VEGETATION TREATMENT EFFECTS IN A WYOMING BIG SAGEBRUSH COMMUNITY AND A COMPARISON OF TWO METHODS FOR ESTIMATING SHRUB CANOPY COVER

A Thesis
Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science
with a
Major in Rangeland Ecology and Management
In the
College of Graduate Studies
University of Idaho

by
Kathrine Santini
Febuary 2012
Major Professor: Stephen C. Bunting, Ph. D

AUTHORIZATION TO SUBMIT THESIS

This thesis of Kathrine Santini, submitted for the degree of Master of Science with a major in Rangeland Ecology and Management and titled "Vegetation treatment effects in a Wyoming big sagebrush community and a comparison of two methods for estimating shrub canopy cover," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor _____Date_____
Stephen C. Bunting

Committee
Members _____Date_____
Eva K. Strand

_____Date_____
Janet L. Rachlow

Department
Administrator _____Date_____
Jo Ellen Force

Discipline's
College Dean _____Date_____
Kurt Pregitzer

Final Approval and Acceptance by the College of Graduate Studies

_____Date_____
Jie Chen

ABSTRACT

This study was conducted to evaluate the effects of chemical, mechanical, and prescribed fire treatments in a Wyoming big sagebrush community (*Artemisia tridentata* ssp. *wyomingensis*) near Pinedale, Wyoming. Treatments included the application of tebuthiuron at rates of 0.9 a.i/ha and 1.9 a.i./ha (light and heavy Spike), Dixie harrow, Ely chain, aerator, low mow, medium mow with forb seeding, high mow, and prescribed fire. One season of pre-treatment and 5 seasons of post-treatment data were collected. Grazing was excluded from half of each treatment site for 3 out of the 5 post-treatment years.

The low mow treatment resulted in the greatest reduction of sagebrush cover while the light spike treatment resulted in the most minimal reduction of sagebrush. Mature sagebrush was most affected by the prescribed fire treatment, and decadent sagebrush was reduced on all plots. By the final year of the study, sagebrush had started to recover and increases in cover were seen on all plots (including the control) except the two spike treatments and the prescribed fire plot. Grazing had a minimal effect on sagebrush steppe attributes including canopy cover, density, and age class distribution.

Mean total grass cover increased on all sites except those treated with the aerator and high mow treatments. Total forb cover, species richness, and Shannon-Wiener Index values increased on all plots; however, little difference was documented between treatments and the control. Herbaceous changes were attributed to differences in year to year fluctuations and seasonality of sampling. Grazing was a significant effect for grass biomass only.

While this post-treatment data serve as a good indicator of initial changes that occurred, continued monitoring for longer time periods would better allow us to assess treatment efficiency or applicability.

In addition, a comparison of line intercept and line-point intercept methodologies for collecting shrub canopy cover estimates was conducted. Both a field trial and a simulated trial using ARC GIS were used. In field trials, estimates based on line-point intercept were higher than estimates based on line intercept, and the two methods differed at the levels of ten and twenty percent cover. For the simulated trial, methods differed at the twenty percent cover level. Also, higher numbers of points for the line–point intercept resulted in more similar predictions of cover between the two methodologies.

ACKNOWLEGMENTS

I would like to thank my major professor, Dr. Bunting for all of his help, guidance, and patience over the last two years. Thank you also to my committee members, Dr. Strand, and Dr. Rachlow. Special thanks to Dr. Strand for not only envisioning simulated sagebrush, but in helping to make it a reality. Also, many thanks to Dr. Williams for his statistical consultation assistance.

This project would not have been possible without the financial support of QEP Energy and the Bureau of Land Management. Special thanks to Peter Guernsey for his help in locating plots and identifying plants.

I would also like to thank Ginny Harris and Meghan Carter for their assistance in the field. I appreciate your fortitude and humor in facing the mosquitos, heat, and wind.

Finally, I would like to thanks my parents, Mike and Dena Santini for their continued support throughout this process.

CONTENTS

TITLE PAGE……i
AUTHORIZATION TO SUBMIT THESIS……ii
ABSTRACT……iii
ACKNOWLEGEMENTS……iv
LIST OF FIGURES……vi
LIST OF TABLES……..vii
LIST OF APPENDICES……...viii
CHAPTER
I. VETETATION TREATMENT EFFECTS IN A WYOMING BIG SAGEBRUSH COMMUNITY.. . . ……..1
LITERATURE CITED……..21
FIGURES……...25
TABLES……28
II. COMPARISON OF TWO METHODS FOR ESTIMATING SHRUB CANOPY COVER……..36
LITERATURE CITED……..45
FIGURES……...48
TABLES……54

APPENDICES……54

FIGURES

CHAPTER I

FIGURE 1. Map of study plots and transects on the Pinedale Mesa, Sublette County,Wyoming…….25

FIGURE 2. Mean temperature by month between 2006 and 2011 compared to the 60-year average for a Wyoming big sagebrush community study near Pinedale, Wyoming. Missing bars denote a lack of available data. Information obtained from Western Regional Climate Center……...26

FIGURE 3. Mean precipitation by month compared to the 60-year average for a Wyoming big sagebrush community study near Pinedale, Wyoming. Missing bars denote a lack of available data. Information obtained from Western Regional Climate Center.....27

CHAPTER II

FIGURE 4. Virtual sagebrush community with 20% sagebrush cover ……..47

FIGURE 5. Distribution of percent cover estimates by method for field trials in a sagebrush community. The box represents the 25th, median, and 75th percentiles for data. Error bars are the 10th and 90th percentiles, and circles denote outliers in the data.……...48

FIGURE 6. Correlation of line intercept and line-point intercept estimates by number of points taken and Pearson correlation coefficients (r). Sample size =78……...……49

FIGURE 7. Distribution of percent cover estimates by method for simulated trials of a sagebrush community. The box represents the 25th, median, and 75th percentiles for data. Error bars are the 10th and 90th percentiles, and circles denote outliers in the data.……...50

FIGURE 8. Correlation of line intercept and line-point intercept estimates by number of points taken and Pearson correlation coefficients (r). Sample size n = 30……..51

FIGURE 9. Simulation trial relative difference (mean and standard error) of line intercept (L), line-point intercept 60 points (P060), line-point intercept 120 points (P120), and line-point intercept 240 points (P240) by cover level. * indicates that the methods were significantly different for cover level..……...52

TABLES

CHAPTER I

TABLE 1. P-values, best fit co-variance model, and results of check of residuals for treatment*grazing repeat measure ANOVA. Co-variance models are as follows; UN denotes unstructured, ARH1 denotes heterogeneous autoregressive, AR 1 denotes autoregressive, and CS denotes compound symmetry. Y denotes that the residuals met model assumptions, N denotes they did not…… 28

TABLE 2. Sagebrush and rabbitbrush cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming……29

TABLE 3. Density values (mean ± se) by age class after vegetation treatments of a Wyoming big sagebrush community in western Wyoming……..….30

TABLE 4. Cover values for the most prevalent grass species and total grass (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming……31

TABLE 5. Grass and forb biomass values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming…….….32

TABLE 6. Cover values for the three most prevalent forb species and total forb (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming……..……..33

TABLE 7. Herbaceous height, species richness and Shannon-Wiener Index values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming...……34

TABLE 8. Litter and bare ground cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming……35

CHAPTER II

TABLE 9. Summary statistics of mean difference between line intercept and line-point intercept for field and simulated trials. Statistics are delineated by cover range and level. P-values are from a paired t-test……..……..53

APPENDICIES

APPENDIX A. Coordinates (UTM) of research transect locations for Wyoming big sagebrush community treatment plots located near Pinedale, Wyoming. All UTM coordinates are reported in Zone 12N of the NAD83 datum……..54

APPENDIX B. Summary of probability values, best fit covariance model, and results of residual check for parameters sampled in 2006-2011in a Wyoming big sagebrush community study near Pinedale Wyoming. PROC MIXED and repeat measure ANOVAs were run separately for years where grazing was a factor…..…….56

APPENDIX C. Tables of (mean ± se) by treatment for all parameters collected for all years in a Wyoming big sagebrush community study near Pinedale Wyoming……..58

APPENDIX D. Percent average species cover (mean ± se) pre-treatment (2006) for a Wyoming big sagebrush community study near Pinedale Wyoming……..65

APPENDIX E. Percent average species cover (mean ± se) post-treatment (2007-2011) for a Wyoming big sagebrush community study near Pinedale Wyoming…….....71

APPENDIX F. Plant master list with plant symbol, common name, family, duration and nativity. Nomenclature based on USDA PLANTS database…….101

CHAPTER I

VEGETATION TREATMENT EFFECTS IN A WYOMING BIG SAGEBRUSH COMMUNITY

INTRODUCTION

This study was designed to quantify and compare the long term effects of chemical, mechanical, and prescribed fire treatments on vegetation age class and diversity on the Pinedale Mesa, which is located in the Upper Green River Basin of the Wyoming Basin. While many sagebrush treatments have been individually assessed, few comparison studies have been done to determine which treatments, if any, are most effective at diversifying sagebrush canopy cover, and increasing grass and forb production in Wyoming big sagebrush communities.

Since the early 1800s, sagebrush (*Artemisia* L. spp.) dominated ecosystems throughout western North America have become increasingly fragmented and altered due to a multitude of land practices (Dobkin and Sauder 2004). Current threats to sagebrush ecosystems include: past land uses, urbanization, farmland conversion, recreation, resource extraction development, altered fire regimes, and expansion of invasive species (Chambers and Wisdom 2009). Sagebrush has been severely reduced in many landscapes due to these and other factors (Knick et al. 2003). In areas where sagebrush remains, the communities, as well as the wildlife habitat they provide are often degraded.

The survival of many species including sage grouse (*Centrocercus* spp.), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*), and pygmy rabbits (*Brachylagus idahoensis*), are dependent on healthy and diverse sagebrush stands (USDA 2005). Focus is often given to sage grouse habitat requirements as these birds are true sagebrush obligates, relying on sagebrush year round for breeding, nesting, brood rearing, and foraging (Rowland 2004). While 60-80% of all food consumed by sage grouse is sagebrush, forbs are particularly important to pre-laying females and young chicks for nutritional needs (Barnett and Crawford 1994; Drut et al. 1994; McAdoo et al. 2002). Ideal sage grouse habitat includes a sagebrush-steppe mosaic with a diverse array of grasses and forbs; varying heights of sagebrush are also desirable (Connelly et al. 2000).

Altered disturbance regimes have caused changes in shrub community composition. Sagebrush cover and density increases have been attributed to fire suppression and excessive grazing (Miller and Eddleman 2001). Conversely, communities affected by annual grass invasion have experienced more frequent fires, resulting in an overall loss of sagebrush. Under both scenarios, the health and productivity of the herbaceous understory is often negatively affected (Baxter 1998).

A decrease in the herbaceous understory, including grasses and forbs, has been attributed to increases in sagebrush cover (Barnett and Crawford 1994). The maximum canopy cover of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) in areas receiving more than 20 cm of annual precipitation is typically no more than 25-30% (Wyoming Interagency Vegetation Committee 2002). With canopy cover of 12-15%, competition can begin to have negative effects on the herbaceous component in the understory; for every 1% increase in Wyoming big sagebrush cover there is an estimated 3.8% decrease in understory herbaceous production (Winward 1991).

Beginning in the late 1940s, numerous range improvement projects were initiated by land management agencies to reduce big sagebrush (*Artemisia tridentata* Nutt.) in the landscape. Wambolt et al. (2001) estimated that over the last 50 years, millions of hectares of sagebrush have been affected by treatments. Many of these projects were conducted in an effort to improve livestock forage and improve range condition (Frischknecht and Bleak 1957; Vale 1974), and methodologies included chemical, mechanical, and prescribed fire treatments (Johnson 1969; Wambolt and Payne 1986; Miller and Eddleman 2001). More recently treatments have been advocated to restore sagebrush communities through diversification of sagebrush age class and reduction of sagebrush density (Barnett and Crawford 1994; Olson and Whitson 2002). While precipitation, understory species, soil properties, and grazing history must be taken into consideration when assessing potential herbaceous yield, some form of sagebrush canopy removal is often required to promote understory productivity (Winward 1991; Welch and Criddle 2003).

Chemical treatments

Initially the herbicide 2, 4-D (2, 4-dichlorophenoxy acetic acid) was used as an effective sagebrush control method. While effective at treating sagebrush, this chemical also caused

decreases in forbs (Baxter 1998). Due to this consequence, recent restoration projects have turned to the use of the herbicide tebuthiuron [1-(5-tert-butyl-1,3,4-thiadiazol-2-yl)-1, 3 dimethylurea], commonly known as Spike 20P. This herbicide works to selectively thin sagebrush stands through the inhibition of photosynthetic activity. At low application rates tebuthiuron has little effect on other plant species. Olson and Whitson (2002) reported that when applied at 0.1-0.5 kg active ingredient (a.i.)/ha, only sagebrush plants within a 0.5-m radius of the individual herbicide pellet were affected. Sagebrush mortality rates comparable to those seen with 2, 4-D have been achieved with application of tebuthiuron at 1 and 2 kg a.i./ha rates (Britton and Sneva 1983).

Achievement of sagebrush canopy reduction for restoration goals using tebuthiuron can be met by considering soil conditions and annual precipitation rates and adjusting application rates. Low precipitation rates and soils with higher sand content have been shown to increase the effects of tebuthiuron. Application rates between 1.1 kg a.i./ha and 3.35 kg a.i./ha have been recommended for 50-75% reduction in Wyoming big sagebrush at elevations above 1,980 m (Dow AgroSciences 2011).

Tebuthiuron does not dissociate in soils with high pH (Olson and Whitson 2002). It also binds to organic matter and clay particles; however, soils associated with sagebrush ecosystems are typically low in organic content making clay content the most common factor in determining chemical effectiveness.

McDaniel et al. (2005) studied eight different Wyoming big sagebrush plots treated exclusively with tebuthiuron. The authors collected canopy cover and vegetation yield for 20 years post-chemical application, and found that the number of years favorable for sagebrush establishment was the most significant factor affecting Wyoming big sagebrush recovery. Treatments were predicted to last at least 35 years at six of the eight study sites; higher rates of herbicide extended treatment life.

While not specific to tebuthiuron, other studies have shown that herbicide treatments typically last between 14 and 17 years (Johnson 1969). After 17 years, Johnson (1969) determined that young sagebrush plants in sprayed areas exceeded the number of young plants in the control plots, and that 14 years after spraying, live sagebrush crown area had returned to pre-spraying levels. Similarly, Watts and Wambolt (1996) found that Wyoming big sagebrush cover on treated plots exceeded that of the control plot after 10 years. Few

long term studies of the impacts of tebuthiuron on plant community structure and function have been conducted (Miller and Eddleman 2001; Olson and Whitson 2002).

Mechanical Treatments

There are multiple mechanisms including plowing, chaining, disking, mowing, and aerating, available for the mechanical treatment of sagebrush. As opposed to broad-scale treatments like prescribed fire, mechanical treatments allow for a more controlled application, and avoidance of sensitive areas. Studies conducted in the 1940s indicated that mechanical treatments resulted in increased perennial grass cover, and several years after treatments, increases of 200-400% were observed (Barnes 1952; Vale 1974).

Use of one way disc plows for vegetation manipulation was studied by Barnes (1952). Plows created small pits about 40 cm apart, and reduced the vegetative cover by about 30%. Results of the study indicated that plow furrow width patterns of 0.6 m provided optimum vegetation establishment; greater widths did not result in increased herbaceous yields (Barnes 1952). Initial studies indicated that surviving sagebrush plants provided seed for re-colonization of treated sites (Bleak and Miller 1955; Johnson and Payne 1968). Treatments conducted while sagebrush seed was at maturity also resulted in greater sagebrush reestablishment.

Chaining was first advocated as a means of sagebrush thinning in the 1960s (Fairchild et al. 2005). Chaining can scarify soil and prepare a desirable seedbed, while maintaining more shrubs. This allows for more seed production which is beneficial for sagebrush reestablishment. The Ely chain consists of an anchor chain with attached steel bars, which can be welded at every link, every other link, or every third link (Stevens and Monson 2004). The chain is then dragged between two bulldozers in a “U” shape, half circle, or “J” shaped pattern with the “U” pattern providing the most vegetation disturbance (Vallentine 1980).

Mowing, which was implemented more frequently in the past, reduces upright species while retaining low-growing perennials and sprouting species (Vallentine 1980). It also minimized soil impacts unlike some of the other mechanical methods, and different heights could be attained.

The pipe, or Dixie harrow, is composed of small diameter, iron-spiked pipes that are dragged behind a spreader bar (Vallentine 1980). This technique has resulted in reductions of sagebrush of between 30-70%. According to Vallentine (1980), it typically uproots 10-20%

of bunchgrass species and slightly damages annuals and sprouting shrubs. Adequate soil disturbance is obtained for seed coverage.

The Lawson aerator is an apparatus specially designed for soil aeration and the chopping of small brush (Lawson Manufacturing Inc 2011). A large drum with spiraling horizontal blades can mulch brush from 6-10 cm in diameter.

Current restoration objectives differ from those of the 1940s; contemporary restoration plans recommend using strips on the order of 4-8 m. Connelly et al. (2000) advocate the retention of relatively high densities of shrub-canopy cover and treatment of no more than 20% of sage grouse breeding habitat at one time. Older treatments often included seeding with non-native grasses to increase forage palatability for domestic livestock; however, today's seeding should be done with native grasses and forbs if possible (Richards et al. 1998). Recommended seed mixtures often include a variety of shrubs, forbs, and bunchgrasses. In order to facilitate an improved herbaceous response, soil treatments that result in minimal soil disturbance have been advocated; minimal disturbance should create moisture retention, and storage capabilities (Rauzi 1975).

Olson and Whitson (2002) highlighted the importance of considering the possible impacts of annual grasses including field brome (*Bromus arvensis* L.) and cheatgrass (*Bromus tectorum* L.) when planning restoration projects. These grasses can readily colonize disturbed sites and could have a competitive advantage over native species, which should be weighed in the planning process. Hedrick et al. (1966) noticed an increase in cheatgrass and decrease in forbs on mechanically and chemically treated early seral sagebrush communities.

Prescribed fire/wildland fire treatments

Since the 1980s, prescribed fire has become a popular tool for sagebrush removal (Bunting et al. 1987). Like other treatment methods, the effects of fire are largely dependent on environmental factors and individual species and sub-species response. As noted by Bunting et al. (1987) different sagebrush species can have diverse responses to fire; restoration goals should take these unique interactions into account.

Wyoming big sagebrush stands are often difficult to treat with prescribed fire due to a lack of fine fuels (Bunting et al. 1987). Additionally, fire spread is limited by relatively low cover of sagebrush. Low amounts of fuel loading in Wyoming big sagebrush communities can be attributed to the aridity of the regions in which they grow; these areas typically

receive between 18-30 cm of precipitation per year (Wrobleski and Kauffman 2003). In accordance with this precipitation regime, Wyoming big sagebrush communities experience the longest fire–return interval of all the big sagebrush species which is estimated to be between 32-100 years; however, Wright and Bailey (1982) stated that 100 years might be on the lower end of fire frequency for these xeric communities.

While Wyoming big sagebrush will establish from seed post-fire, recurrent fire events may eliminate viable seed (Bunting et al. 1987). Bunting et al. (1987) found that recovery of these communities post-fire was often slower than that observed in other big sagebrush subspecies and that post-fire species diversity was low compared to other big sagebrush steppe vegetation. As Wyoming big sagebrush is a mid-to late- seral species, re-establishment after a fire can take up to 30 years (Wambolt et al. 2001). Baker (2006) suggests the complete recovery may take between 50-120 years.

Wambolt and Payne (1986) found that prescribed fire resulted in very little re-establishment of Wyoming big sagebrush six years after burning, despite seed availability from nearby shrubs. The treatment did increase bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), Sandberg bluegrass (*Poa secunda* J. Presl), total perennial grasses and total vegetation production. In a comparison of 4 different sagebrush treatments Watts and Wambolt (1996) also found that when compared with chemical and mechanical treatments, burning has the longest lasting impact on Wyoming big sagebrush reestablishment; sagebrush growth returned to those similar to control plots after 30 years.

Cheatgrass has become a dominant component of Wyoming big sagebrush communities throughout parts of Idaho, Nevada, and Oregon, and in these systems cheatgrass increases the probability of fire (Bunting et al. 1987). Fire-return intervals have been shortened to less than ten years in some affected areas (Knick et al. 2005), and more than 50% of native sagebrush steppe has been converted to annual grasslands (Knick 2002). Fires that used to burn in a mosaic pattern now leave little area unburned with few areas left to provide seed for native plant reestablishment (Miller and Eddleman 2001). Bottlebrush squirreltail (*Elymus elymoides* (Raf.) Swezey) may be the only native perennial bunchgrass species that increases in areas dominated by cheatgrass (Bunting et al. 1987). Rabbitbush (*Chrysothamnus* Nutt. spp. and *Ericameria* Pall. ssp.) may also increase in Wyoming big sagebrush communities that are exposed to repeated fires (Harniss and Murray 1973; Bunting et al. 1987).

Multiple factors must be considered when using prescribed fire as a restoration tool (Bunting et al. 1987; Miller 2002). Harniss and Murray (1973) noted the improvement of grass and forb yields given appropriate prescribed fire planning. Burn plots might for instance, need to be rested for up to two growing seasons to promote understory growth (Bunting et al. 1987), and the timing of prescribed burns also might be critical to exclude invasive species (Davies et al. 2007). Subsequent vegetation treatments may also need to be halted for up to 30 years to give sagebrush adequate time to re-establish. Wildlife habitat is also an important consideration. Wambolt et al. (2001) stated that empirical evidence supporting positive effects of fire on sage grouse habitat is lacking. The authors suggested that both short and long-term effects are detrimental to sage grouse habitat requirements as a result of loss of security cover and productivity.

Synergistic effects of grazing

The synergistic effects of grazing and sagebrush treatments are important to consider because restoration activities are likely to occur on lands with some level of grazing (S.Schulz, Rangeland Management Specialist, personal communications, August 2010). At a community level, severe grazing can lead to an increase in the density and cover of shrubs and annual grasses (Miller and Eddleman 1969). Vale (1974) noted a decrease in perennial forb species due to grazing. Baker (2006) and Vale (1974) suggested that biomass might be reduced and that grass and sedge health also might be affected. Loeser et al. (2007) reported that high severity grazing led to a decline in perennial forb cover and increase in annual plants, especially cheatgrass. A twofold increase in non-native plant cover was found at highly impacted sites following a severe drought. An increase in sagebrush and rabbitbrush has also been attributed to repeated severe grazing (Peters and Bunting 1994). In a study by Frischknect and Bleak (1957), young sagebrush far outnumbered their older counterparts where grazing use had been consistently severe.

Timing of grazing, climatic fluctuations, and landscape scale disturbances can impact community composition. Laycock (1967) observed that severe spring grazing caused an increase in sagebrush and cheatgrass while simultaneously decreasing perennial grasses and forbs. This decline in perennial grasses and forbs could be attributed to grazing the species during their active stages of growth (Laycock 1967). However, Bates (2009) concluded that

after one growth cycle post-fire, moderate grazing had little to no effect on recovery of the Wyoming big sagebrush community.

Vegetation Treatments in Western Wyoming

This study focused on Wyoming big sagebrush improvement efforts being conducted in the Upper Green River Basin of the Wyoming Basin in west-central Wyoming. Winter range vegetation transects conducted by the Bureau of Land Management (BLM) in 1994 indicated that the sagebrush community on the Pinedale Mesa lacked age-class diversity (USDI 2005). Many of the sagebrush present were classified as older, mature, or decadent with few young plants present. The latest ecological condition inventory, which was conducted in the mid-1980s classified 96% of the area surveyed as late or mid-seral stage (USDI 2007). Median sagebrush canopy cover was reported at 21%.

While herbicide application was the preferred method of vegetation treatments in the 1960s and 1970s, many different treatment types have been conducted in the region since the 1980s (USDI 2007). Prescribed fire is currently the most commonly used method, and over 2,630 ha of the Pinedale Anticline Project Area have been treated with fire or mechanical methods since 1988. These treatments were often conducted with the goal of improving livestock forage and big game winter habitat (USDA 2007).

QEP Energy, one of the primary companies working on the Pinedale Mesa, has been investigating methods of improving existing sagebrush habitat for a number of sagebrush obligate species in an effort to offset sagebrush steppe habitat losses incurred during natural gas development. In addition to providing habitat for greater sage-grouse, the area is considered crucial winter range for mule deer, and pronghorn use the Pinedale Mesa for much of the year. Crucial winter range is defined as the portion of winter range to which a species is confined during periods of heaviest snow cover (USDI 2007). Numerous other animal species are found on the Pinedale Mesa, including; pygmy rabbits, badgers (*Taxidea taxus*), white-tailed prairie dogs (*Cynomys leucurus*), red fox (*Vulpes vulpes*), coyotes (*Canis latrans*) and a variety of raptor species.

STUDY OBJECTIVES

This study was designed to determine how vegetation treatments affect shrub and herbaceous vegetation characteristics over time. Treatment areas were examined with the following objectives in mind:

Determine change in sagebrush cover, density, age-class distribution, and biomass production (kg/ha) resulting from each treatment.

Determine the change in cover of other shrubs after treatment.

Quantify changes in grass and forb cover and biomass (kg/ha) resulting from each treatment.

Determine how treatments affected species richness and diversity.

MATERIALS AND METHODS

Study area

The Pinedale Mesa is situated between the Green and New Fork Rivers, south of the town of Pinedale in west-central Wyoming (Figure 1). The Mesa itself is relatively flat with a mean elevation of 2,250 m, and encompasses approximately 31,000 ha (USDI 2005). The area is administered by the BLM (30,472 ha), the State of Wyoming (325 ha), and private land owners (647 ha). The Pinedale Mesa is part of the larger Pinedale Anticline Project Area (PAPA), which consists of over 80,000 ha (USDI 2005) and currently has over 600 producing oil and gas wells.

The region is semi-arid and continental with short, dry summers and long, cold winters. The hottest months of the year are July and August while the coldest are December and January (Western Regional Climate Center 2010). The January mean temperature is -10.8 C° while the mean temperature in July is 15.5 C° (Figure 2). For the duration of the study, maximum temperatures averaged by water year (October-September), have typically been above the 30-year average. Annual precipitation averaged 26.9cm over the 30 water-year period from 1970-71 through 1999-2000 (USDI 2007). Snowfall averages 147 cm occurring from October to April. Precipitation was consistently below the 30 year average from 2000-2003; however, 2004 and 2005 precipitation values were above the 30-year average (Figure 3) (Western Regional Climate Center 2007).

The project area is dominated by Wyoming big sagebrush. Other shrubs, found in lower densities include: low sagebrush (*Artemisia arbuscula* ssp. *longiloba* (Osterh.) L.M. Shulz), yellow rabbitbrush (*Chryosothamnus viscidiflorus* (Hook.) Nutt.), and antelope bitterbrush (*Purshia tridentata* (Pursh) DC).

Grasses found within the project area include: thickspike wheatgrass (*Elymus lanceolatus* Gould), Sandberg bluegrass, bottlebrush squirreltail, western wheatgrass, Letterman's needlegrass (*Achnatherum lettermanii* (Vasey) Barkworth), Indian ricegrass (*Achnatherum hymenoides* (Roemer & J.A. Schultes) Barrkworth), and prairie junegrass (*Koeleria macrantha* (Ledeb) J.A. Schultes). Forb species include: pussytoes (*Antennaria* Gaertn. spp.) milkvetch (*Astragalus* L. spp.), phlox (*Phlox* L. spp.), clover (*Trifolium* L. spp.), buckwheat (*Eriogonum* Michx. spp.) and desert yellow fleabane (*Erigeron linearis* (Hook.) Piper).

Within the project area, terrace soils can be found. These soils are nearly level, and typically deep, and extremely gravely or cobbly sub soils exist in certain locations. Soil in the area is a Gemdalin gravelly loam series. Quartzite cobbles, ranging from 10-40 cm in diameter, can be found in numerous locations on the Pinedale Anticline (USDI 2005).

Plot location

During the summer of 2006, ten 12-ha plots were established on the Pinedale Mesa as study sites (Figure.1). Plot locations were chosen with the assistance of employees from QEP Energy to avoid placement within areas of know future development. Care was taken to locate plots in areas that were homogeneous. Given the uniform topography of the Pinedale Mesa, differences in aspect and slope were easily minimized. Some plots investigated during initial project planning by the BLM in 2005 were moved due to unexpected energy development plans.

Vegetation monitoring was conducted before and after the implementation of the treatments. Pre-treatment monitoring was conducted during July and August of 2006. Post-treatment monitoring commenced during May of 2007 and continued during peak biomass production in the summers of 2008, 2009, 2010, and 2011. Four permanent, 60-m transects were randomly established in each plot. These transects were marked with rebar stakes, and UTM coordinates were taken with a Garmin GPS unit at each start and end point (Appendix A). Digital photos were taken from each start point. Slope, aspect, and elevation were

recorded. Each plot had two, approximately 3-ha subplots available for grazing and two, 3-ha subplots where grazing was excluded (Appendix A).

Treatments

Ten different treatments were implemented at the study sites. These treatments included: light tebuthiuron (Spike 20P) treatment, high tebuthiuron (Spike 20P) treatment, Dixie harrow, one-way chaining, Lawson aerator, low mowing (10 cm), medium mowing with forb seeding (15 cm), high mowing (35 cm), and prescribed burning. One site served as a control. To exclude grazing from half of each site, every site was subdivided, prior to grazing, with electric fencing. Fencing was removed after the 2009 data collection.

Treatments were assigned randomly to plots; however, a ground disruptive treatment was later assigned to another plot as the randomly chosen site had known sage-grouse nesting areas. Although each treatment was implemented at two paired plots, the lack of treatment replication at different sites resulted in pseudoreplication as detailed by Hurlbert (1984).

Approximately 11 kg of forb seed was distributed after the medium mowing treatment. The two forbs chosen for planting were: Rocky Mountain penstemon – Bandera (*Penstemon strictus* Benth) and Munro globemallow (*Sphaeralcea munroa* (Dougl.ex Lindl.) Spach ex Gray). Equal parts of each forb were included in the seed mixture. The light Spike 15 plot was treated with Spike 20P at a rate of ~0.9 kg a.i./ha; the high Spike plot was treated with ~1.9 kg a.i./ha.

Treatments occurred during the late summer/early fall of 2006. Responsibility for treatment implementation was divided among contributing agencies. The BLM completed the mowing and prescribed fire treatments while the Wyoming Game and Fish was responsible for treating the Lawson aerator and Dixie harrow plots. The Frontier Company applied the low and high tebuthiuron (Spike 20P) treatments. QEP Energy Production provided the Ely chain and heavy equipment operators.

Grazing treatments were subject to cattle drift across the Pinedale Anticline. Approximately 5,000-7,000 cattle are moved across the Anticline each year (USDI 2007). Cattle move north to U.S. Forest Service land at the end of June; return across the Anticline in October. Most livestock use is limited to less than two months a year. As a number of travel routes and water sources are available to stock, there is considerable variability in stock movement from one year to the next.

Vegetation measurements

To assess canopy cover of forbs, grasses, and shrubs, the canopy cover class method (Daubenmire 1959) was used. Measurements were taken within each of twenty 50 x 50-cm quadrats placed at the 3-m mark and every 3 m thereafter along each 60-m randomly located and oriented line transect. The quadrats were laid to the right of the transect line. Ground cover for all species was estimated using cover class categories. The cover classes were defined as: class 1=<1%, 2=1-5%, 3=5-10%, 4=10-25%, 5=25-50%, 6=50-75%, 7=>75%, 8=100%. Any species falling within or hanging over the frame was recorded. Ground cover estimations included the percent cover of litter, rock, and cryptogams. Mosses and lichen were included within the cryptogam category. Bare ground was recorded separately. Average herbaceous height was also measured and recorded for each quadrat.

Cover class midpoints were established to accurately determine the percent cover of each species per transect. Midpoint values are as follows: class 1=0.5%, 2=3%, 3=7.5%, 4=17.5%, 5=37.5%, 6=62.5%, 7=87.5%. Individual cover class values for each species were totaled for each transect. These values for each category were subsequently multiplied by their respective mid-point value. The resulting numbers were averaged to give the percent cover per species and growth form per transect.

Plant specimens were identified, collected, pressed, and stored at the University of Idaho. Nomenclature follows the USDA Plants Database accessed in January 2007 (USDA NRCS 2008). Plant specimens that were unidentifiable in the field were collected and analyzed at the University of Idaho Stillinger Herbarium. While over 1/3 of the forb species encountered could not be identified to species due to phenological stage or missing flower parts, these species were not often encountered and therefore contributed minimally to total forb cover values.

The line intercept method (Canfield 1941) was also used to estimate canopy cover of sagebrush. The length of all sagebrush touching or falling directly below the 60-m tape was measured. Gaps less than 10 cm were included. If a gap exceeded 10 cm, measurement resumed at the location of the next shrub. Dead shrubs were not measured.

Belt density measurements were taken to estimate sagebrush density. All sagebrush within a 1-m belt to the left of the 60-m transect were counted. Only those sagebrush plants rooted within the belt were counted. Sagebrush height and age classification were also

recorded for each plant. Four sagebrush age classes, (young, mature, decadent, and dead), were recorded. Young sagebrush was defined as those having basal stems less than 0.6 cm in diameter with simple branching on elongate growth. Mature sagebrush was defined as those plants having complex branching, with more than half of the crown comprised of living wood. The crowns of decadent sagebrush, on the other hand, were more than half dead. Dead plants were classified as those plants showing no sign of living tissue.

To estimate biomass production, five production clippings were taken pre- and post-treatment at 12-m spacing along the transect lines. Pre-and post-treatment clippings were taken in July in order to sample during peak productivity. All vegetation within the quadrat was clipped. The frame was placed 1 m to the right of the transect line. In order to not resample the same area in consecutive years, 1-m was added in each subsequent sampling year. Sagebrush, grass and forb species groups were collected and bagged separately in paper sacks. Specimens were dried in a fuels oven at 78º C for 24 hours and weighed with an Ohaus 200 digital scale.

Statistical analyses

A repeated measure analysis of variance (ANOVA) for a completely randomized factorial design was used to analyze data; SAS statistical software (SAS Institute 2004) was used. Due to the presences of zeros, species that were not consistently present in plots were aggregated by growth form. Species with the greatest summed presence over the six seasons of data were analyzed separately. Because grazing as a factor was not present in all years of the study, two different ANOVA's were conducted; one for the years in which grazing was a factor, and one for the years and plots where fencing was not present. For each variable-ANOVA combination four different covariance structures where tried and the best fit model was selected based upon the most favorable AIC value (Appendix B). Main effects and interaction were considered significant at an alpha level of 0.05. Appendix B provides a summary of the probability values for PROC MIXED and all repeated measures ANOVAs for all parameters. When significant interactions between main effects were detected the ANOVA was followed by a test for significance between treatments within years, as well as pairwise comparisons. Because grazing was rarely a significant factor, P-values reported are from the ANOVA in which grazing was not considered unless otherwise specified. PC-ORD software (PC-ORD 2011) was used to calculate Shannon-Weiner index values and species

richness. While data from all years can be found in the appendices, only 2006, 2007, and 2011 will be reported in the results section.

RESULTS AND DISCUSSION

Sampling seasonality, as well as year- to- year differences, was thought to have had a considerable effect on recorded changes in species cover, biomass, and diversity. Pre-treatment data were collected in July and August after many species, especially forbs had cured out. Post-treatment data were collected in late June and early July in order to coincide with peak biomass production. Differences in observers might also have contributed to inconsistencies in data collection.

Sagebrush characteristics

Sagebrush cover assessed with the line intercept method differed by treatment and year ($P = <0.0001$) (Table 1). Initially, treatments reduced average sagebrush cover from 14.6 to 8.7% and by the final year of the study, average cover had increased to 10.3% (Table 2). All treatments except the control and the light spike treatment resulted in a reduction of sagebrush cover. The medium mow treatment produced the greatest decrease in sagebrush cover with a pre-treatment average of 17.0% and a post-treatment average of 4.0%. The high spike treatment showed the least initial impact on sagebrush cover with a pre-treatment average of 15.3% and a first year post-treatment average of 13.3%.

As observed by Olson and Whitson (2002) and McDaniel et al. (2005), reduction of sagebrush cover by tebuthiuron treatments was more noticeable the second season following herbicide application. The low mow treatment also showed a further reduction in sagebrush cover the second year post treatment. By the final year of the study, all treatments including the control plot exhibited an increase in sagebrush cover relative to the first year post-treatment. The medium mow treatment showed the greatest increase going from an average of 4.0% first year post-treatment to 9.1% final post-treatment year, while the prescribed fire treatment showed the least recovery (8.5 to 10.3%) by the final year of the study.

Decadent sagebrush density declined on all treatments, and no decadent sagebrush shrubs were counted on seven of the plots after treatment (Table 3). Low densities of decadent sagebrush remained on the Dixie harrow and high mow treatments. By 2011

decadent sagebrush had returned on all plots except the low mow and Dixie harrow treatments. Density of decadent sagebrush on the control plot also initially decreased from 145.8 to 129.2 sagebrush/ha in 2007 and continued to decrease to 120.8 sagebrush per 0.1 ha in 2011. While treatment and year effects were significant (P= < 0.0001) (Table 1), grazing was not.

Initially, declines in mature sagebrush densities were seen on the low mow and prescribed fire sites post-treatment; all other plots including the control exhibited increases. By 2011 mature sagebrush density had increased on all plots except the high spike and low spike treatments. Treatment and year effects were significant (P = 0.0129, P= <0.0001, respectively) (Table 1).

Young sagebrush densities differed by treatment (P = 0.0307) and year (P = 0.0012) (Table 1), and decreased on all plots except those treated with Dixie harrow, chaining, control, and high mow (Table 3). By 2011, young sagebrush density had increased on all plots except the high mow treatment, which did not change, and the low spike and aerator treatments in which young age class decreased. The chaining treatment showed the greatest increase in young sagebrush, increasing from 75 to 2004 per 0.1 ha.

Dead (Table 1), and increased on all plots except Dixie harrow, medium mow, low mow, and the control. The low spike treatment resulted in the greatest initial increase in dead sagebrush. By 2011, dead sagebrush densities had increased on all plots except the medium mow plot. The greatest increase occurred on the high spike treatment, taking densities from 488 plants to 1246 plants per 0.1 ha (Table 3).

Based on total sagebrush counts, age class distribution has shifted little from pre to first year post- treatment, however a greater shift can be seen by the final post-treatment year. Mature sagebrush still made up the majority of the community (66%) (Figure 4), however there was an overall increase in young (15.3%) and dead sagebrush plants (14.2%). Decadent sagebrush decreased about 1% through the duration of the study.

Rabbitbrush was the only other shrub analyzed separately; all other shrubs were present in insufficient quantities for analyses. Rabbitbrush increased on all plots following treatment, and year (P = <0.0001) and treatment (P = 0.0003) (Table 1) effects were significant. Chaining had the greatest change in cover with the mean increasing from 2.7 to 6% (Table 2). By 2011 all plots had returned to cover levels similar to those of pre-treatment except the medium mow which increased from 2.8 to 4.1%.

Herbaceous species characteristics

Grasses. A total of eight grass species were recorded, however many were present in low amounts, so only the three most predominate grasses were analyzed separately. Appendix C and D provide mean pre- and post- treatment cover values for all herbaceous species for all years of the study.

Mean total grass cover differed by treatment (P = 0.0063) and year (P= <0.0001) (Table 1). Average total grass cover increased on all plots except for those treated with high mow and aerator (Table 3). The Dixie harrow treatment resulted in the greatest increase of grass cover (9.5 to 19.4%) while the aerator treatment resulted in the greatest decrease in grass cover (20.7 to 15.7%). The control treatment also exhibited an increase in total grass cover (13.9 to 20.4%), This trend was present for all grass species examined separately. By 2011, all treatments including the control decreased in mean grass production.

Changes in plot cover values for Letterman's needlegrass were similar to those of total grass cover, showing increases on all plots except those treated with high mow and aerator. The Dixie harrow treatment again showed the greatest increase in grass cover (0.2 to 4.6%) post-treatment, while the aerator treatment showed the greatest decrease (5.9 to 3.8%) (Table 4). It should also be noted that the high spike treatment yielded no change, and the control plot also exhibited an increase in cover (2.7 to 3.7%) Year and treatment effects were again significant (P = 0.0002 and (P=0.0001) (Table 1).

First year post-treatment, thickspike wheatgrass cover values increased on all plots except for the chaining and high mow plots. However, by the final year post-treatment all plots including the control showed decreased cover values. Chaining decreased thickspike wheatgrass cover (4.6 to 3.6%), and the high mow treatment remained the same (3.5%) (Table 4). Year effect was significant (P = <0.0001) (Table 1).

From pre-treatment to the first season post-treatment, increases in Sandberg bluegrass cover occurred on six of the ten plots including the control. Decreases in cover were observed on the low mow, high mow, low spike, and aerator treatments (Table 4). Year and treatment effects were significant for this species (P = <0.0005 and P = 0.0005) (Table 1). By the final year post-treatment all plots showed a decrease in the cover of Sandberg bluegrass with the greatest decrease documented in the prescribed fire plot (9.3 to 1.5%).

First year post-treatment, while total grass cover on all plots save those treated with high mow and the aerator increased, grass biomass declined on all treatments except the control and low spike (Table 5). The greatest decline in grass biomass was observed on the Dixie harrow site (272.3 to 86.6 kg/ha). By the conclusion of the study, grass biomass declined on all plots except the control, which increased from 41.65% in 2007 to 44.68% in 2011. Year, grazing, and treatment effects were significant (P =<0.0001) (Appendix B).

Forbs. Thirty two species of forbs were recorded over the 6 years of field study, however many were erratically present in plots. Due to these inconsistencies, only three species were analyzed separately; all others were included as part of total forb cover value. Total forb cover increased across all plots in the year immediately following treatment, and then decreased to similar or lower levels than pre-treatment by 2011 (Table 6). The greatest increase of total forbs occurred on the prescribed fire treatment (6.5 to 16.5%). A significant effect was found for treatment (P = 0.0026) and year (P = <0.0001) (Table 1). These results were similar for the analyses of individual species as well, and the two forbs seeded on the medium mow site were not detected post-treatment.

Desert yellow fleabane values changed slightly depending on treatment (Table 6). The greatest increase (1.5 to 2.4%) was recorded on the medium mow site while the greatest decrease (6.4 to 4.8%) occurred on the high mow plot. By 2011, this species had decreased on all plots.

Granite prickly phlox cover values also differed between plots; the greatest decrease in cover (4.6 to 2.4%) was observed on the aerator plot. The greatest increase in cover was seen on the control plot (1.1 to 2.2%). In the final year of the study, granite prickly phlox had decreased on all plots except for the aerator treatment which actually increased (2.4 to 3.0%). Spiny phlox also increased on for all treatments (Table 6) post-treatment. Greatest increases occurred on the aerator and low mow treatment plots. By the final year of the study, cover values had decreased to levels below those of pre-treatment.

In the year following treatment, forb biomass declines were observed on the chaining, low mow, and aerator treatment sites. All other plots demonstrated an increase in forb biomass with the greatest increase on the high mow plot (13.8 to 61.0 kg/ha) (Table 5). In the final year of the study, an increase of forb biomass was recorded for chaining, and high spike treatments; all other plots exhibited a decrease. No grazing effect was detected, however, a year effect (P= <0.0001) was present (Table 1).

Bare ground and litter. Bare ground decreased for all plots post-treatment, including the control (Table 8). The greatest decrease in percent of bare ground occurred on the Dixie harrow treatment (54.4 to 21.1%). By the final year of the study, bare ground had increased on all plots except prescribed fire, which decreased from 23.6% in 2007 to 21.75% in 2011. Significant effects for treatment (P = 0.0489) and year (P = < 0.0001) were found (Table 1). Litter decreased on the control, prescribed fire, high mow, aerator, and light spike treatments with the control plot showing the greatest decrease (43.69 to 23.51%). All other plots increased in litter post-treatment. In the final year of the study, litter declined on all study plots except the Dixie harrow, aerator, and prescribed fire which increased in litter amounts. The greatest decrease occurred on the low spike treatment (25.6 to 7.5%), while the greatest increase occurred on the aerator treatment (25.4 to 27.9%) Treatment and year were significant (P =<0.0001) (Table 1).

Species richness and diversity. Species richness and the Shannon-Wiener diversity index increased across all plots post- treatment (Table 7). On average richness increased from 15 to 19 species, and the greatest number of species (33) was found on the Dixie harrow plot. While individual plot richness fluctuated for all plots, overall mean richness increased to 19 by 2011. Treatment and year effects were significant (P = 0.0002 and P<0.0001 respectively) (Table 1). The Shannon-Wiener index averaged across all plots increased from 1.78 to 2.23 during the first year post treatment. Again, the Dixie harrow treatment showed the greatest improvement increasing from 1.75 to 2.73. By the final year of the study the chaining, control, low and medium mow, and high spike all displayed increases in diversity while the remaining plots exhibited a decrease. For diversity, only the year effect was significant (P =<0.0001) (Table 1).

CONCLUSIONS

All treatments had some effect on the sagebrush community we studied, however, recommendation of treatment type should be based upon desired vegetation characteristics and treatment objectives. The Dixie harrow, medium mow, and prescribed fire treatments resulted in initial reduction of sagebrush cover and density, while at the same time retaining an age-class distribution similar to that of pre-treatment. Only the low mow treatment exhibited an increase of rabbitbrush post-treatment.

The Dixie harrow treatment exhibited the greatest increases in total grass cover but also the greatest decrease in grass biomass. Forb cover post-treatment was greatest on the prescribed fire plot, while the medium mow treatment showed the greatest increase in forb biomass. Trends for both grasses and forbs were similar to those measured for the control plot. While many of the treatments showed an initial increase in grasses and forbs most had decreased to pre-treatment levels by the end of the study. Species richness and diversity increased the most on the Dixie harrow plot, however, increases in diversity were also exhibited on the chaining, medium mow, and control treatments.

MANAGEMENT IMPLICATIONS

This study was designed to investigate long-term changes from treatments in this vegetative community. Certain treatment effects may take longer to appear than others, and while we are able to see initial changes, long-term data should be collected to better discern among treatment characteristics. A minimum of 10 years post-treatment monitoring is recommended (USDI 2006). However, for projects such as this one where vegetation recovery may take many years, more information might be obtained by collecting data at 5, 10, 15, and 20 years post-treatment.

Grazing was examined the first three of the five post-treatment seasons and was a significant effect only for grass biomass. It is possible that impacts of grazing take more time to manifest and a longer duration study would be necessary to detect significant effects for other grass parameters.

While there was statistically significant difference among treatments, the control plot often followed similar trends to those of other treatments for all study years. Additionally, treatments did not significantly affect species diversity. It is possible that more emphasis should be placed on seasonal temperature and precipitation variation, timing of data collection, and site conditions to explain differences in forb and grass characteristics and production.

Treatments such as Dixie harrow, medium mow, and prescribed fire may help to achieve restoration goals. These are the plots that retained some sagebrush cover while also simultaneously showing an increase in herbaceous understory. Before any restoration treatment is conducted, the sagebrush community should first be assessed for current

composition, as well as to identify treatment goals and objectives. If treatment is determined to be an appropriate management action, those treatments that minimize community disturbance and retain function are advocated. Retention of a predetermined sagebrush overstory and herbaceous understory may help to minimize invasion by non-native species and provide critical habitat for sagebrush-steppe obligates.

LITERATURE CITED

Baker, W.L. 2006. Fire and restoration of sagebrush ecosystems. *Wildlife Society Bulletin* 34:177-185.

Baker, W.L. and D. Ehle. 2001. Uncertainty in surface-fire history: the case of ponderosa pine forests in the western United States. *Canadian Journal of Forest Research* 31:1205-1226.

Barnes, O.K. 1952. Mechanical treatments on Wyoming range land. *Journal of Range Management* 3:198-203.

Barnett, J.K. and J.A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon. *Journal of Range Management* 47:114-118.

Bates, J.D., E.C. Rhodes, K.W. Davies, and R. Sharp. 2009. Postfire succession in big sagebrush steppe with livestock grazing. *Rangeland Ecology and Management* 62:98-110.

Baxter, G. 1998. Thinning Dense Sagebrush Stands with Spike 20P. *Rangelands* 20:14-16.

Bleak , A. T. and W.G. Miller. 1955. Sagebrush seedling production as related to time of mechanical eradication. *Journal of Range Management* 8:66-69.

Britton, C.M., and F.A. Sneva. 1983. Big sagebrush control with tebuthiuron. *Journal of Range Management* 36:707-708.

Bunting, S.C., B.M. Kilgore, and C.L. Bushey. 1987. Guidelines for prescribed burning in sagebrush-grass rangelands in the Northern Great Basin. Ogden, UT, USA: US Department of Agriculture, Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-231. 33 p.

Canfield, R. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:386-394.

Chambers, J.C. and M.J. Wisdom. 2009. Priority research and management issues for the imperiled Great Basin of the western United States. *Restoration Ecology* 17:707-714.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.

Daubenmire, R.F. 1959. A canopy-coverage method of vegetation analysis. *Northwest Science* 33:224-227.

Davies, K.W,. J.D. Bates, and R.F. Miller. 2007. Short-term effects of burning Wyoming big sagebrush steppe in southeast Oregon. *Rangeland Ecology and Management* 60: 515-522.

Dobkin, D.S. and J.D. Sauder. 2004. Shrubsteppe landscapes in jeopardy. Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR.: 194 p.

DowAgroSciences. 2011. Improve rangeland with Spike 20P herbicide. Available at: http://www.dowagro.com/PublishedLiterature. Accessed 17 February 2011.

Drut, M.S., W.H. Pyle, and J.A. Crawford. 1994. Technical Note: Diets and food selection of sage grouse chicks in Oregon. *Journal of Range Management* 47:90-93.

Fairchild, J.A., J.N. Davis, and J.D. Brotherson. 2005. Big sagebrush response to one-way and two-way chaining in southeastern Utah. *In*: Shaw, N.L., M. Pellant, and S.B. Monsen [COMPS.]. Proceedings: Sage-grouse Habitat Restoration Symposium; 4-7 June 2001; Boise, ID, USA: Fort Collins, CO, USA: US Department of Agriculture, Forest Service, RMRS-P-38. p. 70-74.

Frischknecht, N. C. and A. T. Bleak. 1957. Encroachment of big sagebrush on seeded range in
northeastern Nevada. *Journal of Range Management* 10:165-170.

Harness, R.O. and R.B. Murray. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. *Journal of Range Management* 26:322-325.

Hedrick, D.W., D.N. Hyder, F.A. Sneva, and C.E. Poulton. 1966. Ecological response of sagebrush-grass range in central Oregon to mechanical and chemical removal of *Artemisia*. *Ecology* 47:432-439.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187-211.

Johnson, R.J. and G.F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences. *Journal of Range Management* 21:209-212.

Johnson, W.M. 1969. Life expectancy of sagebrush control in central Wyoming. *Journal of Range Management* 22:177-182.

Knick, S.T. 2002. What will we do with all the GIS maps? A spatial view of restoration in the Great Basin. 4-8 November 2002; Elko, NV, USA: Restoration and Management of Sagebrush/Grass Communities Workshop. 3 p.

Knick, S. T., A.L. Holmes, and R.F. Miller. 2005. The role of fire in structuring sagebrush habitats and bird communities. *Studies of Avian Biology* 30:63-75.

Laycock W.A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. *Journal of Range Management* 20:206-213.

Lawson Manufacturing Inc. 2008. Single-drum pasture aerator. Available at: http://www.lawsonaerator.com/Single_drum_pasture_aerator.asp. Accessed 18 February 2011.

Loeser, M.R.R., T.D. Sisk, and T.E. Crews. 2007. Impact of grazing intensity during drought in an Arizona grassland. *Conservation Biology* 21:87-97.

McAdoo, J.K., S.R. Swanson, B. Schultz, and P.F. Brussard. 2002. Habitat requirements of sagebrush-associated species and implications for management. 4-8 November 2002; Elko, NV, USA: Restoration and Management of Sagebrush/Grass Communities Workshop. 4 p.

McDaniel, K.C., L.A. Torell, and C.G. Ochoa. 2005. Wyoming big sagebrush recovery and understory response with tebuthiuron control. *Rangeland Ecology and Management* 58:65-76.

Miller, R.F. and L.L. Eddleman. 2001. Spatial and temporal changes of sage grouse habitat in the sagebrush biome. Technical Bulletin 151, Corvallis, OR: Oregon State University Agricultural Experiment Station. 35 p.

PC-ORD. 2011. Multivariate Analysis of Ecological Data. Version 6. MjM Software, Gleneden Beach, Oregon, U.S.A.

Olson, R.A. and T.D. Whitson. 2002. Restoring structure in late-successional sagebrush communities by thinning with tebuthiuron. *Restoration Ecology* 10:146-155.

Peters, E.F. and S.C. Bunting. 1994. Fire condition pre-and post-occurrence of annual grasses on the Snake River Plain. *In* S.B. Monsen and S.G. Kitchen [EDS.]. Proceedings – Ecology and management of annual rangelands; 18-22 May 1992; Boise, ID. USA. General Technical Report INT-GTR-313, Ogden, UT:. US Department of Agriculture, Forest Service, Intermountain Research Station. Pp. 31-36.

SAS Institute. 2011. SAS 9.1.3 Service Pack 3, Cary, NC, USA: SAS Institute, Inc.

Stevens, R. and S.B. Monsen. 2004. Mechanical plant control. *In*: S.B. Monsen, R. Stevens, and N.L. Shaw [EDS.]. Restoring western ranges and wildlands. General Technical Report RMRS-GTR-136-vol-1, Ft. Collins, CO, USA: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pp. 65-87.

Rauzi, F. 1975. Severe mechanical and chemical range renovation in northeastern Wyoming. *Journal of Range Management* 28:319-326.

Richards, R.T., J.C. Chambers, and C. Ross. 1998. Use of native plants on federal lands: Policy and practice. *Journal of Range Management* 51:625-632.

Rowland, M.M. 2004. Effects of management practices on grassland birds: Greater sage-grouse. Jamestown, N.D.: Northern Prairie Wildlife Research Center. 47 p.

USDA, NRCS. 2011. The PLANTS Database available at: http://plants.usda.gov. Accessed, 28 November 2011.

USDI Bureau of Land Management. 2005. Environmental assessment Mesa sagebrush enhancement. Pinedale Field Office. Sublette County, Wyoming. 29 p.

USDI Bureau of Land Management. 2007. DRAFT Environmental Impact Statement for the Pinedale Resource Management Plan. Pinedale Field Office. Sublette County, Wyoming.
Vale, T.R. 1974. Sagebrush conversion projects: An element of contemporary environmental change in the Western United States. *Biological Conservation* 6:274-284.

Vallentine, J.F.1980. Range developments and improvements. 2nd edition. Provo, UT, USA: Brigham Young University Press. 545 p.

Watts, M.J. and C.L. Wambolt. 1996. Long-term recovery of Wyoming big sagebrush after four treatments. *Journal of Environmental Management* 46:95-102.

Wambolt, C.L. and G.F. Payne. 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. *Journal of Range Management* 39:314-319.

Wambolt, C.L., K.S. Walhof, and M.R. Frisina. 2001. Recovery of big sagebrush communities after burning in south-western Montana. *Journal of Environmental Management* 61:243-252.

Welch, B.L. and C. Criddle. 2003. Countering misinformation concerning big sagebrush. Research Paper. Ogden, UT, USA: US Department of Agriculture, Forest Service, RMRS-RP-40. 28 p.

Western Regional Climate Center. 2010. Wyoming Climate Summaries. Available at: http://www.wrcc.dri.edu/summary/Climsmwy.html. Accessed on 30 March 2010.

Winward, A.H. 1991. A renewed commitment to management of sagebrush grasslands. *In:* Management in the sagebrush steppe. Special Report 880. Corvallis, OR: Oregon State University Agricultural Experiment Station. Pp. 2-7.

Wright, H.A. and A.W. Bailey. 1982. Fire Ecology, United States and Southern Canada. NewYork, USA: John Wiley & Sons. 546 p.

Wrobleski, D.W. and J.B. Kauffman. 2003. Initial effects of prescribed fire on morphology, abundance, and phenology of forbs in big sagebrush communities in Southeastern Oregon. *Restoration Ecology* 11:82-90.

Wyoming Interagency Vegetation Committee. 2002. Wyoming guideline for managing sagebrush communities with emphasis on fire management. Cheyenne, WY: Wyoming Game and Fish Department and Wyoming BLM. 53 p.

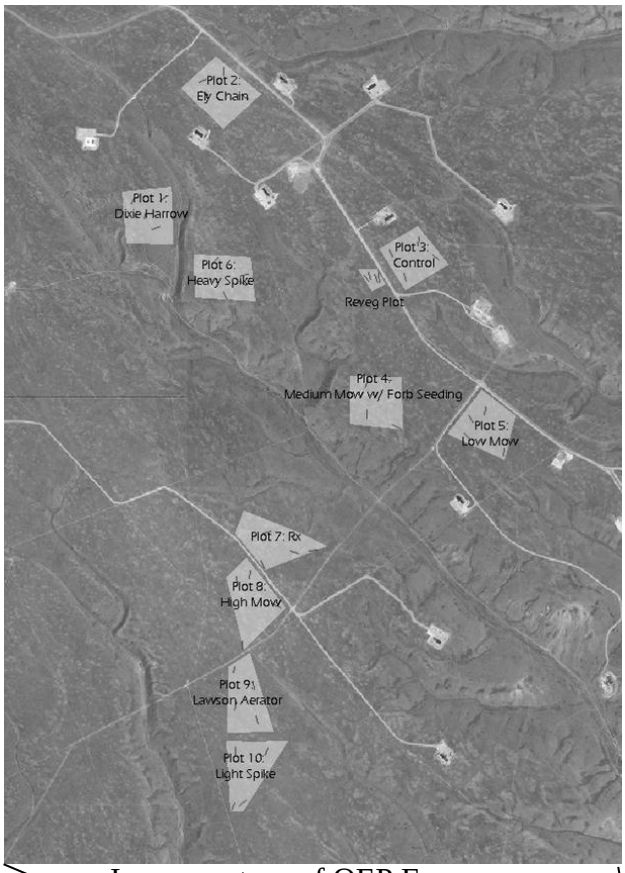
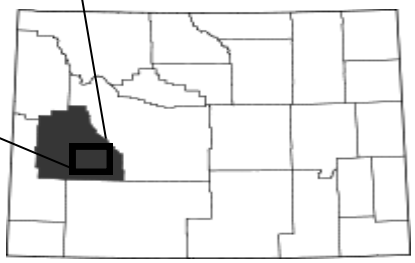


Image curtsey of QEP Energy



N

Sublette County (in grey), Wyoming

Figure 1. Map of study plots and transects on the Pinedale Mesa, Sublette County, Wyoming.

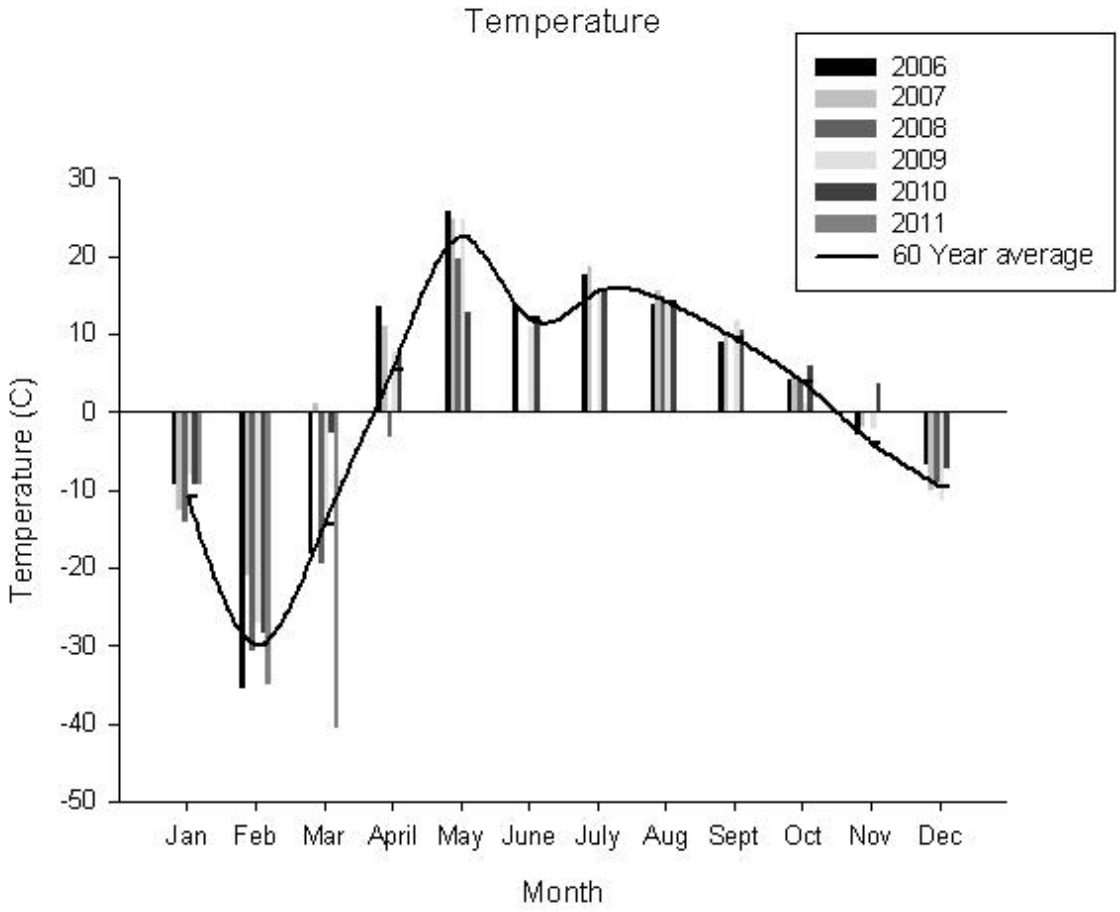


Figure 2. Mean temperature by month between 2006 and 2011 compared to the 60-year average for a Wyoming big sagebrush community study near Pinedale, Wyoming. Missing bars denote a lack of available data. Information obtained from Western Regional Climate Center.

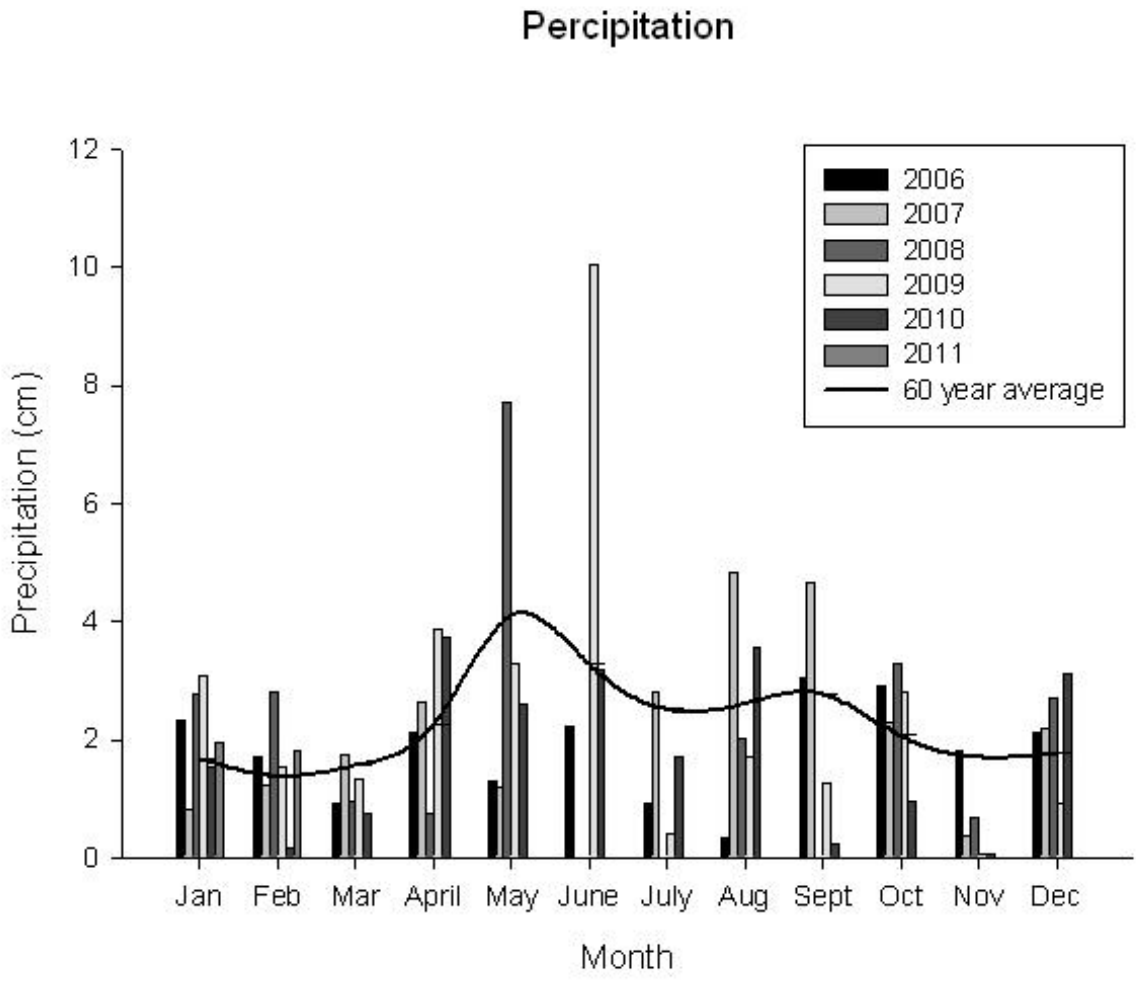


Figure 3. Mean precipitation by month compared to the 60-year average for a Wyoming big sagebrush community study near Pinedale, Wyoming. Missing bars denote a lack of available data. Information obtained from Western Regional Climate Center.

Table 1. P-values, best fit co-variance model, and results of check of residuals for treatment*grazing repeat measure ANOVA. Co-variance models are as follows; UN denotes unstructured, ARH1 denotes heterogeneous autoregressive, AR 1 denotes autoregressive, and CS denotes compound symmetry. Y denotes that the residuals met model assumptions, N denotes they did not.

Metric	Year and Treatment Repeat measures ANOVA				
Ground Cover	Treatment	Year	Treatment*year	Covarience	Residual check
Poa secunda	0.0005	<.0001	<.0001	UN	Y
Elymus lancelatus	0.2073	<.0001	<.0001	ARH1	Y
Achantherum lett	0.0002	0.0001	0.0016	UN	Y
Perienial grasses	0.0091	<.0001	<.0001	ARH1	Y
Phlox hoodii	0.0949	<.0001	<.0001	UN	Y
Lianthus pungens	0.1842	<.0001	0.0004	UN	Y
Erigeron linearis	<.0001	<.0001	<.0001	UN	N
Perienial forb	0.0435	<.0001	<.0001	UN	Y
Artemisia tridentata	0.0005	<.0001	0.0199	ARH1	Y
Chrysothamnus vis	0.0003	<.0001	0.0005	UN	Y
Other brush	0.0018	<.0001	0.0214	ARH1	Y
Grass	<.0001	<.0001	<.0001	UN	Y
Forb	0.0026	<.0001	0.1552	CS	Y
All shrub	0.0003	<.0001	0.0018	ARH1	Y
Litter	<.0001	<.0001	<.0001	ARH1	Y
Bare ground	0.0489	<.0001	0.0004	CS	Y
Biomass					
Grass	0.0005	<.0001	<.0001	ARH1	Y
Forb	0.1129	<.0001	0.001	ARH1	Y
Belt density					
Young	0.0307	0.0012	<.0001	ARH1	Y
Mature	0.0129	<.0001	<.0001	UN	Y
Decadent	<.0001	<.0001	<.0001	ARH1	Y
Dead	0.0008	<.0001	<.0001	UN	Y
Cover					
Line Intercept	<.0001	<.0001	<.0001	UN	Y
Cover class	0.0017	<.0001	0.0388	ARH1	Y
Richness and Diversity					
Richness	0.0002	<.0001	0.1204	ARH1	Y
Diversity	0.1101	<.0001	0.002	UN	Y

Table 2. Sagebrush and rabbitbrush cover values (mean ± se) after vegetation treatments in a Wyoming big sagebrush community in western Wyoming.

	Artimisia tridentata spp. *wyomiensis* (Line Intercept)			*Chrysothamnus viscidiflorus* (Cover class)			Shrub total (Cover Class)		
	Cover (%)								
Treatment	2006	2007	2011*	2006	2007	2011	2006*	2007 *	2011
Control	10.2 ± 1.5 a	12.4 ± 1.5	17.5 ± 0.3 a	4.3 ± 1.4	6.5 ± 0.8	3.5 ± 0.4	21. 2 ± 1.3 ab	23.6 ± 1.8	15.0 ± 1.1 bcf
Dixie Harrow	13.5 ± 1.1 ab	6.8 ± .7	9.5 ± 0.8 ab	1.6 ± 0.9	1.7 ± 0.5	1.7 ± 0.5	17.5 ± 1.1 ab	11.3 ± 1.9	6.0 ± 0 .8 ade
Chaining	9.8 ± 0.3 ab	7.1 ± 1.1	11.7 ± 0.8 ab	2.7 ± 0.6	6.0 ± 1.0	4.3 ± 0.3	12.5 ± 1.9 a	14 ± 2.1	12 ± 1.8 ace
Aerator	15.4 ± 0.3 ab	5.5 ± 1.6	9.8 ± 1.0 ab	2.7 ± 0.6	2.8 ± 0.5	1.1 ± 0.3	24.1 ± 2.0 ab	10.7 ± 1.2	7.4 ± 0.5 ade
Low Mow	11.4 ± 1.5 ab	1.3 ± .4	3.6 ± 0.4 b	1.8 ± 0.6	2.8 ± 0.4	4.1 ± 1.5	19.2 ± 3.1 ab	5.6 ± 0.3	6.1 ± 1.5 ade
Med Mow	17 ± 0.8 ab	4 ± 1.0	9.1 ± 2.0 b	1.5 ± 0.4	2.6 ± 0.9	1.6 ± 0.6	19.3 ± 3.9 ab	10.4 ± 2.4	6.6 ± 0.5 ade
High Mow	17.5 ± 1.7 ab	9.5 ± 1.8	13.7 ± 1.4 ab	1.1 ± 0.5	1.7 ± 0.5	0.8 ± 0.2	24.0 ± 5.1 ab	18.2 ± 3.3	9.9 ± 0.8 ade
Low Spike	17.5 ± 2.5 ab	18.2 ± 3.3	14.8 ± 1.4 ab	3.1 ± 0.8	3.5 ± 1.0	1.4 ± 0.7	24.6 ± 1.7 ab	22.8 ± 4.5	10.7 ± 1.0 adf
High Spike	15.7 ± 2.1 ab	13.3 ± 1.6	6.8 ± 3.7 ab	2.5 ± 0.9	3.1 ± 1.0	1.3 ± 0.6	22.7 ± 1.1 ab	15.1 ± 3.6	4.0 ± 1.7 adf
Prescribed Fire	17.5 ± 1.7 b	8.5 ± 2.3	7.8 ± 3.2 ab	2.5 ± 1.0	3.2 ± 0.5	2.4 ± 1.4	31. 3 ± 4.8 b	14.2 ± 2.3	10.5 ± 2.7 ade
Mean	14.9 ± 0.7	8.7 ± 0.9	10.7 ± 0.8	2.4 ± 0.3	3.4 ± 0.3	2.2 ± 0.3	21.6 ± 1.1	14.6 ± 1.1	8.8 ± 0.6

Cover estimates were obtained using either line intercept method or the Daubenmire (1959) cover class method. *Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 3. Density values (mean ± se) by age class after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

Belt density (mean ± se) in 1/10 ha by age class by treatment by year												
	Young (1/10 ha)			Mature (1/10 ha)			Decadant (1/10 ha)			Dead (1/10 ha)		
Treatment	2006	2007	2011*	2006	2007	2011*	2006	2007	2011*	2006	2007	2011*
Control	133.3 ± 32.6 a	137. 5 ± 38.1	175.0 ± 16.0 a	1325.0 ± 101.0	2054. 2 ± 169.6	2104.2 ± 92.4 ab	145. 8 ± 18.5	129.2 ± 29.9	120.8 ± 31.5 ab	104.2 ± 24.9	75. 0 ± 25.9	162.5 ± 8.0 a
Dixie Harrow	45.8 ± 10.5 a	91.7 ± 19.8	104.0 ± 23.9 a	1520.8 ± 123.9	1862.5 ± 186.4	2412.5 ± 200.2 a	75 ± 22.0	8.3 ± 8.3	0 ± 0 a	108.3 ± 40.0	91. 7 ± 38.8	141.7 ± 14.4 a
Chaining	50.0 ± 11.8 a	75.0 ± 14.4	1004.2 ± 734.1 b	1270.83 ± 326.1	1325.0 ± 101.0	1779.2 ± 98.2 a	66.7 ± 18.0	0 ± 0	29.1 ± 8.0 a	95.8 ± 22.9	100.0 ± 15.2	308.3 ± 45.9 a
Aerator	308.3 ± 92.4 a	166.7 ± 28.1	108.3 ± 45.4 a	1329.2 ± 170.8	1629.2 ± 130.2	2079.2 ± 153.0 a	108.3 ± 14.4	0 ± 0	141.7 ± 38.8 ab	100.0 ± 22.6	412.5 ± 213.5	604.2 ± 158.6 ab
Low Mow	179.2 ± 23.9 a	154.2 ± 35.6	579.2 ± 248.8 a	1162.5 ± 25.8	870.8 ± 105.3	991.7 ± 52.9 ab	79.2 ± 37.5	0 ± 0	0 ± 0 a	154.2 ± 32.2	4.2 ± 4.2	16.7 ± 6.8 a
Med Mow	87.5 ± 15.8 a	83.3 ± 13.6	312.5 ± 167.5 a	1462. 5 ± 105.7	1545.83 ± 305.8	1783.3 ± 285.6 b	129.2 ± 34.9	0 ± 0	145.8 ± 21.9 ab	133.3 ± 32.6	37.5 ± 21.9	33.3 ± 22.6 a
High Mow	16.7 ± 9.6 a	70.8 ± 33.6	70.8 ± 17.2 a	1254.2 ± 86.0	1412.5 ± 236.8	1683.3 ± 171.7 ab	91.7 ± 21.0	20.8 ± 15.8	220.8 ± 10.5 b	54.2 ± 4.2	116.7 ± 16.7	195.8 ± 24.9 a
Low Spike	625.0 ± 162.0 b	266.7 ± 65.6	254.2 ± 40.5 a	1358.3 ± 80.7	2479.2 ± 378.7	2070.8 ± 307.0 a	250.0 ± 70.4	0 ± 0	250.0 ± 70.4 b	50.0 ± 15.2	358.3 ± 232.8	583.3 ± 216.6 ab
High Spike	79.2 ± 21.9 a	58.3 ± 10.8	137.5 ± 66.1 a	1558.3 ± 167.4	1900.0 ± 212.2	958.3 ± 285.3 b	62.5 ± 17.2	0 ± 0	100.0 ± 18.0 ab	87.5 ± 18.5	487.5 ± 272.6	1245.8 ± 370.3 b
Prescribed Fire	83.3 ± 24.5 a	62.5 ± 23.9	150.0 ± 50.0 a	1454.2 ± 67.1	1070.8 ± 441.1	1395.8 ± 299.7 bc	91.7 ± 24.1	0 ± 0	133.3 ± 44.1 ab	54.2 ± 14.2	283.3 ± 43.0	388.9 ± 102.9 a
Mean	160.0 ± 32.7	116.7 ± 13.4	395.7 ± 116.2	1369.6 ± 45.3	1602.5 ± 104.2	1709.8 ± 97.1	95.4 ± 7.8	15.8 ± 6.9	117.1 ± 15.4	94.2 ± 8.6	196.7 ± 45.5	367.5 ± 71.4

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 4. Cover values for the most prevalent grass species and total grass (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Achanatherum lettermanii			*Elymus lancelolatus*		
	Cover (%)					
Treatment	2006*	2007	2011	2006	2007	2011
Control	2.7 ± 0.8 ab	3.7 ± 0.9	1.8 ± .3 ab	3.6 ± 0.3	4.4 ± 0.5	0.6 ± 0.5
Dixie Harrow	0.2 ± .2 a	4.6 ± 1.8	0.9 ± 0.2 ab	3.3 ± 1.0	3.7 ± 0.5	0.6 ± 0.1
Chaining	0.7 ± 0.5 a	3.3 ± 1.2	0 .9 ± 0.4 ab	4.6 ± 1.2	3.6 ± 0.3	0.6 ± 0.3
Aerator	5.9 ± 2.0 b	3.8 ± 1.0	3.0 ± 0.6 a	2.8 ± 0.3	3.2 ± 0.8	0.6 ± 0.1
Low Mow	3.5 ± 0.5 ab	4.8 ± 1.1	2.3 ± 0.3 ab	2.0 ± 0.4	3.7 ± 0.4	0.8 ± 0.1
Med Mow	2.0 ± 0.8 ab	4.5 ± 2.2	2.3 ± 0.9 ab	3.1 ± 0.5	3.9 ± 0.5	0.7 ± 0.1
High Mow	3.1 ± 0.9 ab	2.0 ± 1.1	2.0 ± 0.1 ab	3.5 ± 0.3	3.5 ± 0.3	0.8 ± 0.1
Low Spike	0.9 ± 0.5 ab	1.4 ± 0.8	0.4 ± 0.01 b	3.4 ± 0.2	4.0 ± 0.6	0.6 ± 0.2
High Spike	2.8 ± 1.3 ab	2.8 ± 1.1	1.7 ± 1.0 ab	2.6 ± 0.4	3.1 ± 0.1	0.5 ± 0.2
Prescribed Fire	2.2 ± 0.4 ab	3.1 ± 1.0	1.3 ± 0.1 ab	2.4 ± 0.5	4.7 ± 0.4	0.6 ± 0.1
Mean	2.4 ± 0.4	3.4 ± 0.39	1.7 ± 0.2	3.1 ± 0.2	3.8 ± 0.2	0.6 ± 0.04
	Poa secunda			Grass Total		
	Cover (%)					
Treatment	2006*	2007	2011	2006*	2007*	2011
Control	5.4 ± 0.9 a	9.0 ± 0.6	2.5 ± 0.5	13.86 ± 1.15 ab	20.4 ± 2.2	5.4 ± 0.8
Dixie Harrow	5.1 ± 0.9 a	9.8 ± 0.8	4.2 ± 0.5	9.51 ± 1.79 a	19.4 ± 2.8	6.1 ± 0.5
Chaining	3.0 ± 0.6 a	9.8 ± 0.8	4.2 ± 0.5	8.38 ± 0.90 a	14.5 ± 2.6	4.6 ± 0.8
Aerator	10.7 ± 1.1 b	7.0 ± 0.4	1.0 ± 0.4	20.67 ± 2.19 b	15.7 ± 1.2	5.0 ± 0.3
Low Mow	10.2 ± 0.8 b	9.3 ± 0.7	2.1 ± 0.8	21.43 ± 3.05 b	24.3 ± 0.8	5.9 ± 0.5
Med Mow	7.0 ± 0.7 ab	7.5 ± 1.4	2.6 ± 0.9	14.86 ± 1.37 ab	20.6 ± 0.8	6.0 ± 0.8
High Mow	9.3 ± 1.3 ab	8.5 ± 1.0	2.9 ± 0.6	16.76 ± 0.71 ab	15.0 ± 2.6	5.8 ±0.6
Low Spike	8.5 ± 1.5 ab	4.9 ± 2.1	1.7 ± 0.2	15.65 ± 2.41 ab	16.5 ± 3.4	3.5 ± 0.2
High Spike	4.1 ± 0.5 a	6.3 ± 0.2	2.6 ± 0.7	10.78 ± 1.71 a	15.8 ± 1.2	5.8 ± 1.1
Prescribed Fire	8.0 ± 1.3 ab	9.3 ± 1.4	1.5 ± 0.1	14.46 ± 1.10 ab	19.1 ± 2.8	5.8 ± 1.1
Mean	7.1 ± 0.5	7.8 ± 0.4	2.4 ± 0.2	14.63 ± 0.82 a	18.1 ± 0 .8	5.3 ± 0.2

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 5. Grass and forb biomass values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

Biomass	Grass (kg/ha)			Forbs (kg/ha)		
Treatment	2006*	2007	2011	2006	2007	2011
Control	184 .5 ± 29.6	196.7 ± 48.5	56.1 ± 3.4	4.5 ± 4.5	33.7 ± 13.1	29.61 ± 4.05 ab
Dixie Harrow	272.3 ± 80.1	86.5 ± 16.7	61.7 ± 11.1	46.3 ± 28.4	50.8 ± 17.9	14.13 ± 1.29 a
Chaining	149.5 ± 41.0	41.7 ± 8.1	44.7 ± 5.2	35.5 ± 19.8	11.2 ± 4.4	21.58 ± 1.64 ab
Aerator	233.3 ± 31.7	163.4 ± 14.7	55.0 ± 10.2	59.8 ± 35.7	51.2 ± 10.1	25.98 ± 14.74 ab
Low Mow	208.5 ± 40.9	142.7 ± 15.3	81.8 ± 11.7	61.0 ± 35.2	41.6 ± 23.0	12.0 ± 3.44 a
Med Mow	276.3 ± 107.3	202.6± 24.2	68.9 ± 13.9	25.3 ± 25.3	70.6 ± 15.5	18.87 ± 3.96 ab
High Mow	172.5 ± 16.7	138.8 ± 22.4	52.4 ± 8.1	17.3 ± 6.6	76.2 ± 12.8	25.94 ± 6.32 ab
Low Spike	136.8 ± 29.5	197.9 ± 45.9	41.4 ± 8.6	20.0 ± 11.6	69.0 ± 14.7	11.79 ± 2.80 a
High Spike	156.3 ± 44.7	87.2 ± 11.7	46.5 ± 8.2	0 ± 0	21.4 ± 12.5	23.55 ± 5.63 ab
Prescribed Fire	198.3 ± 24.5	138.5 ± 36.9	64.0 ± 3.0	27.8 ± 33.2	66.4 ± 24.2	40.62 ± 4.61 b
Mean	198.8 ± 16.2	139.5 ± 11.6	57.1 ± 3.2	29.7 ± 6.8	49.2 ± 5.5	21.94 ± 1.76

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 6. Cover values for the three most prevalent forb species and total forb (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Erigeron linearis			*Linanthus pungens*		
	Cover (%)					
Treatment	2006*	2007*	2011	2006*	2007	2011
Control	0.63 ± 0.28 a	0.5 ± 0.2	0.1 ± 0.1	1.1 ± 0.4	2.2 ± 1.0	0.8 ± 0.3
Dixie Harrow	1.05 ± 1.0 a	1.1 ± 0.6	0.02 ± 0 .01	2.4 ± 0.8	2.3 ± 0.6	0.7 ± 0.3
Chaining	0.85 ± 0.65 a	0.6 ± 0.3	0.2± 0.2	0.9 ± 0.2	0.7 ± 0.2	0.4 ± 0.1
Aerator	0.59 ± 0.34 a	0.8 ± 0.5	0 .01 ± 0.01	4.6 ± 1.4	2.4 ± 0.5	3.0 ± 0.6
Low Mow	0 ± 0 a	0.2 ± 0.1	0.1 ± 0.04	2.2 ± 0.5	1.9 ± 0.7	1.5 ± 0.7
Med Mow	1.52 ± 0.69 a	2.4 ± 1.2	0.1 ± 0 .04	1.2 ± 0.9	1.8 ± 0.9	0.7 ± 0.4
High Mow	6.35 ± 3.0 b	4.8 ± 2.3	0 ± 0	2.6 ± 1.5	2.4± 1.5	0.8 ± 0.4
Low Spike	0 ± 0 a	0.1 ± 0.1	0 ± 0	2.9 ± 1.7	1.4 ± 0.9	0.3 ± 0.2
High Spike	7.19 ± 0.74 b	6.0 ± 1.0	0.3 ± 0.1	0.4 ± 0.1	0.8 ± 0.3	0.3 ± 0.2
Prescribed Fire	2.14 ± 0.91 ab	2.5 ± 1.2	0 ± 0	1.2 ± 0.5	1.4 ± 1.0	0.1 ± 0 .1
Mean	2.03 ± 0.05	1.9 ± 0.4	0.1 ± 0.02	1.94 ± 0.3	1.7 ± 0.3	0.7 ± 0.1
	Phlox hoodii			Forb Total		
	Cover (%)					
Treatment	2006*	2007*	2011	2006 *	2007	2011*
Control	2.7 ± 0.8	3.7 ± 1.0	1.0 ± 0.7	4.55 ± 1.13 b	12.5 ± 1.8	3.45 ± 0.63 a
Dixie Harrow	1.4± 0.7	2.4 ± 1.0	0.4 ± 0.1	6.13 ± 1.63 ab	14.1 ± 1.8	3.15 ± 0.50 a
Chaining	2.3 ± 1.2	3.6 ± 0.3	2.1 ± 0.2	4.83 ± 2.09 ab	11.4 ± 0.9	4.62 ± 0.57 ab
Aerator	0.5 ± 0.2	1.9 ± 0.2	0.3 ± 0.2	7.01 ± 1.45 a	11.7 ± 0.4	3.34 ± 0.42 a
Low Mow	1.4 ± 0.8	2.7 ± 0.8	1.4 ± 0.6	3.68 ± 0.47 b	13.2± 1.1	4.37 ± 0.75 ab
Med Mow	3.8 ± 1.4	4.4 ± 0.9	1.0 ± 0.5	7.49 ± 1.92 ab	14.3 ± 1.4	3.99 ± 0.21 ab
High Mow	1.3 ± 0.9	2.2 ± 0.1	0.4 ± 0.2	11.88 ± 1.47 a	14.2 ± 1.4	6.40 ± 1.32 ab
Low Spike	3.1 ± 0.8	3.1 ± 0.8	0.6 ± 0.2	6.06 ± 1.50 ab	10.4 ± 1.4	2.46 ± 0.36 a
High Spike	3.1 ± 1.0	3.4 ± 0.8	2.1 ± 0.7	10.75 ± 1.60 b	13.8 ± 1.5	7.44 ± 1.17 b
Prescribed Fire	1.8 ± 0.5	2.7 ± 0.3	0.4 ± 0.2	6.50 ± 1.25 b	16.5 ± 2.4	2.78 ± 1.20 a
Mean	2.1 ± 0.3	3. 0 ± 0.2	1.0 ± 0.2	6.88 ± 0.58	13.2 ± 0.5	4.24 ± 0.33

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 7. Herbaceous height, species richness and Shannon-Wiener Index values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Herbaceous Height (cm)			Species Richness			Shannon-Wiener Index		
Treatment	2006	2007	2011	2006	2007	2011	2006	2007	2011*
Control	13.5 ± 0.3	13.8 ± 0.7	15.3 ± 1.3	11.0 ± 0.3	18.0 ± 0.6	28.0 ± 0.3	1.8 ± 0.4	1.9 ± 0.5	2.0 ± 0.3
Dixie Harrow	17.6 ± 0.9	12.6 ± 1.2	9.0 ± 0.2	12.0 ± 1.5	22.0 ± 1.0	30.0 ± 0.1	1.8 ± 0.4	2.7 ± 0.2	2.3 ± 0.1
Chaining	13.3 ± 0.6	11.1 ± 0.3	12.0 ± 1.1	12.0 ± 1.0	19.0 ± 1.0	30.0 ± 0.2	1.9 ± 0.2	2.1 ± 0.3	2.2 ± 0.2
Aerator	18.6 ± 1.5	11.9 ± 0.7	8.7 ± 0.3	11.0 ± 1.0	20 ± 1.0	26.0 ± 0.2	1.8 ± 0.5	2.5 ± 0.3	2.1 ± 0.2
Low Mow	17.9 ± 0.7	12.9 ± 0.3	7.9 ± 0.3	9.0 ± 0.5	9.0 ± 1.2	27.0 ± 0.2	1.8 ± 0.4	2.1 ± 0.2	2.3 ± 0.1
Med Mow	17.6 ± 1.5	14.5 ± 0.9	8.8 ± 0.6	11.0 ± 0.6	17.0 ± 0.9	28.0 ± 0.1	1.9 ± 0.3	2.1 ± 0.2	2.3 ± 0.1
High Mow	15.7 ± 1.2	12.7 ± 0.7	9.2 ± 0.4	12.0 ± 0.3	16.0 ± 0.8	26.0 ± 0.2	1.8 ± 0.5	2.2 ± 0.4	2.0 ± 0.2
Low Spike	16.1 ± 0.9	11.9 ± 0.5	13.5 ± 1.1	8.0 ± 0.5	16.0 ± 1.1	26.0 ± 0.2	1.6 ± 0.5	2.2 ± 0.4	1.7 ± 0.2
High Spike	14.3 ± 0.8	12.0 ± 0.3	10.9 ± 0.6	14.3 ± 0.8	12.0 ± 0.9	28.0 ± 0.1	1.8 ± 0.5	2.3 ± 0.3	2.4 ± 0.1
Prescribed Fire	18.8 ± 0.7	11.7 ± 0.3	10.3 ± 1.5	12.0 ± 0.3	20.0 ± 1.4	26.0 ± 0.2	1.6 ± 0.6	2.2 ± 0.3	2.1 ± 0.2
Mean	16.3 ± 0.4	12.5 ± 0.3	10.6 ± 0.4	11.0 ± 0.4	18.0 ± 0.6	27.5 ± 0.2	1.8 ± 0.5	2.2 ± 0.3	2.1 ± 0.2

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

Table 8. Litter and bare ground cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Litter			Bareground		
	Cover (%)					
Treatment	2006*	2007*	2011*	2006 *	2007	2011*
Control	43.69 ± 4.49 b	23.51 ± 23.51a	22.03 ± 3.67 a	35.08 ± 4.15 ab	12.9 ± 1.2	44 ± 4.07 b
Dixie Harrow	14.83 ± 2.61 a	17.61 ± 2.96 a	19.4 ± 2.06 a	54.44 ± 3.94 a	21.1 ± 2.7	43.25 ± 1.53 ab
Chaining	23.59 ± 2.68 a	23.59 ± 2.68 a	22.03 ± 2.36 a	44.09 ± 4.38 ab	22.3 ± 0.8	38.38 ± 3.42 ab
Aerator	36.75 ± 1.68 b	25.42 ± 3.62a	27.93 ± 2.66 a	38.31 ± 2.72 ab	19.1 ± 2.4	42.41 ± 0.92 b
Low Mow	43.94 ± 5.06 b	46.56 ± 4.98 b	33.03 ± 2.44 a	30.26 ± 5.17 b	8.3 ± 1.1	34.19 ± 2.64 ab
Med Mow	21.38 ± 2.0 a	32.83 ± 5.09 ab	23.79 ± 4.44 a	33.96 ± 3.90 b	12.8 ± 2.4	45.69 ± 3.72 b
High Mow	36.37 ± 4.65 b	30.00 ± 2.27 ab	18.43 ± 2.35 a	38.63 ± 0.63 ab	16.7 ± 4.4	48.13 ± 2.79 b
Low Spike	37.63 ± 2.38 b	25.63 ± 2.44 ab	7.54 ± 1.99 a	45.01 ± 3.06 ab	16.4 ± 1.2	40.31± 3.08 b
High Spike	25.00 ± 3.08 ac	26.74 ± 4.42 ab	14.11 ± 5.68 ab	36.86 ± 1.96 ab	13.7 ± 3.0	36.86 ± 1.96 b
Prescribed Fire	38.90 ± 2.30 bc	19.36 ± 2.88 a	21.75 ± 1.93 b	42.76 ± 1.75 ab	23.6 ± 4.6	21.75 ± 1.93 a
Mean	31.76 ± 1.85	27.07 ± 1.57	20.47 ± 1.53	39.94 ± 1.54	16.7 ± 1.1	40.55 ± 1.53

* Indicates that significance was detected between treatments within year. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P < 0.05$).

CHAPTER 2

COMPARISON OF TWO METHODS FOR ESTIMATING SHRUB CANOPY COVER

INTRODUCTION

Since the early 1800s sagebrush (*Artemisia* L. spp) dominated ecosystems throughout western North America have become increasingly fragmented and altered due to a multitude of land use practices including conversion to agricultural crop lands, urban growth, climate change, altered fire regimes, and rapid expansion of invasive species (Dobkin and Sauder 2005; Chambers and Wisdom 2009). These alterations have changed the sagebrush ecosystem structure and ecological function, and reduced the diversity of native plants and animals (Wisdom 2005) with particular emphasis being placed on sagebrush obligate species such as sage grouse (*Centrocercus* spp.) (Connelly et al. 2000).

Tracking changes in sagebrush ecosystems is a monumental task. These systems are heterogeneous and offer limitless possibilities for inventory and monitoring (West 2003). Monitoring of these systems is often constrained by a lack of natural resource specialists and funding needed to cover the large areas to be sampled (Breckenridge et al. 2006; West 2003). The process is further confounded by a lack of unified monitoring standards or methods nationwide (West and Smith 1997). Despite widespread interest in monitoring and change detection, few studies comparing methodologies have been undertaken.

There are many indicators used for monitoring and assessing rangeland health in sagebrush ecosystems; however, vegetation canopy cover and bare ground are two of the most frequently measured (Booth and Tueller 2003). Canopy cover data provide information relative to ecological structure, nutrient cycling, and soil stability (Pyke et al. 2002). Multiple techniques exist for the estimation of canopy cover, and they are described in the interagency technical reference guide (Coulloudon et al.1999). The decision on which method to use is

generally a function of time available, cost, and collection objectives (Elzinga 1997; Coulloudon et al. 1999). Tradition and continuity from older methodologies also might be incorporated in the decision-making process.

Two field-based methods commonly used by federal land management agencies to obtain shrub canopy cover data are the line intercept and line-point intercept methods. Line interception (Canfield 1941) uses the length of a line intercepted by a species divided by the total length of line sampled to estimate the proportion of the area covered by a species. Line-point interception methods record species that intercept vertically or inclined projections of a number of points established on the area being sampled (Goodall 1952; Greig-Smith 1983).

True values of cover parameters are seldom known in natural ecosystems (Bonham 2004). Therefore, precision or repeatability of different procedures is used to compare field studies instead of accuracy (Schultz et al. 1961). Many of the studies conducted to compare line intercept and line-point intercept precision also include other methodologies such as ocular or aerial estimates of cover (Booth 2003; Booth 2006; Godinez-Alvarez et al. 2009).

While the canopy cover estimates from line intercept and line-point intercept methods are often used interchangeably, the two methods can produce different results. Floyd and Anderson (1983) compared line interception, line-point interception, and canopy coverage estimation. They found that line and line-point intercept methods were similar, but that the line intercept method produced significantly higher estimates of shrub cover while line-point intercept produced higher estimates of bare ground. Line-point interception also achieved a precision similar to that of line interception in less sampling time (Floyd and Anderson 1983; Heady et al. 1959).

Most studies have found that the two methodologies predict similarly for shrub and forb cover, however, little investigation has been done to verify if predictions might differ with shrub cover percentage or the number of points taken for a given a line transect. For instance Heady et al. (1959) noted much higher variation between the methods at lower cover levels, suggesting that the line intercept method produced better estimates in low cover. Also, Leujak (2007) noted that while conducting coral reef surveys, line-point intercept required large numbers of points to achieve similar precision to other methods tested including line intercept.

STUDY OBJECTIVES

This study was designed with the following objectives in mind:

1. Determine the precision of canopy cover estimates collected with line-point and line intercept sampling methods.
2. Examine the relationship between the number of points used in data collection and precision of estimates of cover collected.
3. Determine if precision of methods differs with changes in shrub canopy cover.

MATERIALS AND METHODS

Using the standard deviation of shrub canopy cover estimation from a pilot study conducted in Wyoming big (*Artemisia tridentata* Nutt. ssp. *wyomingensis*) and mountain big (*Artemisia tridentata* Nutt. ssp. *vaseyana*) sagebrush communities in 2009, an *a priori* paired t-test power analysis was conducted to determine the number of replication sites needed to adequately access variation in cover estimates. Cover values for this project were obtained in two ways; one using standard field collection methods and the other by creating a virtual sagebrush population using ArcMap (ERSI 2011). The creation of virtual populations allows

us to know the true value of cover thereby allowing us to test method accuracy, as well as precision.

Field Population Methods

Transects were located based on estimated sagebrush cover percentages to ensure all cover ranges were represented for testing. Ranges sampled were 0-10%, 10-20%, and >20% cover. At each transect a GPS point was taken. Sampling procedures for each method followed those set forth in the Interagency Technical Reference Guide (Coulloudon et al. 1999). At each sample location, both methods were completed on two 60-m transects. The GPS location served as a center stake for the two transects, from which, one line ran North, and the other ran South, unless the point was located on a slope greater than 5%. In that circumstance, transects ran parallel across slope.

For point intercept, all readings were taken from the right side of the tape. The first point was randomly determined. Each subsequent point was read 0.25 m from the previous point. For line intercept, the length of all sagebrush canopy touching or falling directly below the 60-m tape was measured. Gaps of less than 10 cm were included. If a gap exceeded 10 cm, measurement resumed at the next shrub canopy location. Dead shrubs were not measured.

Simulated Population Methods

Simulated shrublands were 75 x 75 m, which provided adequate area for 60-m transects to be generated. Sagebrush size distribution was based on a sample taken from a Wyoming big sagebrush community in Pinedale, Wyoming. Using this sample, 3 size categories of plants were delineated; small, medium, and large. The median plant size from each group was then used to represent each class size in the models and are as follows; small: 10 cm, medium: 30 cm, and large: 60 cm. Belt density transects from the Pinedale sample were used to assign a

percentage of the overall cover to each size class (small were 6%, med 82%, and large were 12%). Hawth's tools (Beyer 2004) random point generator was then used to create the correct number of sagebrush for each size category. Once the points were created, a buffer was applied to each point by size class, in effect creating a sagebrush canopy around the point. When the separate size class buffers were completed, they were compiled into one layer (Figure 4). Total cover could then be attained by using the statistics function from the attribute table in Arc Map (ERSI 2011).

Once the sagebrush population was created, ten transects were established in a new shape file. Each transect was randomly located and was approximately 60-m in length. Points were established on each line every 0.25, 0.50, and 1 m using the Hawth's tool function, animal movements (convert paths to points).

By using the sagebrush cover layer and the transect layer or point layer, in conjunction with the intersect tool from Arc toolbox, cover percentages could be calculated using both line and line-point intercept methods. In order to address the possibility that line intercept method might predict cover differently at different cover levels, 3 populations were created having 10, 20, and 30% total sagebrush cover. Each population was sampled with 10 transects. Additionally, each of the ten transects were sampled with line-point intercept using three numbers of points: 60, 120, and 240.

Statistical Analyses

A paired t-test was used to evaluate significant differences between the two methodologies for each cover level using SAS statistical software (SAS Institute 2011). Values were significant at $\alpha = 0.05$. Also for both field and simulated trials, line intercept was compared to line-point intercept using a Pearson correlation for 3 different numbers of points; 60 (line-point$_{60}$), 120 (line-point $_{120}$), and 240 (line-point $_{240}$).

RESULTS AND DISSCUSION

Field Trials

Shrub cover for field sites varied from 0-47.5%. Cover estimates produced by line-point intercept method tended to be greater than those of line intercept (69% of the time). However the absolute average difference between the methods across the gradient of sagebrush coverage was only 1.03%. Significant differences between line intercept and line-point intercept$_{240}$ were found for the 0-10% and 10-20% cover ranges (P= 0.0112 and P = 0.0028) (Table1).

In addition, line intercept and line-point intercept were compared using three different numbers of points along the 60-m transect. All three estimates of line-point intercept predicted greater cover as compared to line intercept method. Estimates for the 10-20% cover range were most commonly greater. Average differences decreased with increasing numbers of points used in the estimates; 60 points 1.91, 120 points 1.59, and 240 points 1.03%. Distribution of the data by method indicated that while the median of all line-point methods was similar, variation around that median was greater for 60 and 120 point samples than for the 240 point samples (Figure 5). The line intercept estimate was most similar in distribution to the line-point$_{240}$ method. When line intercept cover was plotted against the line-point intercept estimates, the 120-point and 240-point values were more closely grouped with higher correlation coefficients (r = 0 .93 and 0.98, respectively), while the 60-point estimate exhibited a much greater spread and lower correlation coefficient (r = 0.90) (Figure 6).

Simulation Trials

For the simulated trials, shrub cover estimates varied from 3.8-48.3%. As with the field trials, cover estimates produced in the simulated trials by line-point intercept tended to be greater than those predicted by line intercept method (80% of the time). The absolute average difference between the two methods was 0.62%. A significant difference between the two methodologies was found at the 20% cover level (P=0.0184) (Table 1).

As with the field trials, line intercept and line-point intercept at three numbers of point levels (60, 120, and 240) were compared. All three estimates of line-point intercept method were greater than the line intercept estimate (63, 70, and 80% of the time, respectively). The line-point cover estimate for the 10% sagebrush cover level was greater most frequently. Average differences between the estimates decreased with increasing number of sample points taken with the line-point method (2.45, 1.34, and 0.64). While overall distribution of the data was similar for all four methods, the median and variation around the median was much greater for the 60 point estimate (Figure 7). When line intercept estimates were compared to the 3 line-point methods using correlation (Figure 8), the line-point$_{240}$ estimate exhibited the closest grouping to the line as well at the highest correlation coefficient (r = 0.99).

Additionally, the four estimates were then compared to the actual cover value for their respective community. Relative differences for the four methods indicated that line intercept was closest to the actual value for the 10% cover level, and that line intercept $_{240}$ predicted values closer to the actual value for the 20 and 30% levels (Figure 6). Relative differences resulting from the line-point$_{60}$ estimate were greater than those of the line intercept and the line-point$_{120}$ and line-point$_{240}$ estimates, especially for the 20 and 30% cover levels.

CONCLUSIONS

For field trials, line-point estimates of shrub cover tended to be greater than line intercept estimates, particularly when sagebrush cover was relatively sparse (≤ 20%). Also, increasing the number of points used in the line-point estimates tended to reduce the difference between the two collection methods.

For simulated trials the accuracy of the line intercept method was better than line-point method when shrub cover was low (≤ 20%). However when cover was ≥ 20%, use of 240 points when conducting the line-point intercept method resulted in better estimates than the line intercept method. Additionally, the accuracy of the line-point method increased greatly as the number of points increased from 60-240.

MANAGEMENT IMPLICATIONS

Our findings of higher cover estimates produced by the line-point intercept method relative to the line-point intercept method are similar to those of Whitman and Siggerirsson (1954) in perennial grass communities, however, they conflict with those of Floyd and Anderson (1982), in which line intercept gave higher cover estimates in sagebrush systems. While significant differences between the methods were detected, the average differences for both field and simulated trials were only about 1-2%. Acceptable rates of error should be determined by the context in which the data are collected and used, however, differences between line-intercept and line-point intercept methods may be relatively small in comparison to other sources of error in monitoring rangeland systems.

When monitoring, canopy cover present on a site should be considered a critical factor in deciding what method to use. In areas of low sagebrush cover, the line intercept method is recommended. If using line-point intercept, special consideration should be taken

ensure that an adequate number of points are taken per line to accurately represent existing cover, or that greater numbers of lines are completed. Leujak (2007) and Whitman and Siggerirsson (1954) stress the importance of sample size in attaining similar precision between the methodologies.

We did not examine repeatability of each method on the same transect by the same individual, however, this might warrant further exploration. The line intercept method requires interpretation by the observer when omitting gaps in canopy cover and deciding whether partially dead canopy cover should be included or not. In using the line-point method, a point is either touching canopy or not and therefore, this method likely requires less training to attain the same repeatability. The 1-2% absolute cover difference between line and line-point intercept might be a good tradeoff if observer bias is a concern. Additionally, these results should be tested in other community types.

LITERATURE CITED

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools.

Brady, W.W., Mitchell, J.E., Bonham, C.D., and J.W. Cook. 1995. Assessing the power of the point-line transect to monitor changes in plant basal cover. *Journal of Range Management* 48:187-190.

Breckenridge, R. P., M. Dakins, S. Bunting, J. L. Harbour, and R. D. Lee. 2006. Employing unmanned aerial vehicles for monitoring habitat in sagebrush-steppe ecosystems. In: J. R. Greer, ed. Proceedings of the 11th Biennial USDA Forest Service Remote Sensing and Applications Center Conference. 24–28 April 2006; Salt Lake City, UT: USDA Forest Service, Remote Sensing applications Center.

Bonham, C.D., D.E. Mergen, and S. Montoya. 2004. Plant cover estimation: a contiguous Daubenmire frame. *Rangelands* 26: 17-22.

Booth, D.T. and P.T. Tuller. 2003. Rangeland monitoring using remote sensing. *Arid Land Research and Management* 17: 455-467.

Booth, D.T., S.E. Cox, T.W. Meikle, and C. Fitzgerald. The accuracy of ground-cover measurements. *Rangeland Ecology and Management* 59: 179-188.

Canfield, R. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:386-394.

Chambers, J.C. and M.J. Wisdom. 2009. Priority research and management issues for the imperiled Great Basin of the western United States. *Restoration Ecology* 17:707-714.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.

Coulloudon, B., K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, M. Pellant, P Podborny, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. Sampling vegetation attributes. Interagency Technical Reference. National Applied Resource Sciences Center. Denver CO, USA: Department of the Interior, Bureau of Land Management, BLM/RS/ST-1734-4. 171 p.

Dobkin, D.S. and J.D. Sauder. 2004. Shrubsteppe landscapes in jeopardy. Distributions, abundances, and the uncertain future of birds and small mammals in the Intermountain West. High Desert Ecological Research Institute, Bend, OR. Pp 194.

ESRI (Environmental Systems Resource Institute). 2011. ArcMap 9.2. ESRI, Redlands, California.

Elzinga, C. E., D.W. Salzer, J.W. Willoughby, J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Science Inc. 15 p.

Floyd, D.A. and J.E. Anderson. 1987. A comparison of three methods for estimating plant cover. *Journal of Ecology* 75:221-228.

Godinez-Alvarez, H., J.E. Herrick, M. Mattocks, D. Toledo, and J. Van Zee. 2009. Comparison of three vegetation monitoring methods: Their relative utility for ecological assessment and monitoring. *Ecological Indicators* 9:1001-1008.

Goodall, D.W. 1952. Some considerations in the use of point quadrants for the analysis of vegetation. *Australian Journal of Scientific Research* 5:1-41.

Greig-Smith, P. 1983. Quantitative Plant Ecology. 3rd Edition. University of California Press. Berkeley CA, USA . 374 p.

Heady, H.H., R.P. Gibbens, and R.W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. *Journal of Range Management* 12:180-188.

Leujak, W., and R.F.G. Ormond. 2007. Comparative accuracy and efficiency of six coral community survey methods. *Journal of Experimental Marine Biology and Ecology* 351:168-187.

Pyke, D.A., J.E. Herrick, P. Shaver and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. *Journal of Range Management* 55:584-597.

SAS Institute. 2011. SAS 9.1.3 Service Pack 3, Cary, NC, USA: SAS Institute, Inc

Schultz, A. M., R. P. Gibbens, and L. Debano. 1961. Artificial populations for teaching and testing range techniques. *Journal of Range Management* 14:236–242.

West N. E. and L.E. Smith. 1997. Improving the monitoring of rangelands. *Rangelands* 19:9-14.

West N.E. 2003. Theoretical underpinnings of rangeland monitoring. *Arid Land Research and Management* 17:333-346.

Whitman, W.C., and E.I. Siggerirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. *Ecology* 35: 431-436.

Wisdom, M. J., M. M. Rowland, and R. J. Tausch. 2005. Effective management strategies for sage-grouse and sagebrush: a question of triage? *Transactions, North American Wildlife and Natural Resources Conference* 70**:**206–228.

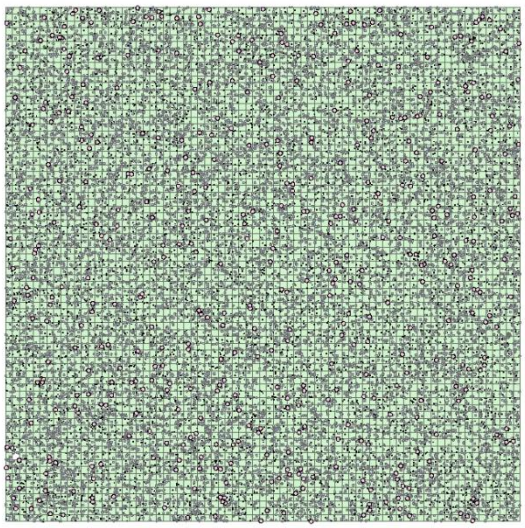


Figure 4.Simulated Wyoming Big sagebrush community with 20% shrub canopy cover.

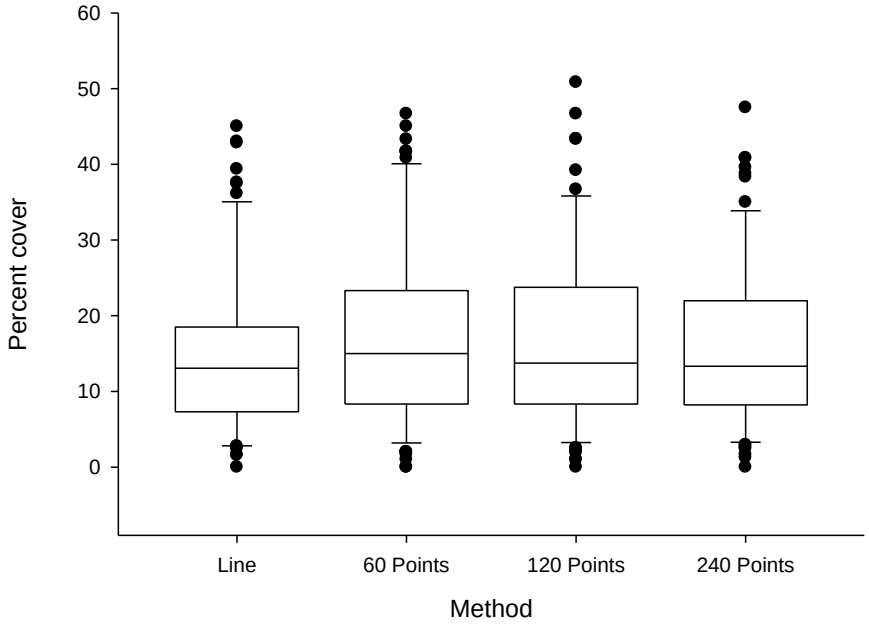


Figure 5. Distribution of estimates of percent cover of shrubs by method for field trials in a sagebrush community. The box represents the 25th, median, and 75th percentiles for data. Error bars are the 10th and 90th percentiles, and circles denote outliers in the data.

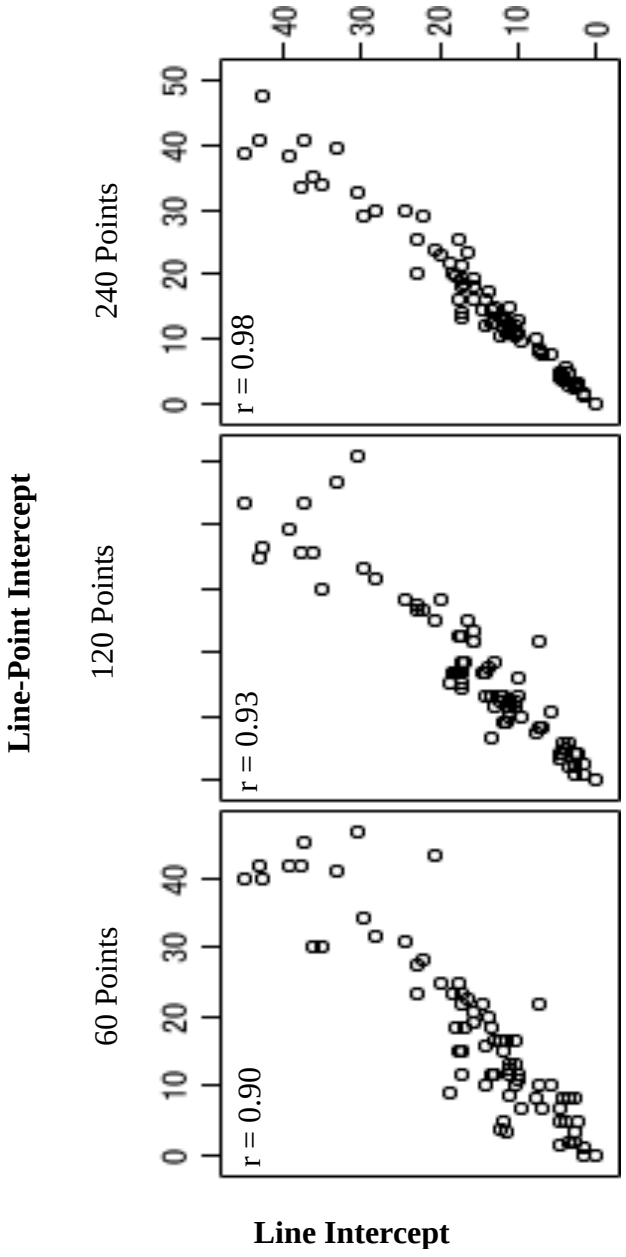


Figure 6. Correlation of line intercept and line-point intercept estimates by number of points taken and Pearson correlation coefficients (r) for field trials. Sample size =78.

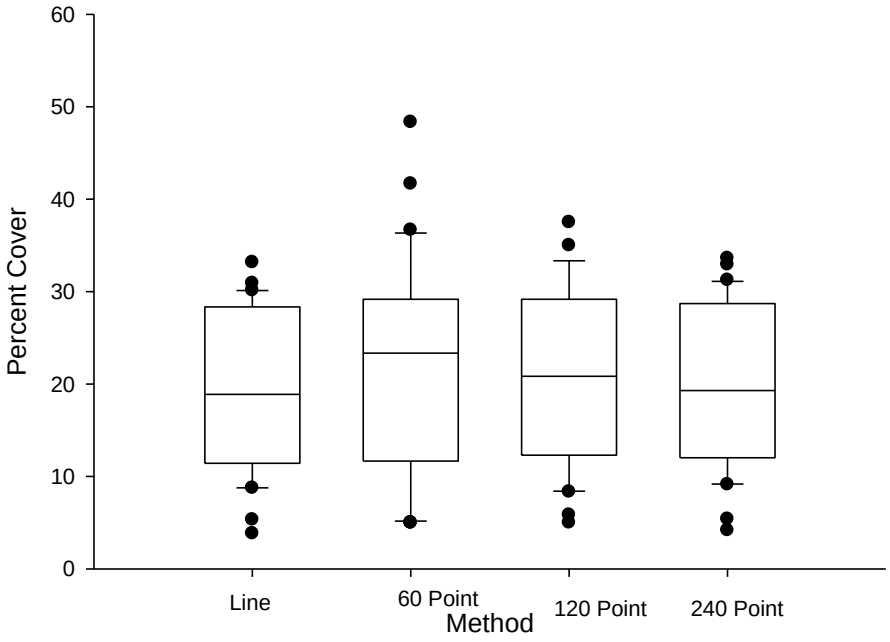


Figure 7. Distribution of estimates of percent cover of shrubs by method for simulated trials of a sagebrush community. The box represents the 25th, median, and 75th percentiles for data. Error bars are the 10th and 90th percentiles, and circles denote outliers in the data.

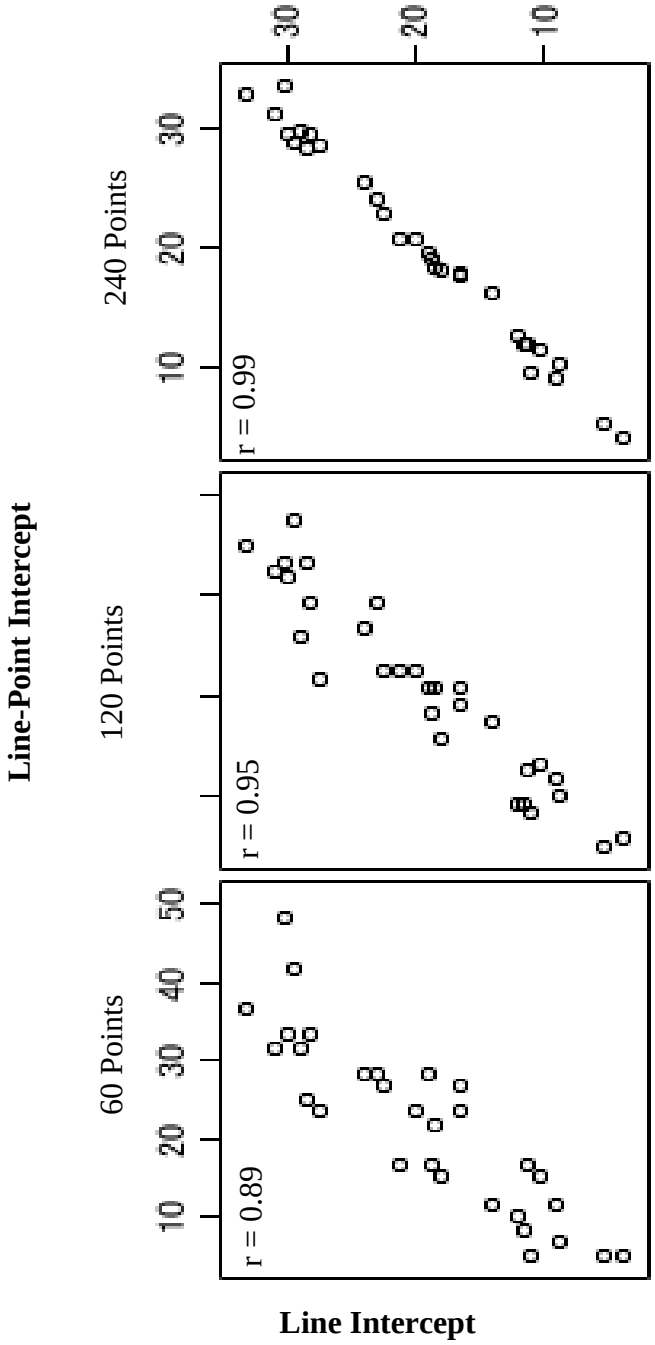


Figure 8. Correlation of line intercept and line-point intercept estimates by number of points taken and Pearson correlation coefficients (r) for simulated trials. Sample size n = 30.

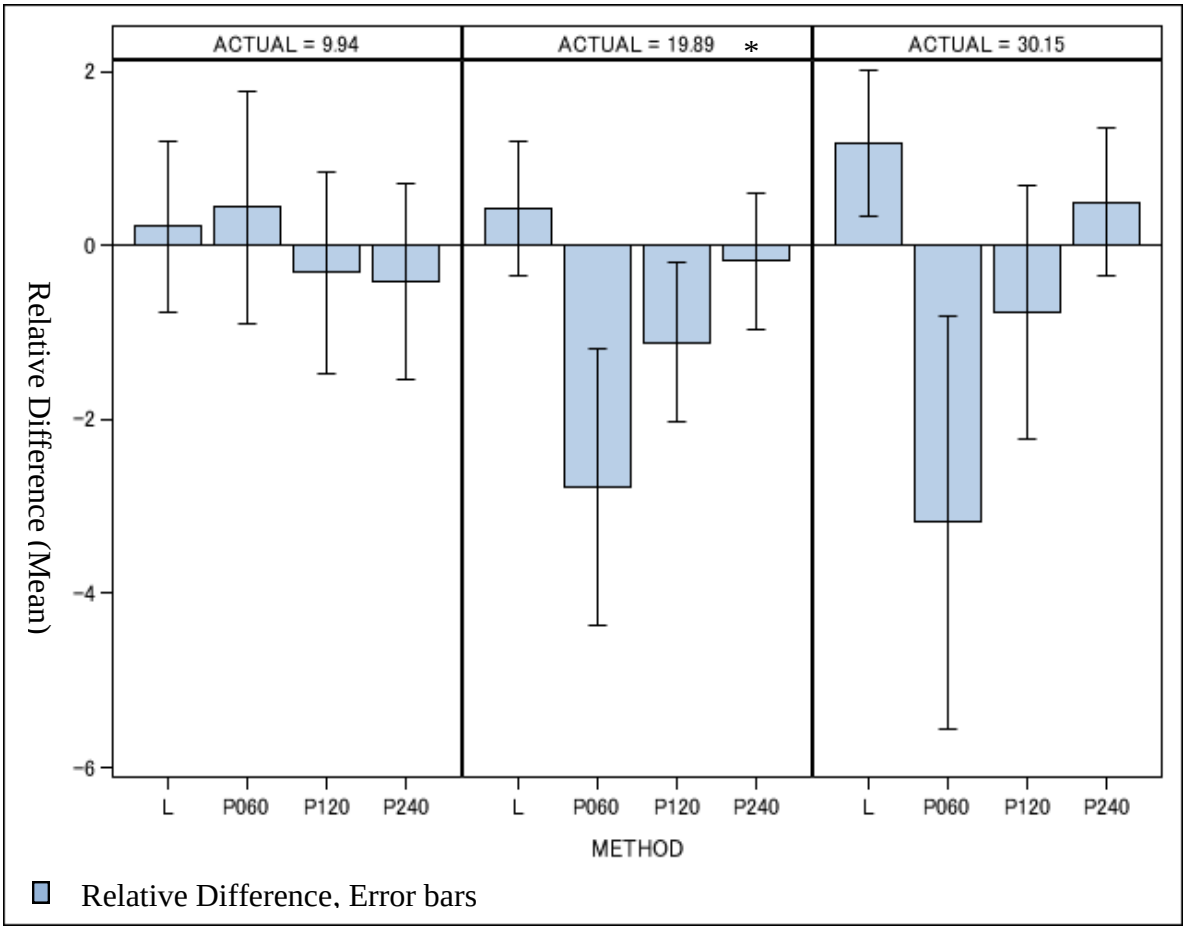


Figure 9. Simulation trial relative difference (mean and standard error) of line intercept (L), line-point intercept 60 points (P060), line-point intercept 120 points (P120), and line-point intercept 240 points (P240) by cover level. * indicates that the methods were significantly different for cover level.

Table 9.Summary statistics of mean difference between line intercept and line-point intercept for field and simulated trials. Statistics are delineated by cover range and level. P-values are from a paired t-test.

	Field trial			Simulated trial		
	Cover ranges			Cover levels		
Metric	0-10	10-20	>20	10	20	30
Mean	-0.47	-1.30	-1.23	-0.63	-0.60	-0.68
St. Dev	0.81	2.38	3.59	1.01	0.66	1.19
Std err	0.17	0.40	0.80	0.32	0.21	0.38
N	23.00	35.00	20.00	10.00	10.00	10.00
P-value	0.011	0.003	0.142	0.079	0.017	0.108

Appendix A. Coordinates (UTM) of research transect locations for Wyoming big sagebrush community treatment plots located near Pinedale, Wyoming. All UTM coordinates are reported in Zone 12 N of NAD83. F denotes a fenced transect; U denotes an unfence transect.

Site	Fencing	Transect	Northing	Easting	Bearing (°)
Plot 1	F	Start 1-1	4735302	591175	215
		End 1-1	4735257	591144	
	F	Start 1-2	4735210	591252	195
		End 1-2	4735152	591236	
	U	Start 1-3	4735280	591345	58
		End 1-3	4735317	591404	
	U	Start 1-4	4735106	591347	252
		End 1-4	4735087	591288	
Plot 2	U	Start 2-1	4735991	591671	295
		End 2-1	4736015	591620	
	F	Start 2-2	4735955	591944	304
		End 2-2	4735991	591891	
	F	Start 2-3	4736112	591771	1
		End 2-3	4736176	591772	
	U	Start 2-4	4736078	591605	74
		End 2-4	4736094	591660	
Plot 3	U	Start 3-1	4735034	593079	184
		End 3-1	4734973	593075	
	F	Start 3-2	4734954	592881	155
		End 3-2	4734900	592906	
	F	Start 3-3	4734736	592995	348
		End 3-3	4734795	592982	
	U	Start 3-4	4734876	593216	314
		End 3-4	4734916	593174	
Plot 4	F	Start 4-1	4734022	592719	16
		End 4-1	4734085	592737	
	U	Start 4-2	4734084	592844	96
		End 4-2	4734078	592904	
	U	Start 4-3	4733748	592969	295
		End 4-3	4733779	592904	
	F	Start 4-4	4733816	592729	360
		End 4-4	4733879	592729	
Plot 5	F	Start 5-1	4733565	593647	5
		End 5-1	4733623	593652	
	F	Start 5-2	4733903	593525	184
		End 5-2	4733843	593521	
	U	Start 5-3	4733839	593413	148
		End 5-3	4733789	593444	
	U	Start 5-4	4733725	593384	141
		End 5-4	4733680	593421	

Appendix A Continued.

Site	Fencing	Transect	Northing	Easting	Bearing (°)
Plot 6	F	Start 6-1	4734784	591944	268
		End 6-1	4734782	591887	
	U	Start 6-2	4734903	591735	223
		End 6-2	4734857	591692	
	U	Start 6-3	4734614	591796	332
		End 6-3	4734666	591768	
	F	Start 6-4	4734707	591930	301
		End 6-4	4734739	591877	
Plot 7	U	Start 7-1	4733065	592094	259
		End 7-1	4733054	592037	
	U	Start 7-2	4732808	592044	337
		End 7-2	4732866	592019	
	F	Start 7-3	4732931	592220	108
		End 7-3	4732912	592280	
	F	Start 7-4	4732935	592345	83
		End 7-4	4732942	592406	
Plot 8	F	Start 8-1	4732268	591898	359
		End 8-1	4732327	591897	
	U	Start 8-2	4732554	592158	289
		End 8-2	4732576	592095	
	U	Start 8-3	4732800	591948	189
		End 8-3	4732746	591939	
	F	Start 8-4	4732765	591858	176
		End 8-4	4732704	591862	
Plot 9	U	Start 9-1	4732002	591977	351
		End 9-1	4732062	591968	
	F	Start 9-2	4732159	591842	187
		End 9-2	4732109	591836	
	F	Start 9-3	4731924	591854	189
		End 9-3	4731863	591844	
	U	Start 9-4	4731773	592002	346
		End 9-4	4731829	591988	
Plot 10	U	Start 10-1	4731191	591823	23
		End 10-1	4731246	591846	
	F	Start 10-2	4731222	591878	47
		End 10-2	4731270	591929	
	F	Start 10-3	4731615	592067	203
		End 10-3	4731563	592045	
	U	Start 10-4	4731622	591848	180
		End 10-4	4731560	591848	

Appendix B. P-values, best fit co-variance model, and results of check of residuals for both repeat measure ANOVAs. Co-variance models are as follows; UN denotes unstructured, ARH1 denotes heterogeneous autoregressive, AR 1 denotes autoregressive, and CS denotes compound symmetry. Y denotes that the residuals met model assumptions, N denotes they did not.

Metric	Year and Treatment Repeat measures ANOVA				
Ground Cover	Treatment	Year	Treatment*year	Covarience	Residual check
Poa secunda	0.0005	<.0001	<.0001	UN	Y
Elymus lancelatus	0.2073	<.0001	<.0001	ARH1	Y
Achantherum lettermanii	0.0002	0.0001	0.0016	UN	Y
Perienial grasses	0.0091	<.0001	<.0001	ARH1	Y
Phlox hoodii	0.0949	<.0001	<.0001	UN	Y
Lianthus pungens	0.1842	<.0001	0.0004	UN	Y
Erigeron linearis	<.0001	<.0001	<.0001	UN	N
Perienial forb	0.0435	<.0001	<.0001	UN	Y
Artemisia tridentata	0.0005	<.0001	0.0199	ARH1	Y
Chrysothamnus viscidiflorus	0.0003	<.0001	0.0005	UN	Y
Other brush	0.0018	<.0001	0.0214	ARH1	Y
Grass	<.0001	<.0001	<.0001	UN	Y
Forb	0.0026	<.0001	0.1552	CS	Y
All shrub	0.0003	<.0001	0.0018	ARH1	Y
Litter	<.0001	<.0001	<.0001	ARH1	Y
Bare ground	0.0489	<.0001	0.0004	CS	Y
Biomass					
Grass	0.0005	<.0001	<.0001	ARH1	Y
Forb	0.1129	<.0001	0.001	ARH1	Y
Belt density					
Young	0.0307	0.0012	<.0001	ARH1	Y
Mature	0.0129	<.0001	<.0001	UN	Y
Decadent	<.0001	<.0001	<.0001	ARH1	Y
Dead	0.0008	<.0001	<.0001	UN	Y
Cover					
Line Intercept	<.0001	<.0001	<.0001	UN	Y
Cover class	0.0017	<.0001	0.0388	ARH1	Y
Richness and Diversity					
Richness	0.0002	<.0001	0.1204	ARH1	Y
Diversity	0.1101	<.0001	0.002	UN	Y

Appendix B Continued.

Metric	Grazing repeat measures ANOVA								
Ground Cover	yr	treat	grazest	treatment*graze	treat*yr	yr*graze	treat*graze*year	Covarience	Residual check
Poa secunda	<.0001	0.053	0.5515	0.8942	0.0004	0.2817	0.6605	ARH1	Y
Elymus lancelatus	<.0001	0.0036	0.6645	0.3617	0.2021	0.9977	0.8557	ARH1	Y
Achantherum lettermanii	0.0014	0.3084	0.3835	0.6467	0.192	0.7813	0.7032	CS	Y
Perienial grasses	0.4289	0.0096	0.0889	0.0712	0.0313	0.915	0.8667	CS	Y
Phlox hoodii	<.0001	0.3697	0.7082	0.1432	0.0066	0.831	0.4881	AR1	Y
Lianthus pungens	0.0044	0.3921	0.3441	0.5424	0.2241	0.6112	0.2199	UN	N
Erigeron linearis	<.0001	0.0407	0.5034	0.8961	0.0006	0.0414	0.4244	UN	N
Perienial forb	<.0001	0.0295	0.7956	0.8852	0.0029	0.7049	0.9276	ARH1	Y
Artemisia tridentata	0.7574	0.001	0.562	0.6049	0.1735	0.866	0.7193	AR1	Y
Chrysothamnus viscidiflorus	<.0001	0.0003	0.4829	0.0193	0.1198	0.6674	0.0758	UN	Y
Other brush	<.0001	0.0015	0.4282	0.0606	0.106	0.9418	0.4566	UN	Y
Grass	<.0001	0.0063	0.1605	0.9809	0.0233	0.7084	0.8349	UN	Y
Forb	<.0001	0.0639	0.354	0.5828	0.0292	0.8896	0.716	ARH1	Y
All shrub	0.3867	0.0002	0.3724	0.5613	0.2659	0.9615	0.666	AR1	Y
Litter	<.0001	0.024	0.833	0.2794	0.1614	0.6081	0.9814	CS	Y
Bare ground	<.0001	0.0516	0.3779	0.1503	0.1615	0.703	0.5992	UN	Y
Biomass									
Grass	<.0001	<.0001	<.0001	0.6121	<.0001	0.0588	0.2479	ARH1	N
Forb	<.0001	0.1135	0.6704	0.8825	0.0154	0.9881	0.9489	ARH1	Y
Belt density									
Young	<.0001	0.0406	0.3844	0.2218	0.0017	0.9782	0.3642	AR1	N
Mature	<.0001	0.0048	0.9921	0.0983	0.1107	0.775	0.6449	AR1	Y
Decadent	<.0001	<.0001	0.5436	0.2344	<.0001	0.7895	0.6728	ARH1	N
Dead	0.6105	0.013	0.6884	0.9465	0.0058	0.1574	0.456	UN	N
Cover									
Line Intercept	<.0001	<.0001	0.4193	0.0002	<.0001	<.0001	<.0001	CS	Y
Cover class	0.8932	0.0019	0.8799	0.6036	0.2643	0.95	0.9066	AR1	Y
Richness and Diversity									
Richness	<0.0001	0.002	0.59	0.357	0.033	0.156	0.095	AR1	Y
Diversity	<0.0001	0.008	0.776	0.861	0.011	0.7649	0.908	UN	Y

Appendix C. Tables with values for all metrics (mean ± se) for all years after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

Table 1: Sagebrush and rabbitbrush cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Artimisia tridentata spp. wyominensis (Line Intercept)						Artimisia tridentata spp. wyominensis (Cover class)					
	Cover (%)											
Treatment	2006	2007*	2008*	2009	2010*	2011*	2006*	2007	2008	2009	2010	2011
Control	10.2 ± 1.5 a	12.4 ± 1.5	16.8 ± 0.63	15.7 ± 1.3	16.3 ± 0.8 ab	17.5 ± 0.3 a	16.9 ± 1.4 ab	16.9 ± 1.9	18.2 ± 1.6 ab	22.6 ± 2.3	12.8 ± 2.0 b	11.4 ± 0.8 b
Dixie Harrow	13.5 ± 1.1 ab	6.8 ± 0.7	7.9 ± 1.3	9.5 ± 1.5	9.0 ± 3.4 ab	9.5 ± 0.8 ab	15.9 ± 1.3 ab	8.9 ± 1.7	8.2 ± 1.4 a	4.4 ± 3.7	1.2 ± 1.1 a	4.9 ± 0.5 a
Chaining	9.8 ± 0.3 ab	7.1 ± 1.1	9.9 ± 1.4	9.9 ± 1.4	9.7 ± 1.5 ab	11.7 ± 0.8 ab	9.6 ± 2.3 a	7.8 ± 1.9	10.2 ± 3.6 ab	8.0 ± 2.6	8.3 ± 2.1 a	7.4 ± 2.0 b
Aerator	15.4 ± 0.3 ab	5.5 ± 1.6	7.6 ± 0.9	9.3 ± 0.3	12.0 ± 0.6 b	9.8 ± 1.0 ab	21.4 ± 2.4 ab	7.5 ± 1.3	10.6 ± 2.3 ab	7.5 ± 0.5	6.9 ± 1.1 a	6.1 ± 0.7 a
Low Mow	11.4 ± 1.5 ab	1.3 ± 0.4	1.7 ± 0.4	2.0 ± 0.3	3.0 ± 0.4 a	3.6 ± 0.4 b	17.4 ± 3.5 ab	2.7 ± 0.2	6.3 ± 3.3 a	2.7 ± 0.9	2.6 ± 0.3 a	1.8 ± 0.5 a
Med Mow	17 ± 0.8 ab	4 ± 1.0	6.8 ± 1.9	8.1 ± 1.4	12.8 ± 5.2 ab	9.1 ± 2.0 b	17.8 ± 4.3 ab	7.6 ± 2.9	6.4 ± 3.2 ab	11.0 ± 2.3	5.8 ± 2.1 a	4.9 ± 0.6 ab
High Mow	17.5 ± 1.7 ab	9.5 ± 1.8	12.5 ± 2.4	14.0 ± 2.1	16.7 ± 2.3 b	13.7 ± 1.4 ab	22.5 ± 5.1 ab	16 ± 2.9	19.3 ± 2.1 b	13.7 ± 1.1	10.8 ± 2.7 b	8.9 ± .9 b
Low Spike	17.5 ± 2.5 ab	18.2 ± 3.3	15.6 ± 3.4	15.0 ± 1.6	17.2 ± 1.5 ab	14.8 ± 1.4 ab	21.4 ± 2.0 ab	19.2 ± 4.7	14.0 ± 2.5 ab	14.0 ± 2.5	12.4 ± 1.2 b	9.4 ± 1.0 b
High Spike	15.7 ± 2.1 ab	13.3 ± 1.6	5.8 ± 3.3	6.3 ± 3.3	6.6 ± 4.2 ab	6.8 ± 3.7 ab	20.3 ± 0.8 ab	11.7 ± 3.3	6.3 ± 3.3 ab	7.9 ± 5.0	5.8 ± 3.6 a	2.6 ± 1.4 a
Prescribed Fire	17.5 ± 1.7 b	8.5 ± 2.3	10.7 ± 2.4	12.6 ± 2.8	13.8 ± 3.6 ab	7.8 ± 3.2 ab	28.4 ± 5.0 b	10.3 ± 2.6	15.1 ± 3.6 ab	14.1 ± 3.6	6.8 ± 1.5 a	5.8 ± 3.9 a
Mean	14.9 ± 0.7	8.7 ± 0.9	9.4 ± 0.9	10.3 ± 0.8	10.7 ± 0.1	10.7 ± 0.8	19.1 ± 1.2	10.8 ± 1.1	11.2 ± 1.1	10.6 ± 1.2	6.1 ± 0.7	6.3 ± 0.6
	Chrysothamnus viscidiflorus (Cover class)						Shrub total (Cover Class)					
	Cover (%)											
Treatment	2006	2007	2008	2009	2010	2011	2006*	2007*	2008*	2009*	2010*	2011
Control	4.3 ± 1.4	6.5 ± 0.8	7.4 ± 1.5	6.6 ± 1.4	3.7 ± 0.8	3.5 ± 0.4	21. 2 ± 1.3 ab	23.6 ± 1.8	26.2 ± 1.6 b	29.7 ± 2.7	16.5 ± 1.6 b	15.0 ± 1.1 bcf
Dixie Harrow	1.6 ± 0.9	1.7 ± 0.5	2.6 ± 1.1	2.7 ± 1.9	0.9 ± 0.4	1.7 ± 0.5	17.5 ± 1.1 ab	11.3 ± 1.9	11.8 ± 2.0 a	14.1 ± 1.7	5.4 ± 1.9 a	6.0 ± 0 .8 ade
Chaining	2.7 ± 0.6	6.0 ± 1.0	8.4 ± 2.0	9.6 ± 0.8	4.4 ± 0.8	4.3 ± 0.3	12.5 ± 1.9 a	14 ± 2.1	18.7 ± 3.9 ab	17.6 ± 1.8	12.7 ± 2.5 ab	12 ± 1.8 ace
Aerator	2.7 ± 0.6	2.8 ± 0.5	2.6 ± 0.4	4.7 ± 1.3	1.6 ± 0.3	1.1 ± 0.3	24.1 ± 2.0 ab	10.7 ± 1.2	13.7 ± 2.5 ab	12.3 ± 1.6	8.5 ± 1.0 ab	7.4 ± 0.5 ade
Low Mow	1.8 ± 0.6	2.8 ± 0.4	4.9 ± 1.6	3.9 ± 1.4	1.9 ± 0.4	4.1 ± 1.5	19.2 ± 3.1 ab	5.6 ± .32	8.6 ± 1.5 ab	6.6 ± 2.3	4.5 ± 0.2 ac	6.1 ± 1.5 ade
Med Mow	1.5 ± 0.4	2.6 ± 0.9	2.0 ± 1.0	3.6 ± 2.1	1.7 ± 0.6	1.6 ± 0.6	19.3 ± 3.9 ab	10.4 ± 2.4	8.6 ± 3.2 ab	17.2 ± 2.5	7.5 ± 1.8 ab	6.6 ± 0.5 ade
High Mow	1.1 ± 0.5	1.7 ± 0.5	3.0 ± 0.9	2.4 ± 0.6	1.3 ± 0.3	0.8 ± 0.2	24.0 ± 5.1 ab	18.2 ± 3.3	22.6 ± 2.7 ab	16.6 ± 1.7	12.2 ± 2.9 ab	9.9 ± 0.8 ade
Low Spike	3.1 ± 0.8	3.5 ± 1.0	4.3 ± 1.8	3.8 ± 0.8	2.6 ± 1.1	1.4 ± 0.7	24.6 ± 1.7 ab	22.8 ± 4.5	18.5 ± 4.0 ab	17.7 ± 3.0	15.0 ± 2.3 ab	10.7 ± 1.0 adf
High Spike	2.5 ± 0.9	3.1 ± 1.0	35 ± 1.4	3.1 ± 1.4	2.0 ± 0.6	1.3 ± 0.6	22.7 ± 1.1 ab	15.1 ± 3.6	9.9 ± 3.9 ab	12.0 ± 5.2	8.0 ± 3.5 ab	4.0 ± 1.7 adf
Prescribed Fire	2.5 ± 1.0	3.2 ± 0.5	4.1 ± 0.9	3.4 ± 0.6	2.0 ± 0.7	2.4 ± 1.4	31. 3 ± 4.8 b	14.2 ± 2.3	20.0 ± 3.6 ab	17.7 ± 3.6	8.9 ± 0.9 ab	10.5 ± 2.7 ade
Mean	2.4 ± 0.3	3.4 ± 0.3	11.2 ± 1.1	10.6 ± 1.2	7.3 ± 0.1	2.2 ± 0.3	21.6 ± 1.1	14.6 ± 1.1	15.9 ± 1.3	16.2 ± 1.2	9.9 ± 0.8 ab	8.8 ± 0.6

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure (P<0.05).

Appendix C Continued.

Table 2: Density values (mean ± se) by age class after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

Belt density (mean+se) in 1/10 ha by age class by treatment by year												
	Young (1/10 ha)						Mature (1/10 ha)					
Treatment	2006	2007	2008	2009	2010*	2011*	2006	2007	2008	2009	2010*	2011*
Control	133.3 ± 32.6 a	137. 5 ± 38.1	107.5 ± 26.9	87.5 ± 24.9	79.2 ± 24.9 a	175.0 ± 16.0 a	1325.0 ± 101.0	2054. 2 ± 169.6	1837.5 ± 65.7	1233.3 ± 97.9	2195.8 ± 122.6 b	2104.2 ± 92.4 ab
Dixie Harrow	45.8 ± 10.5 a	91.7 ± 19.8	5.0 ± 5.0	212.5 ± 71.5	33.8 ± 27 a	104.0 ± 23.9 a	1520.8 ± 123.9	1862.5 ± 186.4	1904.2 ± 240.5	1525.0 ± 167.3	1046.4 ± 365.7 a	2412.5 ± 200.2 a
Chaining	50.0 ± 11.8 a	75.0 ± 14.4	15.0 ± 8.7	137.5 ± 34.9	33.3 ± 49.5 ab	2004.2 ± 734.1 b	1270.8 ± 326.1	1325.0 ± 101.0	1254.2 ± 151	983.3 ± 130.7	954.2 ± 119.3 a	1779.2 ± 98.2 a
Aretator	308.3 ± 92.4 a	166.7 ± 28.1	0 ± 0	62.5 ± 27.5	29.2 ± 14.2 a	108.3 ± 45.4 a	1329.2 ± 170.8	1629.2 ± 130.2	1637.5 ± 90.4	1175.0 ± 406.3	2070.8 ± 134.4 a	2079.2 ± 153.0 a
Low Mow	179.2 ± 23.9 a	154.2 ± 35.6	25.0 ± 10.41	208.3 ± 46.4	1025.0 ± 564.1 b	579.2 ± 248.8 a	1162.5 ± 25.8	870.8 ± 105.3	987.5 ± 40.5	962.5 ± 29.2	570.8 ± 17.18 a	991.7 ± 52.9 ab
Med Mow	87.5 ± 15.8 a	83.3 ± 13.6	22.5 ± 16.5	145.8 ± 47.3	179.2 ± 124.4 ab	312.5 ± 167.5 a	1462. 5 ± 105.7	1545.8 ±305.8	1808.3 ± 352.1	1020.8 ± 128.3	1475.0 ± 283.9 a	1783.3 ± 285.6 b
High Mow	16.7 ± 9.6 a	70.8 ± 33.6	0 ± 0	58.3 ± 17.4	37.5 ± 17.2 a	70.8 ± 17.2 a	1254.2 ± 86.0	1412.5 ± 236.8	1554.2 ± 146.5	1112.5 ± 61.8	2166.7 ± 179.8 b	683.3 ± 171.7 a
Low Spike	525.0 ± 162.0 b	266.7 ± 65.6	12.5 ± 7.5	120.8 ± 24.9	141.7 ± 60.3 ab	254.2 ± 40.5 a	1358.3 ± 80.7	2479.2 ± 378.7	2112.5 ± 642.2	1416.7 ± 195.6	2137.5 ± 342.9 a	2070.8 ± 307.0 a
High Spike	79.2 ± 21.9 a	58.3 ± 10.8	97.5 ± 91.0	137.5 ± 48.8	133.3 ± 58.5 ab	137.5 ± 66.1 a	1558.3 ± 167.4	1900.0 ± 212.2	1058.3 ± 273.2	291.7 ± 129.5	391.7 ± 195.4 a	958.3 ± 285.3 b
Perscribed Fire	83.3 ± 24.5 a	62.5 ± 23.9	0 ± 0	33.3 ± 18.0	54.2 ± 4.2 a	150.0 ± 50.0 a	1454.2 ± 67.1	1070.8 ± 441.1	1395.8 ± 299.7	637.5 ± 243.1	500.0 ± 282.1 a	395.8 ± 299.7 b
Mean	160.0 ± 32.7	116.7 ± 13.4	28.5 ± 10.5	120.4 ± 14.4	184.6 ± 68.8	395.7 ± 116.2	1369.6 ± 45.3	1602.5 ± 104.2	1555.0 ± 97.7	1035.8 ± 75.7	1450.9 ± 122.3	1709.8 ± 97.1
	Decadant (1/10 ha)						Dead (1/10 ha)					
Treatment	2006	2007	2008	2009*	2010*	2011*	2006	2007	2008 *	2009*	2010*	2011*
Control	145. 8 ± 18.5	129.2 ± 29.9 b	112.5 ± 51.5	316.7 ± 23.6 b	258.3 ± 42.3 b	120.8 ± 31.5 ab	104.2 ± 24.9	75. 0 ± 25.9	117.5 ± 25.0	58.3 ± 10.8	325.0 ± 42.2 ab	162.5 ± 8.0 a
Dixie Harrow	75.0 ± 22.0	8.3 ± 8.3 a	0 ± 0	54.2 ± 24.9 a	60.9 ± 27.6 a	0 ± 0 a	108.3 ± 40.0	91. 7 ± 38.8	45.0 ± 30.7	91.7 ± 28.5	159.7 ± 54.2 a	141.7 ± 14.4 a
Chaining	66.7 ± 18.0	0 ± 0 a	0 ± 0	79.2 ± 25.8 a	112.5 ± 31.5 ab	29.1 ± 8.0 a	95.8 ± 22.9	100.0 ± 15.2	65.0 ± 11.9	79.2 ± 10.5	412.5 ± 42.7 ab	308.3 ± 45.9 a
Aretator	108.3 ± 14.4	0 ± 0 a	0 ± 0	191.7 ± 80.7 a	83.3 ± 23.6 ab	141.7 ± 38.8 ab	100.0 ± 22.6	412.5 ± 213.5	62.5 ± 12.5	100.0 ± 45.6	187.5 ± 57.9 a	604.2 ± 158.6 ab
Low Mow	79.2 ± 37.5	0 ± 0 a	0 ± 0	0 ± 0 a	91.7 ± 30.8 ab	0 ± 0 a	154.2 ± 32.2	4.2 ± 4.2	0 ± 0	4.2 ± 4.2	354.2 ± 65 ab	16.7 ± 6.8 a
Med Mow	129.2 ± 34.9	0 ± 0 a	0 ± 0	562.5 ± 130.9 1	325.0 ± 79.8 b	145.8 ± 21.9 ab	133.3 ± 32.6	37.5 ± 21.9	27.5 ± 14.9	33.3 ± 13.6	412.5 ± 124.4 ab	33.3 ± 22.6 a
High Mow	91.7 ± 21.0	20.8 ± 15.8 a	0 ± 0	308.3 ± 49.3 al	108.3 ± 14.4 ab	220.8 ± 10.5 b	54.2 ± 4.2	116.7 ± 16.7	60.0 ± 12.2	108.3 ± 10.76	170.8 ± 14.2 a	195.8 ± 24.9 a
Low Spike	250.0 ± 70.4	0 ± 0 a	0 ± 0	416.7 ± 82.8 ab	345.8 ± 45.8 abc	250.0 ± 70.4 b	50.0 ± 15.2	358.3 ± 232.8	470.0 ± 272.4	475.0 ± 177.5	512.5 ± 216.6 ab	583.3 ± 216.6 ab
High Spike	62.5 ± 17.2	0 ± 0 a	0 ± 0	325.0 ± 16.0 al	291.7 ± 29.3 b	100.0 ± 18.0 ab	87.5 ± 18.5	487.5 ± 272.6	1015.0 ± 359.8	1100.0 ± 380.1	1141.7 ± 314.2 b	1245.8 ± 370.3 b
Perscribed Fire	91.7 ± 24.1	0 ± 0 a	0 ± 0	100.0 ± 48.6 a	95.8 ± 20.8 ab	133.3 ± 44.1 ab	54.2 ± 14.2	283.3 ± 43.0	250.0 ± 104.7	175.0 ± 71.5	1091.7 ± 441.9 b	388.9 ± 102.9 a
Mean	95.4 ± 7.8	15.8 ± 6.9	11.3 ± 7.0	235.4 ± 32.2	177.3 ±15.4	117.1 ± 15.4	94.2 ± 8.6	196.7 ± 45.5	211.3 ± 63.0	222.5 ± 63.4	476.8 ± 75.1	367.5 ± 71.4

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix C Continued.

Table 3: Grass Cover values (mean ± se) after vegetation treatment of a Wyoming big sagebrush community in western Wyoming.

	Cover (%)											
Treatment	2006*	2007	2008	2009	2010	2011	2006	2007	2008	2009*	2010	2011
Control	2.7 ± 0.8 ab	3.7 ± 0.9	1.5 ± 0.2 ab	1.6 ± 0.1	1.6 ± 0.4	1.8 ± .3 ab	3.6 ± 0.3	4.4 ± 0.5	3.4 ± 0.3	1.5 ± 0.8	0.5 ± 0.1 b	0.6 ± 0.5
Dixie Harrow	0.2 ± .2 a	4.6 ± 1.8	2.0 ± 1.1 ab	1.5 ± 0.9	2.0 ± 0.6	0.9 ± 0.2 ab	3.3 ± 1.0	3.7 ± .5	4.1 ± 0.7	0.04 ± 0.04	1.6 ± .5 ab	0.6 ± 0.1
Chaining	0.7 ± 0.5 a	3.3 ± 1.2	1.5 ± 0.5 ab	2.0 ± 1.2	1.8 ± 0.9	0 .9 ± 0.4 ab	4.6 ± 1.2	3.6 ± 0.3	3.9 ± 0 .4	0.6 ± 0.6	2.1 ± 0.9 ab	0.6 ± 0.3
Aerator	5.9 ± 2.0 b	3.8 ± 1.0	3.2 ± 1.6 ab	4.5 ± 1.9	3.1 ± 0.8	3.0 ± 0.6 a	2.8 ± 0.3	3.2 ± 0.8	3.5 ± 0.6	1.9 ± 0.5	0.5 ± 0.1 ab	0.6 ± 0.1
Low Mow	3.5 ± 0.5 ab	4.8 ± 1.1	6.1 ± 1.6 a	2.8 ± 1.2	4.4 ± 0.3	2.3 ± 0.3 ab	2.0 ± 0.4	3.7 ± 0.4	7.1 ± 1.9	2.3 ± 0.7	2.4 ± 0.2 a	0.8 ± 0.1
Med Mow	2.0 ± 0.8 ab	4.5 ± 2.2	0.9 ± 0.3 b	1.8 ± 1.3	2.5 ± 0.7	2.3 ± 0.9 ab	3.1 ± 0.5	3.9 ± 0.5	3.0 ± 1.0	3.5 ± 1.0	0.8 ± 0.1 ab	0.7 ± 0.1
High Mow	3.1 ± 0.9 ab	2.0 ± 1.1	2.4 ± 1.0 ab	3.0 ± 0.8	2.3 ± 0.5	2.0 ± 0.1 ab	3.5 ± 0.3	3.5 ± 0.3	4.7 ± 0.6	1.9 ± 0.5	0.5 ± 0.1 ab	0.8 ± 0.1
Low Spike	0.9 ± 0.5 ab	1.4 ± 0.8	0.5 ± 0.4 b	0.01 ± 0.01	1.2 ± 0.6	0.4 ± 0.01 b	3.4 ± 0.2	4.0 ± 0.6	3.7 ± 0.6	2.7 ± 1.5	0.5 ± 0.1 ab	0.6 ± 0.2
High Spike	2.8 ± 1.3 ab	2.8 ± 1.1	1.6 ± 0.7 ab	1.6 ± 0.8	2.3 ± 0.5	1.7 ± 1.0 ab	2.6 ± 0.4	3.1 ± 0.1	2.9 ± 0.5	0.6 ± 0.4	1.1 ± 0.4 ab	0.5 ± 0.2
Prescribed Fire	2.2 ± 0.4 ab	3.1 ± 1.0	3.0 ± 1.0 ab	1.5 ± 0.6	2.0 ± 0.6	1.3 ± 0.1 ab	2.4 ± 0.5	4.7 ± 0.4	5.7 ± 1.3	5.1 ± 1.5	0.7 ± 0.3 ab	0.6 ± 0.1
Mean	2.4 ± 0.4	3.4 ± 0.4	2.3 ± 0.4	2.0 ± 0.3	2.3 ± .2	1.7 ± 0.2	3.1 ± 0.2	3.8 ± 0.2	4.2 ± 0.3	2.1 ± 0.3	1.1 ± 0.2	0.6 ± .04
	Poa secunda						Grass Total					
	Cover (%)											
Treatment	2006*	2007	2008	2009	2010	2011	2006*	2007 *	2008 *	2009	2010	2011
Control	5.4 ± 0.9 a	9.0 ± 0.6	5.7± 1.3	3.13 ± 1.19 b	2.63 ±0.204	2.5 ± 0.5	13.86 ± 1.15 ab	20.42 ± 2.16	13.86 ± 1.15	7.79 ± 1.19	5.15 ± 0.262 b	5.44 ± 0.76
Dixie Harrow	5.1 ± 0.9 a	9.8 ± 0.8	4.3 ± 0.7	6.21 ± 0.572 a	2.25 ± 0.721	4.2 ± 0.5	9.51 ± 1.79 a	19.41 ± 2.79	12.46 ± 1.1	13.74 ± 1.53	6.45 ± 2.0 ab	6.12 ± 0.48
Chaining	3.0 ± 0.6 a	9.8 ± 0.8	4.4 ± 0.9	2.63 ± 1.07 ab	3.28 ± 1.07	4.2 ± 0.5	8.38 ± 0.90 a	14.48 ± 2.64	10.78 ± 1.16	9.46 ± 1.52	8.31 ± 1.57 ab	4.60 ± 0.84
Aerator	10.7 ± 1.1 b	7.0 ± 0.4	9.8 ± 1.0	4.63 ± 0.526 al	2.76 ± 0.241	1.0 ± 0.4	20.67 ± 2.19 b	15.73 ± 1.19	6.82 ± 0.68	12.73 ± 2.6	6.82 ± 0.68 ab	5.03 ± 0.30
Low Mow	10.2 ± 0.8 b	9.3 ± 0.7	16.5 ± 4.0	1.75 ± 0.859 b	1.56 ± 0.354	2.1 ± 0.8	21.43 ± 3.05 b	24.26 ± 0.75	34.79 ± 7.58	10.04 ± 2.61	5.11 ± 0.72 a	5.93 ± 0.51
Med Mow	7.0 ± 0.7 ab	7.5 ± 1.4	4.9 ± 1.6	1.75 ± 0.681 b	2.98 ± 0.643	2.6 ± 0.9	14.86 ± 1.37 ab	20.63 ± 0.82	11.42 ± 3.82	9.09 ± 1.49	6.94 ± 0.528 ab	5.95 ±0.76
High Mow	9.3 ± 1.3 ab	8.5 ± 1.0	8.31 ± 1.34	4.58 ± 0.95 ab	3.19 ± 0.244	2.9 ± 0.6	16.76 ± 0.71 ab	14.97 ±2.62	17.19 ± 2.56	9.79 ± 1.4	6.18 ± 0.26 ab	5.75 ±0.61
Low Spike	8.5 ± 1.5 ab	4.9 ± 2.1	5.63 ± 3.26	3.5 ± 1.72 b	1.67 ± 0.162	1.7 ± 0.2	15.65 ± 2.41 ab	16.48 ± 3.42	14.16 ± 2.38	7.06 ± 2.59	4.36 ± 1.6 b	3.49 ± 0.17
High Spike	4.1 ± 0.5 a	6.3 ± 0.2	3.36 ± 0.957	2.49 ± 0.760 al	1.08 ± 0.089	2.6 ± 0.7	10.78 ± 1.71 a	15.82 ± 1.16	9.71 ± 0.521	8.19 ± 1.98	5.11 ± 0.722 b	5.76 ± 1.12
Prescribed Fire	8.0 ± 1.3 ab	9.3 ± 1.4	13.38 ± 2.27	1.14 ± 2.27 b	2.36 ± 0.225	1.5 ± 0.1	14.46 ± 1.10 ab	19.14 ± 2.83	27.05 ±4.89	9.43 ± 1.36	5.58 ± 0.474 ab	5.76 ± 1.12

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix C Continued.

Table 4: Grass and forb biomass values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

Biomass	Grass (kg/ha)						Forbs (kg/ha)					
Treatment	2006*	2007	2008*	2009	2010	2011	2006	2007	2008*	2009	2010	2011
Control	184 .5 ± 29.56	196.68 ± 48.54	13.93 ± 0.66 ab	7.79 ± 1.19 ab	5.15 ± 0.262 b	56.1 ± 3.41	4.50 ± 4.50	33.73 ± 13.09	53.43 ± 7.09	5.95 ± 1.74	2.44 ± 1.52 a	29.61 ± 4.05 ab
Dixie Harrow	272.25 ± 80.11	86.48 ± 16.69	12.46 ± 1.1 ab	13.74 ± 1.53 ab	6.46 ± 2.0 a	61.65 ± 11.05	46.25 ± 28.37	50.83 ± 17.91	125.8 ± 28.49	10.93 ± 2.54	3.49 ± 1.32 a	14.13 ± 1.29 a
Chaining	149.5 ± 41.03	41.65 ± 8.09	10.78 ± 1.16 b	7.79 ± 1.19 ab	8.31 ± 1.57 a	44.68 ± 5.23	35.50 ± 19.83	11.15 ± 4.41	43.58 ± 11.36	7.17 ± 2.56	2.94 ± 1.92 a	21.58 ± 1.64 ab
Aerator	233.25 ± 31.69	163.35 ± 14.68	19.79 ± 2.19 ab	12.73 ± 2.6 ab	6.82 ± 0.68 ab	55.0 ± 10.22	59.75 ± 35.7	51.23 ± 10.11	67.63 ± 10.51	5.51 ± 1.78	20.2 ± 17.66 ab	25.98 ± 14.74 ab
Low Mow	208.5 ± 40.87	142.68 ± 15.32	34.79 ± 7.58 a	10.03 ± 2.61 a	10.35 ± 0.490 a	81.80 ± 11.69	61.0 ± 35.22	41.63 ± 22.97	50.08 ± 11.6	2.68 ± 1.35	3.52 ± 1.42 a	12.0 ± 3.44 a
Med Mow	276.25 ± 107.25	202.58 ± 24.21	11.42 ± 3.82 ab	9.09 ± 1.49 ab	6.94 ± 0.528 ab	68.92 ± 13.92	25.25 ± 25.25	70.58 ± 15.51	95.75 ± 29.06	7.56 ± 1.45	6.56 ± 4.55 ab	18.87 ± 3.96 ab
High Mow	172.5 ± 16.70	138.75 ±22.39	17.18 ± 2.56 ab	9.79 ± 1.40 b	6.18 ± 0.261 b	52.36 ± 8.13	17.25 ± 6.61	76.23 ± 12.79	104.83 ± 25.03	3.23 ± 1.21	31.17 ± 23.22 ab	25.94 ± 6.32 ab
Low Spike	136.75 ± 29.48	197.18 ± 45.94	14.16 ± 2.38 ab	7.06 ± 2.59 ab	4.36 ± 1.60 b	41.40 ± 8.64	20.0 ± 11.58	68.98 ± 14.74	32.85 ± 14.39	3.3 ± 1.18	15.42 ± 10.14 ab	11.79 ± 2.80 a
High Spike	156.25 ± 44.71	87.15 ± 11.69	9.71 ± 0.521 b	8.19 ± 1.98 b	5.58 ± 0.474 ab	46.48 ± 8.20	0 ± 0	21.38 ± 12.49	153.45 ± 30.87	1.91 ± 0.87	75.88 ± 33.24 b	23.55 ± 5.63 ab
Prescribed Fire	198.25 ± 24.54	138.53 ± 36.86	27.05 ± 4.89 ab	9.42 ± 1.36 ab	5.58 ± 0.474 ab	64.02 ± 3.03	27.75 ± 33.24	66.38 ± 24.19	82.23 ± 23.68	12.4 ± 5.39	16.16 ± 7.29 ab	40.62 ± 4.61 b
Mean	198.8 ± 16.20	139.50 ± 11.57	178.48 ± 15.78	106.64 ± 8.5	57.06 ± 3.19	57.07 ± 3.19	29.73 ± 6.79	49.21 ± 5.53	80.96 ± 8.31	6.06 ± 0.847	17.78 ± 5.31	21.94 ± 1.76

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix C Continued.

Table 5: Forb cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Erigeron linearis						Linanthus pungens					
	Cover (%)											
Treatment	2006*	2007*	2008*	2009	2010	2011	2006*	2007	2008	2009	2010	2011
Control	0.63 ± 0.28 a	0.49 ± 0.22	0.054 ± 0.371	0.006 ± 0.006	0.013 ± 0.007 ab	0.09 ± 0.05	1.1 ± 0.39	2.2 ± 1.04	1.73 ± 0.774	1.21 ± 0.525	0.819 ± 0.344	0.77 ± 0.31
Dixie Harrow	1.05 ± 1.0 a	1.05 ± 0.60	1.28 ± 0.812	0.10 ± 0.029	0 ± 0 ab	0.02 ± 0 .01	2.35 ± 0.75	2.27 ± 0.63	1.94 ± 0.69	0.688 ± 0.389	0.263 ± 0.19	0.67 ± 0.33
Chaining	0.85 ± 0.65 a	0.59 ± 0.27	1.16 ± 0.503	0.05 ± 0.034	0.088 ± 0.024 b	0.19 ± 0.15	0.93 ± 0.24	0.67 ± 0.18	0.738 ± 0.266	0.087 ± 0.051	0.513 ± 0.107	0.37 ± 0.14
Aerator	0.59 ± 0.34 a	0.84 ± 0.54	1.08 ± 0.378	0 ± 0	0.006 ± 0.006 ab	0 .01 ± 0.01	4.57 ± 1.35	2.38 ± 0.51	3.01 ± 0.59	1.54 ± 0.34	1.05 ± 0.269	3.01 ± 0.59
Low Mow	0 ± 0 a	0.19 ± 0.11	0.506 ± 0.458	0.006 ± 0.006	0 ± 0 ab	0.06 ± 0.04	2.22 ± 0.51	1.93 ± 0.74	2.95 ± 1.12	1.73 ± 0.612	0.83 1± 0.307	1.53 ± 0.65
Med Mow	1.52 ± 0.69 a	2.41 ± 1.16	2.08 ± 1.35	0.019 ± 0.019	0.006 ± 0.006 ab	0.05 ± 0 .04	1.19 ± 0.89	1.79 ± 0.87	0.502 ± 0.189	1.01 ± 0.65	0.756 ± 0.331	0.71 ± 0.37
High Mow	6.35 ± 3.0 b	4.79 ± 2.33	6.99 ± 3.67	0.006 ± 0.006	0 ± 0 ab	0 ± 0	2.58 ± 1.53	2.38 ± 1.51	2.53 ± 1.36	0.713 ± 0.608	1.21 ± 0.594	0.84 ± 0.42
Low Spike	0 ± 0 a	.08 ± .08	0.075 ± 0.075	0.006 ± 0.006	0 ± 0 ab	0 ± 0	2.85 ± 1.65	1.44 ± 0.85	1.12 ± 0.646	0.70 ± 0.44	0.956 ± 0.546	0.27 ± 0.16
High Spike	7.19 ± 0.74 b	6.03 ± 1.04	5.23 ± 0.968	0.063 ± 0.030	0.031 ± 0.012 a	0.26 ± 0.14	0.36 ± 0.08	0.75 ± 0.26	0.381 ± 0.188	0.581 ± 0.229	0.356 ± 0.224	0.32 ± 0.16
Prescribed Fire	2.14 ± 0.91 ab	2.53 ± 1.18	3.68 ± 1.95	0 ± 0	0 ± 0 ab	0 ± 0	1.23 ± 0.46	1.42 ± 1.04	1.67 ± 1.02	0.175 ± 0.105	0.719 ± 0.209	0.13 ± 0 .13
Mean	2.03 ± 0.05	1.9 ± 0.42	2.26 ± 0.536	0.026 ± 0.007	0.014 ± 0.024	0.07 ± 0.02	1.94 ± 0.32	1.72 ± 0.26	1.66 ± 0.26	0.84 ± 0.148	0.747 ± 0.106	0.67 ± 0.12
	Phlox hoodii						Forb Total					
	Cover (%)											
Treatment	2006*	2007*	2008	2009	2010	2011	2006 *	2007	2008	2009	2010	2011*
Control	2.72 ± 0.81	3.73 ± 1.04	1.83 ± 0.759	1.04 ± 0.761	0.919 ± 0.51	1.03 ± 0.65	4.55 ± 1.13 b	12.46 ± 1.78	5.0 ± 1.67	3.93 ± 1.14	3.25 ± 0.71	3.45 ± 0.63 a
Dixie Harrow	1.37 ± 0.65	2.41 ± 0.95	1.0 ± 0.384	0.856 ± 0.308	0.819 ± 0.462	0.44 ± 0.1	6.13 ± 1.63 ab	14.12 ± 1.80	6.48 ± 1.61	3.77 ± 1.25	3.04 ± 0.677	3.15 ± 0.50 a
Chaining	2.32 ± 1.24	3.57 ± 0.31	2.52 ± 0.523	1.7 ± 0.072	1.89 ± 0.358	2.06 ± 0.22	4.83 ± 2.09 ab	11.43 ± 0.85	5.86 ± 0.753	2.79 ± 0.631	3.71 ± 0.287	4.62 ± 0.57 ab
Aerator	0.53 ± 0.19	1.88 ± 0.20	1.63 ± 0.244	0.513 ± 0.210	0.70 ± 0.133	0.32 ± 0.16	7.01 ± 1.45 a	11.71 ± 0.37	6.81 ± 0.275	2.78 ± 0.552	2.6 ± 0.306	3.34 ± 0.42 a
Low Mow	1.43 ± 0.76	2.74 ± 0.78	1.54 ± 0.556	2.71 ± 0.95	1.02 ± 0.257	1.42 ±0.63	3.68 ± 0.47 b	13.18 ± 1.12	5.52 ± 1.66	4.78 ± 1.6	2.98 ± 0.58	4.37 ± 0.75 ab
Med Mow	3.79 ± 1.41	4.41 ± 0.94	1.86 ± 0.629	2.43 ± 0.567	1.74 ± 0.629	0.80 ± 0.51	7.49 ± 1.92 ab	14.31 ± 1.41	5.29 ± 1.88	4.93 ± 0.429	3.78 ± 0.48	3.99 ± 0.21 ab
High Mow	1.31 ± 0.90	2.19 ± 0.08	2.18 ± 0.36	0.606 ± 0.235	0.675 ± 0.089	0.43 ± 0.21	11.88 ± 1.47 a	14.21 ± 1.37	12.97 ± 2.89	6.1 ± 1.47	5.07 ± 1.91	6.40 ± 1.32 ab
Low Spike	3.06 ± 0.77	3.10 ± 0.79	2.11 ± 0.844	1.11 ± 0.255	0.563 ± 0.316	0.58 ± 0.23	6.06 ± 1.50 ab	10.41 ± 1.44	3.98 ± 1.26	2.64 ± 0.583	2.37 ± 0.662	2.46 ± 0.36 a
High Spike	3.07 ± 0.99	3.35 ± 0.82	2.36 ± 0.885	0.981 ± 0.459	1.10 ± 0.298	2.10 ± 0.72	10.75 ± 1.60 b	13.84 ± 1.52	9.23 ± 2.05	6.71 ± 1.44	5.76 ± 1.28	7.44 ± 1.17 b
Prescribed Fire	1.82 ± 0.50	2.74 ± 0.29	2.77 ±0.37	0.925 ± 0.224	1.49 ± 0.117	0.37 ± 0.19	6.50 ± 1.25 b	16.52 ± 2.39	11.67 ± 1.33	3.46 ± 0.267	4.89 ± 0.655	2.78 ± 1.20 a
Mean	2.14 ± 0.29	3. 01 ± 0.23	1.98 ± 0.183	1.29 ± 0.122	1.09 ± 0.122	0.99 ± 0.16	6.88 ± 0.58	13.21 ± 0.50	7.28 ± 0.652	4.19 ± 0.361	3.75 ± 0.301	4.24 ± 0.33

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix C Continued.

Table 6: Herbaceous height, species richness and Shannon-Wiener Index values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming

	Herbaceous Height (cm)			Species Richness						Shannon-Wiener Index					
Treatment	2006	2007	2011	2006	2007	2008	2009*	2010*	2011	2006	2007	2008	2009	2010 *	2011*
Control	13.53 ± 0.33	13.76 ± 0.66	15.33 ± 1.29	13.0 ± 0.39	15.0 ± 0.47	20 ± 0.434	23 ± 0.5	24 ± 0.21	28 ± 0.26	1.83 ± 0.39	1.92 ± 0.47	1.9 ± 0.6	1.67 ± 0.5	1.74 ± 0.28 a	1.97 ± 0.26
Ditie Harrow	17.6 ± 0.89	12.59 ± 1.18	9.03 ± 0.19	18.0 ± 0.38	33.0 ± 0.23	28.0 ± 0.217	25 ± 0.23	26 ± 0.1	30 ± 0.12	1.75 ± 0.38	2.73 ± 0.23	2.45 ± 0.21	2.23 ± 0.23	2.5 ± 0.1 ab	2.33 ± 0.12
Chaining	13.28 ± 0.57	11.06 ± 0.32	12.03 ± 1.14	17.0 ± 0.24	18.0 ± 0.26	22 ± 0.299	20 ± 0.28	22 ± 0.21	30 ± 0.19	1.92 ± 0.24	2.06 ± 0.26	2.1 ± 0.299	1.82 ± 0.28	2.05 ± 0.21 ab	2.15 ± 0.19
Aerator	18.63 ± 1.53	11.86 ± 0.66	8.68 ± 0.25	14.0 ± 0.52	23 ± 0.25	18 ± 0.294	18 ± 0.23	20 ± 0.17	26± 0.15	1.78 ± 0.52	2.47 ± 0.25	2.1 ± 0.294	1.99 ± 0.229	1.91 ± 0.17 ab	2.09 ± 0.15
Low Mow	17.93 ± 0.67	12.89 ± 0.31	7.90 ± 0.26	11 ± 0.43	13.0 ± 0.23	17 ± 0.413	23 ± 0.14	22 ± 0.13	27 ± 0.17	1.75 ± 0.43	2.10 ± 0.23	2.1 ±0.413	2.3 ±0.14	2.3 ± 0.13 b	2.33 ± 0.12
Med Mow	17.6 ± 1.46	14.46 ± 0.88	8.83 ± 0.56	15.0 ± 0.28	15.0 ± 0.24	22 ± 0.19	24 ± 0.26	20 ± 0.13	28 ± 0.13	1.89 ± 0.28	2.14 ± 0.24	2.2 ± 0.19	2.22 ± 0.26	2.31 ± 0.13 ab	2.33 ± 0.13
High Mow	15.70 ± 1.16	12.65 ± 0.72	9.19 ± 0.44	130 ± 0.53	23.0 ± 0.40	19 ± 0.472	21 ± 0.32	21 ± 0.24	26 ± 0.21	1.83 ± 0.53	2.18 ± 0.40	2.0 ± 0.472	1.87 ±0.32	1.83 ± 0.24 ab	1.99 ± 0.21
Low Spike	16.13 ± 0.92	11.85 ± 0.52	13.54 ± 1.09	20 ± 0.5	23.0 ± 0.44	18 ± 0.686	19 ± 0.31	20 ±0.27	26 ± 0.2	1.62 ±0.49	2.15 ± 0.44	1.98 ± 0.686	1.62 ± 0.31	1.6 ± 0.27 b	1.74 ± 0.20
High Spike	14.25 ± 0.83	11.95 ± 0.30	10.94 ± 0.61	14 ± 0.47	24.0 ±0.30	20 ± 0.203	21 ± 0.21	23 ± 0.16	28 ± 0.12	1.76 ± 0.47	2.31 ± 0.30	2.3 ± 0.203	2.23 ± 0.21	2.1 ± 0.16 ab	2.39 ± 0.12
Prescribed Fire	18.78 ± 0.73	11.69 ± 0.30	10.30 ± 1.45	18.0 ± 0.62	19.0 ± 0.31	23 ± 0.443	22 ± 0.32	23 ± 0.16	26 ± 0.17	1.63 ± 0.62	2.18 ± 0.31	2.3 ± 0.203	1.91 ± 0.32	2.2 ± 0.16 ab	2.10 ± 0.17
Mean	16.34 ± 0.42	12.48 ± 0.25	10.58 ± 0.44	15.3 ± 0.4	20.6 ± 0.31	20.7 ± 0.364	21.6 ± 0.28	22.1 ± 0.19	27.5 ± 0.17	1.78 ± 0.45	2.23 ± 0.31	1.92 ± 0.36	1.99 ± 0.27	2.03 ± 0.19	2.14 ± 0.17

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix C Continued.

Table 7: Litter and bare ground cover values (mean ± se) after vegetation treatments of a Wyoming big sagebrush community in western Wyoming.

	Litter						Bareground					
	Cover (%)											
Treatment	2006*	2007*	2008*	2009*	2010	2011*	2006 *	2007	2008	2009	2010 *	2011*
Control	43.69 ± 4.49 b	23.51 ± 23.51a	30.94 ± 3.41 ab	44.36 ± 2.23	22.03 ± 3.67	22.03 ± 3.67 a	35.08 ± 4.15 ab	12.88 ± 1.22	19.32 ± 2.43	26.19 ± 2.74	48.94 ± 2.43	44 ± 4.07 b
Dixie Harrow	14.83 ± 2.61 a	17.61 ± 2.96 a	30.38 ± 0.982 ab	34.43 ± 5.45	18.73 ± 2.41	19.4 ± 2.06 a	54.44 ± 3.94 a	21.09 ± 2.73	34.13 ± 3.52	26.01 ± 3.63	31.78 ± 2.60	43.25 ± 1.53 ab
Chaining	23.59 ± 2.68 a	23.59 ± 2.68 a	31.94 ± 2.96 ab	41.65 ± 1.92	20.41 ± 2.66	22.03 ± 2.36 a	44.09 ± 4.38 ab	22.26 ± 0.82	31.55 ± 2.41	22.24 ± 1.05	28.79 ± 3.98	38.38 ± 3.42 ab
Aerator	36.75 ± 1.68 b	25.42 ± 3.62a	19.75 ± 5.47 b	55.23 ± 8.81	17.93 ± 2.91	27.93 ± 2.66 a	38.31 ± 2.72 ab	19.12 ± 2.39	17.27 ± 2.81	25.85 ± 3.84	49.5 ± 4.43	42.41 ± 0.92 b
Low Mow	43.94 ± 5.06 b	46.56 ± 4.98 b	58.44 ± 3.43 a	54.21 ± 2.33	25.78 ± 4.30	33.03 ± 2.44 a	30.26 ± 5.17 b	8.25 ± 1.05	11.93 ± 1.78	29.01 ± 5.6	34.19 ± 2.64	34.19 ± 2.64 ab
Med Mow	21.38 ± 2.0 a	32.83 ± 5.09 ab	29.12 ± 10.27 ab	37.6 ± 4.81	15.51 ± 5.18	23.79 ± 4.44 a	33.96 ± 3.90 b	12.83 ± 2.43	14.98 ± 6.83	24.6 ± 6.83	28.91 ± 8.54	45.69 ± 3.72 b
High Mow	36.37 ± 4.65 b	30.00 ± 2.27 ab	28.44 ± 3.69 ab	34.63 ± 5.01	15.73 ± 3.01	18.43 ± 2.35 a	38.63 ± 0.63 ab	16.66 ± 4.38	38.63 ± 6.93	30.9 ± 3.09	50.09 ± 4.64	48.13 ± 2.79 b
Low Spike	37.63 ± 2.38 b	25.63 ± 2.44 ab	16.57 ± 3.43 ab	41.19 ± 5.23	17.3 ± 2.41	7.54 ± 1.99 a	45.01 ± 3.06 ab	16.35 ± 1.18	17.48 ± 3.22	35.29 ± 2.37	53.16 ± 5.26	40.31± 3.08 b
High Spike	25.00 ± 3.08 ac	26.74 ± 4.42 ab	29.66 ± 4.91 ab	32.88 ± 4.60	15.2 ± 1.21	14.11 ± 5.68 ab	36.86 ± 1.96 ab	13.7 ± 2.98	25.61 ± 1.89	37.59 ± 2.86	45.25 ± 3.77	36.86 ± 1.96 b
Prescribed Fire	38.90 ± 2.30 bc	19.36 ± 2.88 a	26.26 ± 1.96 ab	39.06 ± 2.83	11.53 ± 1.89	21.75 ± 1.93 b	42.76 ± 1.75 ab	23.64 ± 4.59	21.21 ± 3.01	26.61 ± 3.81	28.45 ± 12.82	21.75 ± 1.93 a
Mean	31.76 ± 1.85	27.07 ± 1.57	30.15 ± 2.14	41.52 ± 1.78	16.96 ± 1.04	20.47 ± 1.53	39.94 ± 1.54	16.68 ± 1.05	21.24 ± 1.47	26.44 ± 1.53	39.39 ± 2.37	40.55 ± 1.53

* by the year denotes that a slice test detected a significant difference for that year from the others years. Within each column, means with different letters are significantly different using Tukey's honestly significant difference multiple comparison procedure ($P<0.05$).

Appendix D. Percent average pre-treatment species cover (mean ± se) for a Wyoming big sagebrush community study near Pinedale, Wyoming. The cover class method was used to compute values.

	Treatments (1-5)				
Growth form/species	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
GRASSES:					
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0.44 ± 0.25	0 ± 0
Achnatherum lettermanii	2.70 ± 0.75	0.23 ± 0.21	0.68 ± 0.48	2.03 ± 0.79	3.53 ± 0.52
Elymus elymoides	0.26 ± 0.07	0.30 ± .18	0.02 ± 0.01	0 ± 0	1.25 ± 0.26
Elymus lanceolatus	3.55 ± 0.28	3.30 ± 1.03	4.59 ± 1.25	3.08 ± 0.49	1.97 ± 0.43
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Poa secunda	5.39 ± 0.9	5.14 ± 0.86	3.01 ± 0.59	7.03 ± 0.72	10.21 ± 0.82
Pseudoroegeneria spicata	1.96 ± 0.52	0.54 ± 0.31	0.08 ± 0.08	2.28 ± 0.73	4.47 ± 2.29
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0.09 ± 0.09	0 ± 0	0 ± 0
Arabis hirsuta var. pycnocarpa	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arenaria	0 ± 0	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0.006 ±0.006	0.01 ± 0.01	0 ± 0	0.04 ± 0.04	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0 ± 0	0 ± 0	0.27 ± 0.12	0.56 ± 0.1	0.04 ± 0.04
Cymopterus nivalis	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Erigeron engelmanni	0 ± 0	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0
Erigeron linearis	0.63 ± 0.28	1.05 ± 1.00	0.85 ± 0.65	1.52 ± 0.69	0 ± 0
Eriogonum brevicaule var. *micranthum*	0 ± 0	0.04 ± 0.04	0.04 ± 0.04	0.04 ± 0.04	0 ± 0
Eriogonum ovalifolium	0.09 ± 0.09	1.16 ± 0.52	0.22 ±0.22	0.35 ± 0.30	0 ± 0

Appendix D Continued.

Growth form/species	Treatments (1-5)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	1.10 ± 0.39	2.35 ± 0.75	0.93 ± 0.25	1.19 ± 0.89	2.12 ± 0.52
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	2.72 ± 0.81	1.37 ± 0.65	2.32 ± 1.24	3.79 ± 1.41	1.43 ± 0.76
Phlox longifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox multiflora	0 ± 0	0.09 ±0.09	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Trifolium andinum var. andinum	0 ± 0	0.02 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0.04 ± 0.04	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0.05 ± 0.04	0 ± 0	0 ± 0

Appendix D Continued.

	Treatments (1-5)				
Growth form/species	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
SHRUBS:					
Artemisia arbuscula	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	16.87 ± 1.44	15.87 ± 1.4	9.63 ± 2.26	17.79 ± 4.26	17. 36 ± 3.53
Chrysothamnus viscidiflorus	4.25 ± 1.42	1.58 ± 0.9	2.72 ± 0.59	1.53 ± 0.44	1.80 ± 0.60
Krascheninnikovia lanata	0 ± 0	.04 ±0.04	0 ± 0	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0.09 ± 0.09	0.04 ± 0.04
GROUND COVER:					
Bare Ground	35.08 ± 4.15	54.44 ± 3.94	44.09 ± 4.38	33.96 ± 3.90	30.26 ± 5.17
Litter	43.69 ± 4.49	14.83 ± 2.61	19.08 ± 2.05	21.38 ± 2.0	43.94 ± 5.06
Rock	4.93 ± 0.36	7.31 ± 4.01	3.81 ± 0.30	6.51 ± 0.56	4.73 ± 0.83
Lichen	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0.08 ± 0.04	0.04 ± 0.04	0 ± 0	0 ± 0

Appendix D Continued.

	Treatments (6-10)				
Growth form/species	Heavy Spike	Prescribed Fire	High Mow	Areator	Light Spike
GRASSES:					
Achnatherum hymenoides	0 ± 0	0.09 ± 0.09	0.19 ± 0.11	0 ± 0	0 ± 0
Achnatherum lettermanii	2.78 ± 1.31	2.19 ± 0.38	3.13 ± 0.88	5.85 ± 1.96	0.89 ± 0.48
*Elymus elymoide*s	0.08 ± 0.04	0.84 ± 0.45	0.69 ± 0.16	1.33 ± 0.51	2.89 ± 0.71
Elymus lanceolatus	2.61 ± 0.39	2.42 ± 0.47	3.47 ± 0.31	2.78 ± 0.25	3.38 ± 0.23
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Poa secunda	4.11 ± 0.55	8.0 ± 1.31	9.28 ± 1.33	10.71 ± 1.14	8.49 ± 1.53
Pseudoroegeneria spicata	1.21 ± 0.63	0.91 ± 0.52	0 ± 0	0 ± 0	0 ± 0
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0 ± 0	0.09 ± 0.09	0 ± 0
Arabis hirsuta var. pycnocarpa	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0.04 ± 0.04	0.38 ± 0.22	0 ± 0	0.25 ± 0.15	0.08 ± 0.08
Cymopterus nivalis	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Erigeron engelmanni	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Erigeron linearis	7.19 ± 0.74	2.14 ± 0.91	6.26 ± 3.0	0.59 ± 0.34	0 ± 0
Eriogonum brevicaule var. *micranthum*	0.04 ± 0.04	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0
Eriogonum ovalifolium	0.04 ± 0.04	0.22 ± 0.22	0 ± 0	0.60 ± 0.55	0.08 ± 0.08

Appendix D Continued.

Growth form/species	Treatments (6-10)				
Forbs continued	Heavy Spike	Prescribed Fire	High Mow	Areator	Light Spike
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.36 ± 0.08	1.23 ± 0.46	2.58 ± 1.53	4.57 ± 1.35	2.85 ± 1.65
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	3.07 ± 0.99	1.82 ± 0.46	1.31 ± 0.90	0.53 ± 0.19	3.06 ± 0.77
Phlox longifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox multiflora	0 ± 0	0.21 ± 0.16	0.99 ± 0.38	0.38 ± 0.23	0 ± 0
Salsola tragus	0 ± 0	0.47 ± 0.47	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Trifolium andinum var. andinum	0 ± 0	0.006 ± 0.006	0 ± 0	0.01 ± 0.01	0 ± 0
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0.08 ± 0.08	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0.08 ± 0.08	0 ± 0	0 ± 0

Appendix D Continued.

	Treatments (6-10)				
Growth form/species	Heavy Spike	Prescribed Fire	High Mow	Areator	Light Spike
SHRUBS:					
Artemisia arbuscula	20.25 ± 0.77	28.38 ± 4.96	22.47 ± 5.13	21.43 ± 2.37	21.39 ± 2.03
Artemisia tridentata wyomingensis	2.48 ± 0.86	2.52 ± 0.95	1.13 ± 0.50	2.67 ± 0.41	3.1 ± 0.78
Chrysothamnus viscidiflorus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Krascheninnikovia lanata	0.35 ± 0.24	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0.35 ± 0.35	0.39 ± 0.19	0 ± 0	0.13 ± 0.13
GROUND COVER:					
Bare Ground	36.86 ± 1.96	42.76 ± 1.75	38.63 ± 4.65	38.31 ± 2.72	45.0 ± 3.06
Litter	25.0 ± 3.08	38.9 ± 2.3	36.37 ± 4.65	36.75 ± 1.68	37.63 ± 2.38
Rock	9.63 ± 1.7	3.84 ± 0.48	5.68 ± 2.14	2.81 ± 0.53	4.0 ± 0.63
Lichen	0 ± 0	0.21 ± 0.21	0 ± 0	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Percent average species cover (mean ± SE) post-treatment by year for a Wyoming big sagebrush community study near Pinedale, Wyoming.

Growth form/Species 2007	Treatments (1-5)				
Grasses	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	3.28 ± 1.15	4.594 ± 1.779	3.72 ± 0.87	4.49 ± 2.17	4.77 ± 1.08
Elymus elymoides	0.64 ± 0.27	0.488 ± 0.117	1.16 ± 0.51	0.89 ± 0.27	2.72 ± 0.87
Elymus lanceolatus	3.63 ± 0.32	3.669 ± 0.504	4.36 ± 0.46	3.92 ± 0.46	3.74 ± 0.39
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0.04 ± 0.04	0 ± 0	0.038 ± 0.038	0.04 ± 0.04	0.99 ± 0.51
Poa secunda	6.68 ± 1.45	9.825 ± 0.816	9.01 ± 0.63	7.49 ± 1.35	9.27 ± 0.74
Pseudoroegeneria spicata	0.21 ± 0.08	0.838 ± 0.321	2.14 ± 0.204	3.79 ± 0.86	2.78 ± 0.62
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0.119 ± 0.119	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0.075 ± 0.075	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0.09 ± 0.09	0.075 ± 0.043	0 ± 0	0.28 ± 0.17	0 ± 0
Arabis hirsuta var. pycnocarpa	0.13 ± 0.08	0 ± 0	0.025 ± 0.012	0.09 ± 0.05	0.36 ± 0.16
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0.04 ± 0.04	0.113 ± 0.038	0.038 ± 0.038	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0.038 ± 0.038	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	1.18 ± 0.39	0.469 ± 0.18	0.038 ± 0.038	0.68 ± 0.46	0.68 ± 0.46
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.17 ± 0.12	0.313 ± 0.163	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0.17 ± 0.12	0.094 ± 0.094	0 ± 0	0.85 ± 0.35	0.85 ± 0.35
Cymopterus nivalis	0.02 ± 0.12	0.25 ± 0.113	0.263 ± 0.072	0.01 ± 0.01	0.01 ± 0.01
Erigeron engelmanni	0.11 ± 0.04	0.0375 ± 0.0375	0.044 ± 0.036	0.04 ± 0.04	0.04 ± 0.04
Erigeron linearis	0.59 ± 0.27	1.05 ± 0.603	0.488 ± 0.218	2.41 ± 1.16	2.41 ± 1.16
Eriogonum brevicaule var. *micranthum*	0 ± 0	1.213 ± 0.631	0.094 ± 0.094	0 ± 0	0 ± 0
Eriogonum ovalifolium	0 ± 0	0.094 ± 0.094	0 ± 0	0.04 ± 0.04	0.04 ± 0.04

Appendix E Continued.

Growth form/Species 2007	Treatments (1-5)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0.388 ± 0.339	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.67 ± 0.18	0.388 ± 0.339	2.20 ± 1.04	1.79 ± 0.87	1.79 ± 0.87
Lomatium triternatum	0 ± 0	0.325 ± 0.277	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0.36 ± 0.26	1.119 ± 0.407	0.581 ± 0.288	0.19 ± 0.14	0.19 ± 0.14
Phlox hoodii	3.57 ± 0.31	2.41 ± 0.946	3.73 ± 1.04	4.41 ± 0.94	4.41 ± 0.94
Phlox longifolia	0.58 ± 0.21	1.019 ± 0.318	1.39 ± 0.308	1.09 ± 0.74	1.09 ± 0.74
Phlox multiflora	0 ± 0	0.263 ± 0.263	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0.08 ± 0.08	0 ± 0	0.038 ± 0.038	0 ± 0	0 ± 0
Trifolium andinum var. andinum	3.23 ± 0.76	2.39 ± 0.335	2.91 ± 0.621	2.44 ± 0.74	2.44 ± 0.73
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0.12 ± 0.08	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01	0.01 ± 0.01
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0.09 ± 0.09	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0.04 ± 0.04	0.006 ± 0.006	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0.04± 0.04	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2007	Treatments (1-5)				
Grasses	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
SHRUBS:					
Artemisia arbuscula	0 ± 0	0.519 ± 0.187	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	7.78 ± 1.88	8.90 ± 1.65	16.85 ± 1.92	7.63 ± 2.91	7.63 ± 2.91
Chrysothamnus viscidiflorus	6.03 ± 0.99	1.74 ± 0.502	6.5 ± 0.81	2.60 ± 0.89	2.6 ± 0.89
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0.19 ± 0.14	0.19 ± 0.14
Opuntia spp.	0 ± 0	0.219 ± 0.219	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0.19 ± 0.19	0.131 ± 0.089	0.263 ± 0.089	0 ± 0	0 ± 0
GROUND COVER:					
Bare Ground	22.26 ± 0.82	21.09 ± 2.73	12.88 ± 1.22	12.83 ± 2.43	12.83 ± 2.43
Litter	23.59 ± 2.68	17.61 ± 2.96	23.51 ± 1.59	32.83 ± 5.09	32.83 ± 5.09
Rock	4.61 ± 0.47	7.08 ± 1.59	5.06 ± 0.646	6.24 ± 1.09	6.24 ± 1.09
Lichen	0 ± 0	0 ± 0	0.019 ± 0.019	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2007	Treatments (6-10)				
Grasses	Heavy Spike	Prescribed Fire	High Mow	Areator	Light Spike
Achnatherum hymenoides	0 ± 0	0.09 ± 0.09	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	2.82 ± 1.13	3.11 ± 1.03	2.03 ± 1.06	3.81 ± 1.0	1.4 ± .82
*Elymus elymoide*s	0.47 ± 0.12	1.08 ± 0.43	0.98 ± 0.50	0.82 ± 0.23	2.21 ± 0.35
Elymus lanceolatus	3.13 ± 0.08	4.74 ± 0.45	0.98 ± 0.50	3.19 ± 0.81	3.98 ± 0.58
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0.08 ± 0.08	0.53 ± 0.23	0 ± 0	0.95 ± 0.29	0.49 ± 0.20
Poa secunda	6.29 ± 0.24	9.27 ± 1.36	8.51 ± 0.99	6.95 ± 0.43	4.88 ± 2.11
Pseudoroegeneria spicata	3.04 ± 0.69	0.31 ± 0.21	0.006 ± 0.006	0 ± 0	3.52 ± 3.47
FORBS:					
Agoseris glauca var. *dasycephala*	0.08 ± 0.08	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0.04 ± 0.04	0.08 ±0.04	0 ± 0
Arabis hirsuta var. pycnocarpa	0.01 ± 0.01	0.06 ± 0.04	0.04 ± 0.04	0.22 ± 0.06	0.09 ± 0.04
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0.11 ± 0.11	0.46 ± 0.26	0 ± 0	0.18 ± 0.13
Astragalus spp.	0.86 ± 0.20	1.93 ± 0.38	0.23 ± 0.23	0.59 ± 0.20	0.24 ± 0.14
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0.01 ± 0.01	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0
Cordylanthus ramosus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0.15 ± 0.09	0.34 ± 0.22	0.04 ± 0.04	0.11 ± 0.04	0.01 ± 0.01
Cymopterus nivalis	0 ± 0	1.0 ± 0.41	0.59 ± 0.37	0.51 ± 0.14	0.43 ± 0.33
Erigeron engelmanni	0.12 ± 0.03	0.04 ± 0.04	0 ± 0	0.02 ± 0.01	0 ± 0
Erigeron linearis	6.03 ± 1.04	2.53 ± 1.18	4.79 ± 2.33	0.84 ± 0.54	0.08 ± 0.08
Eriogonum brevicaule var. *micranthum*	0.13 ± 0.08	0.39 ± 0.39	0.11 ± 0.07	0.04 ± 0.04	0.04 ± 0.04
Eriogonum ovalifolium	0.26 ± 0.21	0.18 ± 0.13	0.25 ± 0.12	0.11 ± 0.07	0.08 ± 0.04

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
Forbs continued:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.75 ± 0.26	1.42 ± 1.04	2.38 ± 1.51	2.4 ± 0.51	1.44 ± 0.85
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0.28 ± 0.23	0.43 ± 0.24	0.13 ± 0.08	0.82 ± 0.18	0.13 ± 0.06
Phlox hoodii	3.36 ± 0.82	2.74 ± 0.29	2.19 ± 0.08	1.88 ± 0.20	3.1 ± 0.79
Phlox longifolia	0.08 ± 0.08	1.84 ± 0.26	0.48 ± 0.17	0.63 ± 0.15	0.83 ± 0.19
Phlox multiflora	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0.15 ± 0.06	0 ± 0	0 ± 0	0.19 ± 0.08
Trifolium andinum var. andinum	1.75 ± 0.44	3.16 ± 0.51	2.48 ± 0.42	3.46 ± 0.18	3.62 ± 0.40
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.04 ± 0.04
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	2.63 ± 1.43	7.75 ± 3.86	8.93 ± 0.89	6.11 ± 0.70	9.37 ± 1.02
Chrysothamnus viscidiflorus	1.26 ± 0.61	2.38 ± 1.37	0.79 ± 0.19	1.08 ± 0.25	1.36 ± 0.66
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0.1 ± 0.1	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0.06 ± 0.06	0.35 ± 0.26	0.22 ± 0.20	0.08 ± 0.08	0 ± 0
GROUND COVER:					
Bareground	42.69 ± 8.83	21.75 ± 1.93	48.13 ± 2.79	42.41 ± 0.92	40.31 ± 2.07
Litter	14.11 ± 5.68	0.58 ± 0.22	18.42 ± 2.35	27.93 ± 2.66	18.41 ± 1.62
Rock	1.08 ± 0.35	0.08 ± 0.06	0.40 ± 0.08	0.14 ± 0.07	0.05 ± 0.02
Lichen	0.08 ± 0.03	0.02 ± 0.02	0.18 ± 0.03	0.08 ± 0.06	0.29 ± 0.13
Cryptograms	0.01 ± 0.01	0.01 ± 0.01	0.04 ± 0.04	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2008	Treatments (1-5)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0.08 ± 0.04	0 ± 0	0 ± 0	0.08 ± 0.04	0.09 ± 0.09
Achnatherum lettermanii	1.52 ± 0.48	2.03 ± 1.07	1.47 ± 0.149	0.86 ± 0.30	6.11 ± 1.58
Elymus elymoides	0.58 ± 0.24	0.969 ± 0.187	1.40 ± 0.536	0.34 ± 0.25	2.79 ± 1.30
Elymus lanceolatus	3.94 ± 0.44	4.14 ± 0.68	3.43 ± 0.303	2.96 ± 1.06	7.09 ± 1.87
Hesperostipa comata	0.19 ± 0.11	0.450 ± 0.237	0.075 ± 0.075	0.08 ± 0.04	0.34 ± 0.34
Pascopyrum smithii	0 ± 0	0.225 ± 0.225	0 ± 0	2.24 ± 1.33	0 ± 0
Poa secunda	4.43 ± 0.88	4.25 ± 0.698	5.68 ± 1.32	4.86 ± 1.63	16.51 ± 4.00
Pseudoroegeneria spicata	0.04 ± 0.04	0.394 ± 0.202	1.89 ± 0.418	2.24 ± 1.33	1.85 ± 0.65
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0.09 ± 0.09	.006 ± .006	0 ± 0	0.01 ± 0.01	0 ± 0
Arabis hirsuta var. pycnocarpa	0.12 ± 0.08	0.056 ± 0 .04	0.006 ± 0.006	0.05 ± 0.04	0 ± 0
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0.25 ± 0.11	0.113 ± 0.113	0.081 ± 0.047	0.05 ± 0.04	0.04 ± 0.04
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0 ± 0	0.044 ± 0.036	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0.17 ± 0.1	0.113 ± 0.113	0 ± 0	0.49 ± 0.36	0 ± 0
Cymopterus nivalis	0 ± 0	0.119 ± 0.069	0.163 ± 0.103	0 ± 0	0 ± 0
Erigeron engelmanni	0.04 ± 0.04	0.038 ± 0.038	0.006 ± 0.006	0.04 ± 0.04	0 ± 0
Erigeron linearis	1.16 ± 0.50	1.28 ± 0.817	0.538 ± 0.371	2.08 ± 1.35	0.51 ± 0.46
Eriogonum brevicaule var. *micranthum*	0.29 ± 0.18	0.869 ± 0.431	0.006 ±0.006	0 ± 0	0 ± 0
Eriogonum ovalifolium	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	.01 ± .01	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.74 ± 0.27	1.94 ± 0.70	1.73 ± 0.77	0.50 ± 0.19	2.95 ± 1.12
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0.038 ± 0.038	0 ± 0	0.01 ± 0.01	0 ± 0
Phlox hoodii	2.52 ± 0.52	1.00 ± 0.38	1.83 ± 0.759	1.86 ± 0.63	1.53 ± 0.56
Phlox longifolia	0.28 ± 0.52	0.481 ± 0.199	0.36 ± 0.078	0.12 ± 0.03	0.32 ± 0.27
Phlox multiflora	0 ± 0	0.169 ± 0.169	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0.006 ± 0.006	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Trifolium andinum var. andinum	0.16 ± 0.15	0.213 ± 0.095	0.256 ± 0.154	0.05 ± 0.05	0.13 ± 0.13
Unknown 1	0 ± 0	0 ± 0	0.038 ± 0.038	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0.04± 0.04	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.04 ± 0.10
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
SHRUBS:					
Artemisia arbuscula	0 ± 0	0.481 ± 0.243	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	10.21 ± 3.62	8.19 ± 1.41	18.44 ± 1.57	6.48 ± 3.19	3.59 ± 0.10
Chrysothamnus viscidiflorus	8.36 ± 1.99	2.59 ± 1.06	7.36 ± 1.53	1.99 ± 1.02	4.91 ± 1.55
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0.16 ± 0.11	0.09 ± 0.09
Opuntia spp.	0 ± 0	0.094 ± 0.094	0.006 ± 0.006	0 ± 0	0 ± 0
Tetradymia canescens	0.15 ± 0.11	0.519 ± 0.404	0.444 ± 0.395	0 ± 0	0 ± 0
GROUND COVER:					
Bare Ground	31.55 ± 2.41	34.13 ± 3.52	19.32 ± 2.43	14.98 ± 6.84	11.93 ± 1.78
Litter	31.94 ±2.96	30.38 ± 0.982	30.94 ± 3.41	29.12 ± 10.27	58.44 ± 3.43
Rock	5.17 ± 0.23	8.54 ± 2.17	8.27 ± 1.06	5.16 ± 1.84	5.51 ± 0.93
Lichen	0 ± 0	0 ± 0	0.006 ± 0.006	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2008	Treatments (6-10)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0.04 ± 0.04	0.09 ± 0.09	0.29 ± 0.10	0 ± 0	0 ± 0
Achnatherum lettermanii	1.55 ± 0.71	3.04 ± 1.05	2.41 ± 0.99	3.2 ± 1.6	0.54 ±0.38
Elymus elymoide s	0.26 ± 0.15	1.63 ± 0.40	1.14 ± 0.25	1.14 ± 0.18	1.26 ± 0.43
Elymus lanceolatus	2.86 ± 0.45	5.7 ± 1.32	4.73 ± 0.56	3.51 ± 0.62	3.68 ± 0.55
Hesperostipa comata	0.66 ± 0.28	2.2 ± 1.12	0.32 ± 0.23	2.09 ± 0.53	1.32 ± 0.55
Pascopyrum smithii	0 ± 0	0.47 ± 0.47	0 ± 0	0 ± 0	0 ± 0
Poa secunda	3.36 ± 0.96	13.38 ± 2.27	8.31 ± 1.34	9.84 ± 1.03	5.63 ± 3.26
Pseudoroegeneria spicata	0.98 ± 0.35	0.53 ± 0.42	0 ± 0	0 ± 0	1.74 ± 1.74
FORBS:					
Agoseris glauca var. *dasycephala*	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arabis hirsuta var. pycnocarpa	0.10 ± 0.01	0.01 ± 0.01	0.04 ± 0.04	0.04 ± 0.04	0 ± 0
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0.35 ± 0.07	1.02 ± 0.13	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0 ± 0	0.64 ± 0.38	0 ± 0	0.29 ± 0.13	0 ± 0
Cymopterus nivalis	0 ± 0	0.04 ± 0.04	0.04 ± 0.04	0.006 ± 0.006	0 ± 0
Erigeron engelmanni	0.11 ± 0.07	0 ± 0	0 ± 0	0.05 ± 0.03	0.01 ± 0.01
Erigeron linearis	5.23 ± 0.97	3.68 ± 1.95	6.99 ± 3.67	1.08 ± 0.38	0.08 ± 0.08
Eriogonum brevicaule var. *micranthum*	0.23 ± 0.23	0.53 ± 0.37	0.14 ± 0.09	0.13 ± 0.13	0 ± 0
Eriogonum ovalifolium	0.13 ± 0.07	0.04 ± 0.04	0.17 ± 0.17	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
Forbs continued:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.38 ± 0.19	1.67 ± 1.02	2.53 ± 1.36	3.01 ± 0.59	1.12 ± 0.65
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.12 ± 0.12
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	2.36 ± 0.89	2.77 ± 0.37	2.18 ± 0.36	1.63 ± 0.24	2.11 ± 0.84
Phlox longifolia	0 ± 0	0.59 ± 0.14	0.19 ± 0.14	0.11 ± 0.03	0.13 ± 0.12
Phlox multiflora	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2.11 ± 0.84
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Trifolium andinum var. andinum	0.29 ± 0.13	0.69 ± 0.30	0.34 ± 0.15	0.24 ± 0.03	0.19 ± 0.11
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0.34 ± 0.14	0.23 ± 0.09	0.16 ± 0.09

Appendix E Continued.

	Treatments (6-10)				
Growth form/Species	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
SHRUBS:					
Artemisia arbuscula	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	6.25 ± 3.31	15.06 ± 3.57	19.33 ± 2.13	10.58 ± 2.26	13.95 ± 2.51
Chrysothamnus viscidiflorus	3.45 ± 1.42	4.13 ± 0.89	2.97 ± 0.87	2.64 ± 0.42	4.26 ± 1.8
Krascheninnikovia lanata	0.23 ± 0.18	0 ± 0	0.09 ± 0.09	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01
Tetradymia canescens	0 ± 0	0.83 ± 0.47	0.18 ± 0.07	0.46 ± 0.36	0.26 ± 0.26
GROUND COVER:					
Bare Ground	25.61 ± 1.89	21.2 ± 3.01	18.89 ±5.03	17.27 ± 2.81	17.48 ± 3.22
Litter	29.67 ± 4.91	26.26 ± 1.96	28.44 ± 3.69	19.75 ± 5.47	16.57 ± 3.43
Rock	13.06 ± 2.97	8.31 ± 1.55	7.25 ± 2.3	9.66 ± 4.22	6.49 ± 1.52
Lichen	0 ± 0	0.11 ± 0.11	0 ± 0	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2009	Treatments (1-5)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0.150 ± 0.150	0 ± 0	1.02 ± 0.91	0 ± 0
Achnatherum lettermanii	1.98 ± 1.15	1.46 ± 0.904	1.625 ± 0.136	1.79 ± 1.32	2.75 ± 1.23
Elymus elymoides	0.01 ± 0.01	1.24 ± 0.559	0.213 ± 0.075	0.77 ± 0.45	1.56 ± 0.97
Elymus lanceolatus	0.61 ± 0.61	0.038 ± 0.038	1.45 ± 0.843	3.50 ± 0.97	2.28 ± 0.66
Hesperostipa comata	4.24 ± 1.42	4.11 ± 0.751	1.09 ± 0.588	0 ± 0	0.21 ± 0.21
Pascopyrum smithii	0 ± 0	0.225 ± 0.225	0 ± 0	0 ± 0	0.63 ± 0.63
Poa secunda	2.63 ± 1.07	6.21 ± 0.572	3.13 ± 1.19	1.75 ± 0.68	1.75 ± 0.86
Pseudoroegeneria spicata	0 ± 0	0.313 ± 0.207	0.274 ±0.125	0.26 ± 0.36	0.86 ± 0.8
FORBS:					
Agoseris glauca var. *dasycephala*	0.03 ± 0.01	0.113 ± 0.072	0.094 ± 0.048	0.01 ± 0.01	0.01 ± 0.01
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0 ± 0	0. 04 ± 0.04	0 ± 0
Arabis hirsuta var. pycnocarpa	0.09 ± 0.05	0.006 ±0.006	0.006 ± 0.006	0.01 ± 0.01	0.01 ± 0.01
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0.03 ± 0.01	0.05 ± 0.042	0.213 ± 0.103	0.07 ± 0.03	0.04 ± 0.04
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.002 ± 0.002
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0.013 ± 0.013	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.03 ± 0.01	0.013 ± 0.013	0.344 ± 0.112	0.22 ± 0.16	0.03 ± 0.02
Cryptantha flavoculata	0 ± 0	0 ± 0	0 ± 0	0.14 ± 0.13	0.01 ±0.01
Cymopterus nivalis	0.01 ± 0.01	0.038 ± 0.038	0.013 ± 0.013	0 ± 0	0 ± 0
Erigeron engelmanni	0.15 ± 0.15	0.369 ± 0.312	0.550 ± 0.381	0.54 ± 0.28	0 ± 0
Erigeron linearis	0.05 ± 0.03	0.100 ± 0.029	0.006 ± 0.006	0.02 ± 0.02	0.01 ± 0.01
Eriogonum brevicaule var. *micranthum*	0 ± 0	0.663 ± 0.375	0.044 ± 0.036	0.04 ± 0.04	0 ± 0
Eriogonum ovalifolium	0 ± 0	0.038 ±0.038	0 ± 0	0.04 ± 0.04	0.01 ± 0.01

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0.006 ± 0.006	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.09 ± 0.05	0.688 ± 0.385	1.21 ± 0.525	1.01 ± 0.65	1.73 ± 0.61
Lomatium triternatum	0 ± 0	0.063 ± 0.031	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	1.70 ± 0.07	0.856 ± 0.308	1.04 ± 0.761	2.44 ± 0.57	2.72 ± 0.95
Phlox longifolia	1.70 ± 0.07	0 ± 0	0.113 ± 0.060	0.23 ± 0.14	0.13 ± 0.01
Phlox multiflora	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0.044 ± 0.044	0 ± 0	0.01 ± 0.01
Trifolium andinum var. andinum	0.24 ± 0.04	0.131 ± 0.056	0.231 ± 0.062	0.11 ± 0.04	0.06 ± 0.02
Unknown 1	0 ± 0	0.131 ± 0.107	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0.013 ± 0.013	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0.01 ± 0.01	0.019 ± 0.012	0.019 ± 0.012	0.01 ± 0.01	0.01 ± 0.01
Unknown Forb 2	0 ± 0	0.006 ± .006	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0.469 ± 0.469	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01	0.01 ± 0.01
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0.09 ± 0.09	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	7.09 ± 2.68	0 ± 0	2.05 ± 2.05	0 ± 0
Artemisia tridentata wyomingensis	7.98 ± 2.64	4.36 ± 3.65	22.61 ± 2.72	11.03 ± 2.26	2.66 ± 0.93
Chrysothamnus viscidiflorus	9.58 ± 0.84	2.66 ± 1.93	6.63 ± 1.36	3.64 ± 2.05	3.90 ± 1.42
Krascheninnikovia lanata	0.05 ± 0.03	0 ± 0	0.475 ± 0.233	0.44 ± 0.40	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0.006 ± 0.006	0 ± 0	0 ± 0
Tetradymia canescens	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01
GROUND COVER:					
Bare Ground	22.24 ± 1.05	26.01 ± 3.63	26.19 ± 2.74	24.6 ± 6.8	9.15 ± 1.0
Litter	41.65 ± 1.92	34.43 ± 5.45	44.36 ± 2.22	37.6 ± 4.81	54.21 ±2.32
Rock	0 ± 0	2.88 ± 2.07	0 ± 0	0 ± 0	0.05 ± 0.05
Lichen	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2009	Treatments (6-10)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	1.56 ± 0.75	1.51 ± 0.61	3.03 ± 0.80	4.47 ± 1.92	0.01± 0.01
Elymus elymoide s	0 ± 0	0.73 ± 0.45	0.27 ± 0.09	0.19 ± 0.19	0.46 ± 0.18
Elymus lanceolatus	0.64 ± 0.40	5.13 ± 1.53	1.88 ± 0.52	2.56 ± 0.60	2.66 ± 1.52
Hesperostipa comata	2.79 ± 0.8	0.23 ± 0.23	0.4 ± 0.04	0.89 ± 0.61	0.44 ± 0.40
Pascopyrum smithii	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Poa secunda	2.49 ± 0.76	1.14 ± 0.43	4.58 ± 0.95	4.63 ± 0.53	3.5 ± 1.72
Pseudoroegeneria spicata	0.71 ± 0.48	0.69 ± 0.69	0 ± 0	0 ± 0	0 ± 0
FORBS:					
Agoseris glauca var. *dasycephala*	0.06 ± 0.06	0.06 ± 0.04	0.02 ± 0.02	0 ± 0	0.03 ± 0.01
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arabis hirsuta var. pycnocarpa	0.09 ± 0.05	0.04 ± 0.02	0.03 ± 0.01	0.006 ± 0.006	0.07 ± 0.05
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus purshii	0.30 ± 0.15	0.29 ± 0.18	0.20 ± 0.17	0 ± 0	0.01 ± 0.01
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.14 ± 0.09	0.36 ± 0.28	0.01 ± 0.01	0.025 ± 0.02	0.09 ± 0.09
Cryptantha flavoculata	0 ± 0	0.28 ± 0.16	0 ± 0	0.05 ± 0.05	0 ± 0
Cymopterus nivalis	0 ± 0	0.02 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Erigeron engelmanni	4.2 ± 0.89	0.65 ± 0.42	4.06 ± 2.03	0.19 ± 0.17	0.12 ± 0.04
Erigeron linearis	0.06 ± 0.03	0 ± 0	0.01 ± 0.01	0 ± 0	0.01 ± 0.01
Eriogonum brevicaule var. *micranthum*	0.03 ± 0.03	0.27 ± 0.27	0.01 ± 0.01	0.04 ± 0.04	0 ± 0
Eriogonum ovalifolium	0 ± 0	0.04 ± 0.04	0.03 ± 0.03	0.05 ± 0.05	0.01 ± 0.01

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.58 ± 0.23	0.18 ± 0.10	0.71 ± 0.61	1.54 ± 0.34	0.70 ± 0.44
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	0.98 ± 0.46	0.93 ± 0.22	0.61 ± 0.23	0.51 ± 0.21	1.11 ± 0.25
Phlox longifolia	0 ± 0	0.13 ± 0.02	0.61 ± 0.23	0.03 ± 0.01	0.13 ± 0.06
Phlox multiflora	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0	0.02 ± 0.01
Trifolium andinum var. andinum	0.17 ± 0.03	0.19 ± 0.07	0.15 ± 0.02	0.26 ± 0.05	0.31 ± 0.08
Unknown 1	0 ± 0	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0.04 ± 0.01
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0.03 ± 0.01	0.09 ± 0.06	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0.98 ± 0.98	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	7.86 ± 4.98	14.06 ± 3.6	13.69 ± 1.12	7.53 ± 0.51	13.91 ± 2.50
Chrysothamnus viscidiflorus	3.14 ± 1.38	3.42 ± 0.57	2.43 ± 0.58	4.66 ± 1.25	3.77 ± 0.77
Krascheninnikovia lanata	0.19 ± 0.01	0.23 ± 0.14	0.51 ± 0.17	0.08 ± 0.08	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GROUND COVER:					
Bare Ground	37.59 ± 2.86	26.61 ± 3.81	30.9 ± 3.09	25.85 ± 3.84	35.29 ± 2.37
Litter	32.88 ± 4.6	39.06 ± 2.83	34.6 ± 5.31	55. 23 ± 8.81	41.19 ± 5.23
Rock	0 ± 0	0.03 ± 0.01	0 ± 0	0.03 ± 0.03	0.01 ± 0.01
Lichen	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cryptograms	0 ± 0	0.01 ± 0.01	0.11 ± 0.05	0 ± 0	0.05 ± 0.04

Appendix E Continued.

Growth form/Species 2010	Treatments (1-5)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	1.76 ± 0.86	2.02 ± 0.63	1.62 ± 0.39	2.54 ± 0.65	4.43 ± 0.33
Elymus elymoide s	0.26 ± 0.11	0.06 ± 0.04	0.14 ± 0.07	0.22 ± 0.11	0.57 ± 0.22
Elymus lanceolatus	2.12 ± 0.85	1.58 ± 0.54	0.49 ± 0.08	0.81 ± 0.14	2.43 ± 0.24
Hesperostipa comata	0 ± 0	0.41 ± 0.24	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0.9 ± 0.1	0.13 ± 0.12	0.18 ± 0.08	0.4 ± 0.02	0.77 ± 0.13
Poa secunda	3.28 ± 1.07	2.26 ± 0.72	2.63 ± 0.20	2.98 ± 0.64	1.56 ± 0.35
Pseudoroegeneria spicata	0.01 ± 0.01	0 ± 0	0.09 ± 0.04	0.01 ± 0.01	0.61 ± 0.20
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0.09 ± 0.09	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arabis hirsuta var. pycnocarpa	0.01 ±0.01	0.01 ± 0.01	0 ± 0	0.04 ± 0.02	0.09 ± 0.02
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0 ± 0	0.10 ± 0.04	0.01 ± 0.01	0 ± 0	0.01 ± 0.01
Astragalus purshii	0.22 ± 0.1	0.09± 0.09	0.11 ± 0.04	0.04 ± 0.02	0.03 ± 0.02
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.02 ± 0.02
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0 ± 0	0 ± 0	0.24 ± 0.04	0.01 ± 0.01	0.04 ± 0.04
Cryptantha flavoculata	0.04 ± 0.04	0 ± 0	0 ± 0	0.25 ± 0.15	0 ± 0
Cymopterus nivalis	0.09 ± 0.05	0.08 ± 0.04	0.09 ± 0.05	0 ± 0	0.03 ± 0.02
Erigeron engelmanni	0.51 ± 0.3	0.53 ± 0.31	0.21 ± 0.09	0.41 ± 0.30	0.19 ± 0.11
Erigeron linearis	0.09 ± 0.02	0 ± 0	0.01 ± 0.01	0.01 ± 0.01	0 ± 0
Eriogonum brevicaule var. *micranthum*	0 ± 0	0.28 ± 0.20	0.01 ± 0.01	0 ± 0	0 ± 0
Eriogonum ovalifolium	0 ± 0	0.11 ± 0.07	0 ± 0	0 ± 0	0.01 ± 0.01

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
Forbs continued.	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0.11 ± 0.04	0.04 ± 0.02	0.02 ± 0.01	0.06 ± 0.05
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0.16 ± 0.16	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.51 ± 0.11	0.26 ± 0.19	0.82 ± 0.34	0.76 ± 0.33	0.83 ± 0.31
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	1.89 ± 0.36	0.82 ± 0.46	0.92 ± 0.51	1.74 ± 0.63	1.02 ± 0.26
Phlox longifolia	0.06 ± 0.03	0.08 ± 0.06	0.61 ± 0.18	0.23 ± 0.13	0.51 ± 0.14
Phlox multiflora	0 ± 0	0.21 ± 0.16	0 ± 0	0 ± 0	0 ± 0
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Trifolium andinum var. andinum	0.19 ± 0.03	0.16 ± 0.06	0.19 ± 0.03	0.12 ± 0.06	0.17 ± 0.06
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0.09 ± 0.09	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0.02 ± 0.02	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	3.30 ± 2.16	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	8.28 ± 2.10	1.21 ± 2.16	12.78 ± 1.97	5.78 ± 2.05	2.56 ± 0.34
Chrysothamnus viscidiflorus	4.40 ± 0.84	0.86 ± 0.45	3.66 ± 0.82	1.67 ± 0.55	1.87 ± 0.40
Krascheninnikovia lanata	0 ± 0	0 ± 0	0.04 ± 0.04	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0.26 ± 0.26	0.01 ± 0.01	0 ± 0	0 ± 0
Tetradymia canescens	0.04 ± 0.04	0 ± 0	0.04 ± 0.04	0.05 ± 0.05	0.05 ± 0.04
GROUND COVER:					
Bare Ground	28.79 ± 3.98	31.78 ± 2.6	48.94 ± 2.83	28.91 ± 8.53	29.01 ± 5.61
Litter	20.41 ± 2.66	18.72 ± 2.41	11.48 ±1.02	15.51 ± 5.18	25.78 ± 4.30
Rock	0.04 ± 0.02	0.44 ± 0.23	0 ± 0	0.44 ± 0.44	0.05± 0.05
Lichen	0.11± 0.10	0.16 ± 0.09	0.08 ± 0.03	0.04 ± 0.02	0.06 ± 0.04
Cryptograms	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2010	Treatments (6-10)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	2.29 ± 0.51	1.96 ± 0.56	2.26 ± 0.46	3.08 ± 0.79	0 ± 0
*Elymus elymoide*s	0.08 ± 0.03	0.12 ± 0.08	0.12 ± 0.04	0.23 ± 0.20	0 ± 0
Elymus lanceolatus	1.14± 0.41	0.73 ± 0.27	0.53 ± 0.05	0.51 ± 0.12	0 ± 0
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Pascopyrum smithii	0.45 ± 0.9	0.40 ± 0.04	0.08 ± 0.04	0.25 ± 0.11	0 ± 0
Poa secunda	1.08 ± 0.09	2.36 ± 0.22	3.19 ± 0.24	2.76 ± 0.24	0 ± 0
Pseudoroegeneria spicata	0.08 ± 0.08	0 ± 0	0 ± 0	0 ± 0	0 ± 0
FORBS:					
Agoseris glauca var. *dasycephala*	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Allium sp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arabis hirsuta var. pycnocarpa	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0.11 ± 0.11	0.02 ± 0.01	0.04 ± 0.02	0.05 ± 0.03	0.02 ± 0.02
Astragalus purshii	0.08 ± 0.05	0.11 ± 0.02	0.02 ± 0.01	0 ± 0	0.01 ± 0.01
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.01 ± 0.01	0.13 ± 0.08	0 ± 0	0 ± 0	0 ± 0
Cryptantha flavoculata	0 ± 0	0.1 ± 0.09	0 ± 0	0.01 ± 0.01	0.02 ± 0.01
Cymopterus nivalis	0.04 ± 0.04	0.04 ± 0.02	0.02 ± 0.01	0.006 ± 0.006	0 ± 0
Erigeron engelmanni	3.67 ± 0.89	1.56 ± 0.85	2.47 ± 2.07	0.29 ± 0.17	0.02 ± 0.02
Erigeron linearis	0.03 ± 0.01	0 ± 0	0 ± 0	0.006 ± 0.006	0 ± 0
Eriogonum brevicaule var. *micranthum*	0 ± 0	0.16 ± 0.16	0.04 ± 0.04	0.11± 0.10	0.01 ± 0.01
Eriogonum ovalifolium	0.06 ± 0.04	0.16 ± 0.16	0.16 ± 0.07	0.04 ± 0.04	0.04 ± 0.04

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
Forbs continues	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0.02 ± 0.01	0.06 ± 0.04	0.06 ± 0.03	0.04 ± 0.04	0.07 ± 0.03
Lepidium pertoliatum L.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.36 ± 0.22	0.72 ± 0.21	1.21 ± 0.59	1.05 ± 0.26	0.96 ± 0.55
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	1.1 ± 0.30	1.49 ± 0.12	0.68 ± 0.09	0.70 ± 0.13	0.56 ± 0.32
Phlox longifolia	0.06 ± 0.01	0.19 ± 0.03	0.04 ± 0.03	0.01 ±0.01	0.08 ± 0.01
Phlox multiflora	0.01 ± 0.01	0.04 ± 0.04	0.25 ± 0.10	0 ± 0	0.27 ± 0.08
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0.04 ± 0.02	0.05 ± 0.01	0.02 ± 0.01	0.03 ± 0.02	0.01 ± 0.01
Trifolium andinum var. andinum	0.19 ± 0.08	0.16 ± 0.03	0.08 ± 0.03	0.26 ± 0.03	0.30 ± 0.02
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.02 ± 0.01
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	5.84 ± 3.59	6.83 ± 1.53	10.76 ± 2.65	6.94 ± 1.09	12.44 ± 1.20
Chrysothamnus viscidiflorus	1.98 ± 0.62	2.04 ± 0.74	1.31 ± 0.30	1.59 ± 0.33	2.59 ± 1.10
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0.13 ± 0.13	0.04 ± 0.04	0.12 ± 0.07	0 ± 0	0 ± 0
GROUND COVER:					
Bare Ground	45.25 ± 3.77	28.45 ± 12.82	50.09 ± 4.65	49.5 ± 4.43	53.16 ± 5.26
Litter	15.2 ± 1.21	11.53 ± 1.89	15.73 ± 3.01	17.93 ± 2.91	17.3 ± 2.41
Rock	0.01 ± 0.01	0.08 ± 0.07	0 ± 0	0 ± 0	0.05 ± 0.05
Lichen	0.05 ± 0.02	0.02 ± 0.01	0.09 ± 0.03	0.01 ± 0.01	0.13 ± 0.08
Cryptograms	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2011	Treatments (1-5)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Achnatherum lettermanii	0.89 ± 0.37	0.94± 0.23	1.77 ± 0.25	2.25 ± 0.89	2.3 ± 0.28
Elymus elymoides	0.37 ± 0.21	0.29 ± 0.1	0.49 ± 0.13	0.25 ± 0.10	0.66 ± 0.36
Elymus lanceolatus	0.62 ± 0.21	0.29 ± 0.12	0.61 ± 0.05	0.71 ± 0.12	0.77 ± 0.09
Hesperostipa comata	0.04 ± 0.04	0.03 ± 0.03	0.01 ±0.01	0.15 ± 0.11	0 ± 0
Pascopyrum smithii	0.24 ± 0.14	0.13 ± 0.11	0.09 ± 0.06	0.01 ± 0.01	0.14 ± 0.13
Poa secunda	2.41 ± 0.52	4.19 ± 0.48	2.46 ± 0.53	2.58 ± 0.89	2.05 ± 0.80
Pseudoroegeneria spicata	0.04 ± 0.04	0 ± 0	0.01 ± 0.04	0 ± 0	0.01 ± 0.02
FORBS:					
Agoseris glauca var. *dasycephala*	0.12 ± 0.08	0.08 ± 0.02	0.11 ± 0.04	0.04 ± 0.03	0.06 ± 0.02
Allium sp.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Antenaria microphylla	0 ± 0	0 ± 0	0 ± 0	0.09 ± 0.09	0.02 ± 0.01
Arabis hirsuta var. pycnocarpa	0 ± 0	0 ± 0	0.06 ± 0.04	0.12 ± 0.12	0.06 ± 0.02
Arenaria	0.04 ± 0.04	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0.04 ± 0.04	0.05 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0.02 ± 0.01
Astragalus purshii	0.20 ± 0.06	0.11 ± 0.09	0.19 ± 0.04	0.18 ± 0.08	0.19 ± 0.05
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0.04 ± 0.01	0.12 ± 0.05	0.06 ± 0.03	0.11 ± 0.09	0.04 ± 0.01
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.03 ± 0.03	0.08 ± 0.04	0.39 ± 0.01	0.06 ± 0.03	0.01 ± 0.01
Cryptantha flavoculata	0.16 ± 0.15	0 ± 0	0 ± 0	0.25 ± 0.13	0.02 ± 0.01
Cymopterus nivalis	0.07 ± 0.04	0.06 ± 0.03	0.09 ± 0.05	0.05 ± 0.04	0.05 ± 0.04
Erigeron engelmanni	0.4 ± 0.23	0.25 ± 0.22	0.19 ± 0.01	0.3 ± 0.19	0.10 ± 0.10
Erigeron linearis	0.19 ± 0.15	0.02 ± 0.01	0.09 ± 0.05	0.05 ± 0.04	0.06 ± 0.04
Eriogonum brevicaule var. *micranthum*	0.02 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0
Eriogonum ovalifolium	0 ± 0	0.40 ± 0.17	0 ± 0	0 ± 0	0.05 ± 0.05

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0.01 ± 0.01	0.03 ± 0.01	0.01 ±0.01	0.01 ± 0.01	0.01 ± 0.01
Lepidium pertoliatum L.	0.01 ± 0.01	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.37 ± 0.14	0.67 ± 0.33	0.77± 0.31	0.71 ± 0.37	1.53 ± 0.65
Lomatium triternatum	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	2.06 ± 0.22	0.44 ± 0.1	1.03 ± 0.65	0.80 ± 0.51	1.42 ± 0.63
Phlox longifolia	0.13 ± 0.11	0.21 ± 0.14	0.01 ± 0.01	0.77 ± 0.77	0 ± 0
Phlox multiflora	0.11 ± 0.04	0.16 ± 0.02	0.25 ± 0.06	0.18 ± 0.07	0.23 ± 0.09
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0.05 ± 0.02	0 ± 0	0.01 ± 0.01	0.02 ± 0.01	0.05 ± 0.03
Trifolium andinum var. andinum	0.57 ± 0.1	0.42 ± 0.07	0.53 ± 0.14	0.25 ± 0.09	0.40 ± 0.07
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (1-5)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	3.68 ± 1.34	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	7.38 ± 2.03	1.26 ± 1.26	±	4.94 ±0.56	1.82 ± 0.48
Chrysothamnus viscidiflorus	4.30 ± 0.27	1.68 ± 0.53	3.49 ± 0.41	1.64 ± 0.56	4.08 ± 1.54
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Opuntia spp.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0.28 ± 0.12	0.01 ± 0.01	0.13 ± 0.09	0.06 ± 0.06	0.18 ± 0.07
GROUND COVER:					
Bareground	38.38 ± 3.42	43.25 ± 1.53	44.0 ± 4.07	45.69 ± 3.72	34.19 ± 2.64
Litter	22.03 ± 2.36	19.4 ± 2.06	22.03 ± 3.67	23.79 ± 4.44	33.03 ± 2.44
Rock	0.46 ± 0.12	2.4 ± 0.88	0.49 ± 0.10	0.44 ± 0.15	0.1 ± 0.02
Lichen	0.04 ± 0.02	0.08 ± 0.03	0.11 ± 0.05	0.03 ± 0.03	0.11 ± 0.06
Cryptograms	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species 2011	Treatments (6-10)				
GRASSES:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Achnatherum hymenoides	0 ± 0	0.53 ± 0.30	0 ± 0	0.04 ± 0.04	0.04 ± 0.04
Achnatherum lettermanii	1.66 ± 0.98	1.34 ± 0.13	1.96 ± 0.12	3.04 ± 0.59	0.39 ± 0.04
Elymus elymoide s	0.49 ± 0.19	0.34 ± 0.10	0.15 ± 0.02	0.25 ± 0.10	0.29 ± 0.04
Elymus lanceolatus	0.54 ± 0.17	0.64 ± 0.12	0.75 ±0.13	0.59 ± 0.06	0.56 ± 0.24
Hesperostipa comata	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01
Pascopyrum smithii	0.46 ± 0.15	0.05 ± 0.03	0.01 ± 0.01	0.08 ± 0.04	0.44 ± 0.06
Poa secunda	2.57 ± 0.70	1.47 ± 0.14	2.87 ± 0.61	1.03 ± 0.36	1.67 ± 0.16
Pseudoroegeneria spicata	0.04 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0 ± 0	0.10 ± 0.04
FORBS:					
Agoseris glauca var. *dasycephala*	0.08 ± 0.04	0.08 ± 0.06	0.01 ± 0.01	0.04 ± 0.03	0.03 ± 0.02
Allium sp.	0 ± 0	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0
Antenaria microphylla	0.09 ± 0.04	0 ± 0	0 ± 0	0 ± 0	0.03 ± 0.01
Arabis hirsuta var. pycnocarpa	0.01 ± 0.01	0 ± 0	0.03 ± 0.02	0.006 ± 0.006	0 ± 0
Arenaria	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus convallarius	0.01 ± 0.01	0.01 ± 0.01	0.16 ± 0.09	0.32 ± 0.09	0.30 ± 0.05
Astragalus purshii	0.47 ± 0.14	0.4 ± 0.22	0.34 ± 0.19	0.04 ±0.01	0.02 ± 0.02
Astragalus spp. (low)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Astragalus spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Boechera retrofracta	0.04 ± 0.01	0.03 ± 0.14	0.10 ± 0.08	0.05 ± 0.01	0.01 ± 0.01
Carex spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Castilleja angustifolia	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Cordylanthus ramosus	0.03 ± 0.03	0.18 ± 0.10	0.03 ± 0.01	0.04 ± 0.01	0.07 ± 0.02
Cryptantha flavoculata	0.01 ± 0.01	0.31 ± 0.21	0.01 ± 0.01	0 ± 0	0 ± 0
Cymopterus nivalis	0.01 ± 0.01	0.16 ± 0.12	0.07 ± 0.05	0.04 ± 0.01	0.08 ± 0.04
Erigeron engelmanni	3.37 ± 0.60	0.28 ± 0.28	3.63 ± 1.54	0.48 ± 0.28	0.03 ± 0.02
Erigeron linearis	0.26 ± 0.14	0 ± 0	0 ± 0	0.006 ± 0.006	0 ± 0
Eriogonum brevicaule var. *micranthum*	0.01 ± 0.01	0.01 ± 0.01	0.05 ±0.05	0 ± 0	0.01 ± 0.01
Eriogonum ovalifolium	0.08 ± 0.04	0 ± 0	0.24 ± 0.22	0.13 ± 0.09	0.05 ± 0.04

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
Forbs continued	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Junctus balticus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.01 ± 0.01
Lepidium pertoliatum L.	0 ± 0	0.01 ± 0.01	0 ± 0	0 ± 0	0 ± 0
Lepidium spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia pygmaea	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Lewisia redivia Pursh.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Linathus pungens	0.32 ± 0.16	0.13 ± 0.13	0.84 ± 0.42	1.05 ± 0.24	0.27 ± 0.16
Lomatium triternatum	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Microseris nutans	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Phlox hoodii	2.1 ± 0.72	0.37 ± 0.19	0.43 ± 0.21	0.30 ± 0.11	0.58 ± 0.23
Phlox longifolia	0.01 ± 0.01	0.29 ± 0.29	0 ± 0	0.14 ± 0.09	0.13 ± 0.06
Phlox multiflora	0.03 ± 0	0.18 ± 0.09	0.05 ± 0.02	0.02 ± 0.01	0.02 ± 0.01
Salsola tragus	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Schoenocrambe linifolia	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.02	0.01 ± 0.01	0 ± 0
Trifolium andinum var. andinum	0.52 ± 0.23	0.25 ± 0.13	0.40 ± 0.05	0.67 ± 0.12	0.83 ± 0.14
Unknown 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Big Green Base (5-4)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Blue Lomatium	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Forb 2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown New Fuzzy Forb	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Penstemon	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Thistle (2008)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Viney Weed	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Unknown Weed (2006)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Vicia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Appendix E Continued.

Growth form/Species	Treatments (6-10)				
SHRUBS:	Control	Dixie Harrow	Chaining	Medium Mow/forb	Low Mow
Artemisia arbuscula	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Artemisia tridentata wyomingensis	2.63 ± 1.43	7.75 ± 3.86	8.93 ± 0.89	6.11 ± 0.70	9.37 ± 1.02
Chrysothamnus viscidiflorus	1.26 ± 0.61	2.38 ± 1.37	0.79 ± 0.19	1.08 ± 0.25	1.36 ± 0.66
Krascheninnikovia lanata	0 ± 0	0 ± 0	0 ± 0	0.1 ± 0.1	0 ± 0
Opuntia spp.	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Tetradymia canescens	0.06 ± 0.06	0.35 ± 0.26	0.22 ± 0.20	0.08 ± 0.08	0 ± 0
GROUND COVER:					
Bareground	42.69 ± 8.83	21.75 ± 1.93	48.13 ± 2.79	42.41 ± 0.92	40.31 ± 2.07
Litter	14.11 ± 5.68	0.58 ± 0.22	18.42 ± 2.35	27.93 ± 2.66	18.41 ± 1.62
Rock	1.08 ± 0.35	0.08 ± 0.06	0.40 ± 0.08	0.14 ± 0.07	0.05 ± 0.02
Lichen	0.08 ± 0.03	0.02 ± 0.02	0.18 ± 0.03	0.08 ± 0.06	0.29 ± 0.13
Cryptograms	0.01 ± 0.01	0.01 ± 0.01	0.04 ± 0.04	0 ± 0	0 ± 0

Appendix F. Plant master list with plant symbol, common name , family, duration, and nativity. Nomenclature based on USDA PLANTS Database

	Plant Symbol	Common Name	Family	Perennial/ Annual	Naitve/ Introduced
GRASSES:					
Achnatherum hymenoides (Roemer & Schiltes) *Barkworth*	ACHY	Indian Ricegrass	Poaceae	P	N
Achnatherum lettermanii (Vasey) Barkworth	ACLE9	Letterman's Needlegrass	Poaceae	P	N
*Elymus elymoide*s Swezey	ELEL5	bottlebursh squirreltail	Poaceae	P	N
Elymus lanceolatus Gould	ELLA3	thickspike wheatgrass	Poaceae	P	N
Hesperostipa comata (Trin. And Rupr.) Barkworth ssp. comata	HECO8	needle and thread grass	Poaceae	P	N
Pascopyrum smithii (Rydb.) A. Love	PASM	western Wheatgrass	Poaceae	P	N
Poa secunda J. Presl	POSE	Sandberg bluegrass	Poaceae	P	N
Pseudoroegeneria spicata (Pursh) A. Love	PSSP6	Blue bunch wheatgrass	Poaceae	P	N
FORBS:					
Agoseris glauca(Pursh) Raf. var. *dasycephala (Torr. & Gray) Jepson*	AGGLD	pale ageseris	Asteraceae	P	N
Allium L. spp.	ALLIU	wild onion	Liliaceae	P	N
Antenaria microphylla Rydb.	ANMI3	littleleaf pussytoes	Asteraceae	P	N
Arabis hirsuta (L.) Scop var. *pycnocarpa* (M. Hopkins) Rollins	ARHIP	creamflower rockcress	Brassicaceae	A	N
Arabis holboellii hornem. Var. rertofracta (Graham) Rydb.	ARHOR	second rockcress	Brassicaceae	P	N
Arenaria L. spp.	ARENA	sandwort	Caryophyllaceae	P	N
Astragalus convallarius Greene	ASCO12	lesser rushy milkvetch	Fabaceae	P	N
Astragalus purshii Dougl. Ex Hook	ASPU9	woolypod milkvetch	Fabaceae	P	N
Castilleja angustifolia (Nutt.) G. Don	CAAN7	Northwest Indian Paintbrush	Scrophulariaceae	P	N
Cordylanthus ramosus Nutt. Ex Benth	CORA5	bushy bird's beak	Scrophulariaceae	A	N
Cryptantha flavoculata (A.Nels.) Payson	CRFL6	roughseed cryptantha	Boraginaceae	P	N
Cymopterus nivalis S. Wats	CYNI3	snowline spring parsley	Apiaceae	P	N
Erigeron engelmanni A. Nels.	EREN	Englemann's fleabane	Asteraceae	P	N
Erigeron linearis (Hook.) Piper	ERLI	desert yellow fleabance	Asteraceae	P	N
Eriogonum brevicaule var. *micranthum* (Nutt.) *Reveal*	ERBRM	shortstem buckwheat	Polygonaceae	P	N
Eriogonum ovalifolium Nutt. Var. *ovalifolium*	EROVO	cushion buckwheat	Polygonaceae	P	N
Junctus Balticus Willd.	JUBA	baltic reed	Juncaceae	P	N

Appendix F Continued.

Forbs Continued	Plant Symbol	Common Name	Family	Perennial/ Annual	Naitve/ Introduced
Lepidium perfoliatum L.	LEPE2	clasping pepperweed		A	I
Lewisia rediva Pursh.	LERE7	bitter root		P	N
Lewisia pygmaea (Gray) B.L. Robins	LEPY2	alpine lewisia	Portulaceaceae	P	N
Linathus pungens (Torr.) J.M. porter & L.A. Johnson	LIPU11	granite prickly phlox	Polemoniaceae	P	N
Lomatium triternatum (Pursch) Coult. & Rose	LOTR2	nineleaf biscutroot	Apiaceae	P	N
Microseris nutans (Hook.) Schultz-Bip.	MINU	nodding microseris	Asteraceae	P	N
Phlox hoodii Richards	PHHO	spiny phlox	Polemoniaceae	P	N
Phlox longifolia Nutt.	PHLO2	long leaf phlox	Polemoniaceae	P	N
Phlox multiflora A. Nels.	PHMU3	flowery phlox	Polemoniaceae	P	N
Salsola tragus L.	SATR12	Russian thistle	Chenopodiaceae	A	I
Schoenocrambe linifolia (Nutt.) Greene	SCLI	flaxleaf plainsmustard	Brassicaceae	P	N
Trifolium andinum Nutt. var. *andinum*	TRANA3	Intermountian clover	Fabaceae	P	N
SHRUBS:					
Artemisia arbuscula Nutt. Ssp. Longiloba *(Ostern.) L.M. Shulz*	ARARA	little sagebrush	Asteraceae	P	N
Artemisia tridentata Nutt. wyomingensis Beetle & Young	ARTW8	Wyoming big sagebrush	Asteraceae	P	N
Chrysothamnus viscidiflorus (Hook.) Nutt.	CHVI8	yellow rabbitbrush	Asteraceae	P	N
Krascheninnikovia lanata (Pursh) *A.D.J. Meeuse &Smit*	KRLA2	winterfat	Chenopodiaceae	P	N
Opuntia Mill spp.	OPUNT	pricly cactus	Cataceae	P	N
Tetradymia canescens DC.	TECA2	spineless horsebrush	Asteraceae	P	N
Unknown species:					
Unknown 1	-	-	-	-	-
Unknown Big Green Base (5-4)	-	-	-	-	-
Unknown Blue Lomatium	-	-	-	-	-
Unknown Forb 1	-	-	-	-	-
Unknown Forb 2	-	-	-	-	-
Unknown New Fuzzy Forb	-	-	-	-	-
Unknown *Penstemon*	-	-	-	-	-
Unknown Thistle (2008)	-	-	-	-	-
Unknown Viney Weed	-	-	-	-	-
Unknown Weed (2006)	-	-	-	-	-
Vicia spp.	-	-	-	-	-