EFFECTS OF SHEEP GRAZING ON VEGETATION RECOVERY AFTER WILDFIRE IN A SAGEBRUSH STEPPE COMMUNITY AND REVEGETATION OF ANNUAL GRASSLANDS

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

Sagebrush steppe ecosystems are characterized by *Artemisia* species with an understory of perennial herbaceous bunchgrasses and forbs. These ecosystems have been subjected to a number of perturbations, altering the dynamic relationship between natural disturbance, community structure and ecosystem processes. Vast expanses of sagebrush steppe rangelands currently exist in a degraded state, largely as a result of overgrazing that occurred in the early 1900s, poor land management practices, and the problematic cheatgrass wildfire cycle.

Two research projects were conducted on grazing of sagebrush ecosystems in relation to fire and invasive annual grasses. The first study focused on the effects of sheep grazing after fire. Research was conducted from 2001 to 2004 at the USDA Agricultural Research Service Sheep Experiment Station, near Dubois, Idaho. The objectives of the research were to examine the effects of spring and fall sheep grazing after fire on: 1) sagebrush recruitment and establishment, 2) abundance of annual invasive grasses, and 3) persistence of native forbs and grasses. Results of this study showed that sheep grazing after fire did not alter sagebrush recruitment and establishment; did not affect the abundance of annual invasive grasses; and had only marginal impacts on persistence of native perennial forbs and grasses. Grazing reduced the increase of bluebunch wheatgrass (*Psuedoroegneria spicata* spp. *spicata*) cover (P = 0.02) compared to a non-grazed control. Change in frequency of tapertip hawksbeard (*Crepis acuminata*) was affected by seasonal grazing, with greater abundance in the fall grazed treatments compared to the spring grazed treatments (P = 0.01). Overall, grazing effects were not profound and the plant community was recovering even with grazing. Current federal grazing policy often requires removal of livestock grazing post-fire for 2 full seasons. This policy was only marginally supported by this research.

A second study was conducted from 2004 to 2006 in the grassland steppe scablands of Eastern Washington and focused on grazing impacts on invasive annual grasses. This study addressed the potential use of livestock in rehabilitation on two sites: one dominated by cheatgrass (*Bromus tectorum*) and one by medusahead (*Taeniatherum caput-medusae*). Sheep were used to trample perennial grass seed as a mechanical treatment after a fall broadcast seeding, followed by an early spring grazing treatment to remove annual grass biomass and reduce competition to seeded perennials. Overall, the seeding attempt failed. On both the medusahead and cheatgrass sites, annual grass density and height were lower in grazed compared to non-grazed paddocks in both study years ($P < 0.05$). Spring grazing may be an effective tool to slow the recovery of annual grass biomass if applied after the bulk of spring precipitation is received. High year to year variation in annual grass response makes it difficult to apply targeted grazing for the reduction of annual grasses and revegetation.

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CHAPTER I

RESEARCH OVERVIEW

Sagebrush steppe ecosystems dominate western North America covering about 48 million ha in 14 states and 3 Canadian provinces (Blaisdell et al 1982, USGS 2005). Characterized by *Artemisia* species with an understory of perennial herbaceous bunchgrasses and forbs, these complex communities constitute a valuable resource for wildlife habitat, livestock production, recreation, aesthetics, and watershed values (Blaisdell et al. 1982). Since the time of European settlement these ecosystems have been subjected to a number of perturbations, altering the dynamic relationship between natural disturbance, community structure and ecosystem processes. Vast expanses of sagebrush steppe rangelands currently exist in a degraded state, largely as a result of overgrazing that occurred in the early 1900s, poor land management practices, and the problematic cheatgrass wildfire cycle (Pyke 2000).

Ecosystems stressors vary by source and magnitude, but one of the most eminent threats to sagebrush steppe is annual grass invasion and resultant increase in wildfire frequency. Millions of hectares of western rangelands have been converted to dominance by invasive annual grasses including cheatgrass (*Bromus tectorum* L.) (Young and Allen 1997) and medusahead (*Taeniatherum caput-medusae* (L.) Nevski) (Lusk et al 1961). Having opportunistic and aggressive growth strategies, annual grasses are able to rapidly proliferate in disturbed rangeland settings (Young and Allen 1997). Annual grasses flourish in the soils and climate of sagebrush steppe ecosystems, exhibiting a shortened phenology, quickly completing their life cycle and setting seed by early summer (West 1983). These invasive annuals spread rapidly thriving in disturbed conditions and having massive reproductive capabilities. Root growth of annual grasses is quicker than dominant native grasses, such as bluebunch wheatgrass, allowing annuals to take advantage of winter and spring moisture before native perennials (Harris 1967, Harris and Wilson 1970). These adaptations have displaced many native rangeland species and created continuous annual grass stands that are much more susceptible to fire than native vegetation. These continuous fuel sources deliver wildfire into intact sagebrush stands, further proliferating annual grass spread and the subsequent degradation of sagebrush steppe ecosystems (Stewart and Hull 1949, Knick and Rotenberry 1997). Annual grass invasion has altered the successional pathway of native perennial vegetation, maintaining communities in a disturbed state, dominated by weedy vegetation.

Fire functions as a natural disturbance to longstanding stable sagebrush systems and is an important component in the maintenance of diverse sagebrush communities. Wildfires create spatially diverse age classes with dynamic floristic components by periodically shifting species dominance. When fire is removed, more late seral vegetation dominates, eventually shifting dominance to an overstory of woody cover with a floristically poor understory. A common management practice over the last half-century has been to prevent and control wildfires. This unfortunate misunderstanding of disturbance dynamics has contributed to the catastrophic loss of millions of hectares of sagebrush steppe vegetation to wildfire and subsequent conversion to annual grass dominance. Therefore, approaches to management of sagebrush-grasslands after fire should focus on maintaining intact sagebrush communities or restoring perennial dominance.

Livestock grazing is another driving force that has influenced the structure and ecological processes of sagebrush-grasslands. Varying regimes of livestock grazing have directed plant communities over time and added to the spatial heterogeneity of sagebrush rangelands. While the influence of grazing on many native sagebrush-grassland species has been studied extensively, few studies have focused on the influence of grazing after fire as it affects recuperating native plant communities (Bunting et al. 1998). Current policy pertaining to grazing management of federal lands states that burned areas will be closed to livestock grazing for at least two growing seasons to allow plant recovery (BLM 1999). However, this blanket policy is not well supported by research and the delay of grazing may leave annual grass spread unchecked. Many scientists and land managers believe that we should structure policy related to post-fire grazing management around a number of site-specific variables and do away with a blanket policy (Sanders 2000).

Properly managed livestock grazing may be an effective management tool to control annual grass spread in sagebrush steppe rangelands. Selecting the proper class of livestock and applying properly timed intensively managed grazing can effectively reduce the reproductive capacity of cheatgrass and medusahead and manipulate the perennial vegetation toward a more desirable state (Mosely 1996; Taylor 1994).

Other threats to the sagebrush steppe include conversion to agricultural land, urban development, and juniper encroachment. All of these factors combined with the continued spread of annual grasses and increasing frequency of wildfires threaten the floristic diversity of the sagebrush steppe. Of equal concern are threats imposed on ecosystem fauna. The sagebrush steppe region hosts a broad diversity of wildlife species. Many wildlife species co-evolved with the sagebrush steppe ecosystem and are considered sagebrush obligates. These species include the sage grouse, sage sparrow, Brewer's sparrow, sage thrasher, pygmy rabbit, sagebrush vole, sagebrush lizard, and pronghorn (Paige and Ritter 1999). Loss of suitable habitat for sagebrush obligate species has given rise to intensive conservation concerns, particularly for sage grouse.

The research in this thesis is a compilation of two research projects focusing on the adaptive management of invasive annual grasses, mainly cheatgrass and medusahead, in western rangeland ecosystems. The first study focuses on the effects of sheep grazing after fire in a sagebrush steppe community. The effects of season of grazing and the delayed onset of grazing were examined following a wildfire. The second study addresses the potential use of livestock in rehabilitation of annual grass dominated rangelands. Sheep were used to trample perennial seed as a mechanical treatment after a fall broadcast seeding, followed by an early spring grazing treatment to remove annual grass biomass and reduce competition on seeded perennials. Although the studies were conducted in two different regional settings, they reflect similar strategies targeted at controlling the spread of invasive annual grasses and maintaining or restoring intact stands of native perennial vegetation in sagebrush steppe regions of the Intermountain West.

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CHAPTER II

EFFECTS OF SHEEP GRAZING AFTER WILDFIRE IN A SAGEBRUSH STEPPE COMMUNITY

INTRODUCTION

Deferring livestock grazing after fire is a practice employed by land managers intended to promote plant vigor and reproductive capacity (BLM 1999). The concept of extended rest periods to compensate for the cumulative effect of both grazing and fire seems intuitive. However, extended rest periods may not be ecologically important to plant recovery and altered grazing systems can impose unwarranted financial hardship on livestock producers. The challenge to land managers is to determine the appropriate rest period after fire to maintain productivity of native perennial herbaceous species.

Current regulations governing livestock grazing after fire on western rangelands elicits opposing viewpoints. Skepticism of livestock grazing management policies after fire comes from both scientists and managers (Sanders 2000). While there have been many studies related to the impacts of fire (Wright and Klemmedson 1965, Conrad and Poulton 1966, Young and Evans 1978, Uresk et al. 1980, Bunting 1985, West and Hassan 1985, Patton et al. 1988, Robberecht and Defossé 1995) or grazing (Craddock 1938, Pechanec and Stuart 1949, Mueggler 1950, Laycock 1967, Miller et al. 1994, Bork et al. 1998) on vegetation in sagebrush-steppe regions, little research has addressed the topic of plant recovery in response to fire and grazing (Jirik and Bunting 1994, Bunting et al. 1998). Furthermore, season of grazing clearly influences the species composition of grazed communities in the sagebrush steppe (Bork et al. 1998, Seefeldt and McCoy 2003). Thus, examining the recovery of plant communities after fire with a focus on the grazing season could add much to our knowledge for the management of sagebrush steppe after fire.

Major ecological concerns after fire include potential weed invasion and increased erosion. One argument against delaying grazing after fire is that weedy species may have greater opportunity for establishment. Without grazing to suppress them, invasive or noxious weeds may take advantage of nutrient and water resources in the early spring when native species have not yet initiated growth. Thus, post-fire grazing management may inadvertently be facilitating weed invasion. Loss of sagebrush-steppe ecosystems to cheatgrass (*Bromus tectorum*) invasion after fire is a dramatic problem to the management of native biodiversity on western rangelands (DiTamaso 2000, Brooks et al. 2004). Several studies have suggested that carefully applied sheep grazing may be an effective tool to manage cheatgrass (Daubenmire 1940, Pechanec and Stewart 1949, Cook and Harris 1952, Hulbert 1955, Havstad 1994, Mosley 1996). The objectives of the research were to examine the effects of spring and fall sheep grazing after fire on: 1) sagebrush recruitment and establishment, 2) abundance of annual invasive grasses, and 3) persistence of native forbs and grasses.

MATERIALS AND METHODS

Study area

Research was conducted from 2001 to 2004 at the USDA Agricultural Research Service Sheep Experiment Station, about 10 km north of Dubois, Idaho (44˚14’ N. Lat, 112˚ 12’ W. Long.). The study area was a sagebrush steppe ecosystem dominated by three-tip sagebrush (*Artemisia tripartita* spp. *tripartita*), bluebunch wheatgrass (*Psuedoroegneria spicata* spp. *spicata*), arrowleaf balsamroot (*Balsamorhiza sagittata*), and tapertip hawksbeard (*Crepis acuminata*). Soils were fine-loamy, mixed, frigid Calcic Agrixerolls derived from wind-blown loess, residuum, or alluvium on slopes ranging from 0 to 12% (NRCS 1995).

Climate of the study area is characterized by cold winters and warm summers. Average annual precipitation for the research site is 30.3 cm, primarily from spring and summer rains (Fig. 1; Western Regional Climate Center 2006). Average seasonal temperatures range from -6.1˚C in winter to 18.5˚C in summer (Fig. 2). A wet winter and spring followed by a hot and dry summer created optimal fire conditions in 2000. In the winter and spring before the wildfire, the research site received 127% and 121% of the long-term seasonal average precipitation, respectively. Summer 2000 was dry with the area receiving 35% of long-term average summer precipitation (Fig.1). Climate conditions were much drier in subsequent years. In 2001, the site received only half of the long-term average winter and spring precipitation followed by a second year with only two-thirds the long-term average. In 2003, the site received average winter precipitation but was followed by a very wet spring with spring rains totaling 163% of the long-term average. The summer of 2003 was very hot and dry.

Research site

In July 2000, a 474 ha lightning ignited wildfire burned a portion of the U.S. Sheep Experiment Station resulting in a patchwork of burned and unburned vegetation. The research site was a 69 ha area selected where more than 85% of the vegetation had burned.

The research site was divided into 24 paddocks (Fig. 3). The paddocks ranged in size from 2.4 to 3.3 ha. Paddocks included unburned patches that ranged from 4 to 12% of area on average (Table 1). Paddocks were arranged in 4 blocks of 6 paddocks with six grazing treatments randomly applied to the paddocks in each block (Fig. 3).

Grazing treatments[1]

Grazing treatments examined the effects of season of grazing (fall vs. spring) and the delayed onset of grazing after fire (1, 2, or 3 years after fire; Fig. 3). The six grazing treatments included 3 fall treatments (initiated in 2001, 2002, and 2003), 2 spring treatments (initiated in 2002 and 2003), and an un-grazed control. Grazing for fall treatments occurred from late September to mid-October and spring grazing trials occurred from late May to early June. Once grazing treatments were initiated, paddocks were grazed in subsequent study years in designated seasons.

Sheep used for grazed treatments were dry ewes that were crosses of Columbia, Ramboulillet, Targhee, and Polypay breeds. Sheep were provided by the USDA-ARS U.S. Sheep Experiment Station. Average sheep weight was 74 kg (67 to 77kg ± 1.8 SE). Stocking rates varied substantially throughout the trial but averaged about 113 SD/ha (Table 2) and were set to utilize 40% of available forage based on pre-grazing biomass estimates. Paddocks were stocked with 24 to 36 sheep for 7 to 14 days based on available biomass. The fall 2001 grazing trial had a low stocking

[1] All procedures related to animal use were approved by the University of Idaho Animal Care and Use Committee as protocol #2002-12 (Appendix A).

rate of 56 sheep days/ha due to the low post-burn biomass production (Table 2).

Biomass sampling

Biomass was estimated in grazed paddocks before each application of grazing to determine available forage and set appropriate stocking rate. In 2001, ten 0.25-m² plots were clipped in each paddock. However, this size did not adequately estimate utilization. In subsequent years, four 1-m² plots (0.5 x 2 m) were clipped in each paddock. All plots were clipped to ground level in burned areas of each paddock and separated into grasses and forbs in the field. Field samples were oven dried at 60˚C for 48 hours and weighed.

Vegetation measurements

Vegetation composition and site characteristics were first assessed the year after fire in the summer of 2001, before grazing treatments were applied. Vegetation assessment was repeated in 2004 following all treatment applications. Vegetation sampling consisted of cover and density estimates in 60 rectangular quadrats (30.5 x 61.0 cm) located along 3 pace-transects in each paddock. The transects were oriented west to east parallel to the north paddock border and evenly spaced across each paddock. Canopy cover of shrubs, perennial and annual grasses, perennial and annual forbs, and non-vegetated ground cover was estimated to the nearest 5%. These broad cover categories were further subdivided into estimates of individual dominant plant species that contributed to the broad categories (Table 3). Density of cheatgrass was recorded in each quadrat and three-tip sagebrush plants were counted in a 4-m² circular area around each quadrat. The 4-m² area was created using a 113-cm string tied to a center-pivot stake anchored in one corner of the quadrat.

Photo points

A permanent photo point was established in each paddock as a visual record of site conditions in subsequent years after the fire (Appendix B). Photo points were subjectively placed to represent average condition in burned areas of the paddocks and were referenced by a steel t-post. Two photos were taken at each photo point in late July, one facing north and one facing south. A photoboard (1-m tall x 5-cm wide) with alternating white and red 20-cm sections was placed 5-m north or south of the t-post. Photos were taken with the photoboard in the center of the frame (Appendix B).

Fixed plot density measurements

We also examined density of several dominant plants in a 30 m^2 belt transect (1-m x 30-m) located in each paddock. Fixed plots were adjacent to the photo reference posts (Appendix C). The belt transects were placed in 2, 15-m segments beginning 5 meters south or north of the t-post that marked the photo point. Densities of cheatgrass, tapertip hawksbeard, antelope bitterbrush (*Purshia tridentata*), and three-tip sagebrush were recorded each summer in late July from 2001 to 2004.

Statistical analyses

This study was a randomized complete block design with four replications per treatment. Data were separated into two analyses according to sampling procedure: 1) pre- and post-treatment measurements of cover and density, and 2) fixed plot measurements of density. Throughout our analyses, we examined change in cover and density variables calculated as the difference between 2001 and 2004 measurements.

In the pre- and post-treatment samples, we excluded any plots that were located in unburned areas as they were not the focus of this study. Then we averaged the values by line in the paddock. The mean cover and density for each paddock was the sampling unit used throughout our analysis. Data transformations were used to meet assumptions of normality. When observations of specific variables were sparse, means were reported but not analyzed for treatment differences.

Analysis of variance procedures were performed to examine differences in the mean change from 2001 to 2004 by treatment using treatment x block as an error term to test the main treatment effects. We also conducted orthogonal contrasts to examine the effects of grazing (graze vs. no graze), season of graze (fall vs. spring), and delayed onset of grazing (3 vs. 2 vs. 1 year after fire). Statistical analyses were performed in SAS version 9.1 using PROC GLM (SAS 2004). A weighted least squares technique was used for pre- and post-treatment analyses of variance using frequency as the weight variable. Frequency was the proportion of quadrats where a variable occurred along each transect relative to the total number of quadrats sampled in each transect.

Results

Changes in grass cover and density

Perennial grasses.—Change in mean perennial grass cover from 2001, 1 year after fire (YAF), to 2004, 3 YAF, was not influenced by any grazing treatment. A comparison of grazed versus non-grazed treatments did not reveal differences. A t-test revealed that change perennial grass cover was greater than zero in non-grazed control ($P < 0.01$) while perennial grass cover in grazed treatments did not increase or decrease ($P > 0.05$; Fig. 4). We postulate that high variability in the data sets because of dry weather may have prevented us from observing grazing effects on mean perennial grass cover change.

Examination of cover data collected at the species level revealed that the grazing treatment affected bluebunch wheatgrass cover ($P < 0.05$; Fig. 5). Bluebunch wheatgrass was the dominant perennial grass species, contributing the most to the overall perennial grass category in pre- and post-treatment measurement (27% and 42%, respectively). Grazing effectively lessened the magnitude of cover increase ($P = 0.02$) compared to non-grazed treatment, evidenced by treatment difference revealed in orthogonal contrast ($P < 0.001$; Fig. 5).

Annual grasses.—Cover of annual grasses was not affected by grazing treatments (Fig. 6). Although the values of change from 2001 to 2004 appear to be less when spring grazed compared to fall grazed and control, the magnitude of change was less than 1% and the variation among treatments was high. The season of grazing or years that grazing was delayed after fire did not affect cheatgrass densities sampled in paddocks before and after grazing was applied (Fig. 7) or in fixed-plot measurements (Table 4).

Changes in forb cover and density

Change in perennial and annual forb cover was unaffected by season of grazing or years of delay after fire at both the life-form and species level of analysis (Fig. 8 and 9). The two dominant perennial forb species, tapertip hawksbeard and arrowleaf balsamroot, were not affected by grazing, regardless of season or delayed onset of grazing. Analysis of change in frequency of tapertip hawksbeard revealed that season of grazing affected abundance ($P = 0.04$; Fig. 10). Change in frequency of tapertip hawksbeard was greater in the fall grazed treatments compared to the spring grazed treatments ($P = 0.01$). Frequency change was greater in paddocks grazed in the fall 3 YAF compared to control, spring grazed, and paddocks grazed in the fall 1 YAF, and ($P < 0.05$; Fig 10). Change in densities of tapertip hawksbeard sampled in fixed plot measurements were not affected by grazing treatments (Table 4).

Changes in shrub cover and density

Change in shrub cover was not influenced by any of the grazing treatments (Fig. 11). Densities of sagebrush sampled in pre- and post-treatment measurements were unaffected by treatments (Fig. 12). No differences in sagebrush and antelope bitterbrush densities were detected in fixed plot measurements (Table 4).

Changes in subordinate species and frequency of occurrence

Many species sampled in the pre- and post-treatment data collection were quite sparse. Overall, change in cover of several subordinate species did not meet the normality assumptions of our analysis. Consequently, values of pre- and post-treatment measurements (Table 5) are reported for reference but we have focused our analysis on the broad categories of cover and the dominant plant species. We investigated potential treatment differences for change in frequency by life form and species for all variables sampled in pre- and post- treatment measurements (Table 6). However, our analysis of change in frequency measures did not reveal treatment differences with the exception of tapertip hawksbeard.

Discussion and Conclusions

Excluding livestock from burned sites had little or no impact on change after fire in cover, density, or frequency of vegetation sampled in our study area. Effects of grazing were evidenced for bluebunch wheatgrass, the dominant perennial grass, and effects of season of grazing were evidenced for tapertip hawksbeard, the dominant perennial forb.

The natural recovery period for bluebunch wheatgrass is generally two to three growing seasons (Uresk et al. 1980, West and Hassan 1985) but it may take longer to recover with the influence of seasonal grazing. Although the increase in bluebunch wheatgrass cover after fire was less in grazed paddocks compared to the control, we did not detect differences related to season of grazing. However, the extent to which bluebunch wheatgrass cover increased from 2001 to 2004 was less in grazed treatments. If cover could be examined several years into the future, we might expect a separation between fall and spring grazed treatments as evidenced in the current trend of this study.

Seasonal sheep grazing effects are well-documented in this region and numerous studies indicate that spring grazing may lower perennial grass and forb cover compared to fall grazing (Mueggler 1950, Laycock 1967, Bork et al. 1998). Jirik and Bunting (1994) examined the extent of seasonal grazing impacts on bluebunch wheatgrass after fire and found an effect from early season grazing but did not detect differences in late season grazing and controls. However, differences in parameters of measurement may contribute to lack of similarity.

While we anticipated a detectable reduction in cover of dominant perennial forbs following spring grazing treatments, grazing treatments did not impact perennial forb cover or density, regardless of season of grazing or delay of grazing in the short-term. However, we did measure a seasonal difference of tapertip hawsbeard frequency between spring and fall. Overall, Bork et al. (1998) examined the long-term effects of seasonal grazing on this site and found that tapertip hawksbeard was more abundant in fall grazed compared to spring grazed pastures. In our study, fall grazing favored the increased occurrence of tapertip hawksbeard compared to spring grazing.

Sheep grazing did not alter sagebrush recruitment and establishment. Long-lived shrub species, like sagebrush, are slow to recover from seed after burning making it difficult to detect grazing effects on sagebrush in the aftermath of fire (Blaisdell 1982). However, a unique characteristic of three-tip sagebrush is that it may resprout after fire (Blaisdell et al. 1982, Hironaka et al. 1983). Bitterbrush, a valuable wild ungulate forage resource, was not affected by grazing treatments in our study. In eastern Idaho, bitterbrush commonly resprouts from the root crown after fire (Blaisdell and Mueggler 1956, Blaisdell et al. 1982).

We anticipated that cheatgrass would rapidly increase on our study site after disturbance caused by the wildfire which is a common scenario in western rangelands (Whisenant 1990). Contrary to our prediction, cheatgrass contributed very little to the vegetation composition. If cheatgrass had been more abundant we may have observed grazing treatment effects. Population dynamics of winter annual grasses, such as cheatgrass, are largely driven by seasonal climatic conditions. We postulate that the lack of cheatgrass abundance on our study site the year after fire was due to the cold winter conditions post-fire that eliminated most fall germinated seedlings. In the fall after the fire, most cheatgrass plants only developed a meager single leaf – an inadequate maturity to over-winter in this cold semi-arid region. Subsequent years, very little cheatgrass germination was observed in the fall. Spring germinated plants do not have the same advantages as established fall germinated plants which are much more competitive with established vegetation. Spring germinated cheatgrass plants exhibit reduced height and yield (Stewart and Hull 1949) and were likely further limited by low precipitation in the spring following the burn. Cheatgrass seed caryopses may not have been prevalent before the fire and additional mortality may have occurred from heat damage associated with the burn (Young et al.1976). However, limited abundance of cheatgrass in healthy sagebrush stands before fire does not preclude post-fire cheatgrass establishment (West and Hassan 1985, Seefeldt and McCoy 2003).

Current federal policy regulating grazing after fire is marginally supported by our study. The effects of grazing were not profound and the plants were recovering even with the influence of grazing, particularly under fall grazing. Delayed onset of grazing is unsupported by our study as we observed no effects of grazing deferment. Overall, strict adherence to arbitrary policies related to grazing after fire seems unwarranted.

The species of greatest management concern in our study area is bluebunch wheatgrass. A trend for increased bluebunch wheatgrass cover over time suggests that moderate fall grazing may allow bluebunch wheatgrass to slowly increase to levels found in non-grazed paddocks (Fig. 5). Agency standards may need to evaluate burned vegetation on a site specific basis in contrast to mandating a set deferment period. Rest periods may need to reflect pre-fire site conditions (i.e., stable communities vs. at-risk late seral stands or stands with pre-fire weed infestations). Mandatory rest periods may impose undue financial hardship to local livestock producers and prove increasingly challenging to land managers. Careful attention should be placed on planning objectives for fire recovery (i.e., sensitive species, forage resource, weed invasion). Managers must develop post-fire grazing management strategies that limit damage to recovering vegetation while minimizing the threat of weed invasion. Decisions should consider pre-fire ecological conditions, post-fire climatic conditions, and current knowledge of impacts on plant diversity.

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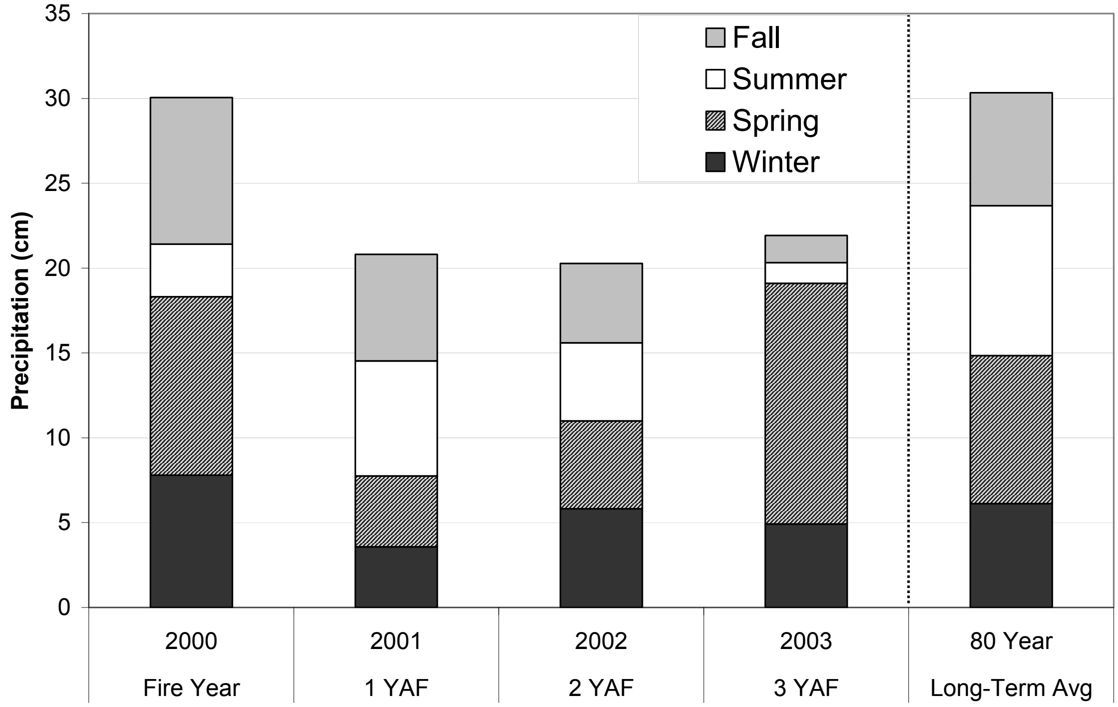

FIG. 1. Mean annual precipitation of research study site at U.S. Sheep Experiment Station near Dubois, ID in 2000 through 2003 (1, 2, and 3 years after fire [YAF]). The long-term average seasonal precipitation is also presented for: Winter (Dec/Jan/Feb), Spring (Mar/Apr/May), Summer (Jun/Jul/Aug), and Fall (Sep/Oct/Nov). (Data obtained from Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?id2707).

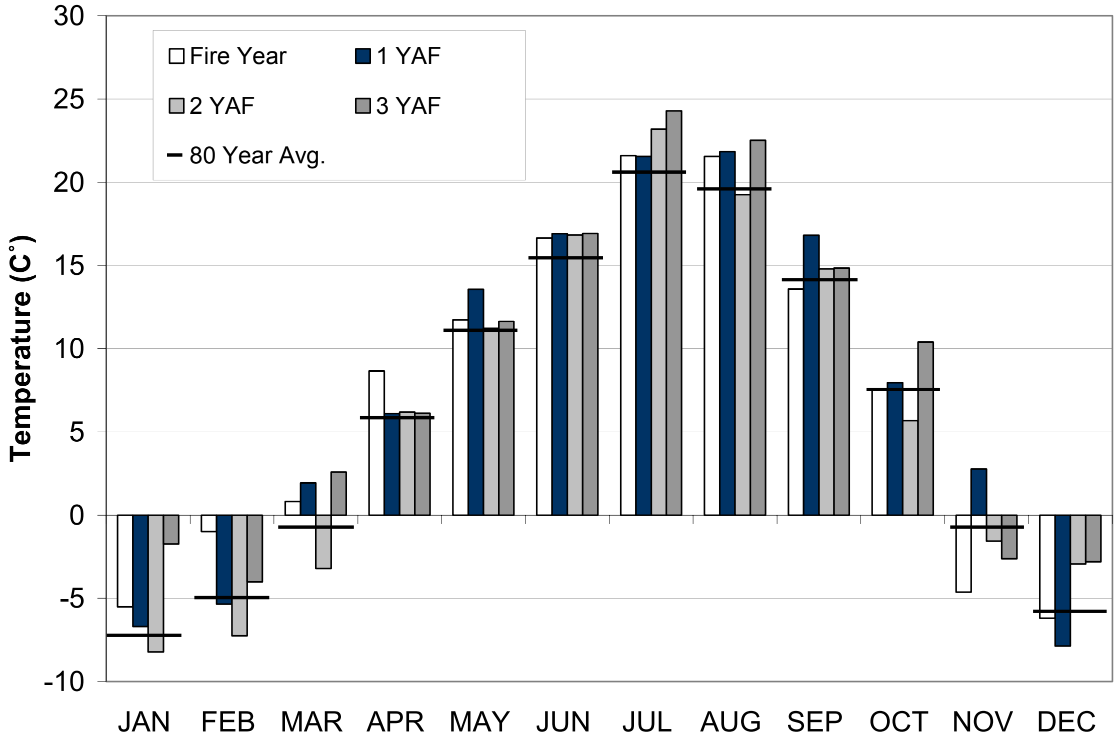

FIG. 2. Mean temperature by month for research study site at US Sheep Experiment Station near Dubois, ID. Fire year represents 2000 and subsequent years after fire (YAF) represent 2001 through 2003. (Data obtained from Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?id2707).

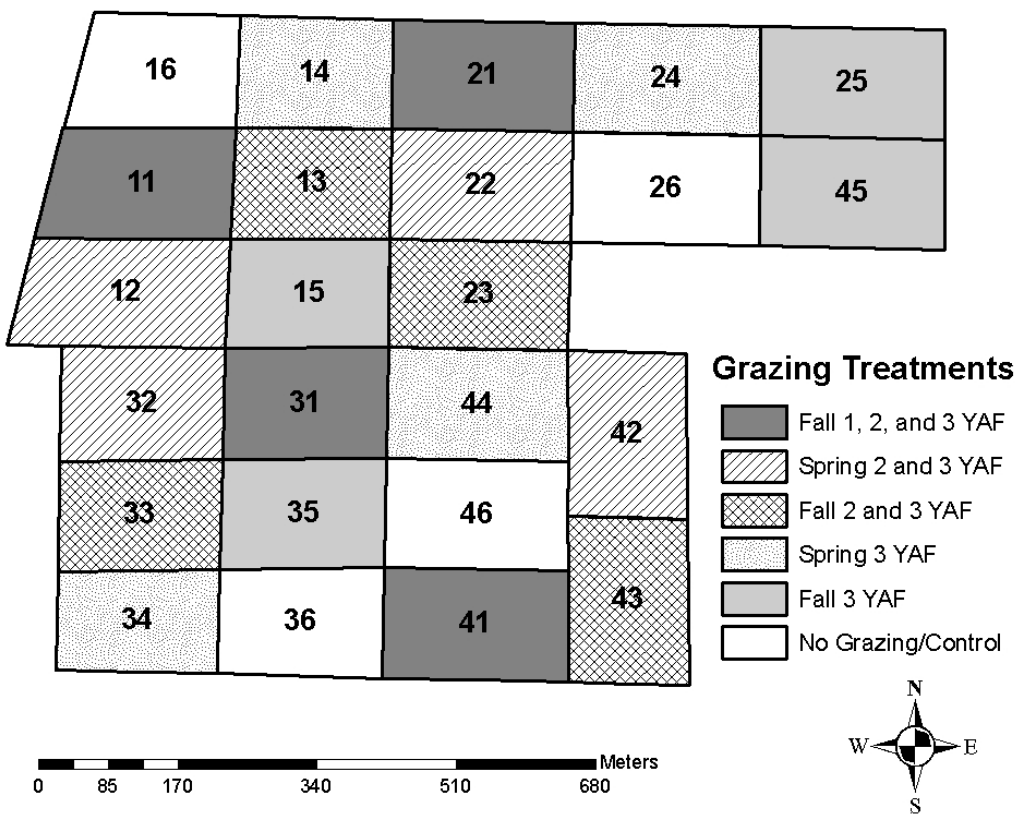

FIG. 3. Layout of grazing treatment paddocks at study site near Dubois, ID to examine effects of grazing after a wildland fire that occurred in 2000. Six grazing treatments were applied with 4 replicated paddocks arranged in 4 blocks. First digit of paddock number indicates block number and second digit represents treatment by season and years after fire (YAF).

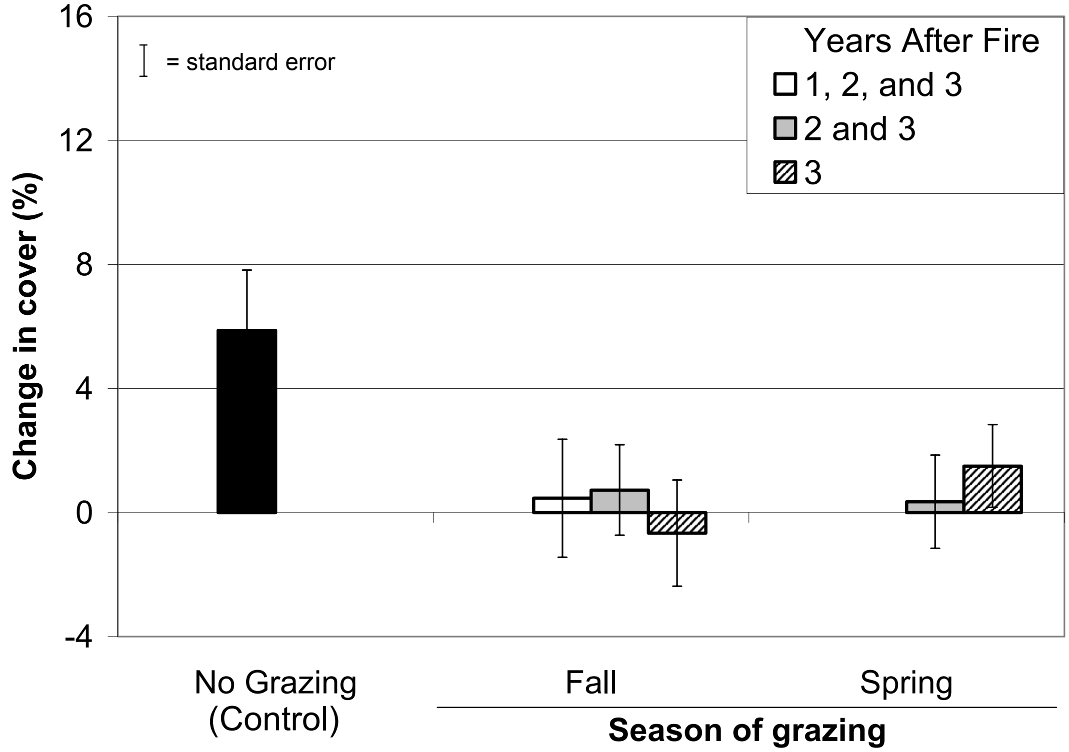

FIG. 4. Change (mean ± SE) from 2001 to 2004 in perennial grass cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

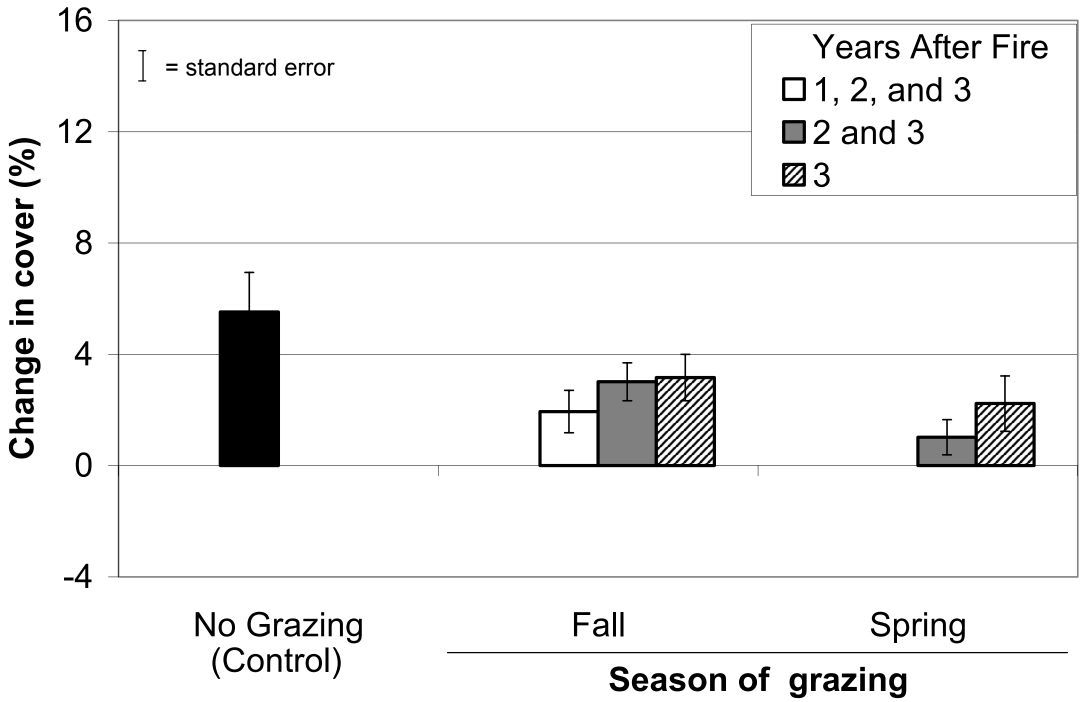

FIG. 5. Change (mean ± SE) from 2001 to 2004 in bluebunch wheatgrass cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

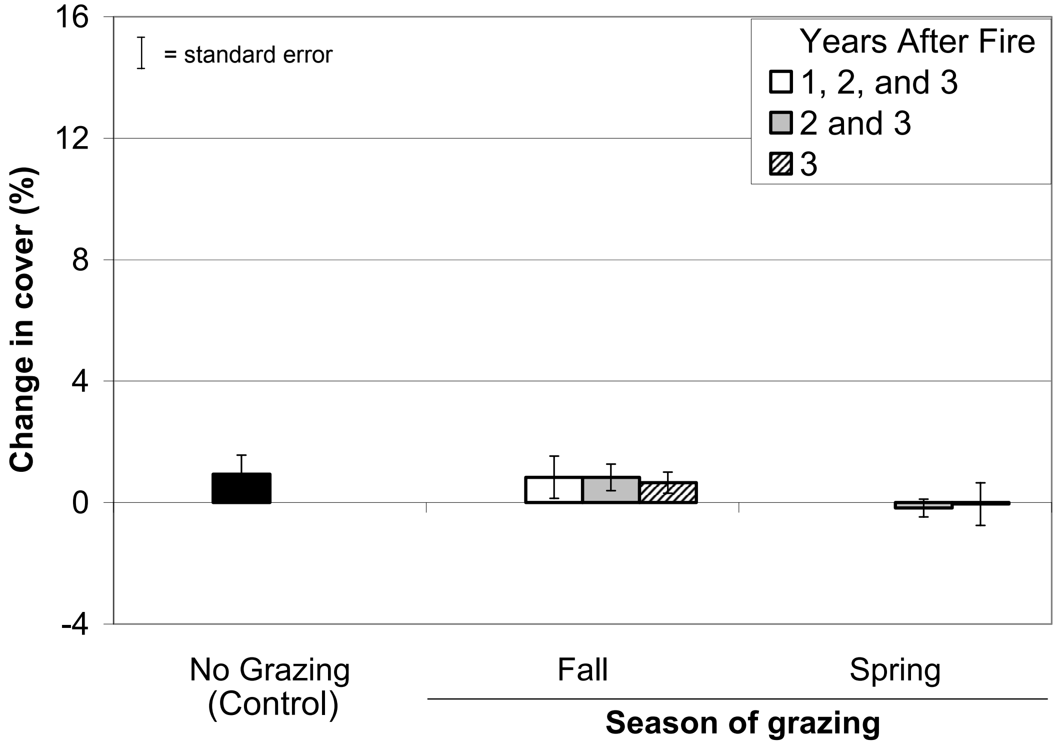

FIG. 6. Change (mean ± SE) from 2001 to 2004 in annual grass cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

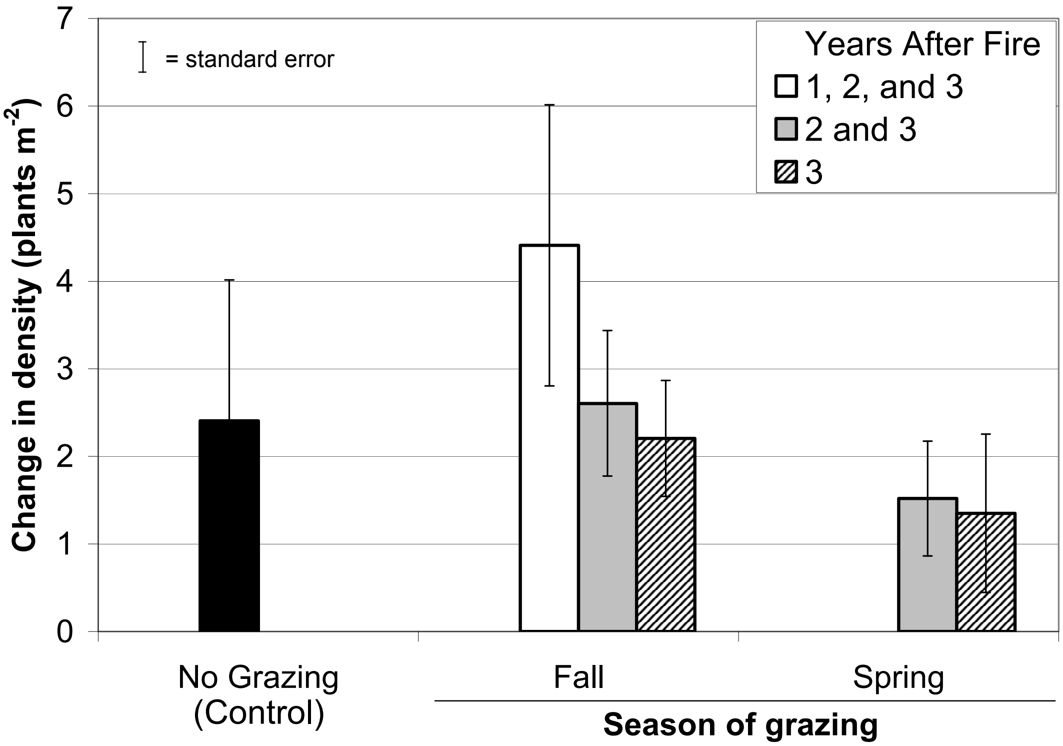

FIG. 7. Change (mean ± SE) from 2001 to 2004 in cheatgrass density for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

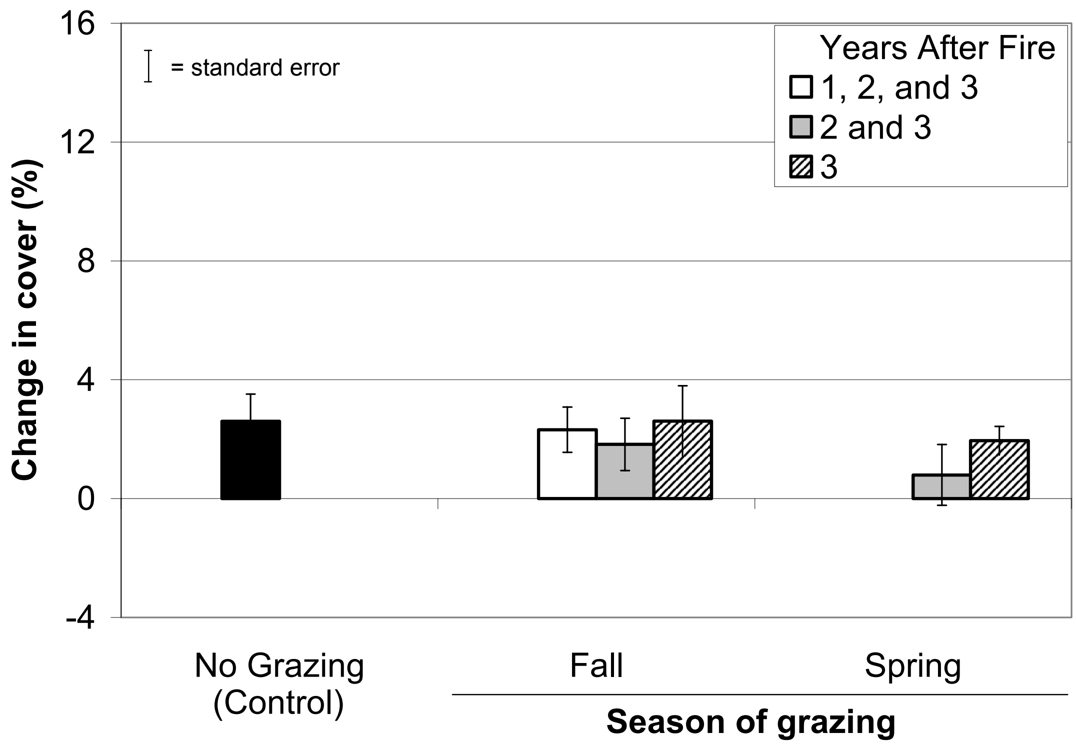

FIG. 8. Change (mean ± SE) from 2001 to 2004 in perennial forb cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

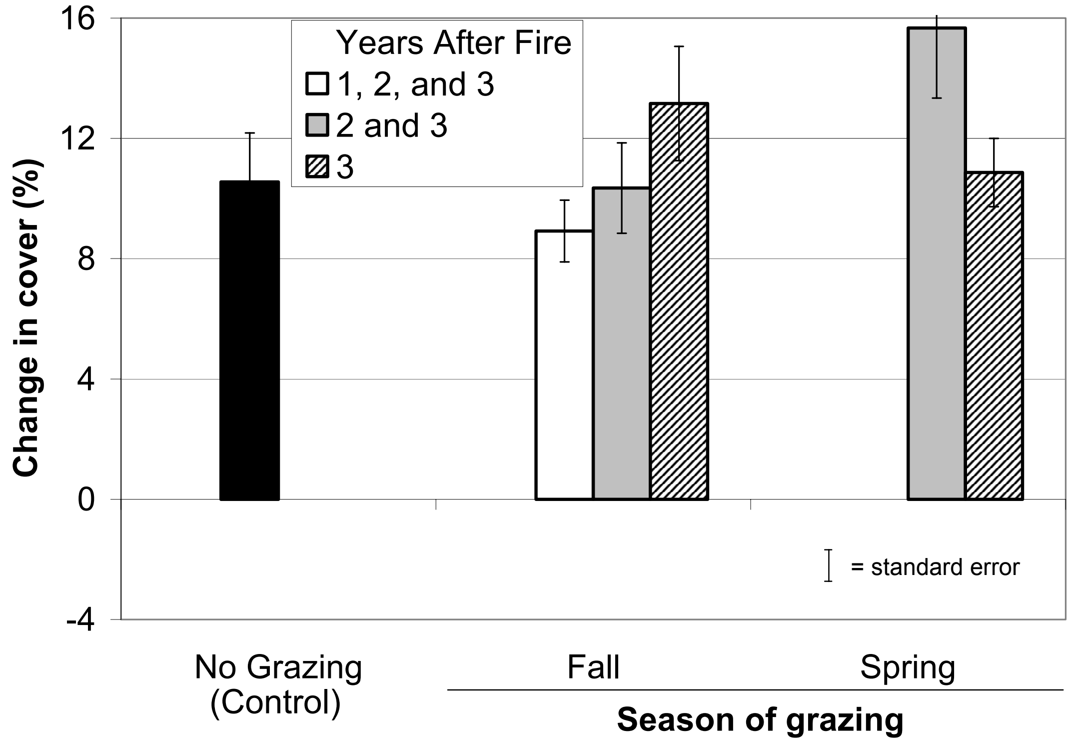

FIG. 9. Change (mean ± SE) from 2001 to 2004 in annual forb cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

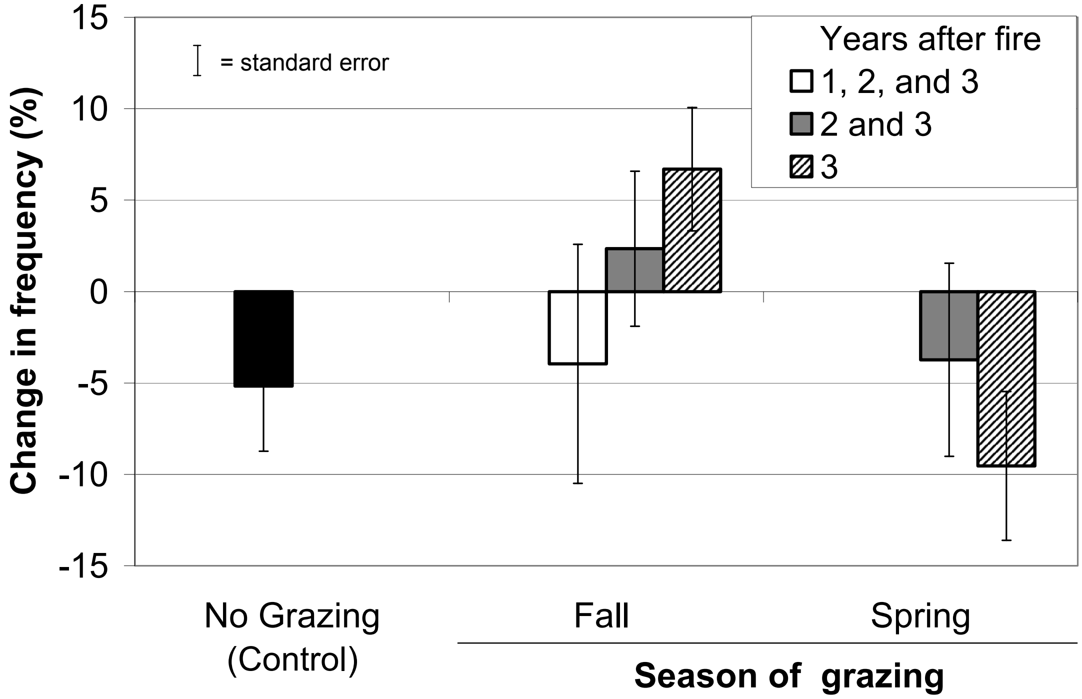

FIG. 10. Change (mean ± SE) from 2001 to 2004 in tapertip hawksbeard frequency for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

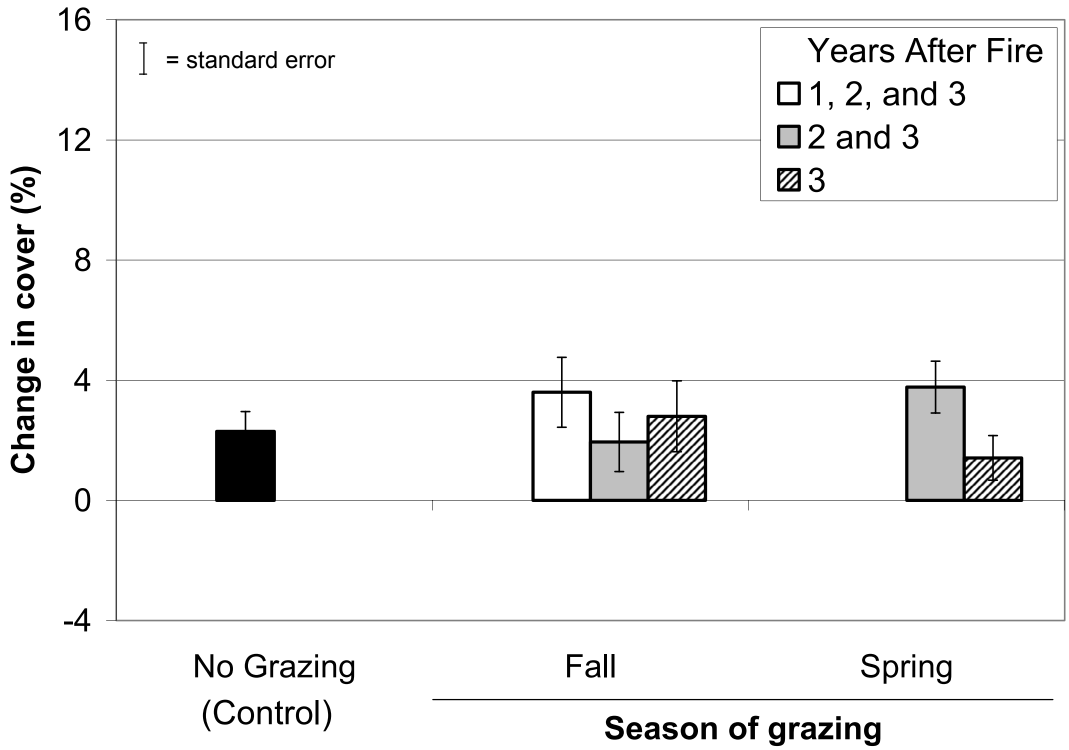

FIG. 11. Change (mean ± SE) from 2001 to 2004 in woody cover for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

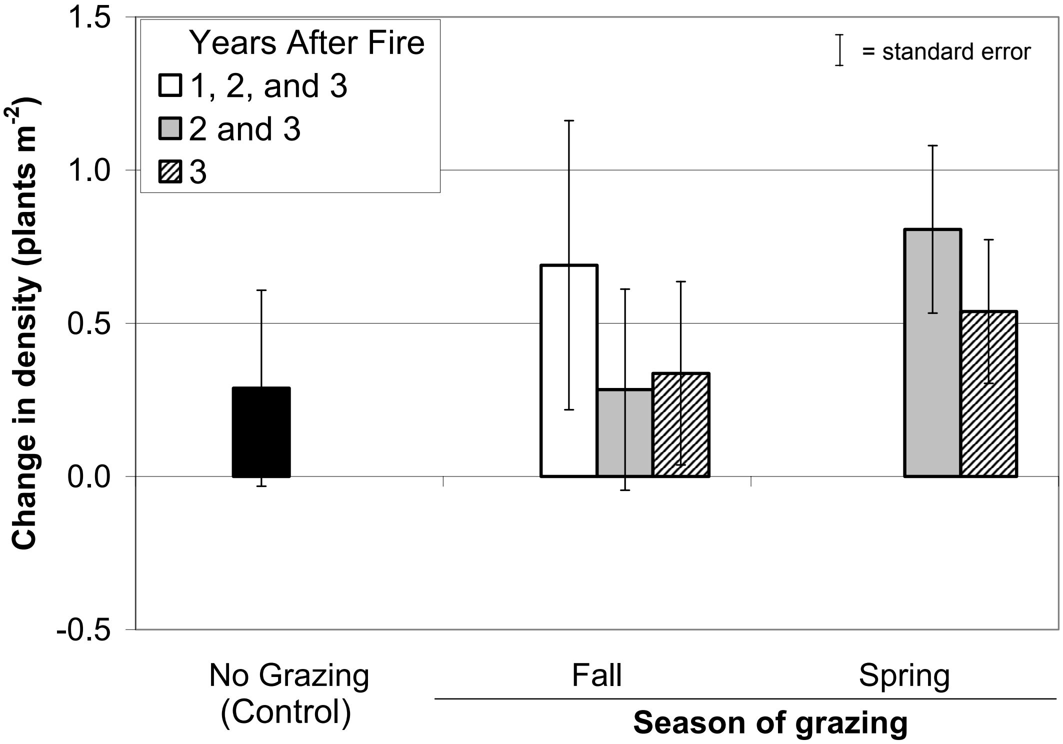

FIG. 12. Change (mean ± SE) from 2001 to 2004 in sagebrush density for paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. The study was conducted in a sagebrush-steppe area in southeastern Idaho.

TABLE 1. Area and portion of paddocks burned (mean ± SE), averaged across 4 replicate paddocks, in a study of sheep grazing treatments applied in fall or spring 1, 2 or 3 years after fire (YAF). Fire occurred in 2000 in a sagebrush steppe community in Southeastern Idaho.

		Grazing Treatment				
		Fall			Spring	
Descriptive Variable	Control	1 YAF	2 YAF	3 YAF	2 YAF	3 YAF
Area Burned (ha)	2.5 ± 0.2	2.6 ± 0.1	2.6 ± 0.1	2.7 ± 0.1	2.8 ± 0.2	2.5 ± 0.1
Portion Burned (%)	88.4 ± 6.9	87.7 ± 5.2	92.5 ± 5.6	95.8 ± 2.0	93.2 ± 5.5	92.3 ± 3.1

TABLE 2. Pre-grazing biomass and stocking rates (SD = sheep days) applied for grazing treatments (1, 2, and 3 years after fire [YAF]) with sheep in a sagebrush steppe site in Southeastern Idaho. Values are averages of 4 replicate paddocks by treatment and year (mean ± SE).

Year	Treatment (YAF)	Spring Biomass (kg/ha)	Spring Stocking Rate (SD/ha)	Fall Biomass (kg/ha)	Fall Stocking Rate (SD/ha)
2001	1	–	–	367.8 ± 61.2	56.3 ± 2.0
2002	1	–	–	1273.3 ± 71.9	120.0 ± 9.2
	2	639.6 ± 27.1	119.4 ± 5.5	1490.3 ± 116.1	116.7 ± 9.3
2003	1	–	–	855.9 ± 123.8	118.7 ± 6.8
	2	649.5 ± 41.0	117.4 ± 9.2	852.6 ± 69.1	119.7 ± 10.0
	3	662.5 ± 43.4	124 3 ± 7.4	951.8 ± 126.4	124.3 ± 5.1

TABLE 3. Plant species examined in 2001 and 2004 in pre- and post-treatment measurements at research site in southeastern Idaho. Paddocks were subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000. Cover measurements were estimated in broad life-form categories and further subdivided by species.

	Common Name	Scientific Name[2]
Perennial grass	Bluebunch Wheatgrass	*Pseudoroegneria spicata*
	Thickspike Wheatgrass	*Elymus lanceolatus*
	Crested Wheatgrass	*Agropyron cristatum*
	Prairie Junegrass	*Koeleria macrantha*
	Indian Ricegrass	*Achnatherum hymenoides*
	Sandberg Bluegrass	*Poa secunda*
	Needle and Thread Grass	*Hesperostipa comata*
Perennial forb	Onion	*Allium* spp.
	Vetch	*Astragalus* spp.
	Arrowleaf Balsamroot	*Balsamorhiza sagittata*
	Tapertip Hawksbead	*Crepis acuminata*
	Bastard's Toadflax	*Comandra umbellata*
	Dandelion	*Taraxacum officinale*
	Yellow Salsify	*Tragopogon dubius*
Annual grass	Cheatgrass	*Bromus tectorum*
Woody	Threetip Sagebrush	*Artemesia tripartita*
	Green Rabbitbrush	*Chrysothamnus viscidiflorus*
	Broom Snakeweed	*Gutierrezia sarothrae*
	Antelope Bitterbrush	*Purshia tridentata*
	Gray horsebrush	*Tetradymia canescens*

[2] Scientific names follow the USDA Plants Database (https://plants.usda.gov) April 20, 2006, April 20, 2007.

TABLE 4. Summary of fixed plot density (plants/10m^2) measurements recorded in belt transects at research site in Southeastern Idaho. Densities were recorded from 2001 to 2004 in paddocks subjected to sheep grazing in spring or fall 1, 2, or 3 years after a wildfire that occurred in 2000.

		Treatment					
Species	Year	Control (Ungrazed)	Grazed Fall 1, 2, 3 YAF	Grazed Spring 2, 3 YAF	Grazed Fall 2, 3 YAF	Grazed Spring 3 YAF	Grazed Fall 3 YAF
		plants/10m^2					
Bromus tectorum	2001	7.7 ± 3.4	18.3 ± 9.8	13.0 ± 5.8	9.8 ± 5.3	54.3 ± 17.3	32.9 ± 14.7
	2002	10.7 ± 8.3	12.4 ± 5.9	49.1 ± 14.6	8.3 ± 4.0	102.7 ± 60.2	36.0 ± 16.8
	2003	10.5 ± 3.4	48.9 ± 38.8	35.6 ± 6.9	25.7 ± 8.8	94.4 ± 45.3	72.7 ± 26.4
	2004	10.4 ± 3.0	49.5 ± 38.3	35.0 ± 6.9	11.8 ± 2.8	59.7 ± 18.4	47.1 ± 20.6
Crepis acuminata	2001	24.5 ± 5.1	26.8 ± 3.7	41.9 ± 5.8	31.0 ± 7.6	27.6 ± 8.9	34.3 ± 16.8
	2002	55.1 ± 7.2	53.2 ± 13.0	56.4 ± 13.6	52.0 ± 6.1	49.0 ± 8.7	49.3 ± 19.0
	2003	67.3 ± 6.4	62.6 ± 12.1	41.6 ± 13.2	72.3 ± 15.7	18.5 ± 2.0	50.4 ± 21.2
	2004	60.3 ± 10.2	58.4 ± 12.7	57.1 ± 11.4	58.1 ± 15.4	43.3 ± 15.9	44.6 ± 20.4
Artemisia tripartita	2001	1.0 ± 0.8	0.9 ± 0.4	3.4 ± 1.8	3.4 ± 2.8	3.1 ± 1.8	1.1 ± 0.5
	2002	2.0 ± 1.2	1.2 ± 1.1	5.2 ± 1.9	5.4 ± 3.5	5.2 ± 3.0	2.2 ± 1.3
	2003	2.2 ± 1.3	2.3 ± 1.3	4.9 ± 1.6	5.5 ± 3.0	5.0 ± 3.1	2.8 ± 1.2
	2004	0.9 ± 0.4	2.7 ± 1.4	4.3 ± 1.9	3.8 ± 1.8	4.4 ± 3.2	2.3 ± 1.4
Purshia tridentata	2001	0.4 ± 0.3	0.3 ± 0.1	0.1 ± 0.1	0.7 ± 0.2	0.0 ± 0.0	0.8 ± 0.5
	2002	0.3 ± 0.2	0.5 ± 0.4	0.3 ± 0.3	0.9 ± 0.4	0.0 ± 0.0	0.7 ± 0.3
	2003	0.6 ± 0.3	0.3 ± 0.2	0.2 ± 0.2	0.8 ± 0.3	0.0 ± 0.0	0.5 ± 0.4
	2004	0.3 ± 0.2	0.2 ± 0.1	0.2 ± 0.2	0.6 ± 0.3	0.0 ± 0.0	0.4 ± 0.3

TABLE 5. Summary of cover and density estimates recorded in 2001 and 2004 in pre- and post-treatment measurements at research site in southeastern Idaho. Paddocks were subjected to sheep grazing in spring or fall 1, 2, or 3 years after a fire (YAF) that occurred in 2000. Cover measurements were estimated in broad life-form categories and further subdivided by species. Density measurements were recorded for sagebrush and cheatgrass only.

Growth-form/species	Control		Grazed Fall 1, 2, 3 YAF		Grazed Spring 2, 3 YAF		Grazed Fall 2, 3 YAF		Grazed Spring 3 YAF		Grazed Fall 3 YAF	
	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
	Cover (%)											
Perennial grasses	13.9 ± 1.0	19.8 ± 1.5	15.9 ± 1.3	16.4 ± 1.0	13.0 ± 1.2	13.3 ± 1.3	14.0 ± 1.0	14.7 ± 1.3	14.1 ± 1.1	15.6 ± 1.4	17.3 ± 1.4	16.6 ± 1.2
Pseudoroegneria spicata	3.9 ± 0.8	9.4 ± 1.2	4.3 ± 0.5	6.2 ± 0.8	3.7 ± 0.4	4.7 ± 0.6	3.9 ± 0.8	9.4 ± 1.2	3.9 ± 0.8	9.4 ± 1.2	3.6 ± 0.4	6.8 ± 0.8
Elymus lanceolatus	1.8 ± 0.5	1.6 ± 0.4	2.5 ± 0.5	2.2 ± 0.5	2.9 ± 0.6	2.4 ± 0.5	1.8 ± 0.5	1.6 ± 0.4	1.8 ± 0.5	1.6 ± 0.4	4.0 ± 0.8	2.7 ± 0.4
Agropyron cristatum	0.1 ± 0.1	0.1 ± 0.1	0.6 ± 0.3	0.1 ± 0.1	0.3 ± 0.3	0.7 ± 0.4	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	—	0.6 ± 0.6
Koeleria macrantha	1.1 ± 0.4	0.1 ± 0.1	1.6 ± 0.2	0.0 ± 0.0	0.9 ± 0.2	0.0 ± 0.0	1.1 ± 0.4	0.1 ± 0.1	1.1 ± 0.4	0.1 ± 0.1	0.9 ± 0.3	0.1 ± 0.1
Achnatherum hymenoides	0.1 ± 0.0	0.7 ± 0.5	0.6 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	0.1 ± 0.0	0.7 ± 0.5	0.1 ± 0.0	0.7 ± 0.5	0.4 ± 0.1	0.1 ± 0.0
Poa secunda	5.4 ± 0.8	6.2 ± 0.6	5.3 ± 0.7	5.8 ± 0.6	3.6 ± 0.5	4.1 ± 0.6	5.4 ± 0.8	6.2 ± 0.6	5.4 ± 0.8	6.2 ± 0.6	6.5 ± 1.2	5.7 ± 0.8
Hesperostipa comata	1.6 ± 0.3	1.6 ± 0.4	0.9 ± 0.3	1.5 ± 0.5	1.0 ± 0.4	1.2 ± 0.5	1.6 ± 0.3	1.6 ± 0.4	1.6 ± 0.3	1.6 ± 0.4	1.8 ± 0.6	0.7 ± 0.2
Perennial forbs	5.0 ± 0.9	7.6 ± 1.0	3.4 ± 0.4	5.7 ± 0.7	6.3 ± 0.7	7.1 ± 0.7	5.3 ± 0.9	7.1 ± 0.8	4.3 ± 0.5	6.3 ± 0.7	6.3 ± 0.9	8.9 ± 1.2
Allium spp.	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.4 ± 0.1	0.2 ± 0.1
Astragalus spp.	1.0 ± 0.4	0.2 ± 0.1	0.5 ± 0.1	0.1 ± 0.0	1.4 ± 0.2	0.1 ± 0	1.0 ± 0.4	0.2 ± 0.1	1.0 ± 0.4	0.2 ± 0.1	1.1 ± 0.2	0.3 ± 0.1
Balsamorhiza sagittata	0.4 ± 0.3	0.6 ± 0.3	0.2 ± 0.1	0.2 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.3	0.6 ± 0.3	0.4 ± 0.3	0.6 ± 0.3	0.2 ± 0.1	0.9 ± 0.4
Crepis acuminata	1.6 ± 0.2	2.9 ± 0.4	1.0 ± 0.3	2.4 ± 0.4	1.7 ± 0.3	2.4 ± 0.4	1.6 ± 0.2	2.9 ± 0.4	1.6 ± 0.2	2.9 ± 0.4	1.4 ± 0.3	2.8 ± 0.7
Comandra umbellata	0.3 ± 0.1	0.4 ± 0.2	0.3 ± 0.2	0.3 ± 0.1	0.5 ± 0.1	0.1 ± 0.0	0.3 ± 0.1	0.4 ± 0.2	0.3 ± 0.1	0.4 ± 0.2	0.5 ± 0.1	0.5 ± 0.2
Taraxacum officinale	0.1 ± 0.0	—	—	—	0.2 ± 0.1	—	0.1 ± 0.0	—	0.1 ± 0.0	—	0.1 ± 0.1	—
Tragopogon dubius	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.5 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.1 ± 0.0
Annual forbs	2.5 ± 0.5	13.0 ± 1.6	2.5 ± 0.4	11.4 ± 1.1	2.7 ± 0.4	18.4 ± 2.2	2.5 ± 0.3	12.9 ± 1.5	3.3 ± 0.5	14.2 ± 1.1	3.4 ± 0.4	16.6 ± 1.6
Annual grasses	1.3 ± 0.2	2.3 ± 0.5	1.5 ± 0.3	2.4 ± 0.6	1.5 ± 0.3	1.3 ± 0.2	1.4 ± 0.2	2.3 ± 0.5	2.0 ± 0.6	2.0 ± 0.3	1.5 ± 0.2	2.2 ± 0.4
Bromus tectorum	0.6 ± 0.2	1.3 ± 0.5	1.1 ± 0.3	1.7 ± 0.6	0.4 ± 0.1	0.7 ± 0.2	0.6 ± 0.2	1.3 ± 0.5	0.6 ± 0.2	1.3 ± 0.5	1.0 ± 0.2	1.5 ± 0.3
Woody species	0.6 ± 0.1	2.9 ± 0.6	0.8 ± 0.2	4.4 ± 1.3	1.0 ± 0.2	4.8 ± 0.8	0.9 ± 0.2	2.8 ± 0.9	1.1 ± 0.4	2.6 ± 0.5	1.3 ± 0.2	4.1 ± 1.1
Artemesia tripartita	0.1 ± 0.1	1.2 ± 0.5	0.2 ± 0.1	2.0 ± 1.0	0.2 ± 0.1	0.4 ± 0.1	0.1 ± 0.1	1.2 ± 0.5	0.1 ± 0.1	1.2 ± 0.5	0.1 ± 0.1	0.6 ± 0.4
Chrysothamnus viscidiflorus	0.1 ± 0.0	0.8 ± 0.4	0.3 ± 0.1	0.8 ± 0.3	0.2 ± 0.1	1.5 ± 0.5	0.1 ± 0.0	0.8 ± 0.4	0.1 ± 0.0	0.8 ± 0.4	0.3 ± 0.1	1.4 ± 0.5
Gutierrezia sarothrae	0.1 ± 0.1	—	—	—	—	—	0.1 ± 0.1	—	0.1 ± 0.1	—	0.2 ± 0.2	—
Purshia tridentata	—	0.2 ± 0.1	—	0.3 ± 0.3	0.1 ± 0.0	0.1 ± 0.1	—	0.2 ± 0.1	—	0.2 ± 0.1	—	0.3 ± 0.3
Tetradymia canescens	0.2 ± 0.1	0.6 ± 0.2	0.2 ± 0.1	1.2 ± 0.5	0.6 ± 0.1	2.8 ± 0.7	0.2 ± 0.1	0.6 ± 0.2	0.2 ± 0.1	0.6 ± 0.2	0.5 ± 0.2	1.8 ± 0.5
	Density (plants/m^2)											
Artemesia tripartita density	0.6 ± 0.2	0.8 ± 0.2	0.5 ± 0.1	1.2 ± 0.5	0.5 ± 0.1	1.3 ± 0.2	0.7 ± 0.2	1.0 ± 0.3	0.7 ± 0.1	1.2 ± 0.3	0.6 ± 0.2	1.0 ± 0.2
Bromus tectorum density	1.1 ± 0.5	3.6 ± 1.5	1.5 ± 0.2	5.9 ± 1.6	0.8 ± 0.3	2.4 ± 0.7	1.1 ± 0.3	3.7 ± 0.9	1.4 ± 0.4	2.8 ± 0.8	1.8 ± 0.4	4.0 ± 0.8

TABLE 6. Summary of frequencies recorded in 2001 and 2004 in pre- and post-treatment measurements at research site in southeastern Idaho. Paddocks were subjected to sheep grazing in spring or fall 1, 2, or 3 years after a fire (YAF) that occurred in 2000. Frequency measurements were calculated from cover estimates.

	Treatment					
Growth-form/species	Control (Ungrazed)	Grazed Fall 1, 2, 3 YAF	Grazed Spring 2, 3 YAF	Grazed Fall 2, 3 YAF	Grazed Spring 3 YAF	Grazed Fall 3 YAF
	%					
Perennial grasses	-6.2 ± 2.4	-1.6 ± 2.6	-0.3 ± 3.3	3.2 ± 4.0	-2.4 ± 3.2	-2.5 ± 3.7
Pseudoroegneria spicata	4.2 ± 5.6	3.4 ± 4.2	-6.2 ± 4.1	7.4 ± 5.3	2.7 ± 6.2	4.3 ± 6.2
Elymus lanceolatus	-12.5 ± 5.1	-2.3 ± 4.0	-12.2 ± 4.6	-3.3 ± 5.0	-6.2 ± 5.4	-2.6 ± 4.0
Agropyron cristatum	-0.7 ± 1.5	-0.5 ± 0.5	1.4 ± 1.0	0.0 ± 0.0	0.0 ± 0.0	1.3 ± 1.3
Koeleria macrantha	-12.1 ± 2.8	-19.8 ± 2.5	-16.9 ± 2.7	-18.6 ± 5.0	-14.3 ± 3.8	-11.7 ± 3.3
Achnatherum hymenoides	1.5 ± 2.0	-6.2 ± 2.2	-2.7 ± 1.5	-5.3 ± 2.6	-3.0 ± 2.8	-5.1 ± 2.0
Poa secunda	-7.6 ± 4.8	-5.7 ± 3.9	-1.3 ± 5.7	-2.0 ± 7.5	-11.4 ± 4.0	-2.8 ± 6.7
Hesperostipa comata	-8.5 ± 2.9	0.1 ± 3.1	1.1 ± 2.7	-2.2 ± 2.4	-4.5 ± 2.2	-10.3 ± 4.3
other perennial grasses	0.0 ± 0.6	1.2 ± 1.4	-0.8 ± 1.0	-1.6 ± 1.1	1.5 ± 2.1	-2.2 ± 0.8
Perennial forbs	3.3 ± 5.5	-4.9 ± 6.9	-5.4 ± 5.2	3.3 ± 5.2	-5.8 ± 5.2	0.5 ± 8.5
Allium spp.	-5.6 ± 2.1	-11.5 ± 2.5	-9.5 ± 4.4	-13.3 ± 3.4	-14.6 ± 3.6	-12.2 ± 4.0
Astragalus spp.	-14.9 ± 4.6	-16.9 ± 4.3	-40.6 ± 4.5	-25.9 ± 4.2	-19.0 ± 2.6	-19.4 ± 5.7
Balsamorhiza sagittata	-0.9 ± 1.2	-0.4 ± 1.0	0.0 ± 1.7	-0.2 ± 1.9	1.4 ± 2.1	3.4 ± 2.1
Crepis acuminata	-5.2 ± 3.6	-4.0 ± 6.5	-3.7 ± 5.3	2.3 ± 4.2	-9.5 ± 4.1	6.7 ± 3.4
Comandra umbellata	-3.3 ± 1.8	-2.1 ± 1.3	-7.6 ± 2.3	-1.9 ± 1.9	-1.6 ± 2.1	-1.9 ± 2.8
Taraxacum officinale	-0.7 ± 1.0	-0.7 ± 1.3	-2.4 ± 1.5	-2.8 ± 1.4	-2.4 ± 1.7	-2.6 ± 1.2
Tragopogon dubius	1.0 ± 2.2	1.4 ± 2.5	-3.6 ± 1.9	1.9 ± 2.6	-4.3 ± 1.8	-0.6 ± 3.2
other perennial forbs	8.0 ± 8.4	1.1 ± 6.2	12.0 ± 6.1	10.7 ± 6.1	10.5 ± 4.4	10.7 ± 6.3
Annual forbs	12.7 ± 4.1	15.9 ± 5.5	19.0 ± 6.6	9.4 ± 2.4	10.7 ± 3.6	10.2 ± 4.6
Annual grasses	12.7 ± 2.9	13.7 ± 6.2	13.7 ± 6.5	11.7 ± 6.0	3.5 ± 5.3	9.1 ± 5.4
Bromus tectorum	6.2 ± 4.4	7.2 ± 4.2	5.9 ± 5.1	14.1 ± 5.3	-0.2 ± 5.2	8.7 ± 4.6
other annual grasses	11.8 ± 4.9	11.4 ± 5.9	6.9 ± 8.4	7.9 ± 5.4	8.3 ± 3.4	9.2 ± 3.7
Woody species	10.5 ± 2.7	9.1 ± 3.2	10.5 ± 4.5	6.6 ± 5.7	6.5 ± 3.3	7.5 ± 4.6
Artemesia tripartita	5.0 ± 1.5	4.7 ± 1.7	0.9 ± 1.4	5.9 ± 4.4	2.7 ± 1.8	3.4 ± 1.6
Chrysothamnus viscidiflorus	4.6 ± 2.2	0.6 ± 1.7	7.1 ± 1.9	3.8 ± 3.0	6.5 ± 2.1	4.1 ± 3.2
Gutierrezia sarothrae	-2.3 ± 0.8	0.0 ± 0.0	-0.4 ± 0.4	-0.8 ± 0.8	-1.4 ± 1.0	-3.0 ± 1.7
Purshia tridentata	1.4 ± 0.7	1.0 ± 1.6	-1.1 ± 0.9	0.4 ± 0.4	-1.1 ± 1.0	0.4 ± 1.0
Tetradymia canescens	2.6 ± 1.9	2.4 ± 2.3	5.7 ± 4.0	-1.1 ± 2.2	1.2 ± 1.9	2.6 ± 3.1
other woody	1.0 ± 1.3	0.9 ± 0.9	-0.4 ± 0.4	-1.2 ± 0.6	-0.5 ± 0.8	-0.9 ± 0.9
Artemesia tripartita density	5.8 ± 4.3	8.7 ± 3.9	11.3 ± 6.0	12.1 ± 5.0	-0.5 ± 5.5	8.4 ± 4.5
Bromus tectorum density	10.5 ± 6.1	5.7 ± 3.5	17.4 ± 4.9	5.8 ± 6.0	8.8 ± 3.7	10.9 ± 5.4

CHAPTER III

TARGETED SHEEP GRAZING TO CONTROL CHEATGRASS AND MEDUSAHEAD AND FACILITATE REHABILITATION OF ANNUAL GRASSLANDS

INTRODUCTION

Many western landscapes formerly dominated by perennial bunchgrasses and sagebrush have been converted to annual grasses such as cheatgrass (*Bromus tectorum* L.) and medusahead (*Taeniatherum caput-medusae* [L.] Nevski) (Evans and Young 1970, Sanders 1994, Pyke 1999). Both these troublesome exotic grasses exhibit tremendous seed production, creating huge seed banks, taking advantage of winter precipitation, and quickly dominating plant communities in semi-arid regions (Hulbert 1955, Young 1992, Young and Allen 1997).

Management goals for these annual grasslands often include restoration strategies aimed at establishment of perennial grasses and forbs. Traditional revegetation methods have included mowing, burning, plowing, and chemical application to prepare the seedbed and reduce competition during seedling establishment. Using domestic livestock as a tool in rangeland rehabilitation has not been well-documented. While livestock grazing and trampling are often considered mechanisms that contributed to weed invasion and spread on western rangelands, the potential of livestock to alter plant communities could be beneficial to degraded landscapes where properly managed (Archer and Pyke 1991, Frost and Launchbaugh 2003).

The mechanical action of livestock trampling may be as effective as traditional seedbed preparation techniques (Winkel and Roundy 1991, Rotundo 2004) for reestablishing perennial grasses into weed dominated communities. The intensity of trampling is an important factor to consider in seedbed preparation. Eckert et al. (1986) found that moderate trampling was useful for creating seed microsites and favorable for the emergence of perennial grasses while heavy trampling was detrimental. However, Winkel and Roundy (1991) found that heavy trampling was favorable to seedling emergence compared to lightly trampled or undisturbed treatments. Trampling has been effective at getting seeds in contact with mineral soil when a soil barrier might otherwise prevent germination of seed broadcast on surface (McIlvanie 1942) and can bury seeds to a desirable depth for emergence (Winkel et al. 1991). Broadcast seeding is not generally the preferred method to sow seeds on rangelands but may be more practical in areas with limited accessibility (Winkel et al. 1991).

Sheep have grazing habits that are generally more selective than cattle or horses due to the unique anatomy of their mouth parts. Mouth features such as a muscular pad on their upper jaw, a narrow muzzle, a dexterous tongue, and a cleft upper lip allow sheep to be effective harvesters (Olsen and Lacey 1994, Mosley 1996). Furthermore, sheep tend to select diets more dominated by grass than goats (Olsen and Lacey 1994). Sheep grazing may be an effective tool to control cheatgrass (Vallentine and Stevens 1994, Mosley 1996) and medusahead (Lusk et al. 1961). Recently, using livestock for fine fuel reduction in annual grasslands has become more common, exhibiting advantages over traditional techniques including increased selectivity, low environmental risk, and cost effectiveness (Taylor 1994, Davison 1996, Taylor 2006). While it is generally accepted that sheep will readily graze cheatgrass when palatable (Pechanec 1949, Harris 1967, Mosley 1996) less well-known is whether sheep will graze medusahead (Lusk et al. 1961). Grazing treatments can reduce the annual grass competition on seedling-stage perennials, a necessary method in restoration efforts (Humphrey and Schupp 2004). Rotundo and Aguiar (2004) suggest that adjusting sheep grazing to the phenology of the plants is a low input technique in regeneration efforts.

Attempts to restore native perennial forage species in rangelands dominated by weedy annual grasses, such as cheatgrass and medusahead, can be difficult because of the stable and highly competitive nature of annual grass communities (Pellant 1990, Allen 1995, McIver and Starr 2001, Cox and Anderson 2004). This study was designed to examine the effectiveness of sheep trampling and grazing for rehabilitating annual grass dominated communities. We attempted to seed a combination of native and introduced grasses using sheep trampling as a disturbance to create favorable soil microsites and mechanically incorporate seed into soil. We also applied spring sheep grazing in an attempt to reduce competition of annual grasses with perennial grass seedlings.

MATERIALS AND METHODS

Study area

Research was conducted from fall of 2004 through summer of 2006 in the grassland steppe scablands of Adams County in eastern Washington, about 24-km southeast of Ritzville (Fig. 1). The study site was located within a fenced 260-ha pasture adjacent to Cow Creek.

Native and exotic grasses and forbs dominated the study site, interspersed by shrubs, predominantly stiff sagebrush (*Artemisia rigida* [Nutt.] Gray) and rabbitbrush (*Chrysothamnus* spp.). Historically, areas of deep and loamy soils on this site were cultivated to harvest grass hay. Many plant species present on the site were a mixture of remnant seed stock from hay plantings and species planted for conservation goals following cessation of cultivation. Livestock grazing is a common practice in the area and has been employed in the pasture in recent years. The combination of disturbance from cultivation and previous grazing has resulted in a patchwork of vegetation composed primarily of: 1) thriving remnant stands of bluebunch wheatgrass vegetation associations, and 2) sites dominated by exotic weedy species.

Native grasses included bluebunch wheatgrass (*Psuedoroegneria spicata [Pursh] A. Löve*), Idaho fescue (*Festuca idahoensis* Elmer), sandberg bluegrass (*Poa secunda* J. Presl), and Great Basin wildrye (*Leymus cinereus* [Scribn. & Merr.] A. Löve*)*. Native forbs included western yarrow (*Achillea millefolium* L. var. occidentalis DC.), yellow salsify (*Tragopogon dubius* Scop.), and slender cinquefoil (*Potentilla gracilis* Dougl. ex Hook.). Disturbed areas of the research site, once dominated by perennial bunchgrasses, have been converted to dominance by exotic species including cheatgrass, medusahead, and rush skeletonweed (*Chondrilla juncea* L.).

Long-term (i.e., 74-year) average annual precipitation of the study area was 24.4 cm and average annual temperature was 9.9°C, ranging from -12.2°C to 24.8°C (WRCC 2006; Fig. 2 and 3). In 2004, the first year of study, wet and warm climate conditions during periods of annual grass germination and growth produced flourishing stands of cheatgrass and medusahead. Drier and warmer conditions in winter and spring of 2005 produced less abundant annual grass stands for initiation of grazing treatments. Wet winter and spring conditions in 2006 provided optimal growing conditions for annual grass species.

Soil types varied substantially along topographical gradients of research site. Soil type in the medusahead research paddocks was a Stratford cobbly silt loam. Generally, finer textured soils, such as the Stratford, can support extensive stands of medusahead (Dahl and Tisdale 1975). Cheatgrass research paddocks were located in deeper Emdent silt loam series soils (Lenfesty 1967). The pattern of infestation by cheatgrass or medusahead was strongly related to texture and depth of the soil.

Paddock arrangement

Research paddocks were constructed in November 2004 to examine the effects of grazing, trampling, and herbicides on the revegetation on two sites: one dominated by cheatgrass and one by medusahead (Appendix D). When using sheep to control weedy plants, animals need to be confined to small areas for short time periods to minimize damage to desirable plants (Olsen and Lacey 1994). On each site, five 12- x 30-m research paddocks were established. Paddocks were located in areas with relative uniformity and density of either cheatgrass or medusahead. Paddock corners were designated by a 1.5-m steel t-post.

Paddocks were subdivided into four, 3x30-m lanes (Fig. 4). The small lane width permitted the use of a small flock of sheep (n = 12) in close proximity to obtain desirable trampling effects. One of four treatments was randomly applied to each of the lanes in each paddock: 1) fall trampling by sheep in Nov. 2004 (trample), 2) spring sheep grazing in 2005 and 2006 (graze), 3) fall trampling in 2004 plus spring grazing in 2005 and 2006 (trample+graze), and 4) no grazing or trampling (control). Two additional treatments and a control were applied to small plots (30x50-cm) in each lane. Plot-level treatments included: 1) seed, 2) herbicide+seed, and 3) no-treatment control. Twenty-four sample plots were located in the lanes assigned to the trample or control treatments, accounting for 8 replications of the 3 nested treatments (seed, herbicide+seed, and control). The herbicide+seed treatment was not included in the trample+graze and graze treatment lanes to allow a clear comparison of spring grazing and herbicide for weed control. This resulted in only 16 sample plots located in the trample+graze and graze treatment lanes accounting for 8 replications of the seed treatment and control. Plot-level treatments were applied using a 130x150-cm plot to account for a 50-cm treatment buffer around smaller sample plots.

To assure that human foot traffic did not impact experimental plots, buffer strips were incorporated into the design (Fig. 5). A 100-cm walking strip ran directly down the center of the lane, 50-cm to either side of the center transect. A 50-cm buffer was also created along the inside of both lane boundaries. All foot traffic took place in these buffer areas.

Plot arrangement

Vegetation response was monitored in sample plot locations in each lane. These plots were oriented along a 20-m transect that ran down the center of each lane. A 5-m buffer on each end of treatment lane permitted an area for excess livestock use for watering and bedding down during the day. Plots were randomly located on right or left sides of the transect at 1.5-m increments starting at 0.5-m mark and ending at 20-m mark. Plots were relocated throughout the study based on location along a center transect.

Seeding treatment

The seeding treatment was applied in December 2004. The seed mix was composed of four grass species developed for regional use by the USDA NRCS Plant Materials Center in Pullman, WA. A combination of native and introduced species was selected for site compatibility and competitive ability with annual grasses (Brown and Amacher 1999). The seed mix included Sherman big bluegrass (*Poa secunda* J. Presl), Whitmar beardless wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve ssp. *inermis* [Scribn. & J.G. Sm.] A. Löve), Covar sheep fescue (*Festuca ovina* L.), and Alkar tall wheatgrass (*Thinopyrum ponticum* [Podp.] Z.-W. Liu & R.-C. Wang). The lowest tested germination rate for seed provided by the Plant Materials Center was 96.25%. A heavy seed rate was selected given site factors such as chosen seeding method, lack of pre-seeding weed control, and minimal seed bed preparation.

The seed mix was compiled using standard guidelines for each species to estimate number of pure live seeds (PLS) per unit weight based on selected species proportions (Table 1). A gross weight of 6 grams of seed, which accounted for seed purity and germination, was applied to each plot treatment area (1.96 m^2).

In the field, each packet of seed was mixed with 10 to 20-g of rice hulls to add quantity to the small amount of seed and allow for more even spread. Seed and hulls were mixed by hand, transferred into a seeding sieve, and rocked with side-to-side motion for controlled rate of spread. Seed was broadcast evenly onto the ground surface within the parameters of the plot treatment frame.

An error was made in the application of plot treatments in the medusahead blocks. All plots with a seed treatment were seeded, but herbicide+seed plots were only seeded in the control lanes. This error resulted in the loss of 40 plots in the herbicide+seed treatment. In the cheatgrass blocks, all plots with a seed or herbicide+seed treatment were correctly applied.

Seed trampling

A small flock of sheep was herded across lanes with a trampling treatment in each paddock shortly after they were seeded in December 2004. The hoof action of the sheep was used to incorporate the broadcast seeding into the soil to create appropriate seed-to-soil contact required for germination. Twelve mature dry ewes (about 80 kg each) were acquired from a local producer to accomplish the trampling treatment.

Netted polywire fences were constructed around the perimeter of the each lane to contain animals and allow them sufficient space to turn around. One person herded the sheep in a small flock while recording passes up and down the length of the lane. A desired trampling effect was obtained by making a total of 21 passes (each pass = up and back). Time in each lane averaged 30 minutes.

Trampling Assessment

An assessment of trampling was made immediately after the removal of animals. Each 30- x 50-cm plot was examined for trampling effects that were categorized by type and level. Impact types included soil disturbance, vegetation impact, and evidence of dung and urine. These impacts included level of hoof activity, grazing impacts, stem breakage, litter removal, and fertilization. The impact levels were indicated on a scale of 0 to 4 summarized: 0=none; 1= Barely Noticeable (1-25% of plot); 2= Evident (26-50%); 3 = Quite Apparent (51-75%); or 4 = Very Apparent (>75% of plot).

Herbicide application

Herbicide was applied to plots assigned an herbicide treatment in December 2004. Weather conditions for spraying were 4 to 10 °C with no wind, sunny skies, and >80% relative humidity. The cheatgrass plants were about 1-3 cm tall and in the 1 leaf stage. The medusahead plants were about 2-3 cm tall and in the 1 leaf stage. The selected herbicide was Roundup Super Concentrate manufactured by Monsanto Corporation (50.2% glyphosate) applied in a 2% (volume/volume) solution. The herbicide was applied using a solo backpack sprayer with a 3 nozzle boom and 9502 nozzles, a standard nozzle for low pressure sprayers. The application height was about 25-cm above ground surface, safely reducing the amount of exposure of the droplets to evaporation. The sprayer was calibrated immediately before application.

The application rate for spraying the research paddocks was 1.7 times the recommended general application rate specified for the herbicide. Each plot was sprayed with about 0.45 L of herbicide solution.

Spring sheep grazing[1]

Spring grazing took place from 11-May to 18-May in 2005 with an average of 4 mature dry ewes (about 80 kg each) per treatment lane and from 18-May to 29-May in 2006 with an average of 5 mature dry ewes per treatment lane. Grazing was

[1] All procedures related to animal use were approved by the University of Idaho Animal Care and Use Committee as protocol #2005-49 (Appendix E).

timed to target annual grasses when they were in a susceptible, yet palatable, stage. The majority of the seed heads had emerged and somewhat ripened, but had not yet achieved seed shatter. Sheep were contained in the treatment lanes using poly-wire netted electric fencing. Sheep entered lanes in the morning, were provided access to water, and were allowed to freely graze until a target level of about 75% utilization of annual grasses was achieved (Table 2). Sheep were removed from lanes in the evenings and housed in a secure holding pen.

Vegetation assessment

Canopy cover was estimated in November 2004 before treatments were applied and then again in the spring of 2005 and 2006. Cover estimates were recorded for seven categories: 1) annual grasses, 2) perennial grasses, 3) annual forbs, 4) perennial forbs, 5) shrubs, 6) rock, and 7) non-vegetated ground cover (NVGC) which included bare ground and litter. Annual grasses were further subdivided into cheatgrass, medusahead, and other. Canopy cover of plants rooted inside plot was estimated as a proportion of total plot area.

Density of annual grasses and perennial grass seedlings were examined in the summer corresponding with the end of the growing season. Annual grasses densities were further categorized as proportions of cheatgrass, medusahead, and other annual grasses. Only perennial grass seedlings of seeded species were counted. Additional measures included: annual grass height (cm), recorded as the mean value of the height of the plant closest to the four corners of the plot; and seedhead rating, or the estimated portion of the annual grass plants in the plot that had developed a seed head, measured on a scale of 1-10 (increments of 10% on a scale of 1-100%).

Biomass was estimated in each plot in the early spring, before and after sheep grazing, and again in the late summer, following the senescence of annual grasses. Extensive field training to achieve accuracy in biomass estimation was conducted near treatment blocks. Plants were then estimated to weight by life form (annual grasses, perennial grasses, and forbs) and then clipped and weighed in the field. Field samples were returned to the lab and oven dried at 60˚C for 24 hours and weighed. Field weight estimates were adjusted for dry weight.

Statistical procedures

This study was a randomized complete block design with five replications per treatment at each site (cheatgrass or medusahead). Treatment differences were examined within years. End of season biomass estimates were expressed as a percent of early season pre-grazing biomass. Statistical analyses were performed with SAS version 9.1 using PROC GLM (SAS 2004). Analysis of variance procedures were performed to examine treatment differences using treatment x block as an error term to test the main treatment effects. The mean cover, biomass, and density for each treatment lane were the sampling unit used throughout analysis. Sites and years were examined separately to capture the treatment application in each year. Treatments were not equivalent among years thus creating difficulty with comparison. Analyses were based on least square means but all figures report mean values and standard error. Data were tested for normality and, where necessary, were transformed to meet assumptions of normality. Cover variables were arcsine square-root transformed and density and biomass variables were transformed using the log function. When observations did not fall within acceptable parameters of normality, means were reported but not analyzed for treatment differences.

Data sets were created based on selection criteria to eliminate plots that did not meet the assumptions of the study. In all three data sets (biomass, cover, and density) plots in grazed plots were removed from analyses if they had less than 10% utilization. For the cover data sets, if plots had greater than 10% rock, the remaining cover variables were adjusted as the portion of the total plot less the rock cover. In the density data sets, plots were excluded from analysis if plots had excess rodent activity (greater than 10% of the plot) or if plots had senesced beyond measurement at the end of the growing season. These plot selection procedures resulted in the removal of less than 5% of 2005 biomass, cover, and density plots, and 2006 biomass and cover plots. A greater majority of plots were removed from the density data sets in 2006 where about 7% and 22% were removed in the medusahead and cheatgrass sites respectively. Plot level treatments included in the vegetation assessment data sets included only seeded and unseeded plots. The herbicide plot level treatments were examined separately.

RESULTS

Vegetation attributes

Annual grass cover.— Baseline estimates of annual grass cover, before treatments were applied, reveal no differences between treatment lanes on the cheatgrass or medusahead site (Table 3). Fall trampling did not affect the cover of annual grasses on the medusahead site in 2005 (Fig. 6). Annual grass cover in the grazed treatments did not differ from controls in 2005 which is not surprising because grazing treatments were not initiated until after cover measurements were made. In 2006, after all treatments were applied, neither trampling nor grazing affected the cover of annual grasses on the medusahead site (Fig. 6). Lanes that were grazed and trampled had similar cover of annual grasses as control lanes that received no impact by sheep.

On the cheatgrass site, treatment differences were observed in 2005 (P = 0.0001; Fig. 6). Trample treatment did not affect the cover of annual grasses but, annual grass cover was greater in the non-grazed treatments (Control and Trample) compared to the grazed treatments (Graze and Graze+Trample; $P < 0.0001$; Fig. 6). This observed difference was not a result of treatments because grazing had not yet been applied. In 2006, the applied treatments influenced annual grass cover (P = 0.0011) with the greatest grass cover observed in the fall Trample treatment and lowest cover in the Graze treatment (Fig. 6). Annual grass cover in Graze and Graze+Trample treatments was not different from cover observed in Control lanes. The collective trampling effect (Trample and Graze+Trample) yielded higher annual grass cover (P = 0.0015) compared to the non-trampled treatments (Control and Graze). The collective effects of grazing (Graze and Graze+Trample) yielded lower annual grass cover (P = 0.0026) compared to non-grazed treatments (Control and Trample) in 2006 but no grazing effects can be inferred since there was a pre-treatment difference measured in previous year.

Annual grass densities.—Trampling and grazing treatments affected annual grass densities on the medusahead site in 2005 (P = 0.0085) and 2006 (P = 0.0002; Fig. 7). In 2005, annual grass density was the lowest in the Graze+Trample treatment. However, the Graze+Trample treatment was not different than the Graze treatment which was not different than the Control and Trample treatments. Overall, trampling did not affect annual grass density in 2005 as a contrast between trampled and non-trampled treatments was not significant. However, annual grass density was lower in grazed compared to non-grazed treatments (P = 0.0024). In 2006, densities of annual grass on the medusahead site were lower in the Graze+Trample and Graze treatments compared to Control and Trample (Fig. 7). Trampling had no clear effect on annual grass densities with trampling treatments (Graze+Trample, Trample) being no different from those in the non-trampled treatments (Graze, Control) in annual grass density. However, annual grass densities on the medusahead site were lower in grazed compared to non-grazed treatments in 2006 (P < 0.0001).

Annual grass densities on the cheatgrass site also revealed treatment differences in 2005 (P = 0.0015) and 2006 (P = 0.0003; Fig. 7). In 2005, the lowest annual grass densities were observed in the Graze+Trample and Graze only treatments (Fig. 7). Densities were greatest in the Control and slightly lower in the Trample only treatment. In 2006, densities were greatest in non-grazed treatments (Control and Trample) compared to grazed treatments (Graze and Graze+Trample). The collective effect of trampling (i.e., a contrast between trampled and non-trampled plots) did not affect annual grass density in 2005 or 2006 (Fig 7). Grazed treatments had lower annual grass densities than non-grazed treatments in 2005 (P = 0.0004) and 2006 (P < 0.0001).

Annual grass height and seedhead rating—Treatment contrasts revealed that spring grazing affected annual grass height measured at the end of the growing season in both years on both sites (P < 0.05; Table 4). Annual grass height was consistently lower in the grazed treatments. Treatment contrasts also revealed that spring grazing affected the annual grass seedhead rating measured at the end of the growing season indicating a lower abundance of seed production on grazed plots (Table 4). On the medusahead site, the seedhead rating was lower in the grazed treatments compared to the non-grazed treatments in both study years (P = 0.0015 and P < 0.0001, respectively). On the cheatgrass site, the seedhead rating was lower in the grazed treatments in 2005 only (P = 0.0045).

Non-vegetated ground cover (NVGC).—Sheep trampling or grazing on the medusahead site did not affect NVGC in 2005 or 2006 (Fig 8). Baseline (2004) estimates of NVGC on the cheatgrass site showed differences among treatment even before sheep trampling or grazing treatments were applied (P = 0.0414) however there were no clear differences between grazed and trampling treatments. The lowest NVGC was recorded in the Trample treatment compared to the Graze treatment (Fig. 8). Control and Graze+Trample treatments were not different than either the Graze or Trample treatments. Analyses in subsequent years, using values of baseline NVGC as covariate, revealed treatment differences in 2005 (P = 0.0193) and 2006 (P = 0.0065). In 2005, NVGC was greatest in the Graze+Trample treatment with no differences between Control, Graze, and Trample. In 2006, trampling treatments (Trample and Graze+Trample) increased NVGC compared to the non-trampled treatments (*P* = 0.0211; Fig. 8). In contrast, 2006 observations indicate that NVGC was lower in trampled treatments compared to non-trampled treatments (*P* = 0.003). The collective effects of spring grazing were not different in study year 2 compared to non-grazed treatments.

Perennial grass cover.—Fall trampling or spring grazing did not affect perennial grass cover (Fig. 9) on the medusahead site in 2005 or 2006. Likewise, fall trampling or spring grazing did not affect perennial grass cover or the cheatgrass site in 2005 or 2006.

Forb cover.—In 2005, fall trampling treatments on the medusahead site did not affect forb cover (Fig. 10). Likewise, forb cover on the medusahead site was not affected by fall trampling or spring grazing in 2006. On the cheatgrass site, forb cover in 2005 was not affected by fall trampling. However, in 2006, forb cover was lowest in the Control treatment (*P* = 0.0054) and highest in the Graze only treatment followed by the Graze+Trample treatment. Forb cover did not differ among Graze, Graze+Trample, and Trample treatments or among the Control, Graze+Trample, and Trample treatments. Forb cover did not differ among trampled compared to non-trampled treatments in 2006. However, forb cover was higher in grazed treatments (Graze and Graze+Trample) compared to non-grazed treatments (Control and Trample) in 2006 (*P* = 0.0009).

Annual grass biomass.—Spring grazing did not affect biomass of annual grasses in mid-summer (expressed as a proportion of spring pre-grazing biomass) on the medusahead site or cheatgrass site in 2005 (Fig. 11). In 2006, grazing affected annual grass biomass, with a lower amount, as a proportion of pre-grazing biomass, present at the end of the growing season in the grazed compared to non-grazed treatments in both the medusahead site (P = 0.0346) and the cheatgrass site (P = 0.0360; Fig. 11). However, biomass in the Trample treatment on both sites was not different than that observed in other treatments. Contrast of grazed (Graze and Graze+Trample) compared to non-grazed treatments (Control and Trample) in 2006 indicated that grazed treatments were not able to recover biomass to pre-grazed levels on both the medusahead site (P = 0.0056) and the cheatgrass site (P = 0.0097).

Total biomass.—Spring grazing did not affect total biomass, as a proportion of pre-grazed biomass, on the medusahead or the cheatgrass site in 2005 (Fig. 12). In 2006, the treatment effects were largely driven by the annual grass component of total biomass because the differences emulate those found in the annual grass biomass data. Spring grazing reduced total mid-summer biomass (representing regrowth from pre-grazing biomass) in the grazed treatments (Graze and Graze+Trample) on the medusahead site (P = 0.0007) and the cheatgrass site (P = 0.0166) compared to non-grazed (Control and Trample) treatments.

Herbicide study and seeding

Herbicide was applied as a method for releasing competition in seeded plots, thus allowing for better characterization of seeding success in grazed treatments. To contrast the effects of herbicide compared to no herbicide, comparisons were made between the Seed plots and Herbicide+Seed plots in the non-grazed (Control and Trample) treatments. To contrast the effects of herbicide and grazing, comparisons were made among the Seed plots in the Graze and Graze+Trample treatments and the Herbicide+Seed plots in the Control and Trample treatments.

Annual grass density.—Non-herbicide plots had greater annual grass densities compared to herbicide treated plots on both the medusahead site (P = 0.0086) and the cheatgrass site (P = 0.0001) in 2005 (Table 5). The herbicide treatment had a carryover effect in 2006 on the cheatgrass site where annual grass densities were again greater in the non-herbicide plots though the difference was not as profound as in 2005 (0.0081; Table 5). However, no effects of herbicide were detected on the medusahead site in 2006 (P = 0.4462).

Annual grass densities on the medusahead site in 2005 varied between treatments (P = 0.0023) but showed no difference between the effects of herbicide and grazing (P = 0.6498; Table 5). Density was lowest in the Herbicide+Seed plots in the Control, but was not different than Seed plots in the Graze+Trample treatment. Annual grass density in Seed plots did not differ between grazed (Graze and Graze+Trample) treatments. The highest annual grass density on the medusahead site was recorded in the Herbicide+Seed plots in the Trample treatment. In 2006, annual grass densities on the medusahead site were lower in the grazed treatments compared to the densities in the herbicide treatments ($P < 0.0001$; Table 5).

Annual grass densities on the cheatgrass site were higher in the grazed treatments compared to the densities in the herbicide treatments in 2005 ($P <$ 0.0001; Table 5). Conversely, annual grass densities in 2006 were higher in the herbicide treatments compared to the grazed treatments ($P < 0.0001$; Table 5).

Perennial grass seedling density.—Despite the application of herbicide to suppress annual grass competition, perennial grass seedling success was negligible on both the cheatgrass and the medusahead sites (Table 5). Although slightly higher perennial grass seedling densities were recorded in the herbicide plots ($P = 0.0138$) compared to the non-herbicide plots, overall the seeding was a failure.

Annual grass cover.—Annual grass cover on the medusahead site was lower in the herbicide plots compared to the non-herbicide plots in 2005 ($P = 0.0056$; Table 6). However, this effect was greatly influenced by the low cover recorded in the Herbicide+Seed plots in the Control treatment. Annual grass cover in this treatment was lower than all other treatments ($P = 0.0049$). No effects of herbicide on annual grass cover were observed in 2006 on the medusahead site. Annual grass cover on the cheatgrass site was lower in herbicide plots compared to non-herbicide plots in both 2005 ($P = 0.0003$) and 2006 ($P = 0.0010$).

Annual grass cover on the medusahead site was lower in the herbicide treatments compared to the grazed treatments in 2005 ($P < 0.0001$; Table 6). However, this effect was greatly influenced by the low cover recorded in the Herbicide+Seed plots in the Control treatment. Annual grass cover in this treatment was lower than all other treatments ($P < 0.0001$). No effects of herbicide compared to grazing were observed in 2006 on the medusahead site. Annual grass cover on the cheatgrass site was higher in the grazed treatments compared to the herbicide treatments in 2005 ($P < 0.0001$; Table 6). No effects of herbicide compared to grazing were observed in 2006.

Perennial grass cover.—On the medusahead site, perennial grass cover was collectively greater in the non-herbicide (Seed) plots compared to the herbicide plots in 2005 (P = 0.0226) and 2006 (P = 0.0189; Table 6). However, perennial grass cover was consistently the lowest in the Herbicide+Seed plots in the Control treatment and the highest in the Seed plots in the Trample treatment. Even though no differences were observed between herbicide and grazed treatments in 2005, the Herbicide+Seed plots in the Control treatment were lower than other grazed and herbicide treatments (P = 0.0090; Table 6). In 2006, overall perennial grass cover was lower in herbicide treatments compared to grazed treatments (P = 0.0320). However, this comparison was influenced by the low cover recorded in the Herbicide+Seed plots in the Control treatment; cover was lowest compared to other treatments (P = 0.0176).

No differences between the herbicide and non-herbicide plots were observed on the cheatgrass site. Grazed treatments had slightly greater overall cover compared to herbicide treatments in 2005 (P = 0.0232; Table 6). However, the difference in cover values was very small (range 0.6% to 3.2%). No differences between the grazed and herbicide treatments were observed in 2006.

Forb cover.—No differences between forb cover were observed on the either the cheatgrass or medusahead site (Table 6).

Discussion and Conclusions

Seeding trampling

This study revealed that using sheep trampling to incorporate a broadcast seeding was not effective in the short-term (i.e., 2 years). The rate and establishment of seeded species is influenced by a number of factors ranging from annual precipitation to soil potential. A minimum of two years is the amount of time normally required for establishment of the species selected for this study. Seeded species generally take longer to establish in the presence of aggressive annuals such as cheatgrass and medusahead (Stevens 2004).

Despite poor seeding success, sheep trampling treatments did have a measurable impact on the soil and we assume this would lead to improved seed-to-soil contact. In the Graze+Trample treatment, the mean soil impact rating was in the range of 26-50% (Evident) for both sites. In the Trample treatment, the mean soil impact rating was in the range of 51-75% (Quite Apparent) for both sites. Trampling intensity likely influenced the detachment and reduction of standing dead plant material (Abdel-Magid et al. 1987). Trampling also affected the litter accumulation that consecutively builds up in the absence of fire and grazing (Stewart and Hull 1949). In areas impacted by disturbance such as sheep trampling, the ubiquitous cycle of yearly residue buildup from cheatgrass and medusahead dominance may impact the ability of these species to establish (Evans and Young 1970). The amount and type of litter on the soil surface effects germination and seedling establishment (Call and Roundy 1991). Trampling may be an effective tool to manipulate the soil surface in the revegetation process.

Spring grazing

Spring sheep grazing had no effect on annual grass cover over the 2-years of this study. In a study which examined the effects of grazing intensity on annual vegetation, Pitt and Heady (1979) concluded that grazing had a negligible influence on cover compared to the influence of annual weather patterns.

Spring grazing reduced the density and height of annual grasses at the end of the growing season in both study sites and years. Tausch et al. (1994) simulated grazing treatments in Northern Nevada to examine the effects of defoliation on cheatgrass biomass and density and found that late spring grazing (from the end of April to mid-May, corresponding with the boot stage) reduced cheatgrass density compared with non-grazed control, fall and early spring grazing, and early spring grazing. Daubenmire (1940) indicated that when cheatgrass dominated ranges in Southeastern Washington are grazed heavily in the spring the species becomes less dominant. Heavy grazing in this region does not necessarily lead to cheatgrass establishment and dominance (Daubenmire 1940, Stewart and Hull 1949). Because the sites in this study area have been heavily infested for a number of years, more than 2 years of grazing are probably needed to considerably limit seed production and reduce annual grass densities in subsequent years. Future studies aimed at examining livestock grazing to reduce invasive annual grasses should attempt to use better defined methods of measuring seed production of annual grasses at the end of the growing season to quantify changes in reproductive capacity.

Spring grazing may be an effective tool to slow the recovery of annual grass biomass if applied after the bulk of spring precipitation is received (i.e., 2006 biomass data). Similarly, Tausch et al. (1994) found that late season grazing reduced total cheatgrass biomass and individual plant biomass compared to non-grazed controls. However, substantial spring rains after the grazing period may allow for subsequent regrowth, such as in 2005, resulting in biomass levels that return to or exceed pre-grazed levels (Pitt and Heady 1979, Vallentine and Stevens 1994). To limit seed production and yield of annual grasses, sheep may need to defoliate these grasses several times in the spring at short (2- to 3-week) intervals (Hulbert 1955, Tausch et al. 1994, Mosley and Roselle 2006). High year to year variation in cheatgrass yield (Stewart and Hull 1949, Mack and Pyke 1984) makes it nearly impossible to interpret effects of sheep grazing on biomass. However, continued grazing pressure at timely intervals during which annual grasses have acceptable levels of palatability may prove effective at decreasing annual grass competition over time.

Perennial grass seeding

Despite favorable germination rates (>96%), perennial grass seedling mortality may be extremely high in most years, especially in arid and semi-arid environments (Humphrey and Schupp 2004). With 19-cm of annual rainfall in the year after seeding, the site probably had less soil water available at depths accessible to seedling plants, limiting the ability of the plant to grow large enough to survive the dry summer. Average annual precipitation generally needs to be greater than 25-cm to be adequate for establishment and survival of planted species (Blaisdell et al. 1982). A difficulty in revegetating annual grasslands is that even when perennial grass seedlings survive the first growing season, annual grass competition may continue to hinder plant growth, survival, and flowering (Humphrey and Schupp 2004).

Herbicide study

Glyphosate can be quite effective at controlling cheatgrass (Cox and Anderson 2004, Neese 2006) and medusahead (Monaco et al. 2005) when applied during active growth in the fall. Spring cover estimates on the medusahead site in 2005 showed that the herbicide did not affect annual grass cover compared to non-herbicide control. We postulate that the glyphosate application may have been impacted by climatic conditions following the herbicide application. Herbicide effectiveness can be affected by soil moisture following application on annual grasses (Adkins et al. 1998). Alternatively, climatic conditions may have favored medusahead germination following the herbicide application.

Management implications

Livestock should not be ruled out for use in integrated approaches to weed management and revegetation even though this study does not strongly support sheep trampling as an effective mechanical treatment for rehabilitating annual grasslands. Weed control and rehabilitation efforts in semi-arid rangelands are challenging tasks for land managers (Young 1983, Allen 1995). However, well-timed and closely controlled spring grazing may be an effective tool to suppress cheatgrass and medusahead.

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FIG. 1. Sheep trampling and grazing study site located in Adams County, Washington near Benge where research was conducted from 2004 to 2006.

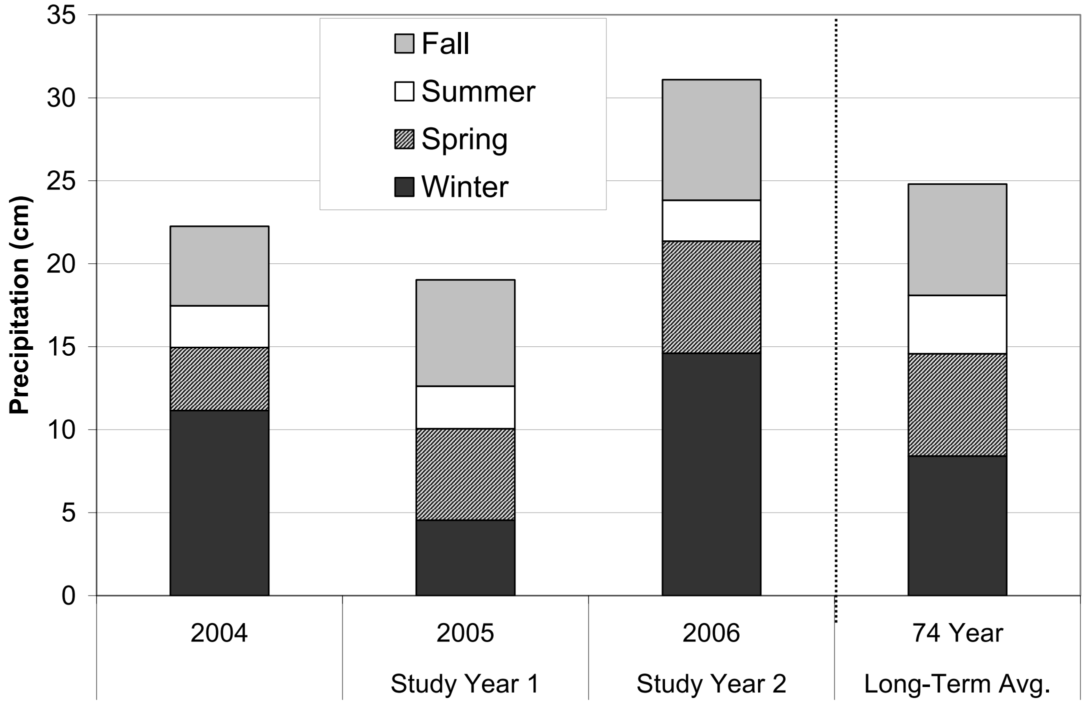


FIG. 2. Mean annual precipitation of research study site near Benge, WA in 2004 through 2006. The long-term (74-year) average seasonal precipitation is also presented for: Winter (Dec/Jan/Feb), Spring (Mar/Apr/May), Summer (Jun/Jul/Aug), and Fall (Sep/Oct/Nov). Data obtained from Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa4679..

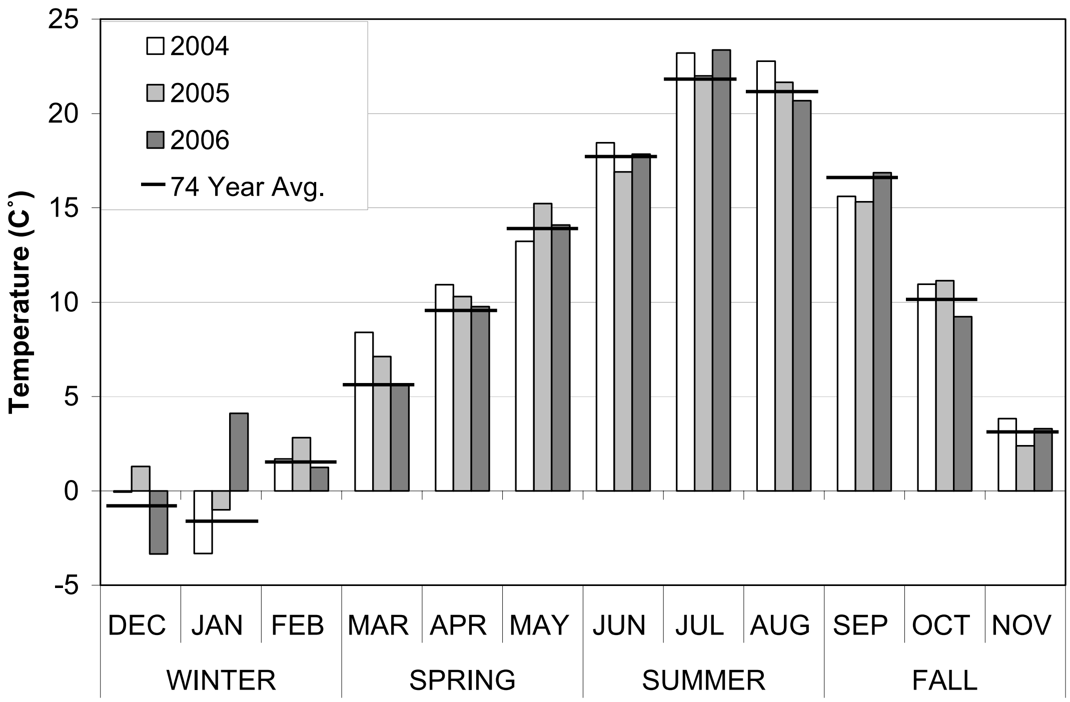


FIG. 3. Mean temperature by month for research site near Benge, WA. Data obtained from Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa4679.

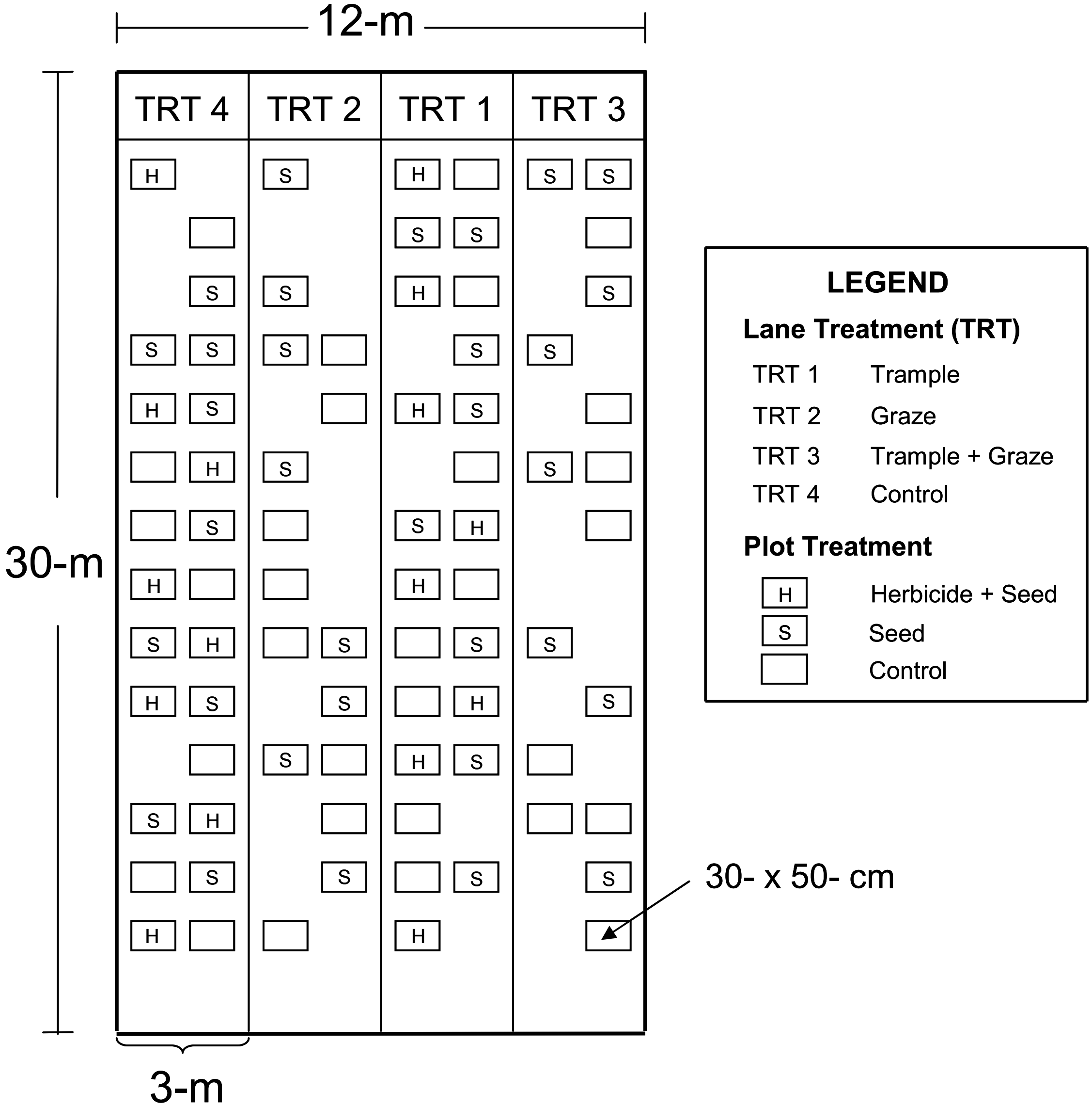


FIG. 4. Example of treatment and plot layout from sheep trampling study near Benge, WA. Lane treatments were randomly assigned and then nested plot treatments were randomly placed in lanes along a center transect.

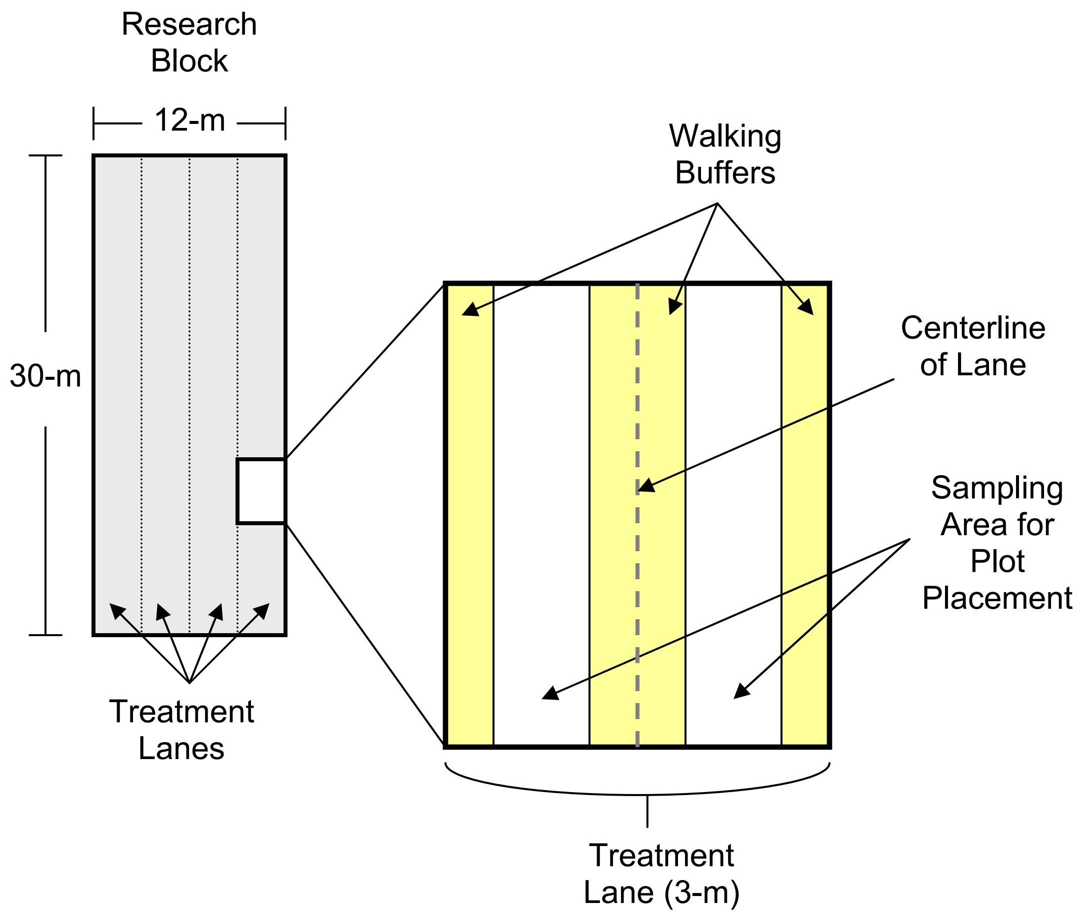


FIG. 5. Layout of treatment lanes in sheep trampling study near Benge, WA. Research blocks consist of 4 side-by-side treatment lanes. Figure illustrates location of walking buffer zones, sampling area, and centerline transect.

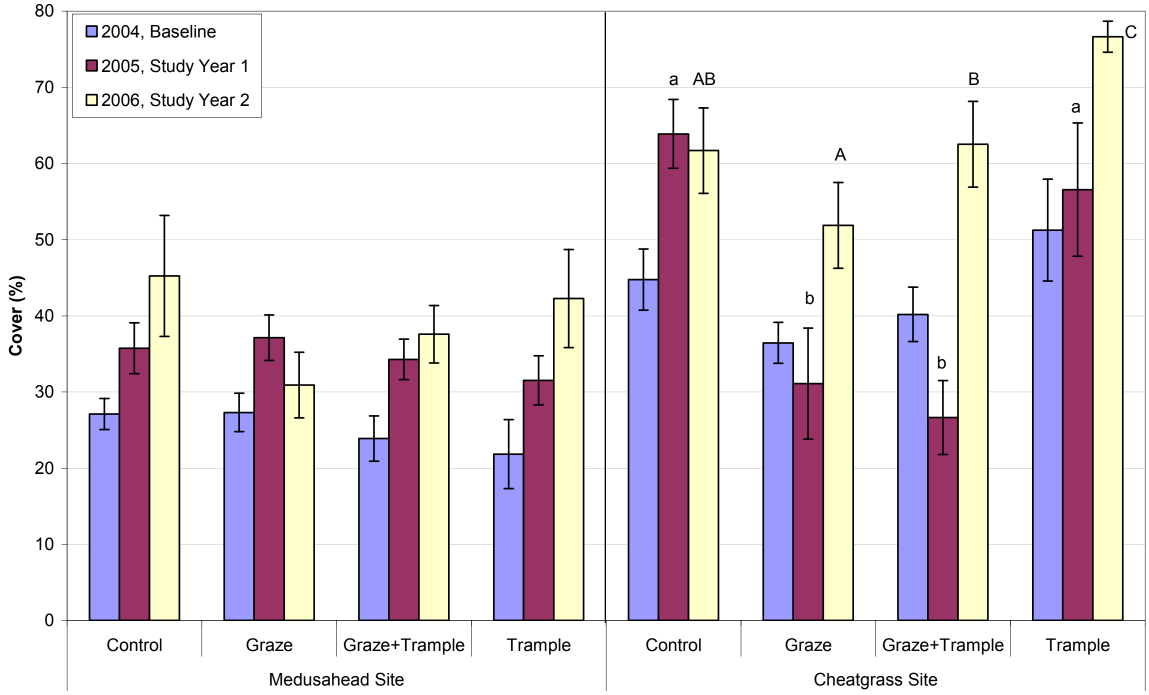


FIG. 6. Annual grass cover (mean ± SE) on two sites near Benge, WA in two years of study. Baseline cover was estimated in fall 2004 prior to sheep trampling and grazing treatments. Cover was estimated in the spring of 2005 and 2006 before spring sheep grazing. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where an overall treatment effect was observed. Bars in 2005, with different lowercase letter (a, b) are different ($P < 0.05$) whereas bars in 2006 with different capital letters (A, B, C) are different ($P < 0.05$).

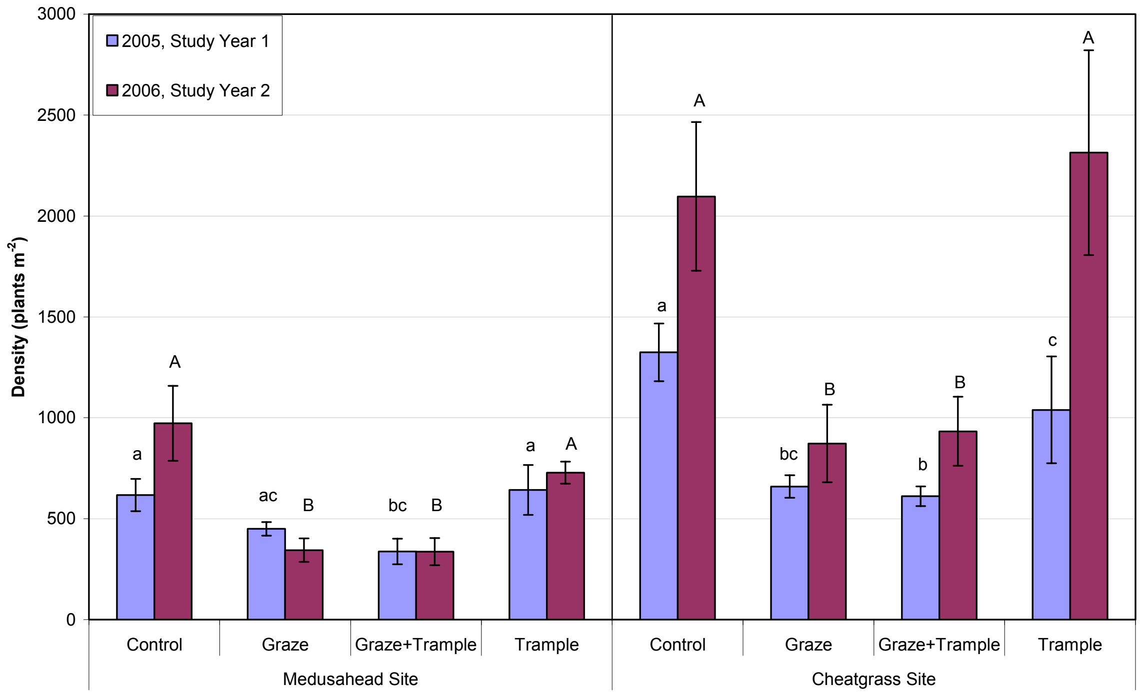


FIG. 7. Density of annual grasses (mean ± SE) on two sites near Benge, WA in two years of study. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where a treatment effect was observed. Bars in 2005, with different lowercase letter (a, b, c) are different ($P < 0.05$) whereas bars in 2006 with different capital letters (A, B) are different ($P < 0.05$).

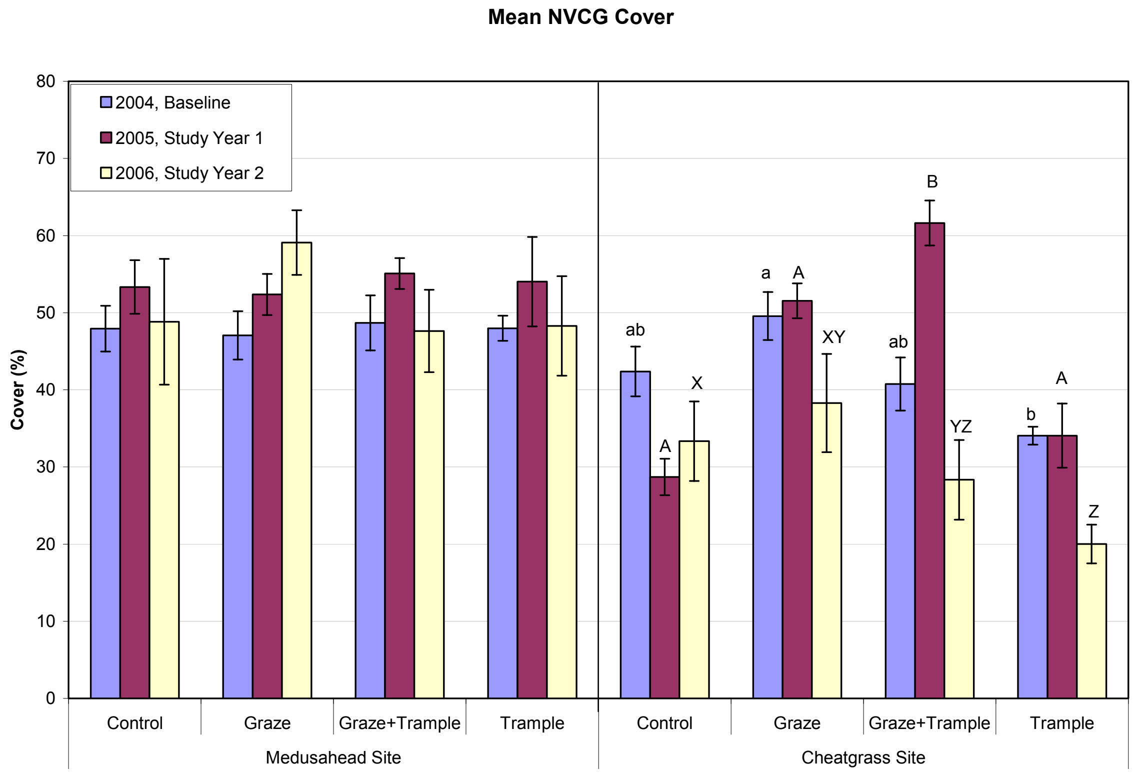


FIG. 8. Non-vegetated ground cover (mean ± SE) on two sites near Benge, WA in two years of study. Baseline cover was estimated in fall 2004 prior to sheep trampling and grazing treatments. Cover was estimated in the spring before early spring sheep grazing. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where an overall treatment effect was observed. Bars in 2004, with different lowercase letter (a, b) are different ($P < 0.05$) whereas bars in 2005 with different capital letters (A, B) are different ($P < 0.05$) and bars in 2006 with different capital letters (X, Y, Z) are different ($P < 0.05$).

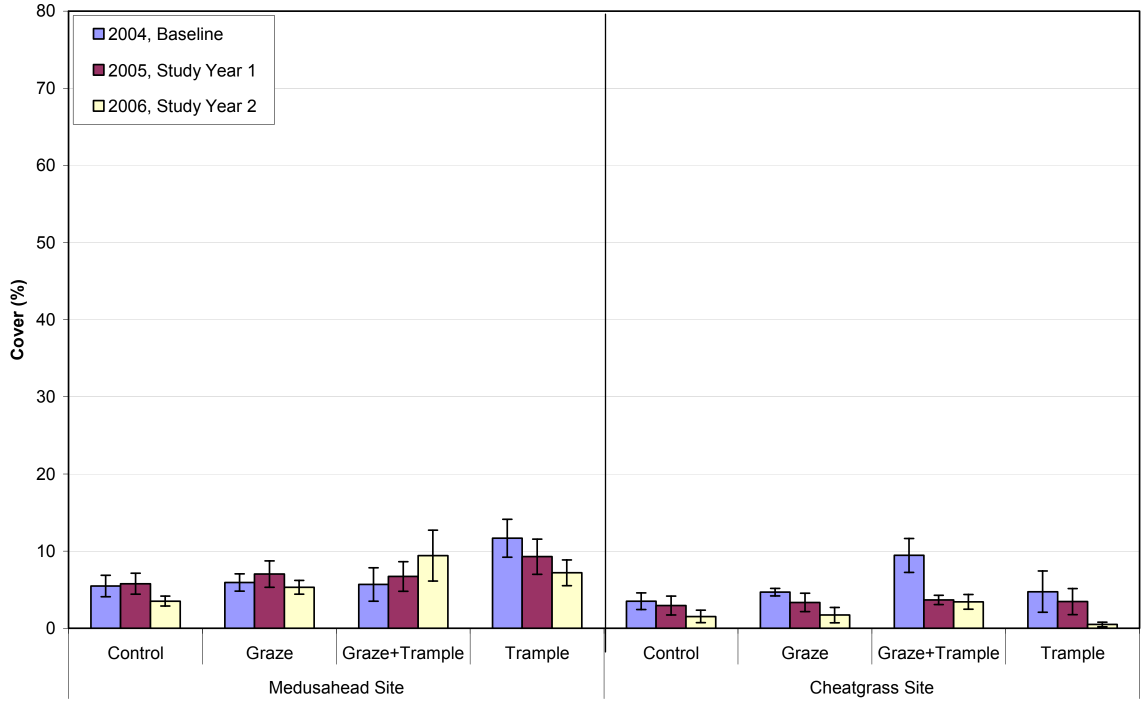


FIG. 9. Perennial grass cover (mean ± SE) on two sites near Benge, WA in two years of study. Baseline cover was estimated in fall 2004 prior to sheep trampling and grazing treatments. Cover was estimated in the spring before early spring sheep grazing. Years and sites were analyzed separately.

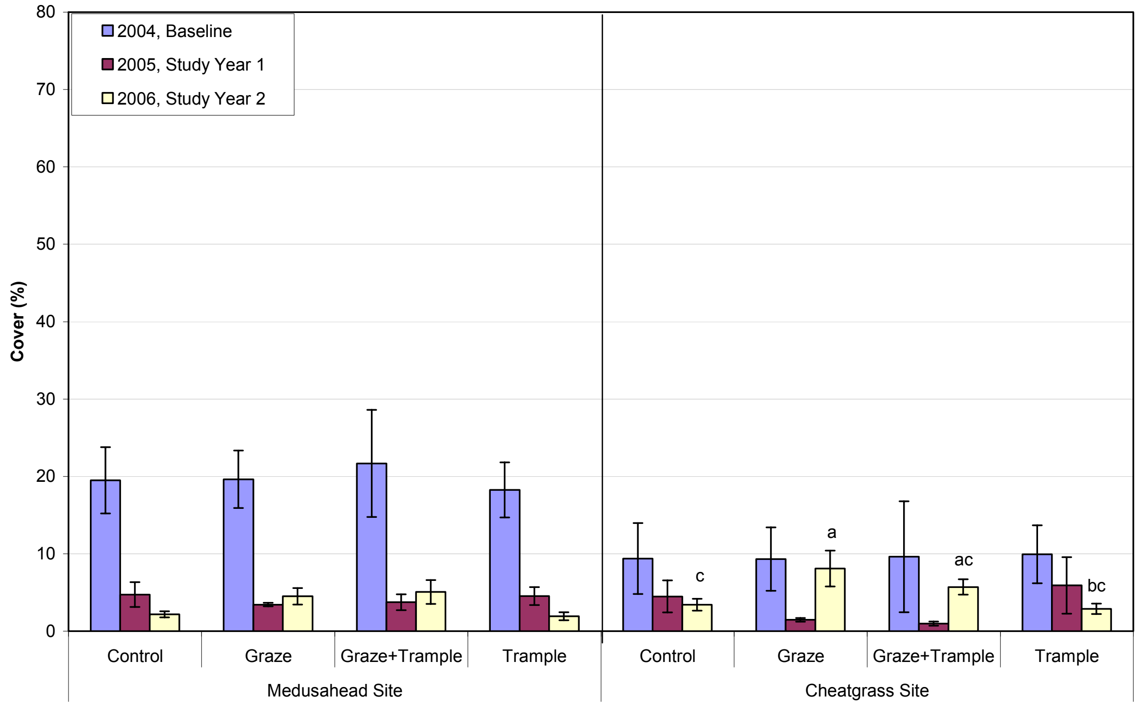


FIG. 10. Forb cover (mean ± SE) on two sites near Benge, WA in two years of study. Baseline cover was estimated in fall 2004 prior to sheep trampling and grazing treatments. Cover was estimated in the spring before early spring sheep grazing. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where an overall treatment effect was observed. Bars in 2006, with different lowercase letter (a, b, c) are different ($P < 0.05$).

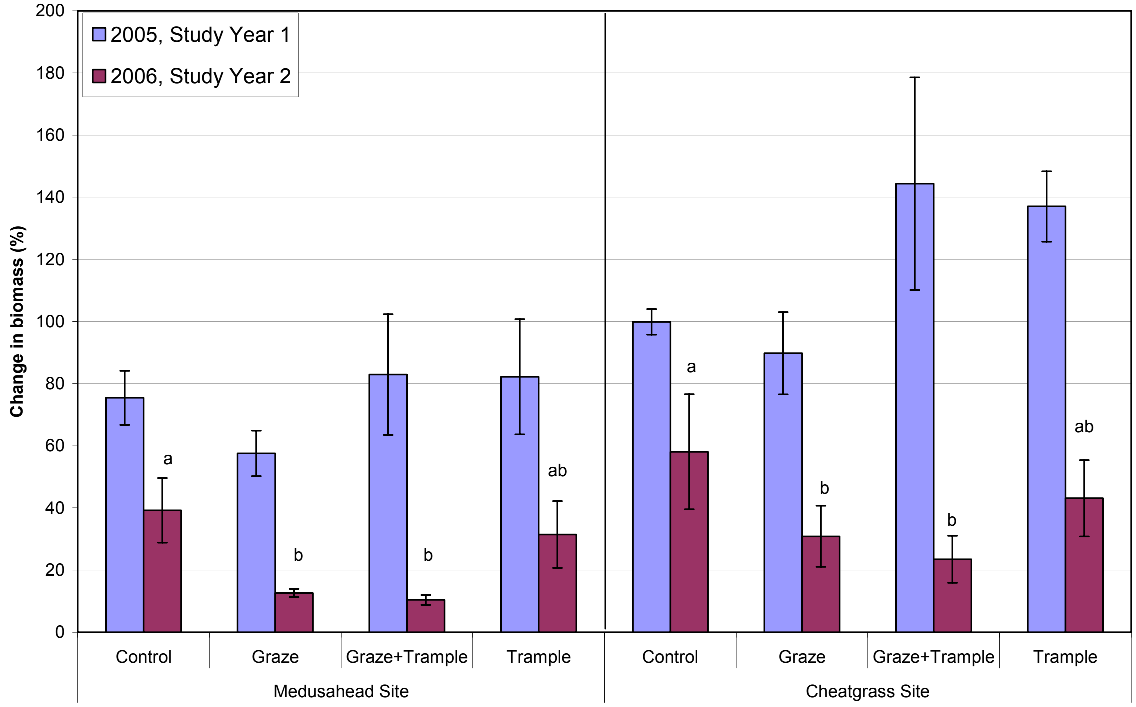


FIG. 11. Annual grass biomass in mid-summer expressed as a percent of pre-grazing May biomass (mean ± SE) on two sites near Benge, WA in two years of study. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where an overall treatment effect was observed. Bars in 2006, with different lowercase letter (a, b) were different (P < 0.05).

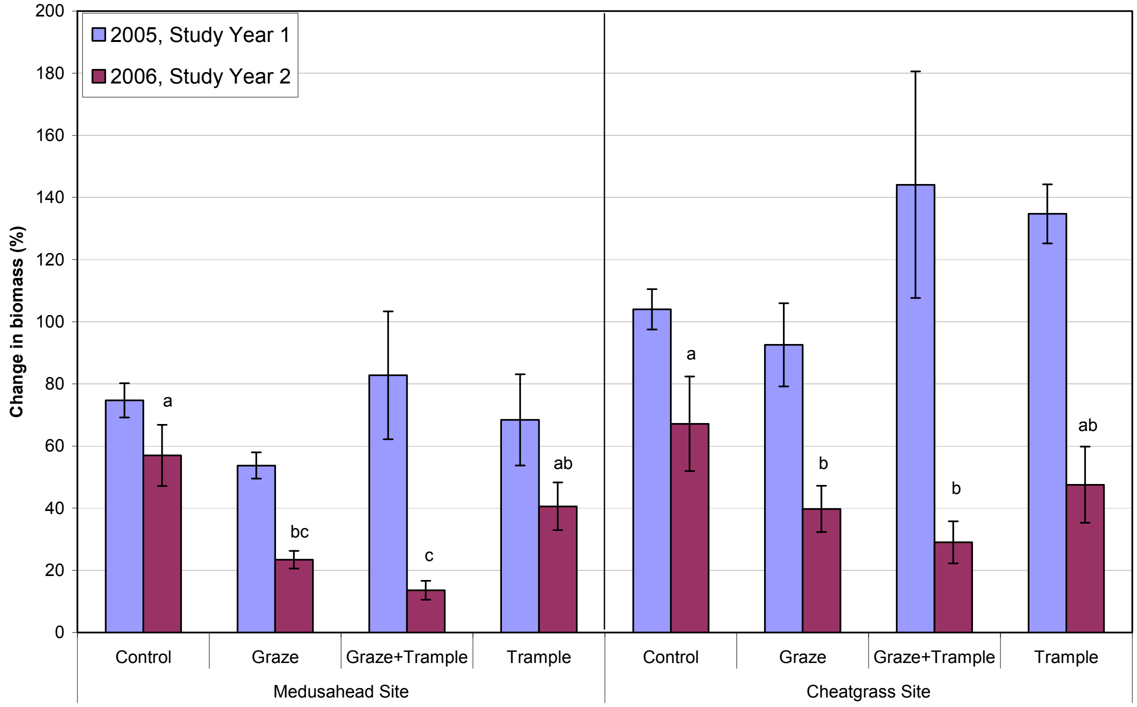


FIG. 12. Total mid-summer biomass expressed as a percentage of May pre-grazing biomass estimates (mean ± SE) on two sites near Benge, WA in two years of study. Years and sites were analyzed separately. Letters above bars indicate treatment comparisons in years and sites where an overall treatment effect was observed. Bars in 2006, with different lowercase letter (a, b, c) were different ($P < 0.05$).

TABLE 1. Composition of a grass seed mix created for a study of fall trampling and spring grazing by sheep near Benge, WA.

Seed Species	seeds/m^2
Sherman big bluegrass	506
Whitmar beardless wheatgrass	312
Covar sheep fescue	506
Alkar tall wheatgrass	204
Total	1562

TABLE 2. Mean available biomass and utilization (mean ± SE) for 2 study sites located near Benge, WA. Treatments were grazed with sheep in the spring of 2005 and 2006.

			Available Biomass (kg/ha)		Utilization (%)	
Study Year	Site	Treatment	Total	Annual Grass	Total	Annual Grass
2005	Cheatgrass	Graze	718.8 ± 42.5	668.4 ± 45.0	78.5 ± 1.9	79.3 ± 1.9
		Graze+Trample	512.6 ± 34.2	438.5 ± 36.0	72.5 ± 2.1	72.3 ± 2.4
	Medusahead	Graze	465.3 ± 18.5	351.2 ± 19.6	79.7 ± 1.5	76.4 ± 2.1
		Graze+Trample	400.6 ± 20.7	292.3 ± 15.3	83.2 ± 1.2	83.2 ± 1.7
2006	Cheatgrass	Graze	1766.4 ± 210.0	1640.2 ± 199.6	71.9 ± 2.7	69.9 ± 2.8
		Graze+Trample	1620.0 ± 106.5	1509.4 ± 109.8	70.8 ± 2.8	69.1 ± 2.9
	Medusahead	Graze	727.7 ± 40.3	583.2 ± 39.9	46.4 ± 3.1	32.7 ± 3.6
		Graze+Trample	929.3 ± 41.5	670.6 ±48.4	59.5 ± 2.7	42.0 ± 3.1

TABLE 3. Summary of probability values from PROC GLM for parameters sampled in 2005 and 2006 in a fall trampling and spring sheep grazing study located on cheatgrass and medusahead dominated sites near Benge, WA.

					Contrasts	
Parameter	Year	Site	Variable	Main Model Effect	Trampled vs. non-trampled	Grazed vs. non-grazed
BIOMASS				------------------------- p-value	-------------------------	
Annual Grass	2005	Cheatgrass	Change	0.0968	0.0171	0.9353
		Medusahead	Change	0.3484	0.1603	0.4397
	2006	Cheatgrass	Change	0.0360	0.1686	0.0097
		Medusahead	Change	0.0346	0.4922	0.0056
Total	2005	Cheatgrass	Change	0.1744	0.0368	0.9545
		Medusahead	Change	0.3504	0.3294	0.7728
	2006	Cheatgrass	Change	0.0400	0.0911	0.0166
		Medusahead	Change	0.0032	0.0747	0.0007
COVER	2004	Cheatgrass	NVGC[1]	0.0414	0.0228	0.0573
			Perennial Grass	0.0703	0.0942	0.0483
			Forb	0.9896	0.7602	0.9036
			Annual Grass	0.1393	0.2470	0.0445
		Medusahead	NVGC	0.9544	0.6816	0.9643
			Perennial Grass	0.1441	0.2368	0.1984
			Forb	0.7997	0.9722	0.4555
			Annual Grass	0.3377	0.0959	0.6188
	2005	Cheatgrass	NVGC	0.0193	0.0211	0.0358
			Perennial Grass	0.8802	0.7655	0.4816
			Forb	0.1739	0.8091	0.0354
			Annual Grass	0.0001	0.2263	<0.0001
		Medusahead	NVGC	0.9663	0.6660	0.9996
			Perennial Grass	0.6215	0.4356	0.8101
			Forb	0.8553	0.9863	0.3980
			Annual Grass	0.6512	0.2953	0.5222
	2006	Cheatgrass	NVGC	0.0065	0.0030	0.4141
			Perennial Grass	0.0605	0.7693	0.0410
			Forb	0.0054	0.1892	0.0009
			Annual Grass	0.0011	0.0015	0.0026
		Medusahead	NVGC	0.4758	0.3438	0.3994
			Perennial Grass	0.2129	0.0654	0.3227
			Forb	0.0995	0.9357	0.0175
			Annual Grass	0.3147	0.7343	0.1085
DENSITY	2005	Cheatgrass	Annual Grass	0.0015	0.0767	0.0004
			Perennial Grass Seedlings	0.4661	0.3116	0.2296
		Medusahead	Annual Grass	0.0085	0.1631	0.0024
			Perennial Grass Seedlings	0.1546	0.0372	0.4096
	2006	Cheatgrass	Annual Grass	0.0003	0.6289	<0.0001
			Perennial Grass Seedlings	0.4262	0.3370	0.3370
		Medusahead	Annual Grass	0.0002	0.4094	<0.0001
			Perennial Grass Seedlings	0.1909	0.1669	0.1156

[1]NVGC = Non-vegetated ground cover

TABLE 4: Annual grass seedhead rating (1-10) and height in cm (mean ± SE) measured on 2 study sites located near Benge, WA.

Site	Year	Treatment	Seedhead rating	Height
Medusahead	2005	Control	9.0 ± 0.2	16.3 ± 1.8
		Graze	7.8 ± 0.3	8.8 ± 0.6
		Graze+Trample	8.1 ± 0.3	9.0 ± 0.9
		Trample	9.2 ± 0.2	15.4 ± 1.5
	2006	Control	9.6 ± 0.1	18.7 ± 1.0
		Graze	8.0 ± 0.4	14.3 ± 1.1
		Graze+Trample	8.6 ± 0.4	13.8 ± 0.6
		Trample	9.8 ± 0.1	17.9 ± 0.4
Cheatgrass	2005	Control	9.3 ± 0.4	26.3 ± 1.8
		Graze	9.0 ± 0.2	12.2 ± 1.1
		Graze+Trample	9.1 ± 0.3	12.4 ± 1.6
		Trample	9.8 ± 0.2	28.0 ± 0.8
	2006	Control	9.8 ± 0.1	24.2 ± 2.9
		Graze	9.7 ± 0.2	18.0 ± 1.9
		Graze+Trample	9.2 ± 0.5	16.1 ± 1.1
		Trample	9.9 ± 0.1	26.6 ± 3.9

TABLE 5. Density (mean ± SE) of annual grasses and perennial grass seedlings (PGS) estimated in herbicide+seed and seed plots nested within 4 different lane treatments for 2 study years in sheep trampling and grazing study in Southeast Washington.

		Treatment					
	Lane Level =	Control		Graze	Graze+Trample	Trample	
	Plot Level =	Herbicide+Seed	Seed	Seed	Seed	Herbicide+Seed	Seed
Medusahead Site				density (plants/m^2)			
Annual Grass	2005	151.8 ± 77.7	632.3 ± 58.5	455.2 ± 33.0	320.3 ± 31.1	695.5 ± 73.4	646.3 ± 65.1
	2006	698.1 ± 61.3	924.5 ± 78.7	367.1 ± 38.5	290.7 ± 43.1	794.1 ± 73.8	729.0 ± 54.5
Perennial Grass Seedlings	2005	4.3 ± 1.2	0.5 ± 0.4	0.8 ± 0.5	4.4 ± 1.4	0.3 ± 0.2	5.5 ± 1.7
	2006	9.7 ± 2.5	1.2 ± 0.7	1.7 ± 0.8	6.5 ± 2.8	0.0	0.8 ± 0.4
Cheatgrass Site							
Annual Grass	2005	12.3 ± 4.5	1271.3 ± 119.7	684.8 ± 42.6	694.0 ± 57.8	36.3 ± 8.3	977.2 ± 111.3
	2006	1581.6 ± 120.7	2624.4 ± 217.5	946.2 ± 136.6	993.4 ± 115.6	1583.4 ± 141.7	2777.9 ± 264.4
Perennial Grass Seedlings	2005	3.3 ± 0.9	0.7 ± 0.3	1.5 ± 0.7	1.2 ± 0.6	2.8 ± 0.8	1.2 ± 0.6
	2006	1.1 ± 0.5	0.0	0.0	0.2 ± 0.2	0.0	0.0

TABLE 6. Cover (mean ± SE) estimated in herbicide+seed and seed plots nested within 4 different lane treatments for 2 study years in sheep trampling and grazing study in Southeast Washington.

		Treatment					
	Lane Level =	Control		Graze	Graze+Trample	Trample	
	Plot Level =	Herbicide+Seed	Seed	Seed	Seed	Herbicide+Seed	Seed
		density (plants/m^2)					
Medusahead Site							
Annual Grass	2005	6.1 ± 2.4	35.7 ± 2.8	37.9 ± 2.7	35.1 ± 2.1	34.3 ± 2.2	30.6 ± 2.5
	2006	42.3 ± 2.6	45.9 ± 3.2	31.9 ± 2.9	37.9 ± 3.7	44.8 ± 2.5	41.0 ± 3.2
Perennial Grass	2005	1.2 ± 0.5	5.9 ± 1.4	7.0 ± 1.5	6.8 ± 1.3	8.5 ± 1.5	10.9 ± 1.6
	2006	0.6 ± 0.2	3.1 ± 0.6	5.6 ± 1.7	9.7 ± 1.9	5.2 ± 1.0	8.9 ± 1.8
Forb	2005	10.9 ± 2.2	4.5 ± 0.9	3.3 ± 0.7	3.6 ± 0.6	3.7 0.7	4.2 ± 0.8
	2006	4.6 ± 0.7	2.8 ± 0.7	4.6 ± 1.3	4.7 ± 0.6	2.4 ± 0.7	2.3 ± 0.6
Cheatgrass Site							
Annual Grass	2005	3.3 ± 1.3	62.6 ± 3.4	32.7 ± 3.4	28.0 ± 2.4	5.8 ± 1.4	54.9 ± 3.8
	2006	51.9 ± 3.5	66.5 ± 3.2	54.9 ± 3.5	63.7 ± 2.5	53.2 ± 3.3	79.0 ± 2.2
Perennial Grass	2005	0.6 ± 0.2	2.3 ± 0.9	3.2 ± 0.8	2.3 ± 0.5	2.2 ± 0.6	2.7 ± 1.3
	2006	0.8 ± 0.7	0.7 ± 0.4	2.3 ± 0.8	3.2 ± 1.1	1.9 ± 0.7	0.4 ± 0.3
Forb	2005	3.3 ± 1.1	4.7 ± 1.3	1.5 ± 0.3	0.9 ± 0.2	3.7 ± 1.1	7.1 ± 2.0
	2006	5.0 ± 0.9	3.9 ± 1.1	5.9 ± 1.1	5.3 ± 0.7	7.5 ± 2.6	3.1 ± 0.7

APPENDIX A. University of Idaho Animal Care and Use approval 2002-12 for grazing after fire study located near Dubois, ID.

University of Idaho
Animal Care and Use Committee

Date: Tuesday, September 04, 2001
To: Karen L. Launchbaugh
From: University of Idaho
Re: Protocol 2002-12
Deferment of Grazing after Fire as it Affects Weed Infestations and Sagebrush Recruitment

Your animal care and use protocol for the project shown above was reviewed by the University of Idaho on Tuesday, September 04, 2001.

This protocol was originally submitted for review on: Thursday, July 12, 2001
The original approval date for this protocol is: Tuesday, September 04, 2001
This approval will remain in affect until: Saturday, September 04, 2004
The protocol may be continued by annual updates until: Saturday, September 04, 2004

Federal laws and guidelines require that institutional animal care and use committees review ongoing projects annually. For the first two years after initial approval of the protocol you will be asked to submit an annual update form describing any changes in procedures or personnel. The committee may, at its discretion, extend approval for the project in yearly increments until the third anniversary of the original approval of the project. At that time, the protocol must be replaced by an entirely new submission.

IACUC Representative

APPENDIX B. Photos taken in 4 study years at permanent photopoint locations within fixed plot sampling locations for grazing after fire study near Dubois, ID.

Plot #11

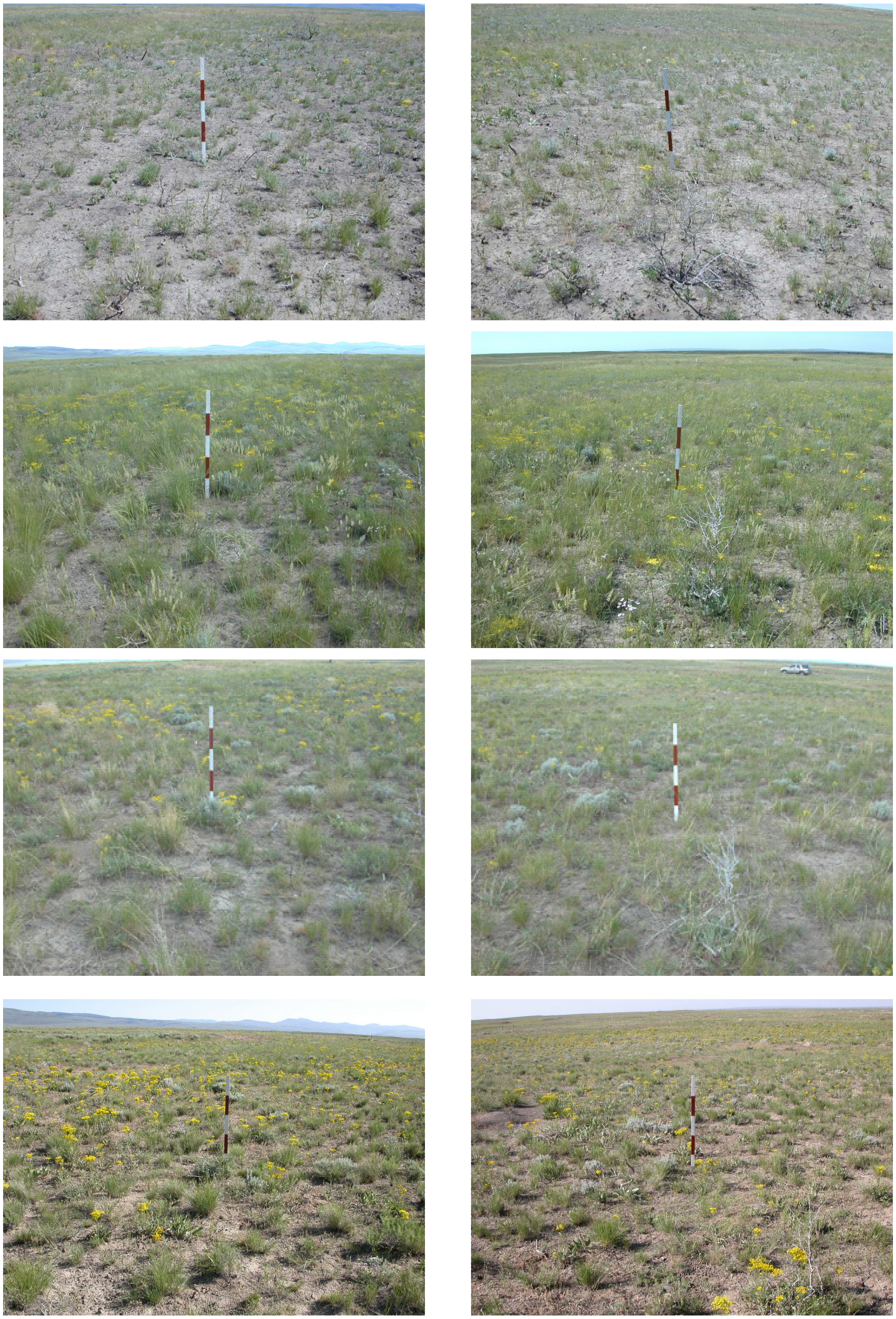
North South

2001

2002

2003

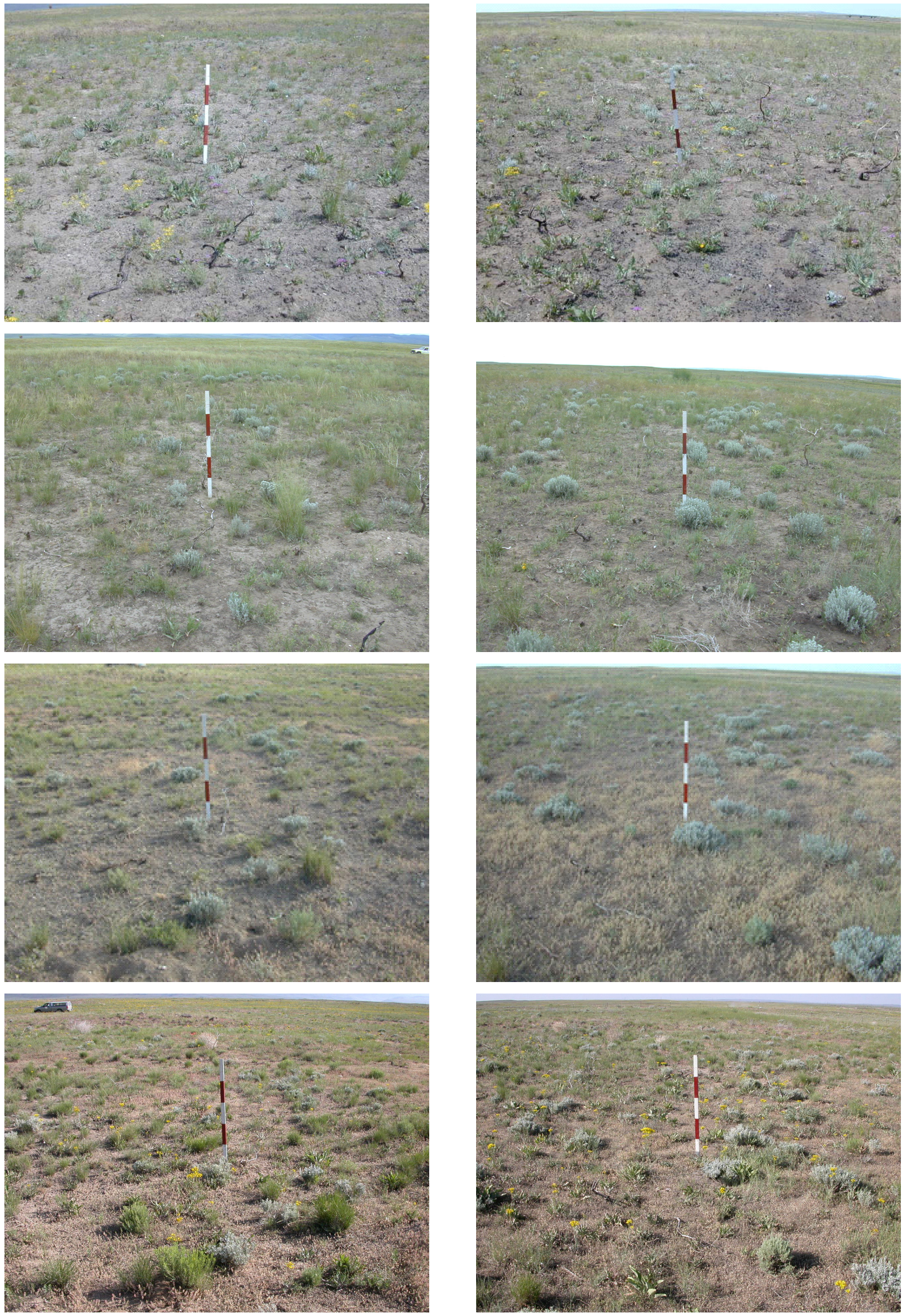
2004



Plot #12

North South

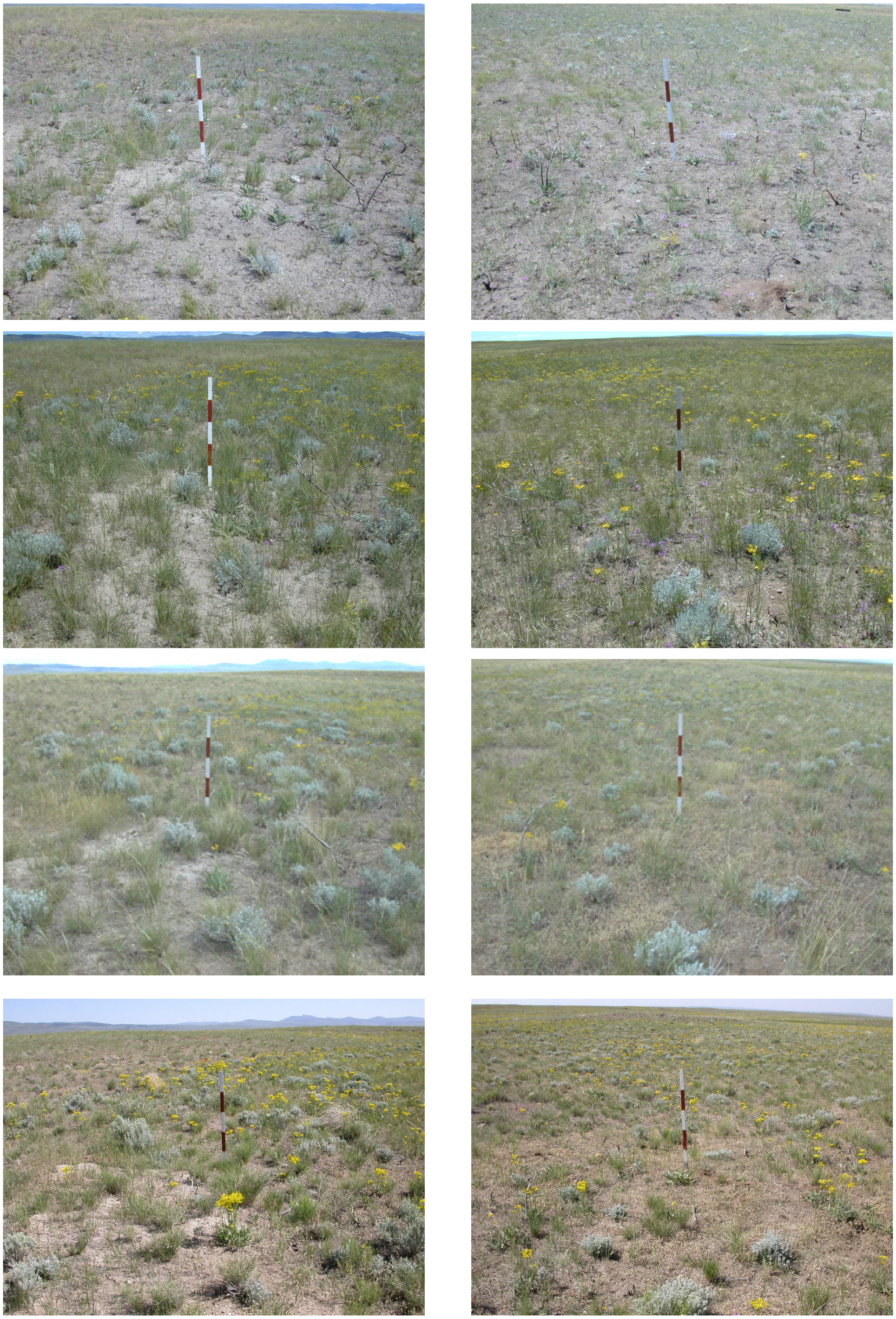
2001
2002
2003
2004



Plot #13

North | South

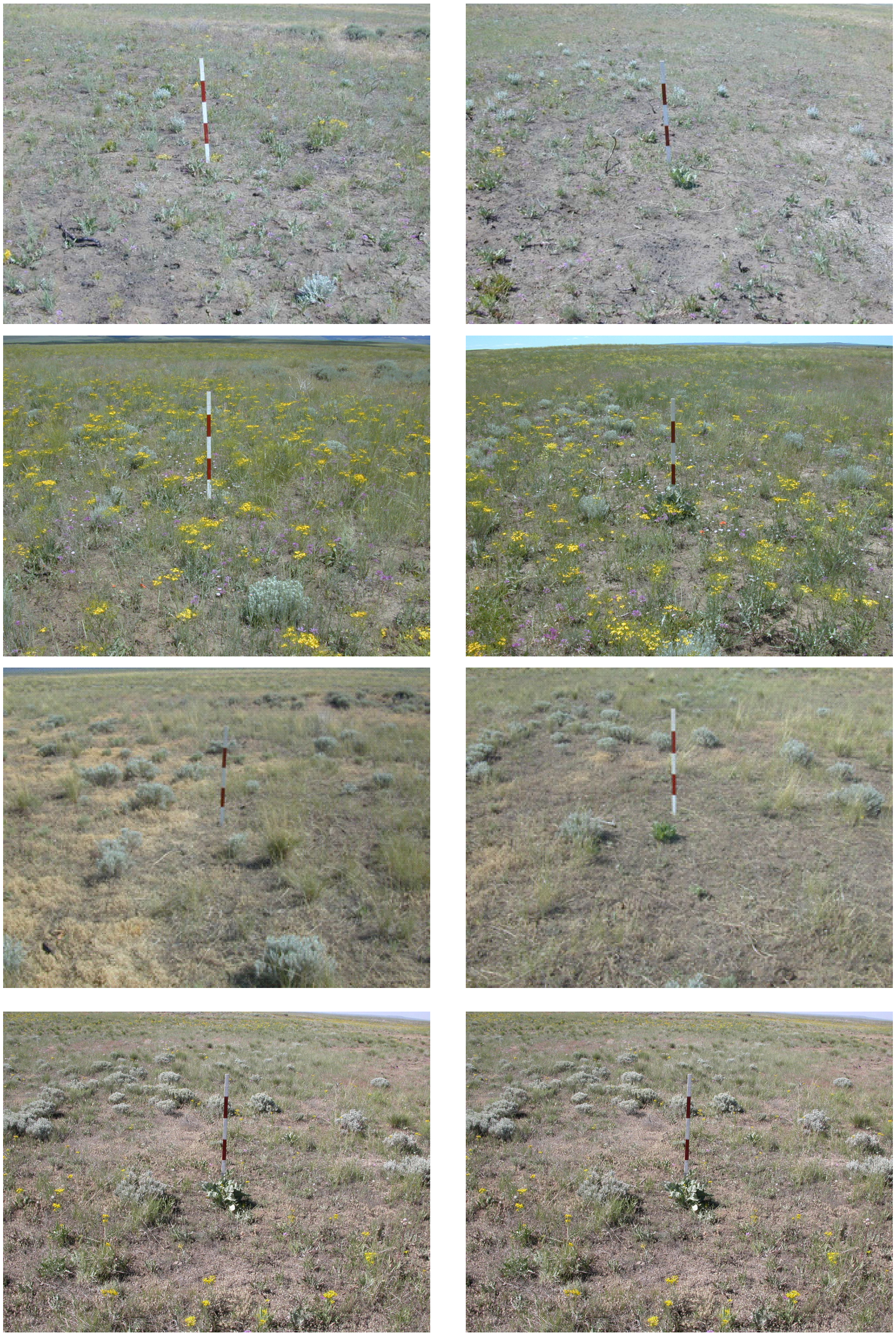
2001, 2002, 2003, 2004



Plot #14

North South

2001
2002
2003
2004



Plot #15

North South

2001

2002

2003

2004

Plot #16

North South

2001

2002

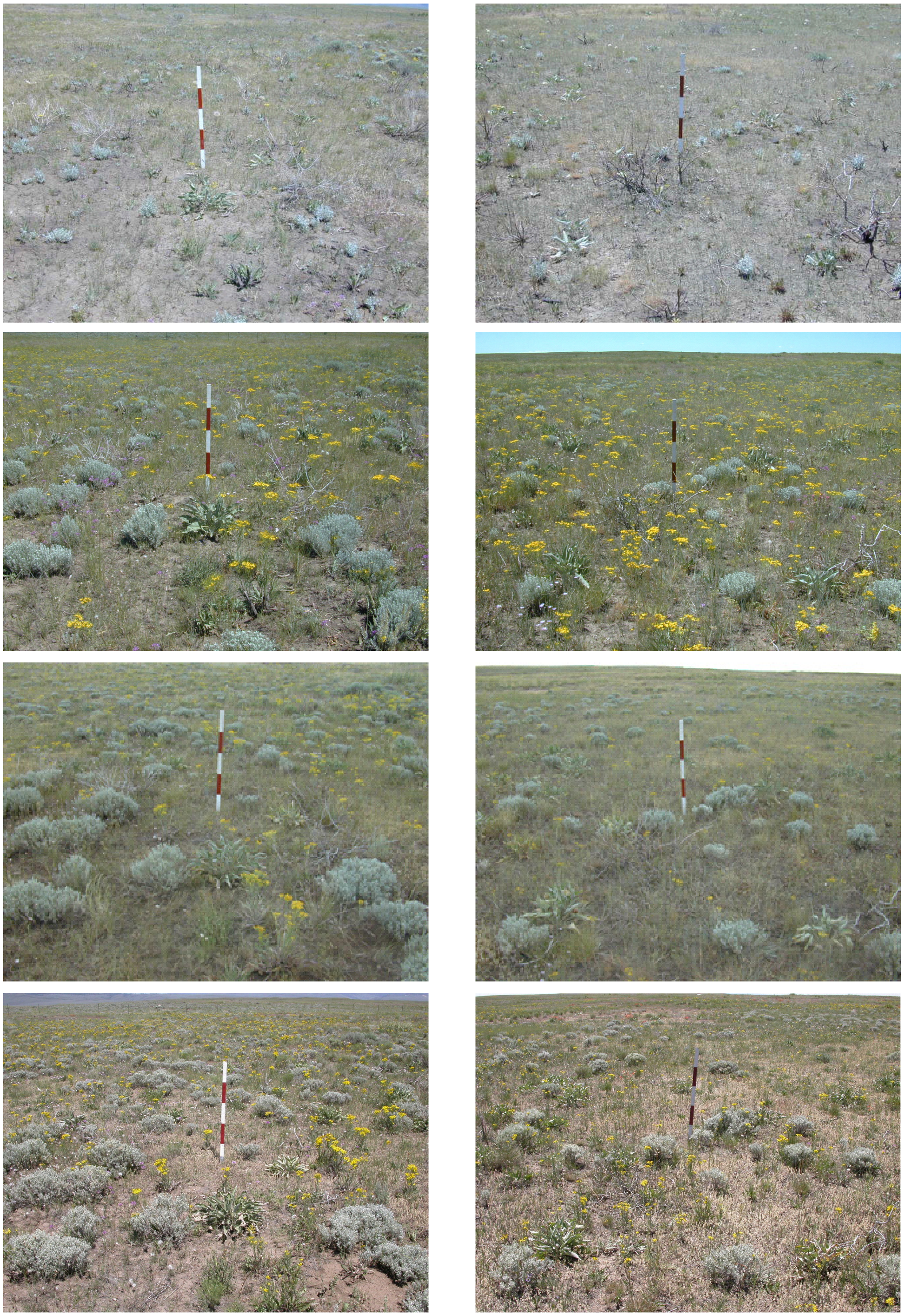
2003

2004

Plot #21

North South

2001 2002 2003 2004



Plot #22

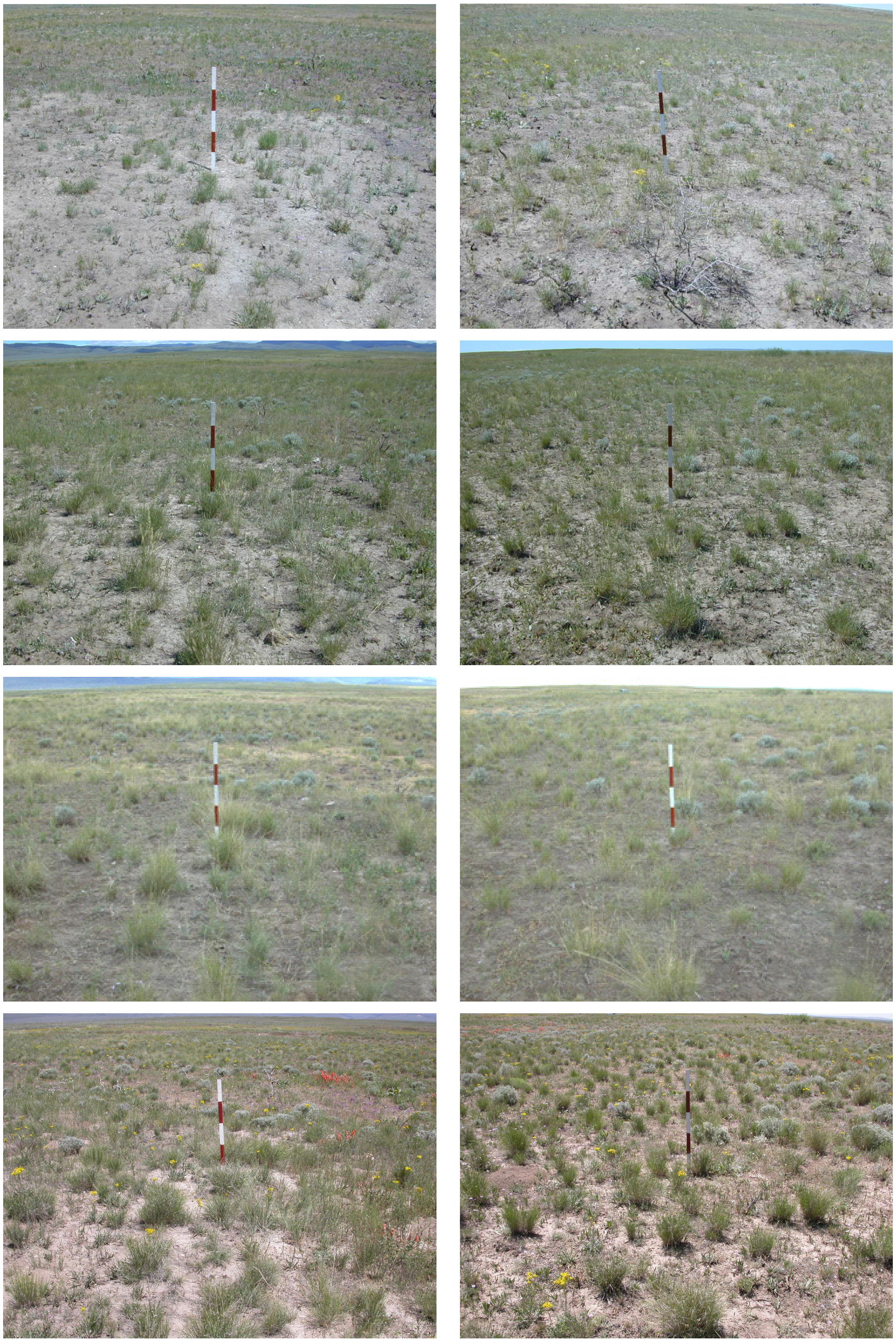
North | South

2001

2002

2003

2004



Plot #23

North South

2001

2002

2003

2004

Plot #24

North South

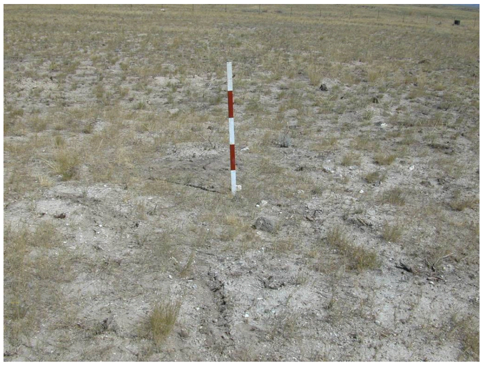
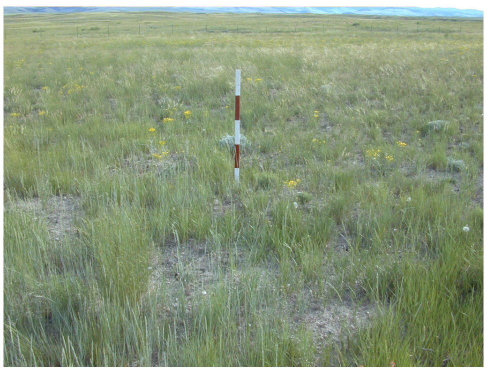
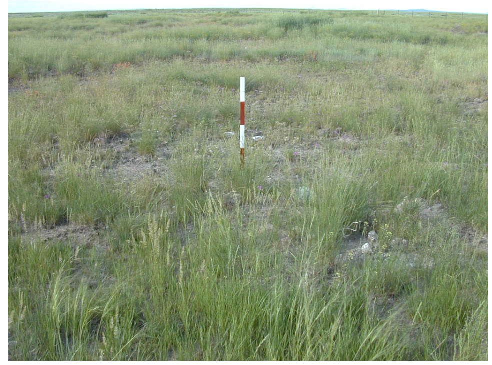
2001


2002


2003


2004


Plot #25

	North	South
2001		
2002		
2003		
2004		

Plot #26

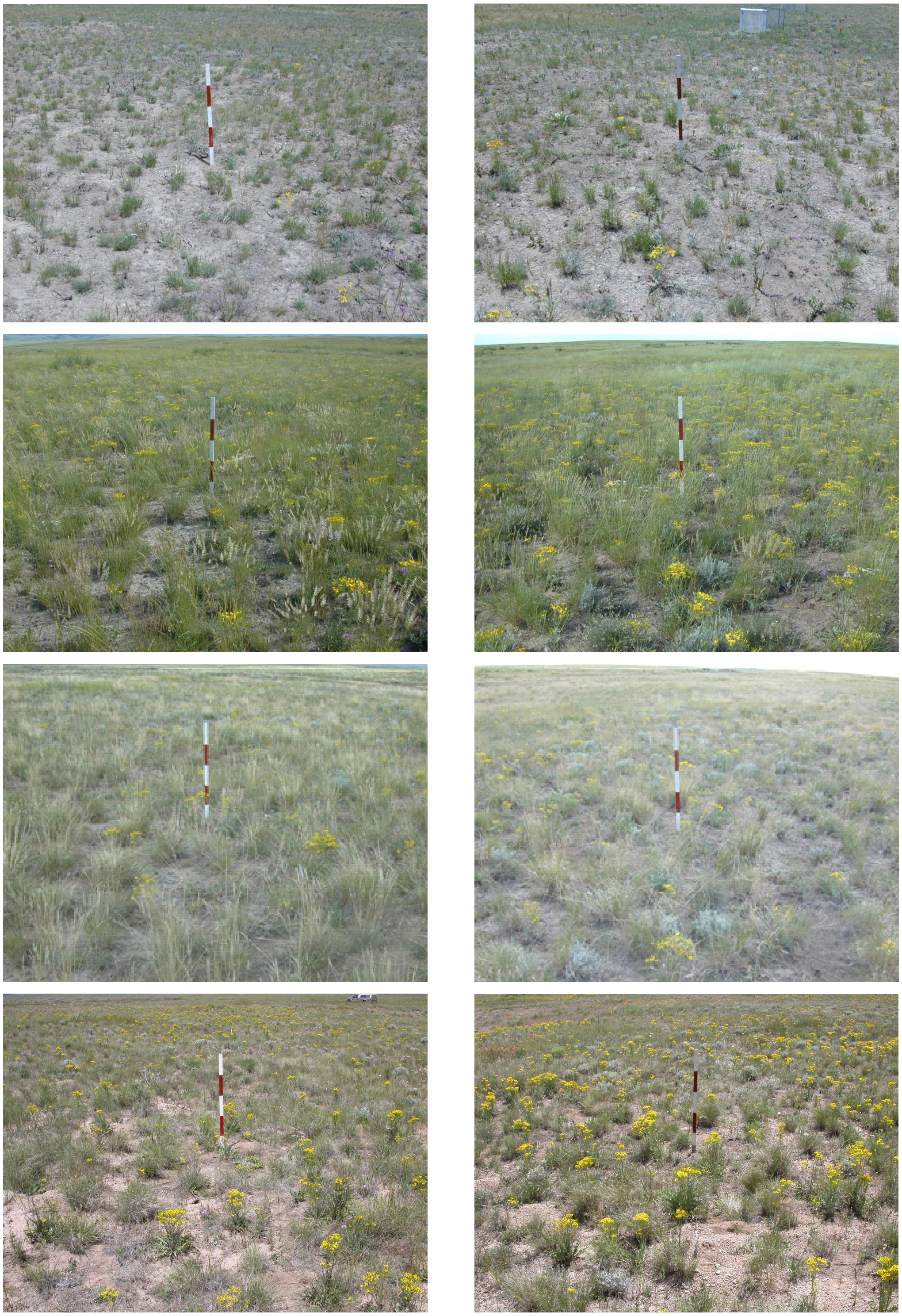
North South

2001

2002

2003

2004



Plot #31

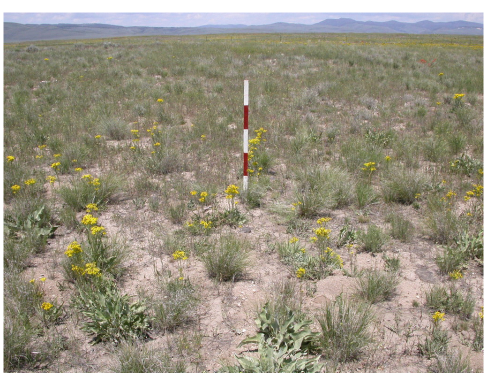
North | South

2001

2002

2003

2004



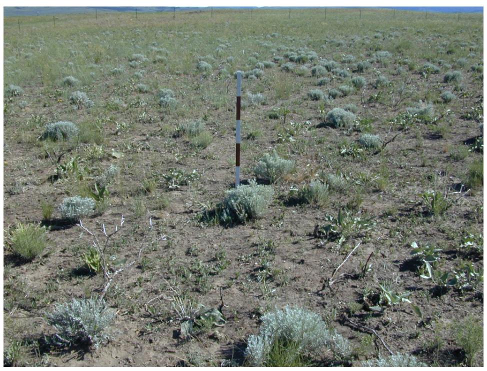
Plot #32

North

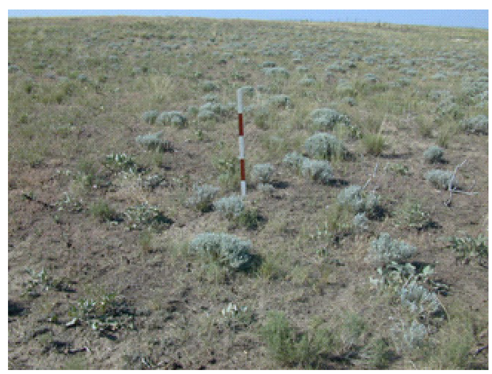
South

2001

2002



2003

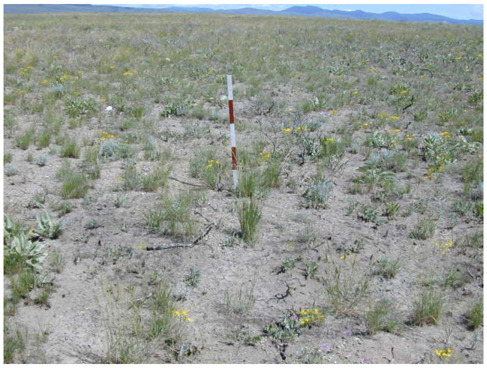


2004

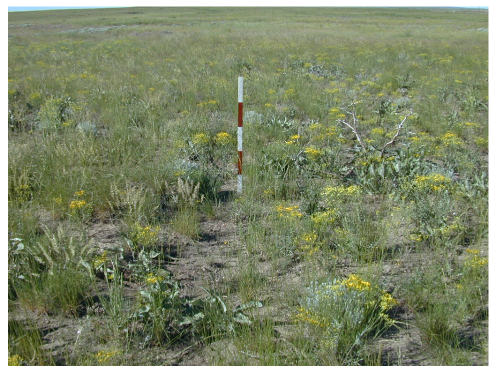
Plot #33

North | South

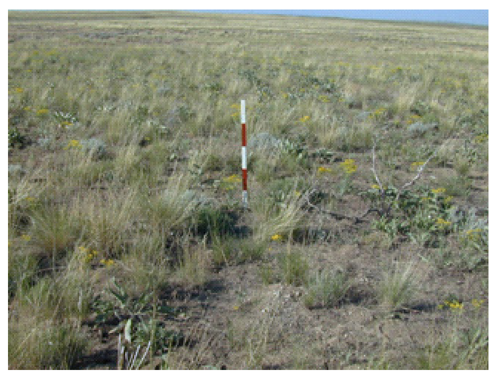
2001




2002

2003

2004

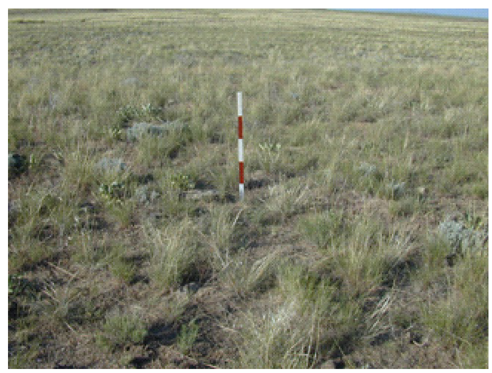

Plot #34

North | South

2001


2002


2003

2004


Plot #35

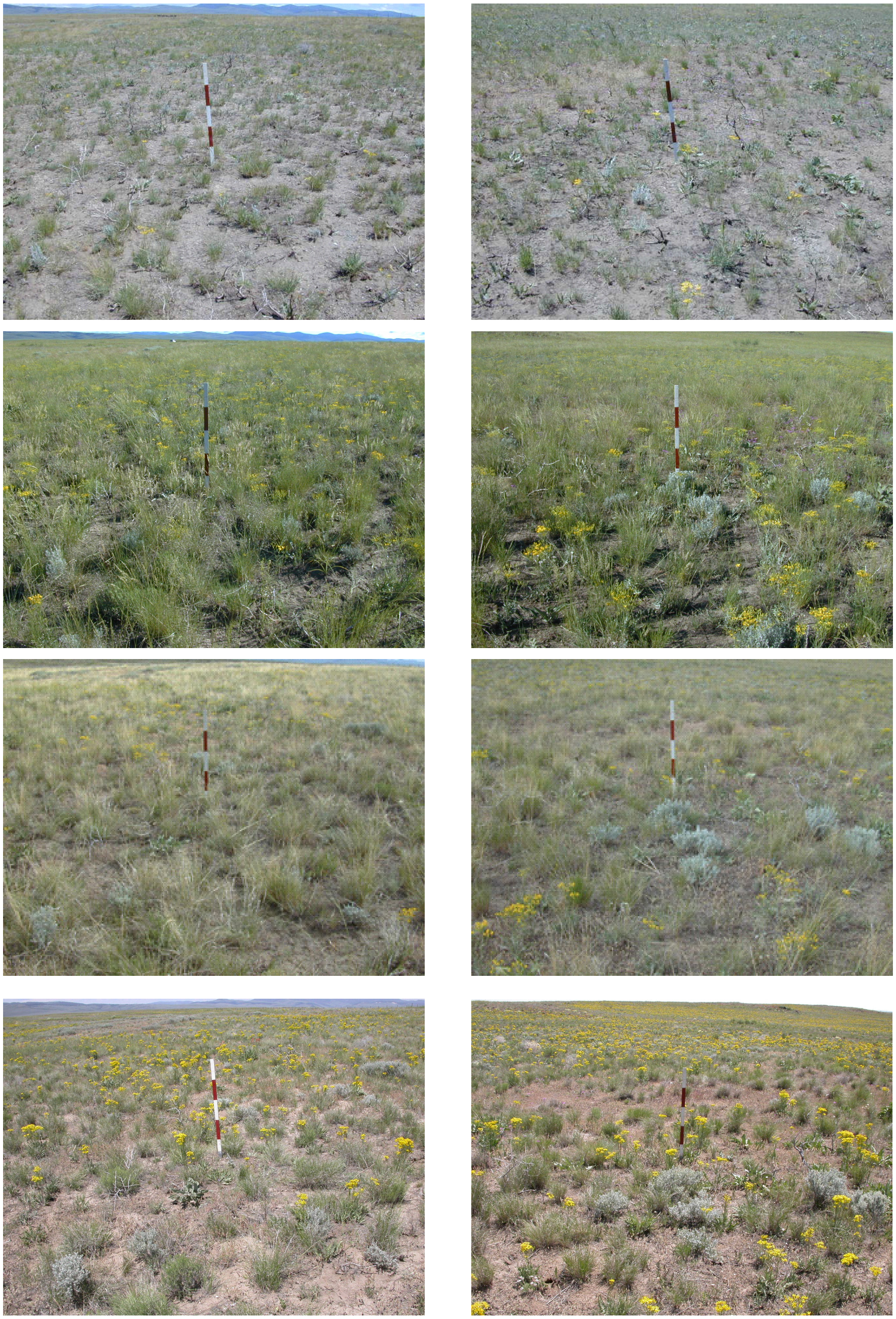
North | South

2001

2002

2003

2004

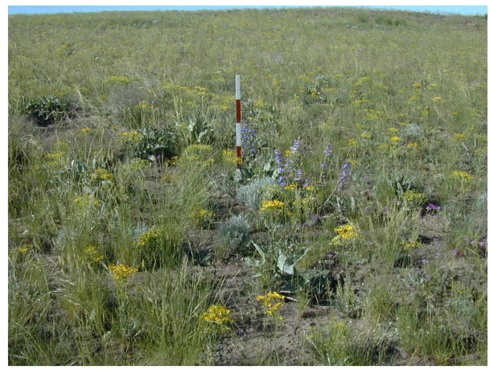


Plot #36

North | South

2001

2002



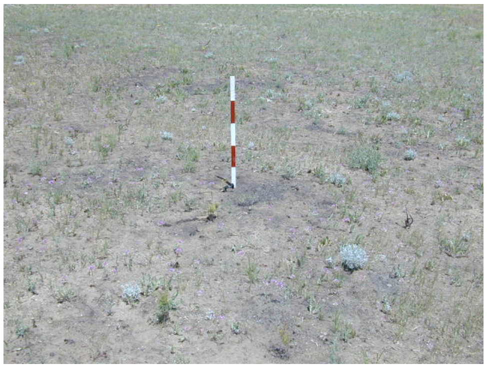
2003

2004

Plot #41

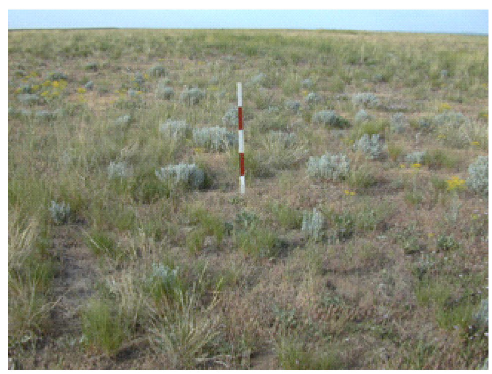
North | South

2001



2002

2003



2004

Plot #42

North | South

2001 | 2002 | 2003 | 2004

Plot #43

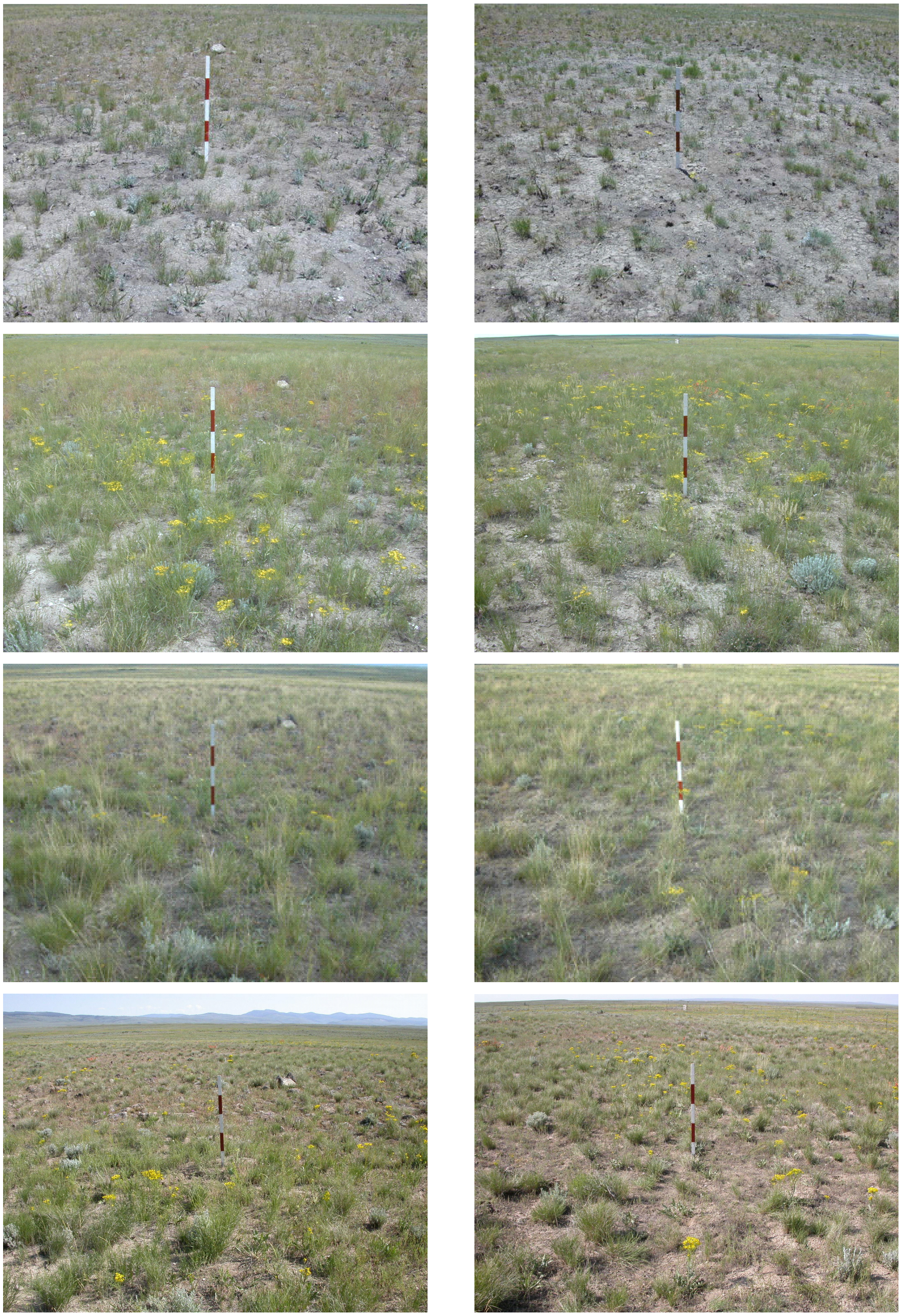
North | South

2001

2002

2003

2004



Plot #44

North | South

2001

2002

2003

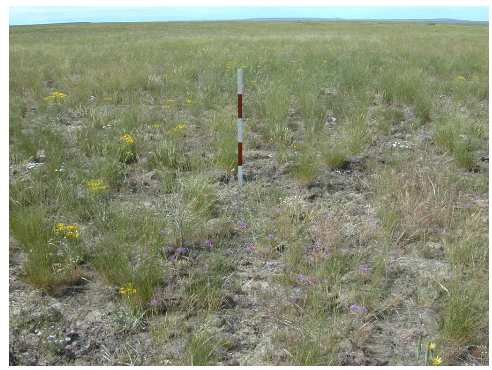
2004

Plot #46

North | South

2001

2002



2003

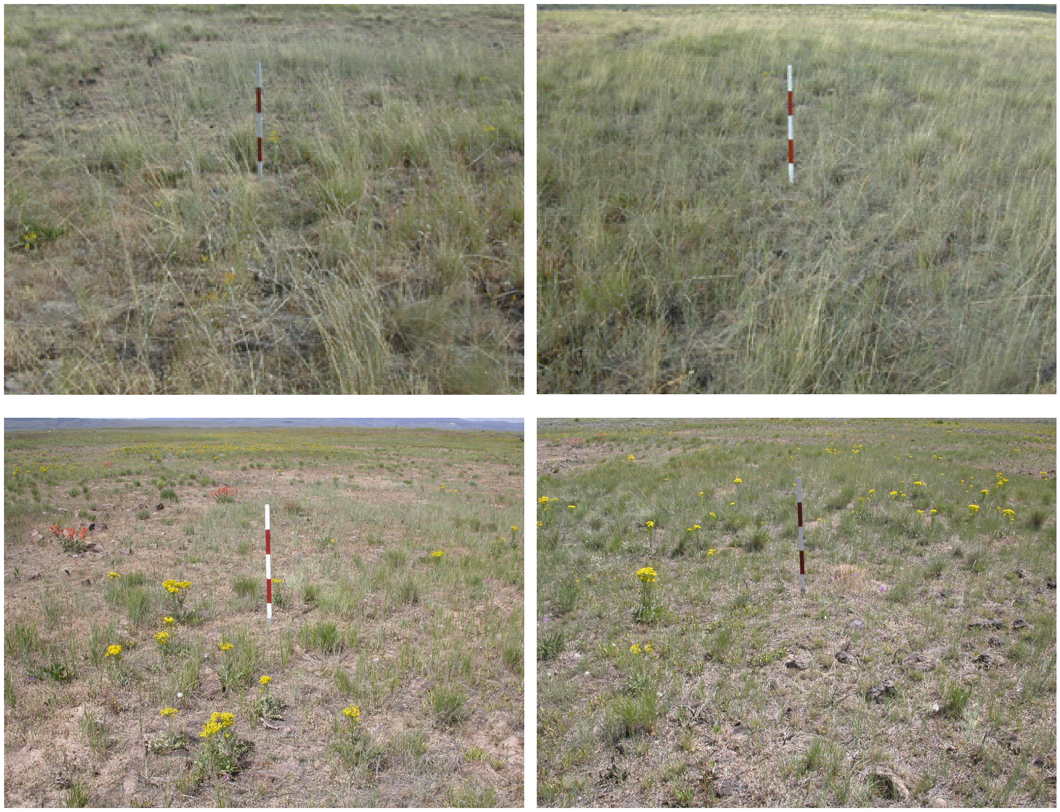
2004

Plot #51

North South

2003

2004



APPENDIX C. Coordinates (UTM) of reference stakes marking the permanent photopoint locations and fixed plot density sampling locations for grazing after fire study near Dubois, ID. All UTM coordinates are reported in Zone 12N of NAD83.

	Plot Coordinates	
Paddock	Easting	Northing
11	0402809E	4901193N
12	0402764E	4901079N
13	0402984E	4901165N
14	0402980E	4901300N
15	0402940E	4901045N
16	0402808E	4901306N
21	0403229E	4901348N
22	0403168E	4901216N
23	0403129E	4901083N
24	0403393E	4901345N
25	0403546E	4901341N
26	0403396E	4901214N
31	0402960E	4900920N
32	0402684E	4900954N
33	0402719E	4900791N
34	0402704E	4900688N
35	0402984E	4900801N
36	0402953E	4900701N
41	0403233E	4900721N
42	0403302E	4900924N
43	0403289E	4900704N
44	0403146E	4900941N
45	0403600E	4901244N
46	0403222E	4900813N

APPENDIX D. Coordinates (UTM) of research block locations for 2 sites (cheatgrass and medusahead) for a fall seed trampling and spring sheep grazing study located near Benge, WA. All UTM coordinates are reported in Zone 11N of NAD83.

Site	Block	Paddock Corners	Easting	Northing
Medusahead	1	NW	406745	5201705
		NE	406757	5201702
		SE	406757	5201672
		SW	406745	5201673
	2	NW	406715	5201804
		NE	406723	5201812
		SE	406746	5201794
		SW	406738	5201785
	3	NW	406733	5202132
		NE	406741	5202141
		SE	406767	5202124
		SW	406759	5202116
	4	NW	406775	5202227
		NE	406783	5202236
		SE	406805	5202214
		SW	406797	5202207
Cheatgrass	5	NW	406871	5202545
		NE	406881	5202540
		SE	406869	5202512
		SW	406858	5202517
	6	NW	407117	5202643
		NE	407128	5202637
		SE	407116	5202611
		SW	407105	5202615
	7	NW	407116	5202683
		NE	407128	5202684
		SE	407130	5202654
		SW	407118	5202653
	8	NW	407144	5202670
		NE	407151	5202679
		SE	407175	5202660
		SW	407167	5202651
	9	NW	407163	5202696
		NE	407174	5202699
		SE	407181	5202670
		SW	407170	5202666
	10	NW	407161	5202725
		NE	407172	5202731
		SE	407186	5202706
		SW	407176	5202700

APPENDIX E. University of Idaho Animal Care and Use approval 2005-49 for sheep trampling and grazing study near Benge, WA.

University of Idaho
Animal Care and Use Committee

Date: Monday, April 25, 2005
To: Karen L. Launchbaugh
From: University of Idaho
Re: Protocol 2005-49
Using sheep for ecological restoration of grasslands dominated by exotic annuals

Your animal care and use protocol for the project shown above was reviewed by the University of Idaho on Monday, April 25, 2005.

This protocol was originally submitted for review on: Tuesday, March 15, 2005
The original approval date for this protocol is: Monday, April 25, 2005
This approval will remain in affect until: Thursday, March 29, 2007
The protocol may be continued by annual updates until: Friday, April 25, 2008

Federal laws and guidelines require that institutional animal care and use committees review ongoing projects annually. For the first two years after initial approval of the protocol you will be asked to submit an annual update form describing any changes in procedures or personnel. The committee may, at its discretion, extend approval for the project in yearly increments until the third anniversary of the original approval of the project. At that time, the protocol must be replaced by an entirely new submission.

Brad Williams DVM

IACUC Representative