Managing Fine Fuels Using Dormant Season Grazing: Improving Wyoming Big Sagebrush Communities in the Northern Great Basin

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Authorization to Submit Thesis

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Abstract

The invasive annual grass medusahead infests rangelands throughout the West, from the Columbia Plateau to the California Annual Grasslands and the Great Basin. Dominating secondary succession in the sagebrush steppe, medusahead can degrade the habitat of threatened species such as the greater sage-grouse. This research explores the potential of dormant season grazing as an applied management strategy to reduce the negative impacts of medusahead while promoting recovery of perennial vegetation at the landscape-scale. In particular, it assessed grazing with four treatments from 2018 – 2020: traditional grazing (May – October), dormant season grazing (October – February), traditional+dormant season grazing (May – February), and no grazing. After two years of grazing treatments, biomass, density, cover, and fuel continuity did not differ between treatments ($p > 0.05$). However, biomass measurements were significantly different between years which is likely due to greater than normal precipitation in 2019 and 2020. Between 2018-2019, annual grass biomass increased by 81% (666 – 1,212 kg ha^{-1}) and perennial grass biomass increased by 165% (118 – 313 kg ha^{-1}). Litter biomass decreased by approximately 15% in every year since 2018 (2,374, 2,012, and 1,678 kg ha^{-1} in 2018 – 2020). There were not significant differences in cover or density of annual and perennial grasses between treatments and years. Our results indicate that two years may not be adequate time for dormant season grazing treatments to be effective in reducing the abundance of medusahead, and that after two years of treatments, dormant season grazing does not have a detrimental effect on perennial vegetation.

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Dedication

Most importantly I would like to thank my parents, Bill and Laurie Price for their unwavering support over the years, I owe a great deal of my success to them. I owe my sister Emily a great deal of gratitude for her tolerating me these past two years, even though she thinks ecology is the "study of how things die." Finally, I would like to thank Darby Biggs for her patience and understanding as I have worked on this study.

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Managing Fine Fuels Using Dormant Season Grazing: Improving Wyoming Big Sagebrush Communities in the Northern Great Basin

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Introduction

Medusahead (*Taeniatherum caput-medusae* (L.) Nevski) is an introduced annual grass primarily from the western Mediterranean region of Eurasia (Young, 1992). Medusahead is capable of dominating secondary succession of western rangelands from the Great Basin to Columbia Plateau and estimates suggest it has invaded over two million hectares (ha) of rangeland across the western United States (Davies and Johnson, 2008; Duncan et al., 2004). Medusahead poses major problems to rangeland health including, but not limited to: decreased species diversity, reduction of forage, and increased accumulation of litter, resulting in increased fine fuel accumulation and reduced fuel moisture content (Davies et al., 2015; Davies and Johnson, 2008; Davies and Nafus, 2013; Duncan et al., 2004; Young, 1992). Perhaps the most significant threat is the development of a more rapid-fire cycle. For example, Whisenant (1992) observed fire frequency increasing from 0.1 fires year^{-1} to 0.5 fire year^{-1} when cheatgrass (*Bromus tectorum* L.) cover increased from 40% to 90%. This increase in fire frequency further perpetuates the dominance of annual grasses, including medusahead, while degrading big sagebrush (*Artemisia tridentata* Nutt.) rangeland (Davies and Svejcar, 2008; Nafus and Davies, 2014; Young, 1992; Young and Evans, 1970).

One of the key reasons medusahead is able to dominate secondary succession is because of the phenological differences between it and native perennial grasses. Like other winter annuals, medusahead can germinate and emerge in the fall after a moisture event with leaf development reaching up to several centimeters in height before stopping due to cold weather (Young, 1992). This early germination provides a considerable advantage over perennial grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve) and crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), as their germination typically does not reach peak rates until April (Humphrey and Schupp, 1999; Young, 1992). This early growth allows medusahead to utilize resources before perennial seedlings, thus limiting their summer survival as they are outcompeted for resources in the semi-arid environment (Harris, 1977; Humphrey and Schupp, 1999).

Another factor that allows medusahead to dominate secondary succession is its ability to develop a thick layer of litter (commonly referred to as thatch) composed of the prior year's growth (Evans and Young, 1970; Mariotte et al., 2017; Young et al., 1971). This layer of litter can persist for multiple years when not disturbed (Torell et al., 1961) allowing mature medusahead seeds to remain suspended above the mineral soil providing better microclimates for medusahead seeds to germinate (Evans and Young, 1970; Mariotte et al., 2017; Young et al., 1971). The litter also reduces competition from native plant species (Davies and Svejcar, 2008; Young and Evans, 1970) by preventing native seeds from contacting mineral soil, which is necessary for their germination (Torell et al., 1961).

An additional effect of the persistence of the litter is that multiple years' growth can accumulate adding considerably to the amount of fine fuels on the landscape. A large abundance of litter is problematic as it increases fuel continuity across invaded landscapes, and reduces fuel moisture content earlier in the summer (Davies and Nafus, 2013). For example, Davies et al. (2015) found that fuel moisture in medusahead dominated rangelands may be less than 20% once plants reach maturity in July. Reduced fuel moisture can contribute to increased fire ignition and spread (Chuvieco et al., 2004; Cruz et al., 2015; Krueger et al., 2016), and the buildup of litter on medusahead invaded landscapes is a major factor that results in a reduced fuel moisture content on rangelands. Reducing herbaceous biomass and fuel continuity can reduce wildfire probability, size, and intensity (Davies et al., 2015; Davies et al., 2016).

The loss of native vegetation in the Northern Great Basin is especially important considering recent concerns over native sagebrush obligates such as the greater sage-grouse (*Centrocercus urophasianus*). One of the largest threats to the greater sage-grouse is habitat loss (Connelly et al., 2000; Stiver et al., 2015). Productive sage-grouse habitat should exceed 15% perennial grass cover and 15-25% sagebrush cover (Connelly et al., 2000; Stiver et al., 2015). Medusahead dominated rangelands do not allow for these conditions to be met, in some cases reducing perennial grass cover by over 90% (Connelly et al., 2000; Nafus and Davies, 2014). Additionally, the loss of habitat due to medusahead invasion is detrimental to other species of wildlife, including introduced granivores such as the chukar partridge (*Alectoris chukar*). Due to medusahead's physical properties, such as a high silica concentration, chukar are less able to utilize medusahead when compared to other introduced grasses such as cheatgrass. This is particularly problematic, as chukar are better adapted to utilize introduced grasses compared to native fauna (Connelly et al., 2000; Davies and Svejcar, 2008; Savage et al., 1969).

Medusahead has been observed to reduce the grazing capacity of rangelands by over 50% (Hironaka, 1961; Young, 1992). Medusahead is unique in that it possesses a high insoluble ash content, of which a large portion is silica (> 11%; Bovey et al., 1961; Swenson et al., 1964). This, combined with stiff awns featuring silicate barbs make the grass almost completely unpalatable once it reaches maturity (Swenson et al., 1964; Villalba and Burritt, 2015; Young, 1992). However, medusahead is palatable in the leaf stage with greater than 10% crude protein (Bovey et al., 1961; Young, 1992).

When considering all of these factors it becomes apparent that an effective means to reduce the impact of medusahead on western rangelands is important. Targeted grazing is often considered as a cost-effective management strategy to control invasive annual species. Launchbaugh and Walker (2006) defined targeted grazing as "the application of a particular kind of grazing animal at a specified season, duration, and intensity to accomplish specific vegetation management goals." Altering the season of grazing by utilizing dormant season grazing, rather than the traditional spring/summer season, it may be possible to reduce the impacts of medusahead on rangelands.

While dormant season grazing has been demonstrated to be effective at managing medusahead at the pasture level (~ 800 – 1,000 ha; Davies et al., 2016), there has not been research looking into the effectiveness on rangeland management units that range in size upwards of 10,000 ha (James et al., 2015). Additionally, the majority of research about the effectiveness of grazing to control medusahead has been done during the spring-summer growing season before medusahead plants reach maturity, with very little research focusing on fall-winter dormant season grazing (Davy et al., 2015; DiTomaso et al., 2008; James et al., 2015). One possible solution to reduce medusahead biomass at a large-scale is dormant season grazing by livestock between October and February. By changing the timing of the grazing in annual grass dominated rangelands, livestock are able to take advantage of the phenological differences between winter annual grasses like medusahead and the more desirable perennial grasses in the West.

By changing the timing of livestock grazing to the fall, grazing animals may select for newly emerged medusahead seedlings as they are more palatable and possess a higher percentage of crude protein (approximately 10%) compared to dormant large statured perennials (Brownsey et al., 2017; Villalba and Burritt, 2015). For example, crude protein in dormant bluebunch wheatgrass and crested wheatgrass is about 4% in the fall (Ganskopp et al., 2007; Ganskopp and Bohnert, 2001). Because cattle will likely select to graze the new medusahead growth within the litter layer in the fall, they may also graze a portion of the litter reducing the amount of dead material on the ground. Observations from other grazing trials on medusahead have shown a positive feedback cycle, when cattle graze medusahead seedlings they also increase the amount of thatch that is consumed (Spackman, 2019). Reducing the negative impacts of the litter layer should be one of the first priorities when improving medusahead dominated rangelands (Perryman et al., 2018). Existing research also supports the shift of the grazing timing to the fall; fall grazing after perennial grasses have gone dormant is minimally detrimental and can actually increase the abundance of perennial grasses in sagebrush stands (Daubenmire, 1940; Laycock, 1967; McLean and Wikeem, 1985).

The objectives of this study were to evaluate the effectiveness of dormant season grazing by cattle across large landscapes (~ 9,000 ha) to: 1) reduce annual grass (i.e., medusahead) fine fuels to lower fire risk, benefitting less fire-adapted species, and 2) promote perennial bunchgrasses by taking advantage of phenological difference between perennial grasses and medusahead.

Methods

Study area

Research was conducted on the Three Fingers Allotment (56,170 ha, 138,800 ac) in southeastern Oregon (43° 25’N, 117° 8’ W), approximately 70 km west of Boise, Idaho, USA (Fig. 1). The Three Fingers Allotment is administered by the Vale District Bureau of Land Management (BLM). Typical of the Northern Great Basin, the study area experiences cool, wet winters with hot, dry summers. Average water year (1 October – 30 September) precipitation over the past 30 years (1991-2020) was 258 mm (10.2 in.), with the majority of the precipitation occurring in the winter and spring months. Water year precipitation during the study was 195 mm in 2018, 378 mm in 2019, and 311 mm in 2020 (7.7, 14.9, 12.2 in.; Western Regional Climate Center, 2021). Topography is variable, with flat valleys and steep, rocky hillsides. Elevation ranges from 950 – 1,400 m (3,100 – 4,600 ft.) with an average slope of 12% (U.S. Geological Survey, 2017). Soil texture is generally loamy to clay, and aspect varies by research site (Table 1). Livestock have been present in the area since the late

19th century, with a deferred rotational grazing system being utilized during the summer grazing period (1 May – 30 September) since the 1980s (Personal communication, local rancher 2019).

The dominant plant community in the Three Fingers Allotment is typical of the Northern Great Basin (Appendix A). Undisturbed areas are dominated by a shrub component of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) and a mix of perennial grasses. Dominant perennial grasses are bluebunch wheatgrass, crested wheatgrass, western wheatgrass (*Pascopyrum smithii* (Rydb.) Á. Löve), and Idaho fescue (*Festuca idahoensis* Elmer). Dominant perennial forbs are lupine (*Lupine spp.*) and tapertip hawksbeard (*Crepis acuminata* Nutt.). Since 1985, 17 wildfires have burned 32,090 ha (79,296 ac) of the Three Fingers Allotment at least once (Fig. 2.). Within the burned areas there is only a minimal component of shrubs and perennial grasses. The burn scars are often still visible as the affected areas have become dominated by medusahead. Especially problematic is the repeated burning on the allotment, nearly 19% (10,571 ha, 26,122 ac) has burned at least twice.

The study is taking place in three pastures within the Three Fingers Allotment: McIntyre (MCI), Saddle Butte (SB), and South Camp Kettle (SCK). Within each pasture, treatments are being concentrated within specified key areas (Fig. 1) that were selected because of marginal ecological conditions, recurrent fire history, and proximity to core greater sage-grouse habitat (Arispe et al., 2018). Each key area was dominated by medusahead with some perennial vegetation present.

Experimental design

To study the effects of dormant season grazing on medusahead dominated rangelands, two sites were randomly placed within each of the three key areas for a total of six research sites (Fig. 1). Each site consists of four 150 X 150 m exclosures (Fig. 3). The exclosures at each site were randomly assigned one of the four grazing treatments: non-grazed (N), traditional grazing from 1 May to 30 September (T), dormant season grazing from 15 October to 28 February (D), and both traditional and dormant season grazing (T+D). The N treatment exclosure was constructed of a permanent four strand fence, with three-strands of barbed wire and a strand of smooth wire on the bottom, on all four sides. The T and D treatment exclosures have permanent barbed wire fence on two sides and a lay-down fence as described in Turner (1960) on two sides to allow cattle access during the prescribed treatment period. The T+D treatment is unfenced year-round. Protein supplements were strategically place next to roads and at least 0.4 km (0.25 miles) away from study sites throughout each of the key areas during the dormant season.

Grazing was applied at the pasture level during the traditional season (1 May – 30 September) in accordance to BLM permits. Dormant season grazing was permitted for a maximum of 1,700 cows across the three pastures, at any one time, from 15 October through 28 February. Utilization varied between 18% and 62% depending on pasture and year due to differences in forage availability, weather, and access to water (Table 2).

Measurements

Fuels and vegetation data were collected in late June of 2018, 2019, and 2020. Fuels data were collected using a modified Fire Effects Monitoring and Inventory System (FIREMON) protocol (Lutes et al., 2006) and modified BLM Assessment, Inventory, and Monitoring Program (AIM) sampling methods (Taylor et al., 2014). Within each exclosure, vegetation and fuel were measured using a 50 X 50 m plot consisting of three, 50 m transects. The three transects were arrayed parallel to each other and spaced 25 m apart (Fig. 4). To ensure destructive sampling points were not measured in repeated years and to capture the heterogeneity of the treatment exclosures, the plot was moved 20 meters in a random direction each year. Fine fuels measurements consisted of herbaceous biomass and fuel continuity. Vegetation measurements consisted of cover and density of both herbaceous and woody species.

Herbaceous biomass was measured every 10 m per transect using a 0.20 m^2 rectangular quadrat for a total of 15 samples per plot. Biomass was collected by functional group and included: annual grass, perennial grass, forbs, standing dead, and litter. Current year growth and standing dead were clipped to 1 cm above ground level and all litter within the quadrat was collected. Samples were dried for 48 hours at 50° C, weighed, and used to calculate total biomass on a kg ha^{-1} basis.

Fuel continuity was assessed using canopy gap between all species regardless of life-span. Along all transects, gap lengths that were devoid of vegetation for at least 20 cm were recorded (Herrick et al., 2005). Percent gap per transect was calculated by adding the total gap in cm, and dividing by 5,000 cm (total area measured). Mean gap size and number of gaps was used to characterize fuel continuity.

The line-point intercept method was used to estimate cover of functional groups. A flag-pin was dropped every 1 m along each transect from a height of 5 cm above the herbaceous canopy, for a total of 150 points for each plot. Every plant species intercepted by the pin was recorded, including dead forb, dead grass, and litter. Ground cover was recorded as one of the following soil surfaces: rock, moss, lichen crust, mineral soil, or in the case of the pin intercepting the base of a plant, the species. Species were then aggregated into functional groups consisting of: annual grass, perennial grass, Sandberg bluegrass (*Poa secunda* J. Presl), annual forbs, perennial forbs, and litter. Cover was calculated by taking the total number of hits per functional group and dividing by 150, then multiplying by 100 to get the percent cover.

Shrub cover was collected using a 2 m belt transect along each of the three transects. Data was collected for sagebrush species and all other woody species that were over 15 cm in height. Extending 1 m to either side of each transect the height of the tallest leaf (excluding inflorescences), longest diameter (D1), and the perpendicular diameter (D2) was recorded for all woody species rooted within the belt transect. Plants with less than 10% live canopy were not measured. Shrub cover was calculated by adding the area (area = π*D1*D2/4) of each shrub (m^2) in the belt transects, and dividing by the total area of the belt transects (300 m^2).

Herbaceous density was measured using a 0.20 m^2 rectangular quadrat every 5 m along each transect, for a total of 30 measurements per plot. Individuals were counted for each of the following life form categories: perennial tall grass, perennial short grass (i.e., Sandberg bluegrass), perennial forbs, and annual forbs. Shrub seedlings < 15 cm in height were counted by species. Density of shrubs > 15 cm in height was collected using the same belt transect as that used for shrub cover. Frequency of invasive annual grasses was recorded by measuring the presence or absence of plants in each quadrat.

Statistical analysis

Analysis of variance (ANOVA) with a restricted maximum likelihood (REML) was used to determine if there was a difference between grazing treatments (JMP®, Version 14. SAS Institute Inc., Cary, NC). Fixed variables were treatment, year, and treatment-by-year interactions. Random variables were block, block-by-treatment, block-by-year, and block-by-treatment-by-year interactions. Means were reported with standard errors (mean ± S.E.) and considered different when $p \leq 0.05$. A Tukey-Kramer HSD test was used to further investigate differences when the REML indicated that there were significant differences between means.

Results

Fuels

Grazing treatments did not have a significant impact on annual grass, perennial grass, forbs, litter, or total biomass (p = 0.96, 0.24, 0.14, 0.86, and 0.81, respectively; Fig. 5). There was a significant year effect for annual grass, perennial grass, and forb biomass (p = 0.049, 0.022, and <0.001; Fig. 5). Mean annual grass biomass increased by 81% from 2018 to 2019 (666 kg ha^{-1} and 1,212 ka ha^{-1} respectively). However, in 2020 annual grass biomass (1,011 kg ha^{-1}) was not significantly different than either 2018 or 2019 (Fig. 5). Perennial grass biomass increased by 165% from 2018 to 2019 (118 kg ha^{-1} to 313 kg ha^{-1}), and 8% between 2019 and 2020 (313 kg ha^{-1} to 339 kg ha^{-1}; Fig. 5). There were only trace amounts of forbs in 2018, however, forb biomass was 183 kg ha^{-1} in 2019 and 141 kg ha^{-1} in 2020. There was not a significant difference between years for litter and total biomass (p = 0.11 and 0.17). While not significant, it should be noted that litter biomass decreased each year since 2018 (2,374 kg ha^{-1} in 2018, 2,012 kg ha^{-1} in 2019, and 1,678 kg ha^{-1} in 2020; Fig. 5).

Fuel continuity, measured by gap, was not different between treatments, year, or treatment-by-year interactions (p = 0.44, 0.14, and 0.54). Overall fuel continuity was very high as percent gap was less than 2.5% all three years (Fig. 6). The mean size of gaps was 27 cm, and there was an average of 4.7 gaps per plot.

Cover

Annual grass and perennial grass cover did not differ between treatment (p = 0.33 and 0.40), year (p = 0.15 and 0.07), or treatment-by-year interactions (p = 0.16 and 0.30; Table 3). Medusahead was the dominant annual grass comprising 82%, 80%, and 73% of the annual grass cover across all treatments and sites in 2018, 2019, and 2020, respectively. Cheatgrass made up 10%, 16%, and 25% of the annual grass cover each year. Bluebunch wheatgrass was the most common perennial grass, accounting for an average 29% of the perennial grass cover in all three years of data collection. Western wheatgrass cover increased each year, as it made up 14%, 25%, and 32% of perennial grass cover in the three years of data collection.

Annual forbs were the only functional group with a significant change, increasing from 1.6% in 2018 to 8.8% in 2019 (p = 0.042; Table 3). This increase in annual forb cover occurred across all treatments and sites and can be attributed to a flush of redstem stork’s bill (*Erodium cicutarium* (L.) L’Hér. ex Aiton) and tall annual willowherb (*Epilobium brachycarpum* C. Presl). In 2018, neither the redstem stork's bill or willowherb were observed at any of the sites, but in 2019 total cover was 5% and 2%, respectively.

Cover of sagebrush and other shrubs was not significantly different between treatments ($p = 0.28, 0.41$), years ($p = 0.83, .073$), or treatment-by-year interactions ($p = 0.52, 0.77$; Table 4). Rubber rabbitbrush (*Ericameria nauseosa* (Pall. Ex Pursh) G.L. Nesom & Baird) was the most common woody species, accounting for 54% of the total shrub cover when averaged across all treatments and sites. Big sagebrush and yellow rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.) were the other common woody species, accounting for 31% and 18% of the total shrub cover, respectively.

Density

There was not a significant change in density of any of the plant functional groups we measured across treatment, year, or treatment-by-year interactions. Perennial tall grass density averaged 1.08 plants per m^2, and perennial short grasses averaged 0.74 plants per m^2 over the three years (Table 5). Density of shrub seedlings (< 15 cm) did not differ between treatment, year, or treatment-by-year interactions ($p = 0.61, 0.91$, and 0.27). Density of sagebrush and other shrubs (> 15 cm) did not change across treatments ($p = 0.44, 0.34$), years ($p = 0.58, 0.70$), or treatment-by-year interactions ($p = 0.49, 0.80$; Table 4).

Discussion

After two years of grazing treatments, there was not a difference in the plant community composition between treatments. The only significant increases were between years in annual grass, perennial grass, and forb biomass. For all three of these groups the biomass increased from 2018, which was a dry year, to 2019, which was an above average year for precipitation (Fig. 7). Total precipitation for the 2018 water year (October 2017 – September 2018) was 195 mm (7.7 in), which is 75% of normal. Total precipitation in 2019 was 378 mm (14.9 in), and in 2020 it was 311 mm (12.2 in); these values are 147% and 121% of normal.

In addition to total precipitation, timing of precipitation is also of great importance to the success of plant growth in the Northern Great Basin and other ecosystems (Bates et al., 2006; Robinson et al., 2013). While 2018 did receive less than normal total precipitation, May and June monthly precipitation was 68% (29 mm, 1.1 in) and 47% (11 mm, 0.4 in) of the monthly normal of 43.1 mm (1.7 in) and 24 mm (0.9 in), respectively. April and May of 2019 received 176% (54 mm, 2.1 in) and 248% (107 mm, 4.2 in) of the monthly normal of 31 mm (1.2 in) and 43 mm (1.7 in), respectively. May and June of 2020 received 198% (85 mm, 3.3 in) and 358% (86 mm, 3.3 in) of the monthly normal. The increase in total precipitation as well as monthly precipitation in important spring months is likely a contributing factor in the increase of biomass in annual grass, perennial grass, and forbs.

The decrease in litter biomass was seen in all treatments, and as such can at least partially be attributed to the greater than normal precipitation in 2019 and 2020, rather than a result of grazing. Prior studies have shown a correlation between increased precipitation and increased decomposition of litter in semi-arid grasslands (Bontti et al., 2009; Epstein et al., 2002; Yahdjian et al., 2006). Higher than normal precipitation in the 2016 – 2017 water year (365 mm, 14.4 in) likely produced a large medusahead crop in 2017 (Poděbradská et al., 2019; Rao and Allen, 2010), and due to the dry year in 2018, the rate of decomposition of that litter was likely reduced resulting in a large amount of litter biomass in 2018 (2,374 kg ha^{-1}; Bontti et al., 2009; Epstein et al., 2002). Subsequent wet years in 2019 and 2020 then provided the necessary moisture to break-down larger amounts of litter biomass.

One factor that may contribute to the lack of treatment differences is a relatively low stocking rate during the dormant season (Table 6). An utilization rate of 40% - 60% during the dormant season has been shown to reduce total litter biomass (Davies et al., 2016). In our study the 2018 – 2019 dormant season estimated utilization within the key areas was 59% and 62% in McIntyre and Saddle Butte pastures, but only 18% in the South Camp Kettle pasture (Table 2). In the 2019 – 2020 dormant season estimated key area utilization in McIntyre was 59%, but only 21% in Saddle Butte and 28% in South Camp Kettle (Table 2). One of the reasons that utilization in the Saddle Butte key area was lower in the 2019 – 2020 dormant season may be attributed to an increase in annual grass biomass of approximately 1,000 kg ha^{-1} within the pasture. Abiotic factors also impacted forage utilization by cattle during the dormant season, with water availability and snow affecting the ability of the cattle to stay on the range.

Perennial grass cover and density likely did not increase (Tables 4 and 6) because of the continued dominance of medusahead, and the persistence of a robust litter layer. In order for perennial grasses to become more competitive and proliferate, the litter layer needs to be disrupted negating some of the competitive advantage (Perryman et al., 2018).

Despite perennial grasses not increasing, there is no evidence suggesting that dormant season grazing is detrimental to perennial vegetation after two years. McLean and Wikeem (1985) showed that there was not a difference in percent mortality, height, biomass production, or culm production when bluebunch wheatgrass was defoliated to a stubble height of 5 cm compared to an un-defoliated control. While the increase in perennial grass biomass can be attributed to the above normal precipitation in 2019 and 2020, the lack of change in perennial grass cover and density suggests that the current stocking rate is not detrimental to perennial grasses.

Sagebrush was present across the site in low amounts, and was not observed to be increasing. This lack of increase can likely be attributed to competition from medusahead, as there has been enough time since the last wildfire (> 20 years) for at least partial recovery of big sagebrush throughout the site (Lesica et al., 2007). This indicates that the removal of the thatch layer associated with medusahead is necessary for the establishment of sagebrush in sites dominated by medusahead.

After two years there is not data showing a reduction in fine fuels (herbaceous biomass) or fuel continuity. However, the lack of impact on perennial vegetation indicates that there is potential for dormant season grazing to reduce the negative impacts of medusahead with more time. Davies et al. (2015) showed that dormant season grazing can reduce fine fuel biomass and continuity after five years of treatment.

Implications

The results after two years suggest that current stocking rate for all treatments will not: 1) reduce annual grass fine fuels, and 2) promote perennial grasses by taking advantage of phenological differences between perennial and winter annual grasses. However, our results also suggest that the current stocking rate is not detrimental to perennial vegetation.

When implementing dormant season grazing it is important to consider the factors that determine the impact of grazing on vegetation: season, frequency, intensity, and type of animal (Davies and Boyd, 2020). The annual grass and litter biomass and cover results suggest that for dormant season grazing to successfully reduce medusahead, it is necessary to conduct grazing treatments for more than two years. While it is not possible to fully understand the impact that higher than normal precipitation had on the results, continuing this research beyond the current two years is necessary due to the variable precipitation patterns in the Northern Great Basin. Currently, the majority of published literature consists of two to three years of treatments, with few comprising more than three years of treatments. Our results also suggest that the stocking rate during the dormant season should be closer to the 40% - 60% utilization as shown in Davies et al., (2016). Since the key areas in this study were not fenced and cattle were able to freely move throughout the pasture, we were not able to fully account for how the cattle grazed and what type of vegetation was selected. In this study, the season of grazing was changed to promote a desirable vegetative response. We did not utilize high intensity grazing, change the frequency of grazing, or change the class of livestock on the range. A similar study using a higher stocking rate may produce different results.

Another important factor in this study is how the cattle were used. While the cattle were permitted to remain on the range from October – February, they were removed by 10 January in both years due to lack of water and signs of loss of body condition. This resulted in the potential for over 2,000 more animal use equivalents (AUEs) that could have been utilized on the range. It may be possible to see changes in the plant community if grazing utilization is placed as a priority over animal gains. Targeted grazing is typically defined as the application of a specific kind of livestock at a determined season, duration, and intensity to accomplish defined vegetation or landscape goals (Frost and Launchbaugh, 2003). This brings up a dilemma, as land managers and livestock producers must make decisions regarding the priorities when using grazing as a tool to manage landscapes. If making landscape objectives the priority, livestock gains may be reduced in the short-term, and the opposite is true if livestock gains are prioritized.

Future research should continue to assess the effectiveness of dormant season grazing as a tool to reduce the impact of medusahead and promote perennial vegetation on a landscape scale. While our results show that two years is not adequate time for significant treatment effects, it is necessary to determine a timeframe when land managers can expect to begin seeing treatment effects. This is critical for land managers who may be developing programs utilizing dormant season grazing as a tool, as they will need as much information as possible to develop complete objectives and timelines. Additional work is needed to understand cattle distribution and grazing behavior across large heterogenous pastures in both traditional and dormant grazing seasons. By better quantifying such cattle behavior it will be possible to make better informed decisions regarding the application of grazing as a tool for landscape recovery.

Tables and Figures

Table 1: Soil texture, slope, aspect, and full soil taxonomic name at each of the six research sites. Soils data was collected in June 2020, texture was obtained using the laboratory hydrometer method (Gavlack et al., 2005).

Research Site	Horizon depth (cm)	Texture	% Slope	Aspect	Taxonomic Classification
McIntyre North	1 – 12	Silt Loam	16	W	Fine Smectic Mesic Vitrixerandic Haplargid
	12 – 25	Silt Loam			
	25 – 38	Clay Loam			
	38 – 63	Clay			
McIntyre South	1 – 10	Silt Loam	12	NE	Fine Smectic Mesic Vitrixerandic Haplargid
	10 – 30	Clay Loam			
	30 – 46	Clay Loam			
	46 – 60	Clay			
Saddle Butte North	1 – 10	Loam	10	N	Fine Smectic Mesic Vitirixerandic Paleargid
	10 – 40	Clay			
	40 – 50	Clay			
	50 – 60	Clay			
Saddle Butte South	1 – 6	Loam	20	NE	Very-fine Smectic Mesic Vitrixerandic Paleargid
	6 – 25	Clay Loam			
	25 – 44	Clay			
	44 – 58	Clay			
South Camp Kettle North	1 – 9	Loam	15	NE	Fine Smectic Mesic Vitrixerandic Haplargid
	9 – 22	Clay Loam			
	22 – 40	Clay			
	40 – 58	Clay			
South Camp Kettle South	1 – 6	Sandy Loam	12	S	Coarse-loamy Mixed Superactive Vitrixerandic Haplocambid
	6 – 24	Silt Loam			
	24 – 38	Loam			
	38 – 62	Loam			

Table 2: AUMs (Animal Unit Months) remaining after the conclusion of the traditional grazing season. Use (AUMs) is the number of AUMs used during the dormant season (15 October – 28 February), and Utilization is the percent utilization for the 2018 – 2019 and 2019 – 2020 dormant seasons in the three key areas.

	2018 – 2019 Dormant Season			2019 – 2020 Dormant Season		
Key Area	AUMs	Use (AUMs)	Utilization	AUMs	Use (AUMs)	Utilization
McIntyre	2,145	1,259	59%	2,968	1,743	59%
Saddle Butte	691	430	62%	5,080	1,047	21%
South Camp Kettle	1,903	348	18%	2,940	815	28%

Table 3: Cover (mean ± S.E.) of plant functional groups collected in 2018-2020. Values reported: yearly mean of the four treatments, traditional grazing (T), dormant season grazing (D), traditional+dormant season grazing (T+D), no graze (NG). Differences between means are considered significant when p ≤ 0.05, and a Tukey-Kramer HSD was performed when the p-value indicated that there was a significant difference. Different letters indicate a significant difference between years.

	Annual Grass (% cover)			**Perennial Grass (% cover)**		
	2018	2019	2020	2018	2019	2020
Mean	66.6 ± 11.2	79.9 ± 8.2	72.3 ± 7.7	9.4 ± 3.8	13.0 ± 3.9	12.6 ± 4.6
T	77.8 ± 10.2	84.3 ± 6.5	69.1 ± 9.5	10.4 ± 4.9	16.0 ± 5.2	13.2 ± 5.7
D	72.9 ± 9.8	79.1 ± 5.8	70.0 ± 6.4	8.2 ± 2.8	12.2 ± 3.1	15.9 ± 4.4
T+D	66.0 ± 9.6	79.1 ± 7.1	85.4 ± 5.8	8.9 ± 3.7	9.4 ± 2.1	5.1 ± 1.6
NG	49.6 ± 15.1	76.9 ± 13.2	64.7 ± 9.0	10.0 ± 3.9	14.4 ± 5.1	16.2 ± 6.8
p-values	Treatment = 0.33, year = 0.15, treatment*year =0.16			Treatment = 0.40, year = 0.07, treatment*year = 0.54		

	Sandberg bluegrass (% cover)			**Annual Forbs (% cover)**		
	2018	2019	2020	2018	2019	2020
Mean	5.9 ± 2.2	3.2 ± 1.3	4.8 ± 2.0	1.6 ± 0.7^{A}	8.8 ± 3.7^{B}	3.6 ± 1.6^{AB}
T	4.2 ± 1.1	1.4 ± 0.6	4.7 ± 1.4	1.1 ± 0.5	6.0 ± 2.5	4.9 ± 2.3
D	4.7 ± 1.8	1.3 ± 0.5	4.6 ± 2.0	1.3 ± 0.6	13.2 ± 7.0	3.6 ± 1.2
T+D	7.3 ± 3.0	4.4 ± 0.7	3.8 ± 1.5	2.2 ± 0.9	8.1 ± 2.3	4.0 ± 2.1
NG	7.3 ± 3.0	5.4 ± 3.2	6.3 ± 3.2	1.6 ± 0.7	7.7 ± 3.2	2.1 ± 1.0
p-values	Treatment = 0.44, year = 0.13, treatment*year = 0.73			Treatment = 0.59, year = 0.042, treatment*year = 0.37		

	Perennial Forbs (% cover)			**Litter (% cover)**		
	2018	2019	2020	2018	2019	2020
Mean	2.5 ± 1.2	3.6 ± 1.4	3.6 ± 1.6	89.8 ± 6.1	86.0 ± 4.7	90.9 ± 2.9
T	3.1 ± 1.4	3.8 ± 1.5	3.2 ± 0.9	93.8 ± 4.1	88.0 ± 4.4	90.4 ± 3.1
D	2.7 ± 1.3	6.2 ± 1.7	3.7 ± 1.6	84.2 ± 10.7	88.2 ± 4.0	89.1 ± 3.3
T+D	2.4 ± 1.3	1.7 ± 1.0	3.1 ± 2.1	92.0 ± 3.1	87.7 ± 4.3	92.7 ± 1.8
NG	1.8 ± 0.9	2.7 ± 1.2	4.3 ± 1.8	89.3 ± 6.6	80.1 ± 6.3	91.3 ± 3.3
p-values	Treatment = 0.28, year = 0.50, treatment*year = 0.34			Treatment = 0.71, year = 0.26, treatment*year = 0.63		

Table 4: Cover and density (mean ± S.E.) of sagebrush and other shrubs greater than 15 cm in height, measured in 2018-2020. Values reported: yearly mean of the four treatments, traditional grazing (T), dormant season grazing (D), traditional+dormant season grazing (T+D), no graze (NG). Differences between means are considered significant when p ≤ 0.05. Sagebrush was comprised of all *Artemisia* spp. and other shrubs was all other woody species (see appendix A for species list).

	Sagebrush Cover (%) 2018	2019	2020	**Other Shrub Cover (%)** 2018	2019	2020
Mean	0.20 ± 0.15	0.19 ± 0.12	0.26 ± 0.17	0.80 ± 0.54	0.97 ± 0.63	1.35 ± 1.10
T	0.21 ± 0.21	0.20 ± 0.20	0.50 ± 0.34	0.31 ± 0.14	0.68 ± 0.49	0.72 ± 0.63
D	0.19 ± 0.14	0.04 ± 0.04	0.06 ± 0.06	0.50 ± 0.32	1.12 ± 0.79	1.72 ± 1.57
T+D	0.28 ± 0.17	0.53 ± 0.25	0.35 ± 0.16	1.40 ± 0.97	1.74 ± 0.94	1.71 ± 1.35
NG	0.11 ± 0.08	0.00 ± 0.00	0.14 ± 0.11	0.98 ± 0.72	0.36 ± 0.30	1.28 ± 0.84
p-values	Treatment = 0.28, year = 0.83, treatment*year = 0.52			Treatment = 0.41, year = 0.73, treatment*year = 0.77		

	Sagebrush Density (plants per m²) 2018	2019	2020	**Other Shrub Density (plants per m²)** 2018	2019	2020
Mean	0.002 ± 0.002	0.003 ± 0.002	0.004 ± 0.003	0.048 ± 0.041	0.038 ± 0.027	0.022 ± 0.018
T	0.002 ± 0.002	0.002 ± 0.002	0.005 ± 0.003	0.017 ± 0.009	0.018 ± 0.011	0.008 ± 0.007
D	0.002 ± 0.002	0.002 ± 0.002	0.002 ± 0.002	0.023 ± 0.012	0.025 ± 0.015	0.025 ± 0.023
T+D	0.002 ± 0.002	0.008 ± 0.003	0.005 ± 0.003	0.090 ± 0.082	0.098 ± 0.076	0.043 ± 0.036
NG	0.002 ± 0.002	0.0 ± 0.0	0.003 ± 0.002	0.063 ± 0.061	0.012 ± 0.008	0.012 ± 0.008
p-values	Treatment = 0.44, year = 0.58, treatment*year = 0.49			Treatment = 0.34, year = 0.70, treatment*year = 0.80		

Table 5: Density (mean ± S.E.) of plant functional groups collected in 2018-2020. Values reported: yearly mean of the four treatments, traditional grazing (T), dormant season grazing (D), traditional+dormant season grazing (T+D), no graze (NG). Differences between means is considered significant when $p \leq 0.05$.

	Perennial Tall Grass (plants per m²)		
	2018	2019	2020
Mean	1.30 ± 0.63	1.02 ± 0.50	0.90 ± 0.42
T	1.37 ± 0.71	1.04 ± 0.43	1.36 ± 0.77
D	1.60 ± 0.78	1.63 ± 0.97	1.09 ± 0.47
T+D	0.95 ± 0.41	0.60 ± 0.20	0.46 ± 0.23
NG	1.31 ± 0.62	0.80 ± 0.39	0.70 ± 0.22
p-values	Treatment = 0.45, year = 0.37, treatment*year = 0.66		

	Perennial Short Grass (plants per m²)		
	2018	2019	2020
Mean	0.90 ± 0.40	0.80 ± 0.50	0.50 ± 0.20
T	0.60 ± 0.30	0.18 ± 0.06	0.31 ± 0.10
D	0.99 ± 0.25	0.45 ± 0.23	0.85 ± 0.43
T+D	0.94 ± 0.34	0.89 ± 0.35	0.25 ± 0.07
NG	1.15 ± 0.55	1.60 ± 1.31	0.72 ± 0.33
p-values	Treatment = 0.40, year = 0.62, treatment*year = 0.52		

	Annual Forbs (plants per m²)		
	2018	2019	2020
Mean	0.05 ± 0.03	3.86 ± 1.82	2.85 ± 1.19
T	0.03 ± 0.02	2.66 ± 1.06	2.13 ± 0.83
D	0.08 ± 0.04	5.95 ± 2.90	4.47 ± 1.83
T+D	0.06 ± 0.04	3.51 ± 1.54	2.77 ± 1.19
NG	0.05 ± 0.03	3.33 ± 1.78	2.06 ± 0.91
p-values	Treatment = 0.16, year = 0.05, treatment*year = 0.31		

	Perennial Forbs (plants per m²)		
	2018	2019	2020
Mean	1.43 ± 0.65	0.37 ± 0.14	0.53 ± 0.20
T	1.59 ± 0.53	0.33 ± 0.12	0.35 ± 0.06
D	2.00 ± 1.25	0.41 ± 0.10	0.95 ± 0.42
T+D	1.33 ± 0.49	0.40 ± 0.17	0.41 ± 0.15
NG	0.81 ± 0.34	0.33 ± 0.16	0.43 ± 0.15
p-values	Treatment = 0.42, year = 0.047, treatment*year = 0.88		

Table 6: Mean stocking rate (ha AUM^{-1}) in each of the grazing periods for each of the grazing treatments. Grazing periods are divided into dormant (October – February) and traditional (May – October). Grazing treatments are: traditional grazing (T), dormant season grazing (D), traditional+dormant season grazing (T+D), no graze (NG).

	Grazing Treatment			
Grazing Period	T	D	T+D	NG
Oct. 2018 - Feb. 2019	0	5.72	5.72	0
May - Oct. 2019	4.34	0	4.34	0
2018 – 2019 Total	4.34	5.72	2.40	0
Oct. 2019 - Feb. 2020	0	2.61	2.61	0
May - Oct. 2020	3.03	0	3.03	0
2019 – 2020 Total	3.03	2.61	1.40	0

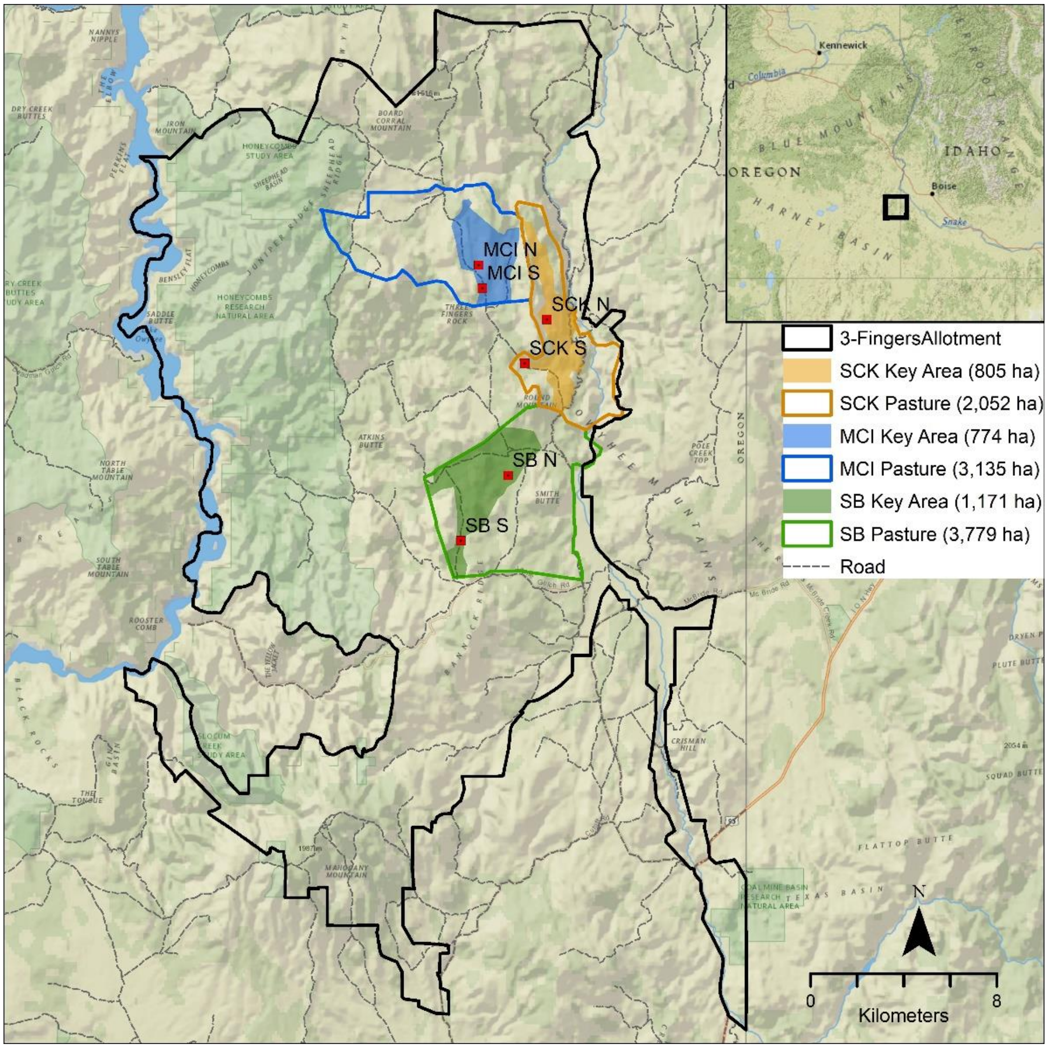

Figure 1: Map of the Three Fingers Allotment and the three pastures (SCK- South Camp Kettle; MCI- McIntyre; SB- Saddle Butte) and key areas within pastures where dormant season grazing was concentrated. Key areas are defined as areas within the larger pasture that are dominated by medusahead with reduced ecological function. Within each key area, there were two research sites, north (N) and south (S). Each research site was a four paddock exclosure where the grazing treatments were applied.

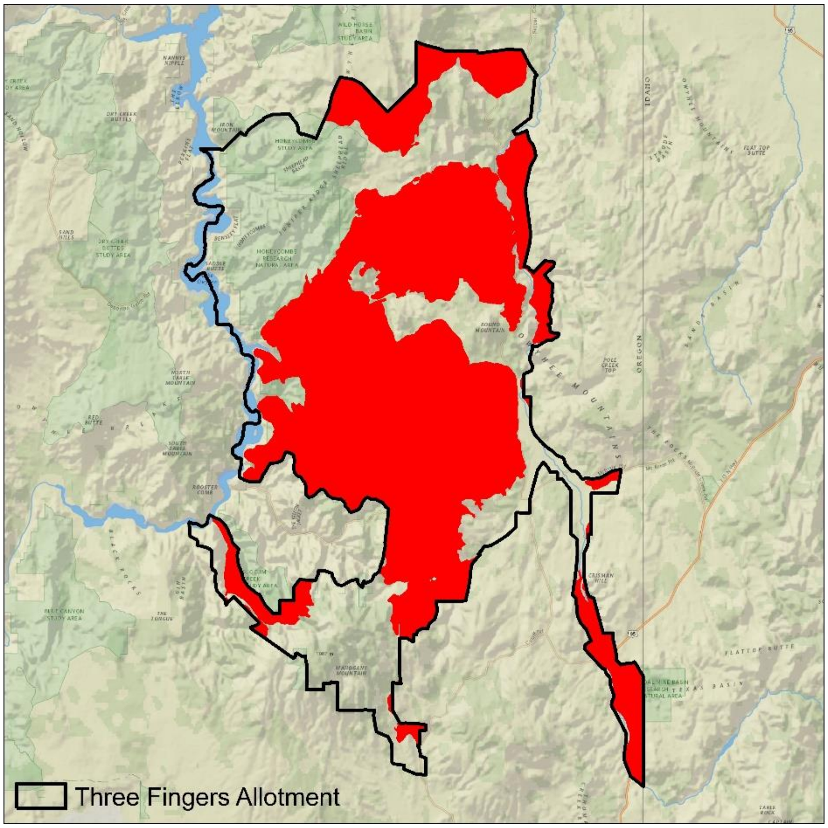

Figure 2: Map showing the footprint of the 17 wildfires (red) that have affected 32,090 ha (57%) of the Three Fingers Allotment since 1985. These wildfires have also resulted in 10,571 ha burning at least two times.

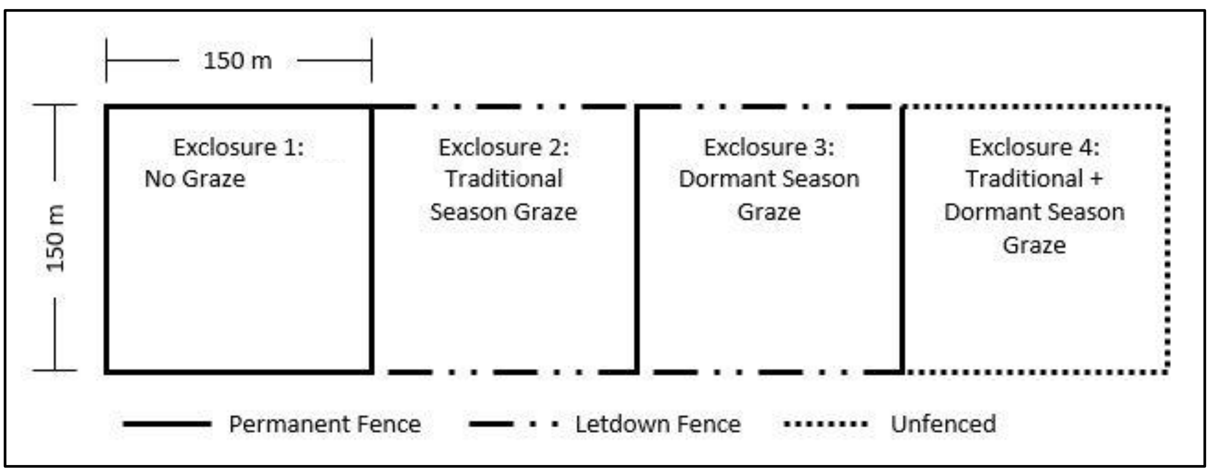

Figure 3: Diagram of the exclosure layout at one of the research sites. Grazing treatments were randomly applied at each research site. Permanent fences are a four-strand fence with three strands of barbed wire and the bottom strand smooth wire to allow for the passage of wildlife. Let down fences are laid down during the seasons when grazing is allowed and put up during the seasons when grazing is excluded.

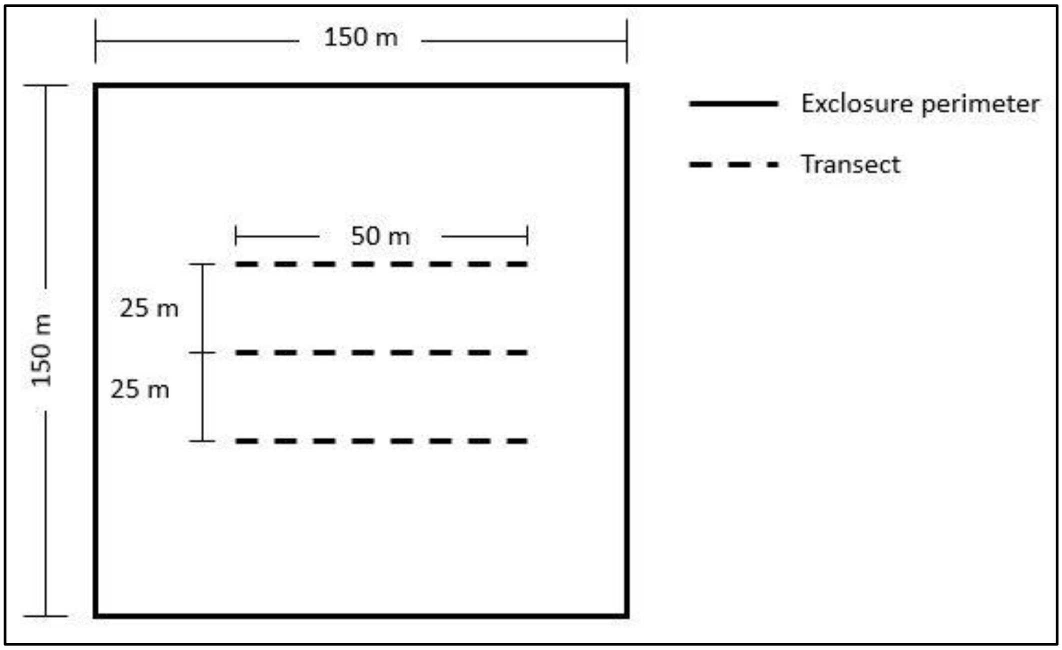

Figure 4: Diagram of the transect layout in one of the grazing exclosures.

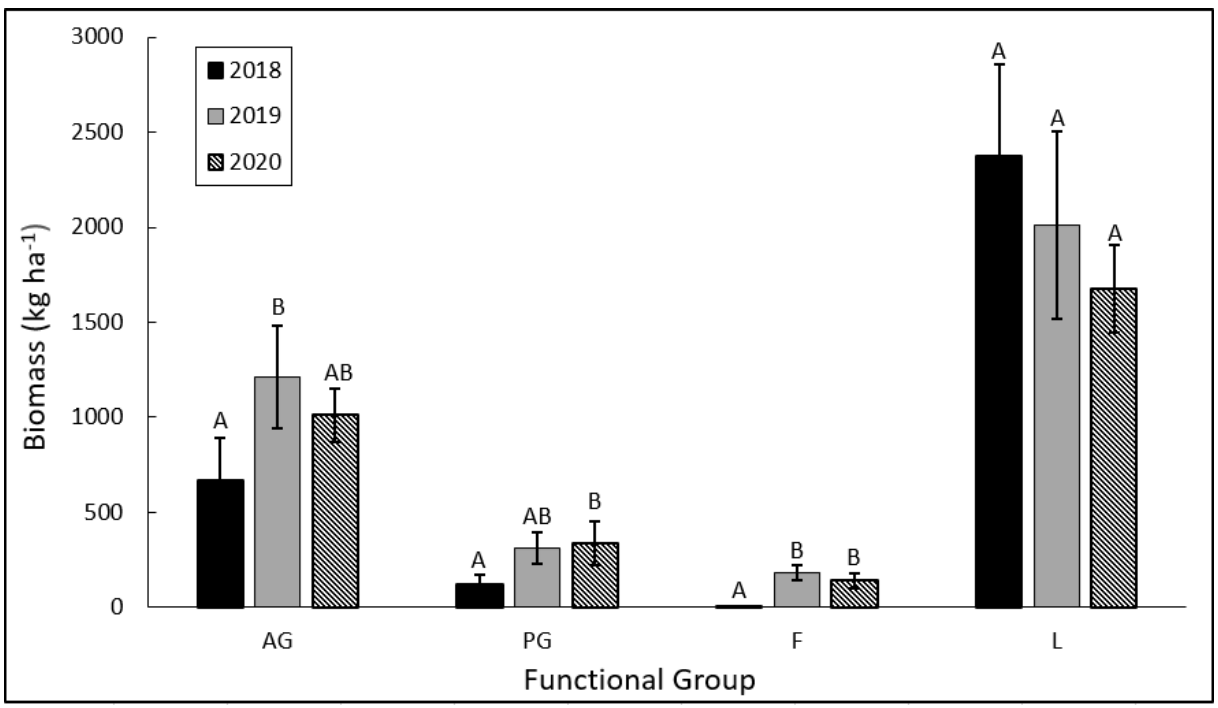

Figure 5: Biomass (mean ± S.E.) of four functional groups collected in 2018-2020; functional groups: annual grass (AG), perennial grass (PG), forbs (F), and litter (L). Significant differences between means within a functional group are indicated by different letters using the Tukey-Kramer HSD test. Differences were considered significant when $p \leq 0.05$. Reported values are the means across all four treatments in each year.

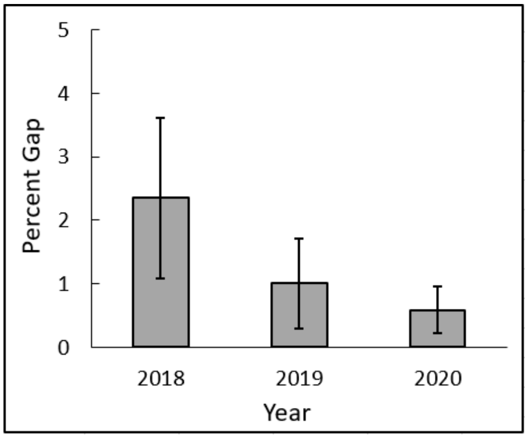

Figure 6: Percent gap (mean ± S.E.) measured in 2018 – 2020, values reported are the means of the four grazing treatments each year. Gaps are defined as a gap devoid of vegetative material along the transect that was at least 20 cm in length.

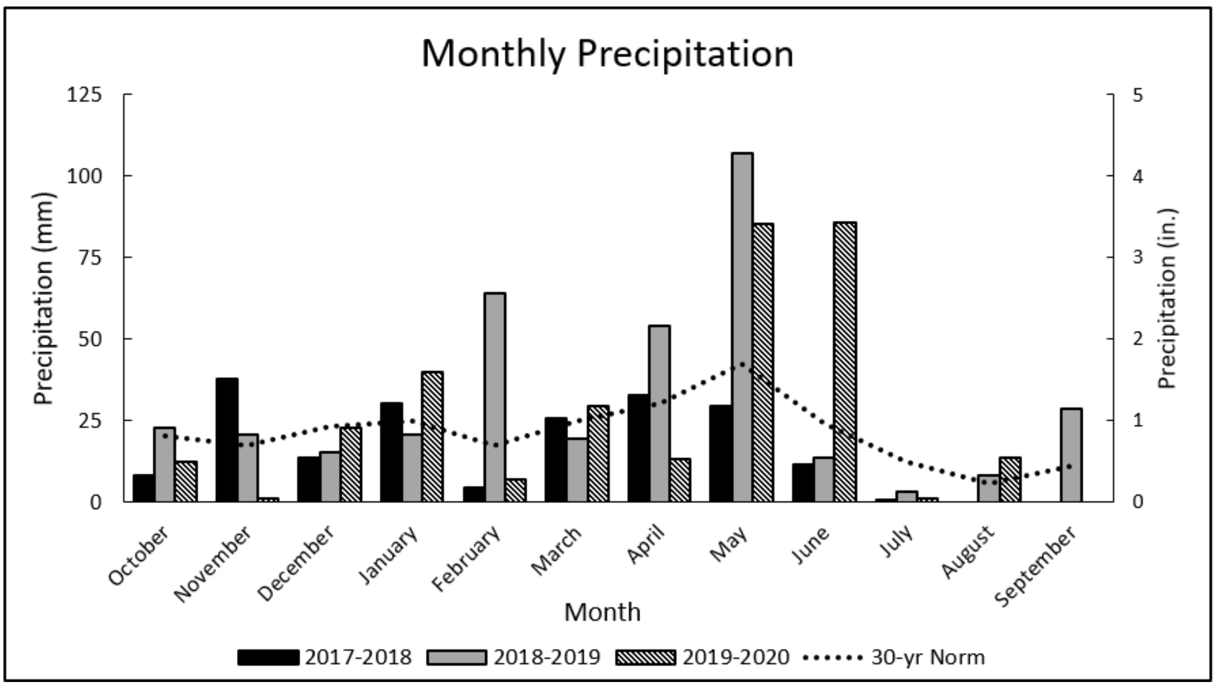

Figure 7: Monthly precipitation for the water year (October – September) at the Owyhee Ridge Remote Automated Weather Station. Water year totals were as follows: 2017 – 2018, 195 mm (7.7 in); 2018 – 2019, 378 mm (14.9 in); 2019 – 2020, 311 mm (12.3 in); and the 30-year normal is 254 mm (10.2 in).

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Appendix A: Species List

List of species observed within the experimental sites from 2018 – 2020. Information provided is scientific name, common name, USDA native status, growth habit, and functional group for biomass, cover, and density data in the study.

	Scientific Name	Common Name	Native Status	Growth Habit	Biomass Functional Group	Cover Functional Group	Density Functional Group
Annual Grass	*Bromus arvensis* L.	Field brome	Introduced	Grass	Annual Grass	Annual Grass	NA
	Bromus tectorum L.	Cheatgrass	Introduced	Grass	Annual Grass	Annual Grass	NA
	Taeniatherum caput-medusae (L.) Nevski	Medusahead	Introduced	Grass	Annual Grass	Annual Grass	NA
	Ventenata dubia (Leers) Coss.	North Africa grass	Introduced	Grass	Annual Grass	Annual Grass	NA
	Vulpia microstachys (Nutt.) Munro	Small fescue	Native	Grass	Annual Grass	Annual Grass	NA
Perennial Grass	*Achnatherum thurberianum* (Piper) Barkworth	Thurber's needlegrass	Native	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Agropyron cristatum (L.) Gaertn.	Crested wheatgrass	Introduced	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Poa bulbosa L.	Bulbous bluegrass	Introduced	Grass	Perennial Grass	Perennial Grass	Perennial Short Grass
	Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	Intermediate wheatgrass	Introduced	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Elymus elymoides (Raf.) Swezey	Squirreltail	Native	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Festuca idahoensis Elmer	Idaho fescue	Native	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Pascopyrum smithii (Rydb.) A. Love	Western wheatgrass	Native	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass
	Poa secunda J. Presl	Sandberg bluegrass	Native	Grass	Perennial Grass	Sandberg bluegrass	Perennial Short Grass
	Pseudoroegneria spicata (Pursh) Á. Löve	Bluebunch wheatgrass	Native	Grass	Perennial Grass	Perennial Grass	Perennial Tall Grass

	Scientific Name	Common Name	Native Status	Growth Habit	Biomass Functional Group	Cover Functional Group	Density Functional Group
Annual Forb	*Alyssum desertorum* Stapf	Desert madwort	Introduced	Forb	Forb	Annual Forb	Annual Forb
	Amsinckia Lehm.	Fiddleneck	Native	Forb	Forb	Annual Forb	Annual Forb
	Blepharipappus scaber Hook.	Rough eyelashweed	Native	Forb	Forb	Annual Forb	Annual Forb
	Collinsia parviflora Lindl.	Maiden blue-eyed Mary	Native	Forb	Forb	Annual Forb	Annual Forb
	Erodium cicutarium (L.) L'Her. Ex Aiton	Redstem stork's bill	Introduced	Forb	Forb	Annual Forb	Annual Forb
	Epilobium brachycarpum C. Presl	Tall annual willowherb	Native	Forb	Forb	Annual Forb	Annual Forb
	Gayophytum ramosissimum Torr. & A. Gray	Pinyon groundsmoke	Native	Forb	Forb	Annual Forb	Annual Forb
	Lactuca serriola L.	Prickly lettuce	Introduced	Forb	Forb	Annual Forb	Annual Forb
	Lepidium perfoliatum L.	Clasping pepperweed	Introduced	Forb	Forb	Annual Forb	Annual Forb
	Tragopogon dubius Scop.	Yellow salsify	Introduced	Forb	Forb	Annual Forb	Annual Forb
Perennial Forb	*Balsamorhiza serrata* A. Nelson & J.F. Macbr.	Serrate balsamroot	Native	Forb	Forb	Perennial Forb	Perennial Forb
	Calochortus macrocarpus Douglas	Sagebrush mariposa lily	Native	Forb	Forb	Perennial Forb	Perennial Forb
	Crepis acuminata Nutt.	Tapertip hawksbeard	Native	Forb	Forb	Perennial Forb	Perennial Forb
	Crepis intermedia A. Gray	Limestone hawksbeard	Native	Forb	Forb	Perennial Forb	Perennial Forb
	Lomatium Raf.	Desertparsley	Native	Forb	Forb	Perennial Forb	Perennial Forb
	Lupinus L.	Lupine	Native	Forb	Forb	Perennial Forb	Perennial Forb

	Scientific Name	Common Name	Native Status	Growth Habit	Biomass Functional Group	Cover Functional Group	Density Functional Group
Shrub	*Artemisia arbuscula Nutt.* Ssp. *Longiloba* (Osterh.) L.M. Shultz	Little sagebrush	Native	Shrub	NA	Sagebrush	Sagebrush
	Artemisia nova A. Nelson	Black sagebrush	Native	Shrub	NA	Sagebrush	Sagebrush
	Artemisia tridentata Nutt. ssp. *wyomingensis* Beetle & Young	Wyoming big sagebrush	Native	Shrub	NA	Sagebrush	Sagebrush
	Chrysothamnus viscidiflorus (Hook.) Nutt.	Yellow rabbitbrush	Native	Shrub	NA	Other shrub	Other shrub
	Eriogonum microthecum Nutt.	Slender buckwheat	Native	Shrub	NA	Other shrub	Other shrub
	Ericameria nauseosa (Pall. Ex Pursh) G.L. Nesom & Baird	Rubber rabbitbrush	Native	Shrub	NA	Other shrubs	Other shrubs
	Gutierrezia sarothrae (Pursh) Britton & Rusby	Broom snakeweed	Native	Subshrub	NA	Other shrub	Other shrub
	Krascheninnikovia lanata (Pursh) A. Meeuse & Smit	Winterfat	Native	Subshrub	NA	Other shrub	Other shrub
	Purshia tridentata (Pursh) DC.	Antelope bitterbrush	Native	Shrub	NA	Other shrub	Other shrub
	Tetradymia nuttallii Torr. & A. Gray	Nuttall's horsebrush	Native	Shrub	NA	Other shrub	Other shrub