untreated cheatgrass-infested areas. Failing to investigate the effect of cheatgrass treatment methods on wildlife could potentially cause the inadvertent degradation of valuable wildlife habitat. For example, some herbicides are known to negatively impact certain butterfly species (Russell & Schultz 2010). Without studies investigating the effects of herbicides on butterflies, herbicides might be used when alternative methods, such as those suggested by Blumenthal et al. (2010), would be more appropriate.

Our results, combined with the literature on fire and cheatgrass interactions, suggest that controlled fire may be a powerful cheatgrass management method in certain ecosystems and regions. Further research should more precisely identify ecological and geographic limits within which fire is a viable cheatgrass control method. Understanding the precise influence of both pre- and post-burn precipitation on cheatgrass regrowth would aid managers in choosing the ideal timing for prescribed burns aimed at controlling cheatgrass. Long-term monitoring and research after both controlled and uncontrolled fires would deepen understanding of cheatgrass-fire interactions and reveal the effectiveness of management strategies.

Conclusion

Our study indicates that mammals and butterflies are impacted by cheatgrass infestation, although in different ways. Mammals respond to a threshold level of cheatgrass cover above which the infested areas are undesirable for foraging. Conversely, butterflies respond to even small changes in cheatgrass cover, likely due to their dependency on native plant availability within a small area. While bird species richness is impacted by cheatgrass cover, we could not conclude that bird numbers are similarly affected (possibly due to variations in other characteristics across our plots). Future research focusing on large mammal, small mammal, bird, and invertebrate populations could help refine the understanding of the impact of cheatgrass infestation on wildlife.

Results following unexpected fire disturbance during our research indicate that fire can reduce cheatgrass infestation in the Colorado Front Range foothills grassland ecosystem, suggesting that prescribed fire is a tool for land managers addressing the environmental degradation caused by this invasive annual grass.

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Illustrations

Tables

Table 1. Table of p-values correlating each primary variable with additional factors in 2020, specifically ranked number of mammals (Mam), ranked number of mammals species (Mam S), ranked mean number of birds (Bird), ranked number of bird species (Bird S), ranked mean number of butterflies (Bfly), ranked number of butterfly species (Bfly S), plot Bare Ground Cover (Bare G), plot distance to human development (DtH), and slope (Slope).

	Slope	**DtH**	**Bare G**	**Bfly S**	**Bfly**	**Bird S**	**Bird**	**Mam S**
Mam	0.126	0.094	0.565	0.053	0.181	0.241	0.091	0.313
Mam S	0.179	0.055	0.612	0.114	0.104	0.068	0.218	
Bird	0.681	0.699	0.715	0.104	0.521	0.081		
Bird S	0.456	0.220	0.331	**0.014**	0.056			
Bfly	0.115	**0.041**	0.054	**0.014**				
Bfly S	0.227	0.180	0.277					
Bare G	**0.038**	0.066						
DtH	**0.005**							

Table 2. Table of p-values correlating each primary variable with additional factors in 2021, specifically ranked number of mammals (Mam), ranked number of mammals species (Mam S), ranked mean number of birds (Bird), ranked number of bird species (Bird S), ranked mean number of butterflies (Bfly), ranked number of butterfly species (Bfly S), plot Bare Ground Cover (Bare G), plot distance to human development (DtH), and slope (Slope).

	Slope	**DtH**	**Bare G**	**Bfly S**	**Bfly**	**Bird S**	**Bird**	**Mam S**
Mam	0.141	**0.037**	0.438	0.120	**0.043**	0.469	0.943	0.488
Mam S	0.198	0.156	0.598	0.117	0.895	0.415	0.491	
Bird	0.833	0.738	0.499	0.347	0.415	0.131		
Bird S	0.096	0.087	0.239	**0.024**	**0.049**			
Bfly	0.152	0.119	0.432	**0.030**				
Bfly S	**0.005**	**0.016**	0.153					
Bare G	**0.008**	0.078						
DtH	**0.005**							

Figures

Figure 1. Diagram illustrating our modified radial distribution of plot sampling locations that increases sampling uniformity for circular plots. Red points indicate sampling locations that deviate significantly from traditional radial sampling methods.

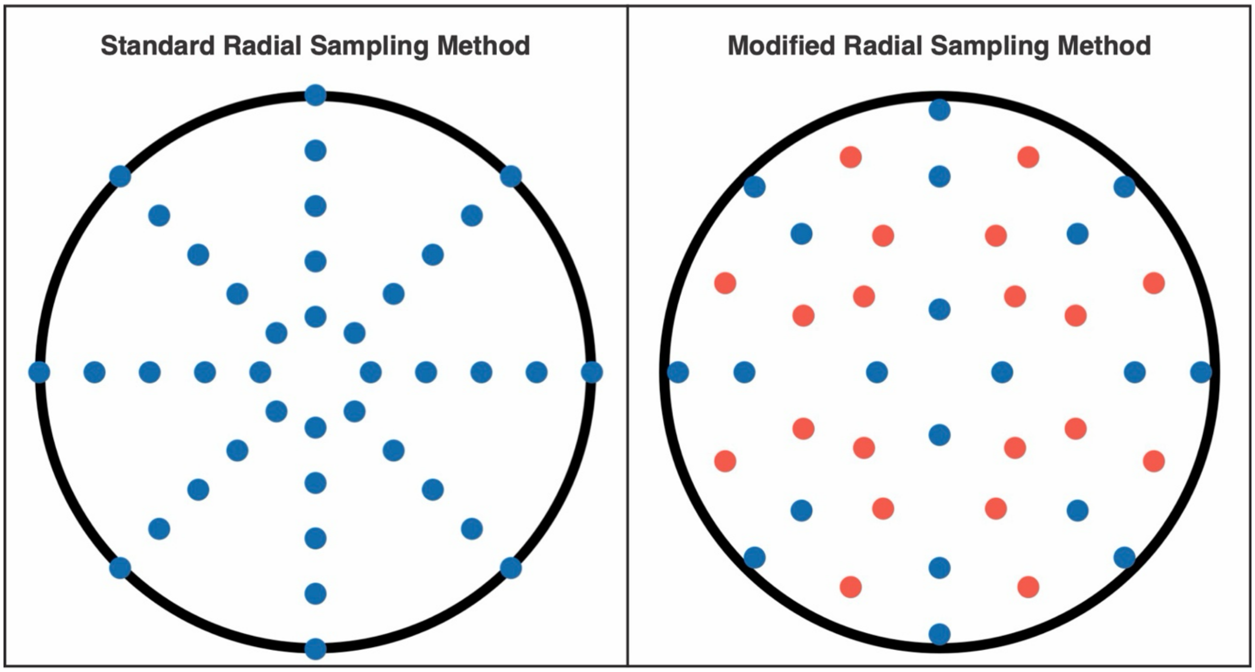

Figure 2. Graph comparing cheatgrass density on each plot between 2020 and 2021 using standard boxplot notation. Blue data points indicate unburned plots, while red data points indicate plots burned between 2020 and 2021. The data points are shifted horizontally to enhance the difference between the box plot and individual data points.

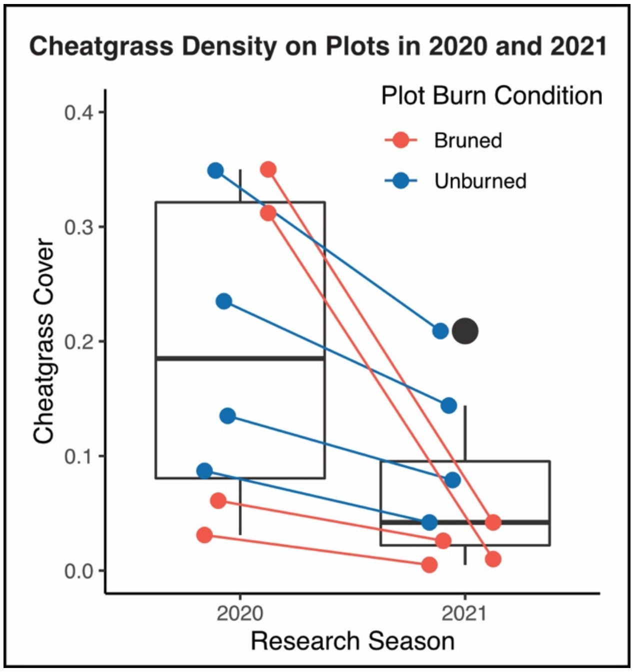

Figure 3. Graph showing the ranked number of observed mammals and mammal species correlated with cheatgrass cover on each plot for 2020 and 2021.

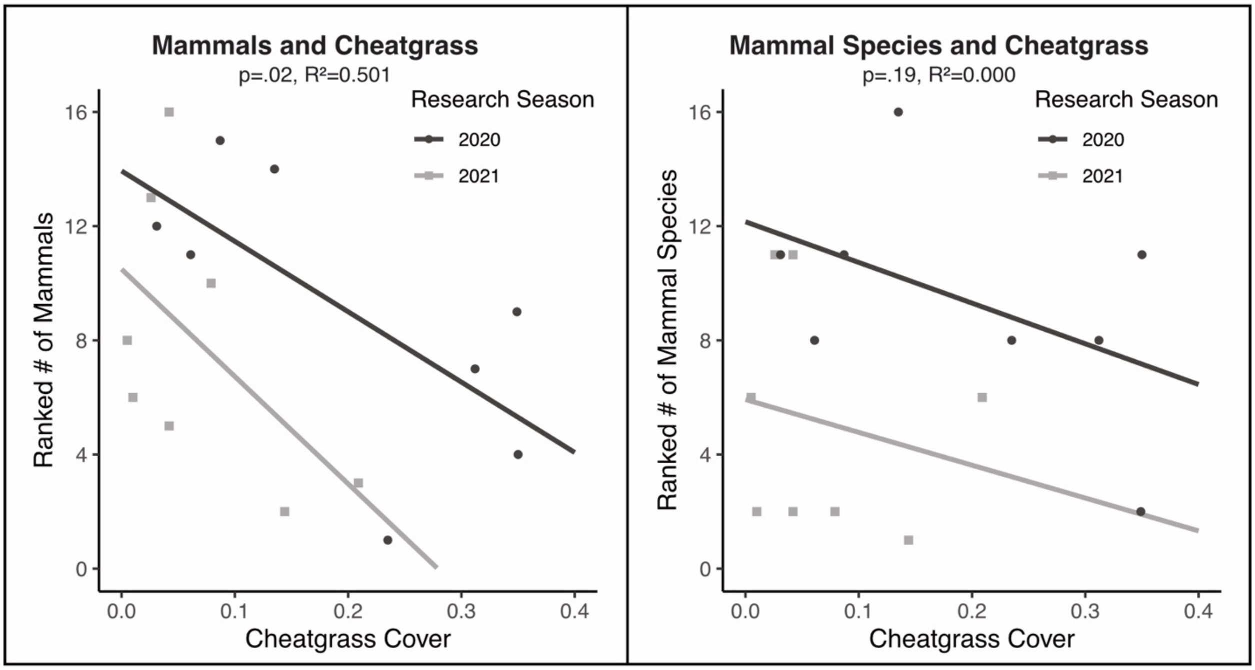

Figure 4. Graph showing the ranked mean number of observed birds and bird species correlated with cheatgrass cover on each plot for 2020 and 2021.

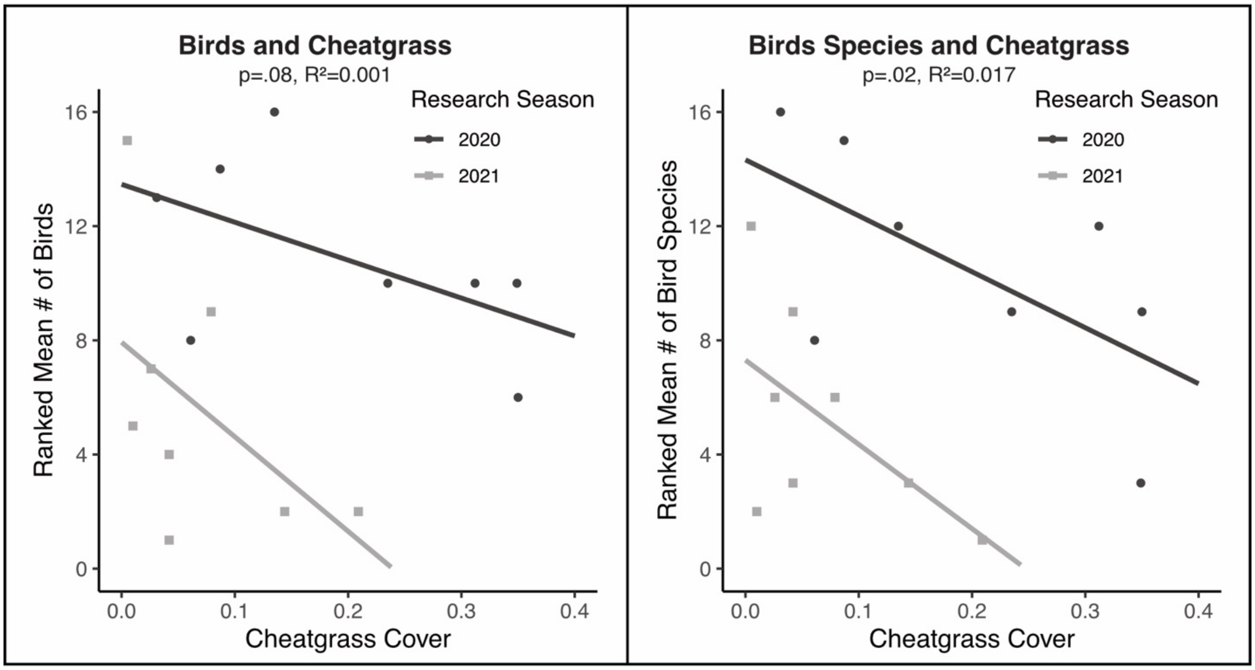

Figure 5. Graph showing the ranked mean number of observed butterflies and butterfly species correlated with cheatgrass cover on each plot for 2020 and 2021.