PATTERNS OF GRAY RUBBER RABBITBRUSH OCCURRENCE IN BURNED SAGEBRUSH-GRASSLANDS, MISSOURI RIVER BREAKS, MONTANA

by

Glenn Curtiss Owings

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Animal and Range Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2012

©COPYRIGHT

by

Glenn Curtiss Owings

2012

All Rights Reserved

APPROVAL

of a thesis submitted by

Glenn Curtiss Owings

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency and is ready for submission to The Graduate School.

Dr. Clayton B. Marlow

Approved for the Department of Animal and Range Sciences

Dr. Glenn C. Duff

Approved for The Graduate School

Dr. Carl A. Fox

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Glenn Curtiss Owings

April 2012

ACKNOWLEDGEMENTS

I would like to thank Dr. Clayton Marlow, Dr. Bok Sowell, Dr. Mike Frisina, and Dr. Bob Skinner for their input on this document. I am indebted to these and other outstanding professionals that have shared their wisdom and experience with me over the course of my academic career.

I would like to thank the Bureau of Land Management for funding this research and providing fire data. Additionally, the Charles M. Russell National wildlife refuge staff, Andy Schell in particular, was instrumental in field navigation and provided valuable fire information.

I would like to thank my family for their patience, love, and encouragement throughout the development of this publication. I am thankful for their support and confidence in my abilities.

TABLE OF CONTENTS

1. INTRODUCTION 1

2. LITERATURE REVIEW 3

Fire in Sagebrush-Grasslands 3
Shrub Response to Fire 4
Browsing Effects on Shrubs 5
Gray Rubber Rabbitbrush Use and Nutritional Value 6
Hypotheses 7
Objectives 7

3. METHODS 9

Study Area 9
Experimental Design 10
Cover 12
Density and Age Class 12
Browsing Assessment 13
Non-Burned Sites 14
Data Analysis 14

4. RESULTS 16

Density and Time Since Fire 16
Analysis of Variance and Cluster Analysis 18
Burned and Non-Burned Comparison 19
Age and Browsing Relationships 21

5. DISCUSSION 25

6. MANAGEMENT IMPLICATIONS 30

REFERENCES CITED 32

APPENDICES 38

APPENDIX A: Soil Descriptions 39
APPENDIX B: Percent Cover by Site 41
APPENDIX C: Normality Test Results and Johnson Transformation Values 43
APPENDIX D: Density (stems/ha) 45
APPENDIX E: Gray Rubber Rabbitbrush Browsing and Plant Age Class Data Raw Count 47

LIST OF TABLES

Table Page

1. Density as a percentage of the shrub community for the four most common shrub species (n=15) 16

2. Means and standard deviations for gray rubber rabbitbrush as a proportion of the shrub community in burned and non-burned sites 19

3. Means and standard deviations for big sagebrush as a proportion of the shrub community in burned and non-burned sites.....20

LIST OF FIGURES

Figure Page

1. Mean fire return intervals for the Charles M. Russell National Wildlife Refuge....4

2. Aerial view of study area in northeastern Montana....9

3. Example of site selection within a recorded burn....11

4. Macroplot design ($625m^2$) and transect orientation....12

5. Browsing classes for gray rubber rabbitbrush according to growth form and characteristics. A "low" value indicates minimal structural deformation, few browsed leaders, and no appreciable stem death. "Moderate" class shrubs show characteristics of some historic use (slight structural alteration, thickened basal stem, some stem mortality) but produce biomass at normal levels and do not appear "dwarfed" by browsing. Individuals given a "high" browsing class value show extensive stem death, reduced productivity and seed production, and high basal stem diameter:height ratios....14

6. Regression for gray rubber rabbitbrush and big sagebrush as a percentage of the shrub community vs. time since fire....17

7. Regression for gray rubber rabbitbrush vs. big sagebrush density as a percentage of the shrub community. Gray rubber rabbitbrush decreases as a proportion of the shrub community as big sagebrush increases....18

8. Dendrogram for cluster analysis of density and time since fire....19

9. Interval plot for gray rubber rabbitbrush as a proportion of the shrub community in burned and non-burned sites....20

10. Interval plot for big sagebrush as a proportion of the shrub community in burned and non-burned sites....21

11. Regression for the proportion of rabbitbrush shrubs in the "high" browsing class vs. the percentage in "mature" age class....22

12. Regression for gray rubber rabbitbrush as a proportion of the shrub community vs. the percentage of shrubs in the "high" browse class....23

LIST OF FIGURES – CONTINUED

Figure Page

13. Big sagebrush (ARTR) and gray rubber rabbitbrush (CHNA) proportion within the shrub community as a function of time since fire. Site data for years 3 (n=3) and 17 (n=2) are averaged.....24

14. A microsite “refuge” for big sagebrush. Note unburned shrubs in the clay pan area and burned shrub skeletons on the perimeter.....27

ABSTRACT

Sagebrush-grasslands represent a large portion of the plant communities within the arid plains of the western United States. Grasses, forbs, and shrubs exist as subdominants to sagebrush that vary in density according to disturbances such as fire, wind, and defoliation. Fire is an important modifier of succession in sagebrush-grasslands, and shrub response to fire may be altered by browsing. The fire response of gray rubber rabbitbrush (*Chrysothamnus nauseosus* (Pallas ex Pursh) Nesom & Baird ssp. *nauseosus*) has not been well documented. Furthermore, it is heavily browsed in central and northeastern Montana and is an important winter forage for ungulates. This study investigated how it responds to fire and browsing. Fifteen sites (9 burned and 6 adjacent non-burned) in the Missouri River Breaks, Montana were analyzed to investigate relationships between shrub density, time since fire, shrub age, and browsing level (n=15). Density was counted in one $625m^2$ macroplot per site. Gray rubber rabbitbrush age (seedling, juvenile, mature) was estimated using basal stem diameter. A qualitative browsing level was assigned based on growth form characteristics (low, moderate, high). Time since fire was not significantly correlated with differences in gray rubber rabbitbrush (P=0.701, R-sq=0.00%) or sagebrush (P=0.391, R-sq=0.00%) density as a percentage of the shrub community (n=9). As a percentage of the shrub community, big sagebrush density at a site was a good indicator of gray rubber rabbitbrush density (n=15, P<.001, R-sq=68.45). Rabbitbrush decreases within the shrub community as sagebrush dominance increases. Gray rubber rabbitbrush composed a higher percentage of the shrub community in burned than non-burned sites (n=6, P=0.005). Big sagebrush composed a higher percentage of the shrub community in non-burned sites than burned sites (n=6, P=0.001). The percentage of gray rubber rabbitbrush shrubs in the "high" browse class was not a statistically significant predictor of density as a proportion of the shrub community (n=13, P-value=0.161, R-sq=9.49%). Results indicate that gray rubber rabbitbrush responds to fire by increasing shortly after disturbance, falling out of the community at some threshold as sagebrush is re-established. Browsing did not affect the ability of gray rubber rabbitbrush to dominate for a period after fire.

CHAPTER 1

INTRODUCTION

Sagebrush-grasslands represent a large component of the vegetation mosaic of the arid plains ecosystem in the western United States (McGinnies 1972). Central and eastern Montana prairies exemplify this pattern and contain an array of sagebrush species dominants (Mackie 1970). Forbs, grasses, and other shrubs exist as community subdominants and indicate unique soil, geologic, and microclimatic regimes (Mackie 1970). Disturbance regimes change the patterns of dominant and subdominant plants on the landscape by altering site conditions and plant production (White 1979). Disturbances such as defoliation, wind, and fire affect plant community structure and dynamics by altering seral stage progression (White 1979, Daubenmire 1968b, Bunting 1985). Browsing can affect succession after fire as less palatable plants are left whole and do not need to rebuild energy stores following defoliation (Davis 1967).

While other rabbitbrushes (*Chrysothamnus viscidiflorus* (Hook.) Nutt. in particular) have undergone significant study in the western U.S., the fire response and seral role of gray rubber rabbitbrush (*Chrysothamnus nauseosus* (Pallas ex Pursh) Nesom & Baird ssp. *nauseosus*) has not been well described for sagebrush-grasslands (Blaisdell 1953, Young and Evans 1974, Wright and Bailey 1982). It is an important component of sagebrush-grasslands in Montana's Missouri River Breaks, and has been found in all but the northwest corner of Montana (Mackie 1970, Winkler 1987, Wood 2004).

Management decisions are often based on assumptions about how species interact after disturbance, but differing responses to environmental inputs between subspecies can be significant and far reaching (Winward 1985). Subspecies of big sagebrush (*Artemisia tridentata* Nutt.) differ in response to fire, and subspecies differences for rabbitbrush could show similar results (Baker 2006, Lesica et al. 2007).

To that end, this study investigated the patterns of occurrence of gray rubber rabbitbrush within burned sagebrush-grassland communities in north central Montana. By defining the successional role of gray rubber rabbitbrush, we can refine our understanding of the way sagebrush-grassland ecosystems respond to fire.

CHAPTER 2

LITERATURE REVIEW

Fire in Sagebrush-Grasslands

Sagebrush-grasslands are characterized by sagebrush dominated series' and associations as described by Mackie (1970), adapted from Daubenmire (1952). They are associated with cool, dry climatic conditions and exhibit stochastic disturbance regimes that influence seral stage progression (Daubenmire 1968a, Mackie 1970).

Fire is an important modifier of succession in sagebrush-grassland environments (Daubenmire 1968a, Bunting 1985, West 2000). Plant community responses to fire affect nutrient cycling, water availability, and habitat suitability for wildlife or domestic animals (Wright and Bailey 1982). Understanding how plants respond to fire allows land managers to predict its effects on vegetation management objectives (Eichhorn and Watts 1984).

Wright et al. (1979) suggest that sagebrush-grasslands historically burn every 32 to 70 years, though longer intervals may be more appropriate for Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) (Wright and Bailey 1982, Baker 2006). Baker (2006) suggests that fire rotation in Wyoming big sagebrush stands may be 100-240 years. In the Charles M. Russell Wildlife Refuge (CMR) region of the Missouri Breaks, common fire return intervals between 21-45 years have been suggested (Reid and Fuhlendorf 2011) (Figure 1).

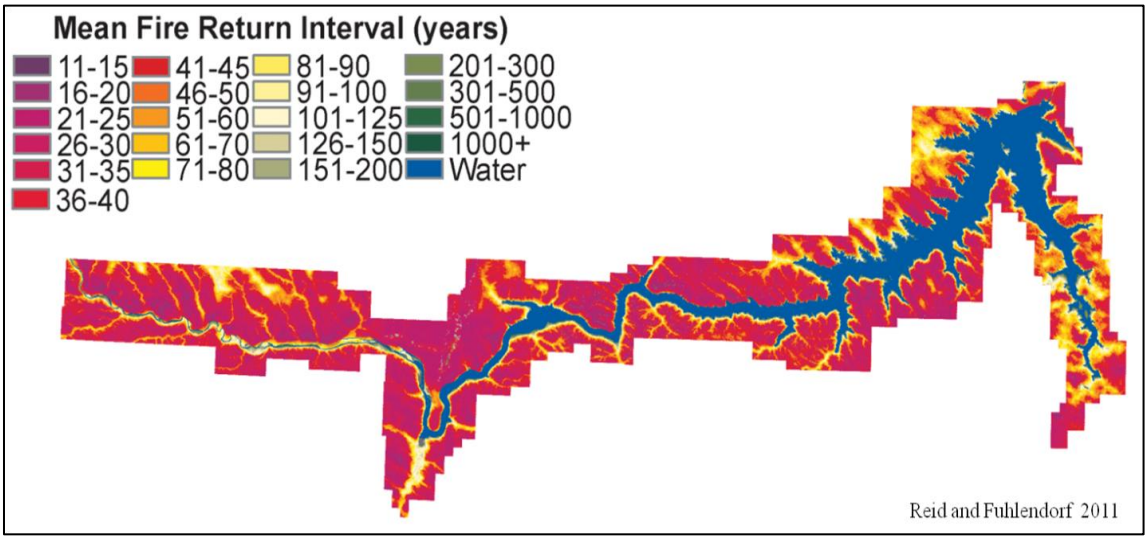


Figure 1. Mean fire return intervals for the Charles M. Russell National Wildlife Refuge.

Shrub Response to Fire

Shrubs such as big sagebrush that do not sprout from the crown are readily killed by wildfire and take longer to re-establish (Blaisdell 1953, Wright and Bailey 1982, Wambolt et al. 2001). Crown sprouting shrubs can quickly recolonize burned rangelands, often dominating the shrub community for 30 or more years (Harniss and Murray 1973, Young and Evans 1978, Wambolt et al. 2001). Forbs, grass, and sprouting shrubs like gray rubber rabbitbrush initiate vegetative recovery by stabilizing soils and cycling nutrients (VanDersal 1972).

The successional role of rubber rabbitbrush has been described as early to mid seral, decreasing in abundance as sagebrush reestablishes after disturbance (Chadwick and Dalke 1965, McLendon and Redente 1991, Wangler and Minnich 1996). While the genus *Chrysothamnus* has been shown to resprout vigorously after perturbation, there is some question as to the response of rubber rabbitbrush and associated subspecies

(Blaisdell 1953, Robertson and Cords 1957, Young and Evans 1974, Wright and Bailey 1982, Johnson and Strang 1983, Young 1986). High intensity fires are more likely to kill resprouting crown tissue, and subspecies *nauseosus* may sprout more epicormically than others (Wright et al. 1979).

In Northwest Colorado rubber rabbitbrush became a dominant early seral shrub five years after soil disturbance (Mclendon and Redente 1991). On settled dune sands in Idaho, Chadwick and Dalke (1965) found that rubber rabbitbrush was a community dominant for years 10-70 following disturbance, yielding to big sagebrush (*Artemisia tridentata*) later in succession. In burned pinyon-juniper woodlands with a sagebrush component, Wangler and Minnich (1996) found that rubber rabbitbrush established quickly after fire and was an important shrub component on 13 sites between 5 and 47 years old. These studies did not distinguish between subspecies of rubber rabbitbrush despite differing traits and responses among subspecies and ecotypes (Winkler 1987).

Seral stage progression after fire in shrublands depends on fire intensity, site characteristics, and plant-animal interactions (White 1979). Browsing of crown sprouting shrubs after fire may affect their recovery and alter successional pathways (Davis 1967, Hobbs 1996). In southern California, insect and ungulate browsing altered community composition during the first three years of succession after fire (Hobbs 1996).

Browsing Effects on Shrubs

Ungulate browsing can alter succession by favoring species that are less palatable, tolerant of browsing, and more able to secure nutrients (Anderson and Katz 1993, Hobbs

1996, Keilland and Bryant 1998). Browsing affects succession and community composition in sagebrush grasslands by limiting productivity, germination, and survival (Singer and Renkin 1995, Wambolt and Sherwood 1999).

As shrubs are browsed by wildlife, forage quality, forage amount, rooting depth, and plant dimension are influenced. The result is an altered capacity to perform ecological functions. Browsing intensity and season dictate changes in individual morphology and physiology (Willard and McKell 1978). Under high browsing pressure removal of terminal leaders causes a change in growth form, influencing production and individual fitness (Keigley and Frisina 1998).

Gray Rubber Rabbitbrush Use and Nutritional Value

Rubber rabbitbrush has been shown to receive heavy winter use by ungulates in N. Central Montana, and was identified by Mackie (1970) as an important early winter forage species for mule deer (Wood 20004). Rabbitbrush was the largest single winter dietary component for mule deer in Montana's Rosebud County (Eustace 1971). Winkler (1987) noted that gray rubber rabbitbrush plants were often browsed to dwarf forms on a site in Dawson County, MT. Because of resource competition between shrub species, even resilient sprouting shrub communities may be altered by ungulate browsing (Wambolt and Sherwood 1999).

Rubber rabbitbrush is nutritionally valuable for browsing ungulates and should be managed as such. Winter crude protein and crude fat for rabbitbrush in northern Colorado are 6-7% and 15-19% respectively (Short et al. 1966). In central Oregon, crude protein

ranged from 8-9% from November to April (Urness 1966). Seven subspecies of rubber rabbitbrush from the western U.S. were analyzed for mid-winter crude protein and digestibility (Bhat et al. 1990). Crude protein varied from 9.2-12.0% and in vitro dry matter digestibility ranged from 35.9-49.7 (Bhat et al. 1990). Digestibility in that range is above average for winter forage (Welch 1989).

Despite its disproportionately high use and nutritional value, little research has been conducted on the fire and browsing response of gray rubber rabbitbrush.

Hypotheses

It is expected that gray rubber rabbitbrush will quickly establish following fire, gradually decreasing in abundance as sagebrush is re-established (Wangler and Minnich 1996). Therefore, we hypothesize that rabbitbrush and sagebrush densities as a proportion of the shrub community will differ between burned and non-burned sites. The null hypothesis is that burned and non-burned sites will show no difference for rabbitbrush and sagebrush density. Additionally, we hypothesize that the gray rubber rabbitbrush component of the shrub community will be negatively correlated with browsing intensity. The null hypothesis is that high browsing levels will not be a good predictor for the proportion of rabbitbrush in the shrub community.

Objectives

1. Determine if time since fire is a viable predictor for sagebrush/gray rubber rabbitbrush community structure

2. Analyze post-fire relationships among shrubs in sagebrush-grasslands to determine what species dominate the site after fire
3. Investigate relationships between gray rubber rabbitbrush density, browsing level, and plant age to consider how age may affect browsing level, and how browsing level may affect density
4. Compare burned and non-burned sites to determine if shrub community structure differs between them

CHAPTER 3

METHODS

Study Area

Sampling was conducted in historic burned areas of the Missouri River breaks in north central Montana (Figure 2). The "breaks" environment is characterized by narrow valleys and sharp ridgelines falling from plateaus to the Missouri River (Mackie 1970). Soils are clays and silt clays; complexes are common (NRCS 2011). The dominant soils are born of the Hell Creek and Bearpaw shale formations, the latter composing the bulk of the sites included in this study (Raines and Johnson 1995). Soil descriptions for the study area can be found in Appendix A (NRCS 2011).

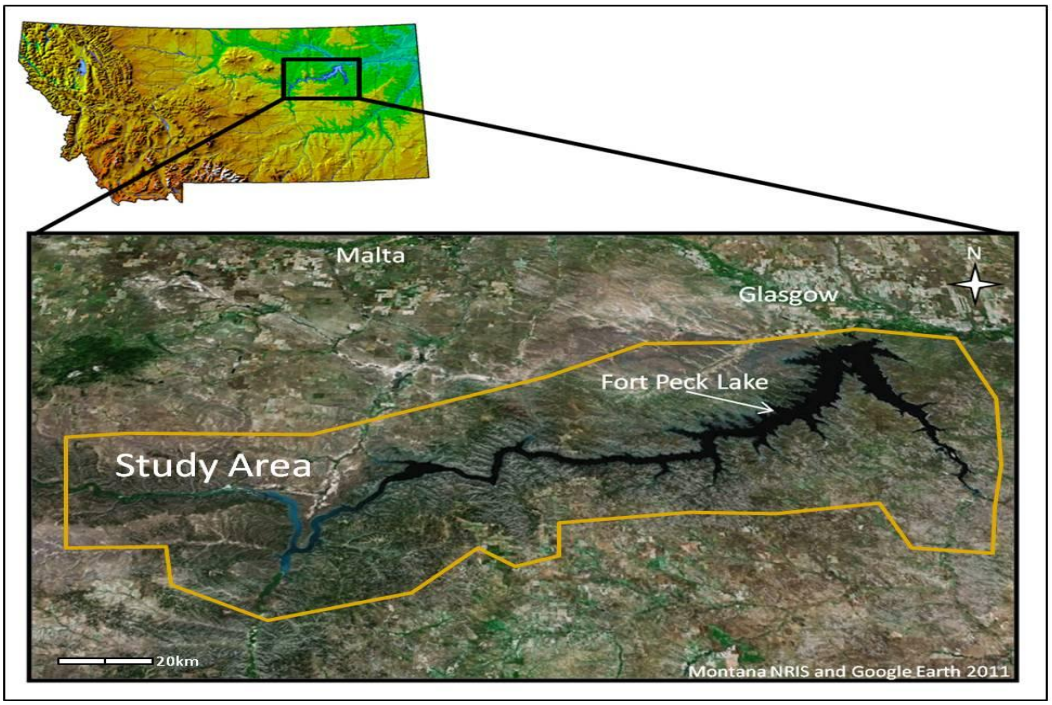


Figure 2. Aerial view of study area in northeastern Montana.

Annual precipitation is low (25-38cm), with 20-30% in the form of snow (Nesser et al. 1997). Average temperatures range from -9 to 21 degrees Celcius (Mackie 1970). Vegetation is characterized by *Artemisia-Agropyron*, *Pseudotsuga-Juniperius*, *Sarcobaus-Agropyron* and *Pinus-Juniperus* habitat types (Mackie 1970). Sampling primarily took place in the *Artemisia-Agropyron* type, though overlap with other types was common.

Land within the study area is adjudicated by the U.S. Fish and Wildlife Service, Bureau of Land Management, and private owners. Seasonal livestock grazing occurs throughout the region. The U.S. Fish and Wildlife Service (USFWS) and Bureau of Land Management (BLM) provided point data for the location of fires dating from 1964, though information on location and burn size was limited for the oldest burns.

Experimental Design

In order to be considered for sampling, a burn was to exhibit a size of at least 50 acres, a sagebrush-grassland habitat type with a gray rubber rabbitbrush component, and it must have not re-burned since the recorded event date. All sites that met these criteria were separated according to age into three classes (0-10, 11-20, and 21-30 years since fire). Three burns were randomly selected for sampling from each class so that a chronological range of vegetative responses could be analyzed.

A sample location within each of the nine selected burns that showed clear evidence of fire was established based on the judgment of a representative vegetative structure and landform (Lesica 2007). Because wildfires burn in a heterogeneous pattern,

an area within the fire perimeter may not have burned (Morgan et al. 2001). Sample sites could not be randomly selected for this reason (Figure 3).

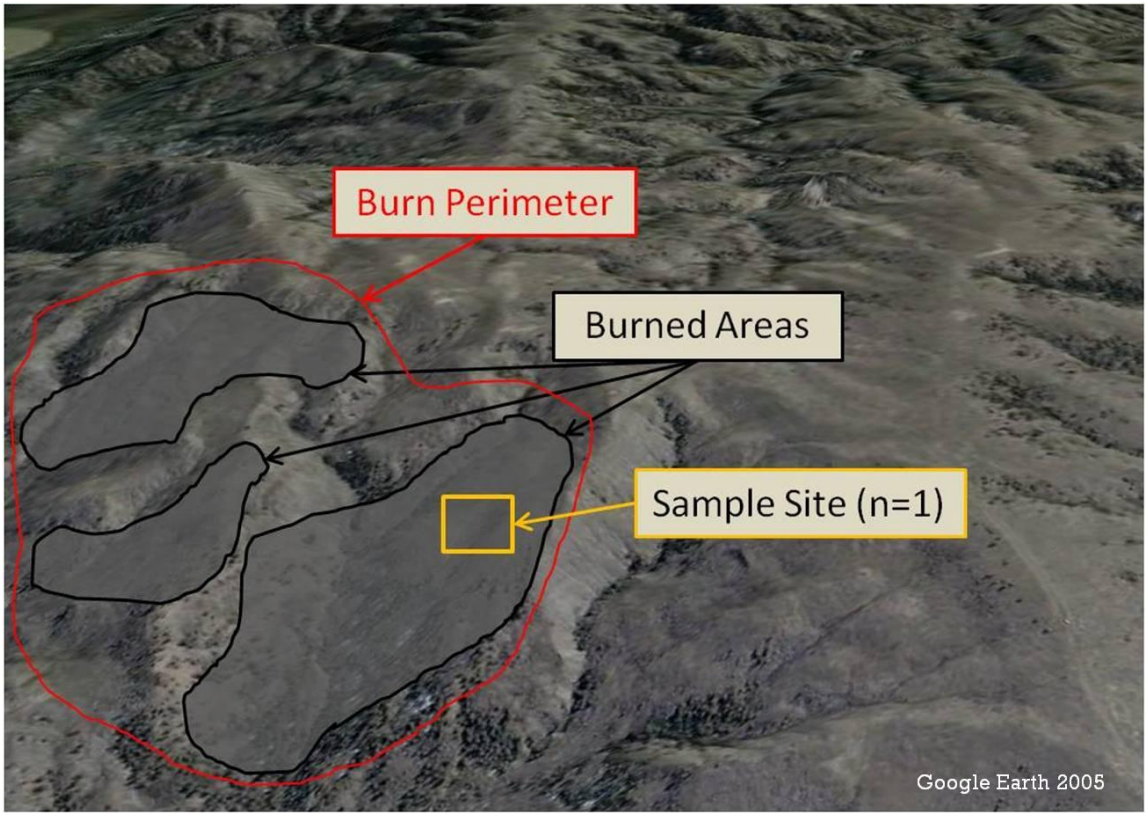


Figure 3. Example of site selection within a recorded burn.

At each site, a 25m x 25m macro-plot ($625m^2$) was established from a point of origin (Figure 4). A large sample plot was necessary to capture the variability associated with the landscape and subspecies of interest (Bob Skinner, USFWS Biologist, Charles M. Russell National Wildlife Refuge, personal communication). Aspect and the cardinal direction (from origin) of the right hand plot boundary were recorded. A 35.4m cross sectional transect was set from the point of origin to the opposite corner. Reference photos were taken along the right hand plot boundary and diagonal transect.

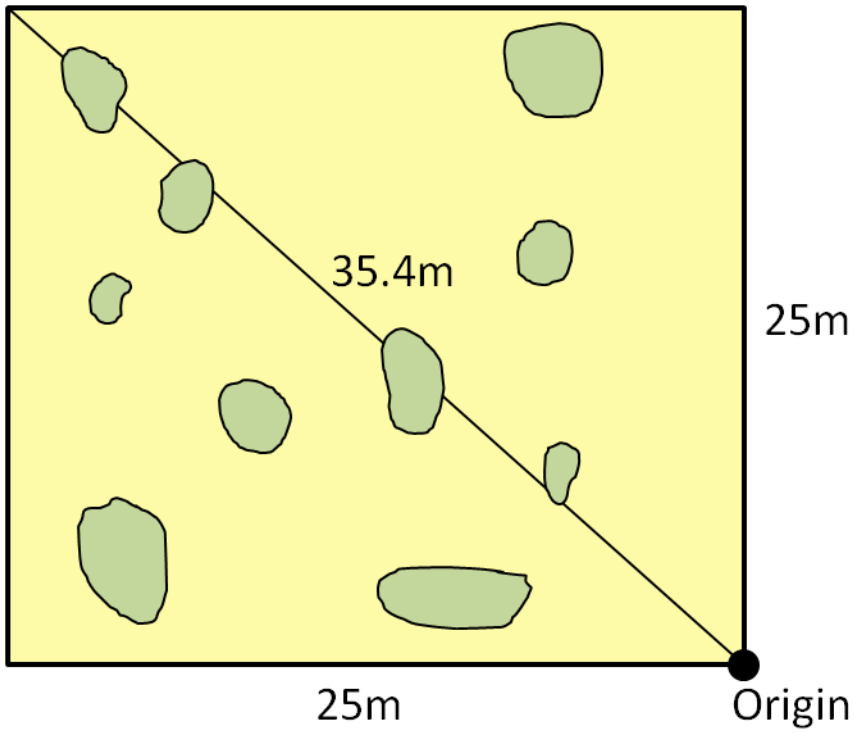


Figure 4. Macroplot design (625m^2) and transect orientation.

Cover

The line intercept method for estimating shrub cover was used along the transect (Canfield 1941). A plumb bob and surveying line were used to ensure accurate measurements of shrub interception, and canopy spaces greater than three centimeters were not included in cover values (Wambolt et al. 2006). Cover measures were recorded for the purpose of future monitoring and were not statistically analyzed. Values can be found in Appendix B.

Density and Age Class

Density was recorded by counting for each shrub species within the macroplot. Density was favored as the primary measurement metric because it is independent of the

seasonal variation associated with cover. In addition, a general shrub age class was assigned to each gray rubber rabbitbrush individual according to maximum basal stem diameter. A vegetative, non-woody stemmed shrub was considered a seedling, a diameter ≤1cm was recorded as juvenile, and >1cm mature (Lesica et al. 2007). Stem diameter has been used as a surrogate age measure in sagebrush when counting age rings is not feasible (Perryman and Olson 2000). It was assumed that approximate rabbitbrush age could be estimated using stem diameter since it shares many growth characteristics with sagebrush and is in the same phenological family (Asteraceae).

Browsing Assessment

With only one field season to collect browsing data, a quantitative measurement based on use was not possible. Rabbitbrush individuals were grouped into one of three browsing classes (low, moderate, high) based on growth form and apparent browsing history (Figure 5). Browsing alters the growth patterns of shrubs and growth form can be used as an indicator of use (Patton and Hall 1966, Willard and McKell 1978, Wambolt et al. 1994). Seedlings were not given a browsing classification because of their diminutive size and absence of physiological browsing response.

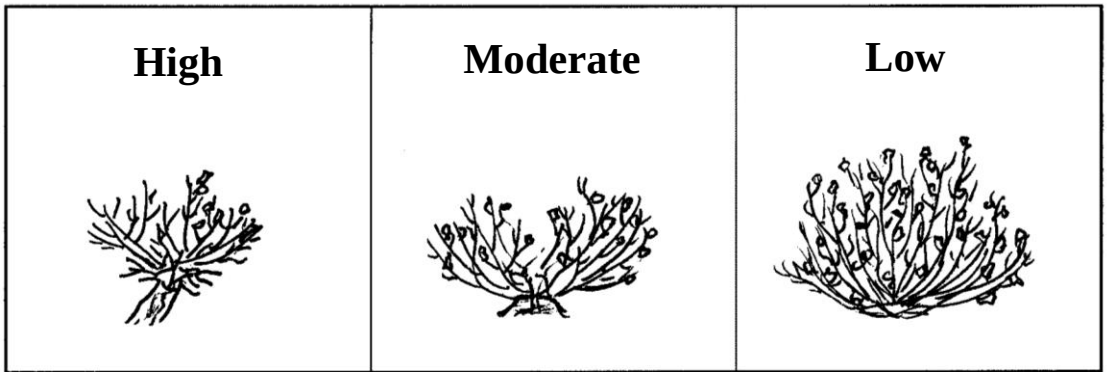


Figure 5. Browsing classes for gray rubber rabbitbrush according to growth form and characteristics. A "low" value indicates minimal structural deformation, few browsed leaders, and no appreciable stem death. "Moderate" class shrubs show characteristics of some historic use (slight structural alteration, thickened basal stem, some stem mortality) but produce biomass at normal levels and do not appear "dwarfed" by browsing. Individuals given a "high" browsing class value show extensive stem death, reduced productivity and seed production, and high basal stem diameter:height ratios.

Non-Burned Sites

Six non-burned sites were sampled adjacent to companion burned sites. Sampling plots were located on slopes, aspects, and landforms similar to the adjacent burned sites in order to minimize differences in soil and microclimate (Lesica et al. 2007). All non-burned sites were less than 100m from their burned counterpart. The same density, cover, age, and browsing assessments were made.

Data Analysis

The data were analyzed using Minitab 16 (Minitab Inc. 2012). A sample site was the experimental unit (n=15). A simple linear regression was run plotting gray rubber rabbitbrush and big sagebrush density as the dependent variables and time since fire as the predictor. Results were considered significant when $P<0.05$.

A one way analysis of variance (ANOVA) was used to determine if rabbitbrush density in initial age class groupings (0-10, 10-20, 20-30 years since fire) were significantly different ($P<0.05$). A cluster analysis of rabbitbrush density and time since fire was used to determine if natural groupings were formed based on those variables (>90% similarity). If so, ANOVA would test for difference between those groups.

Burned sample units with adjacent non-burned sites (n=6) were analyzed using a paired t-test to see if the community percentages of gray rubber rabbitbrush differ between treatments ($P<.05$). Anderson-Darling normality tests were run on burned and non-burned data to assess normality ($P>0.05$) (Appendix C) (Minitab 2012). For gray rubber rabbitbrush, burned sites showed a normal distribution, but non-burned sites required a Johnson transformation ($P>0.05$) to meet normality criteria (Minitab 2012). For big sagebrush, non-burned sites required a Johnson transformation ($P>0.05$) (Minitab 2012).

For each site, the proportion of age class (seedling, juvenile, mature) and browsing level assignments (low, moderate, high) was calculated. Regression analysis ($P<0.05$) was used to detect relationships among densities as a proportion of the shrub community, plant age class, and browsing class.

CHAPTER 4

RESULTS

Density and Time Since Fire

Density data are reported in Appendix D. Because this study focused on changes in community composition after fire, density as a percentage of the total shrub population was a more meaningful indicator of successional dynamics.

Gray rubber rabbitbrush and Wyoming big sagebrush were the dominant shrubs across all study areas, though skunkbush sumac (*Rhus trilobata* Nutt.) and greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) could be considered subdominants at some sites (Table 1) (Appendix D).

Table 1. Density as a percentage of the shrub community for the four most common shrub species (n=15).

Species	Mean Density	Standard Deviation	Minimum	Maximum
Artemisia tridentata	36.74	33.39	0.00	88.10
Chrysothamnus nauseosus* ssp. *nauseosus	33.96	30.95	0.00	86.80
Rhus trilobata	10.47	16.21	0.00	50.00
Sarcobatus vermiculatus	7.9	16.38	0.00	59.90

Time since fire was not significantly correlated with differences in gray rubber rabbitbrush (P=0.701, R-sq=0.00%) or sagebrush (P=0.391, R-sq=0.00%) density as a percentage of the shrub community (n=9) (Figure 6).

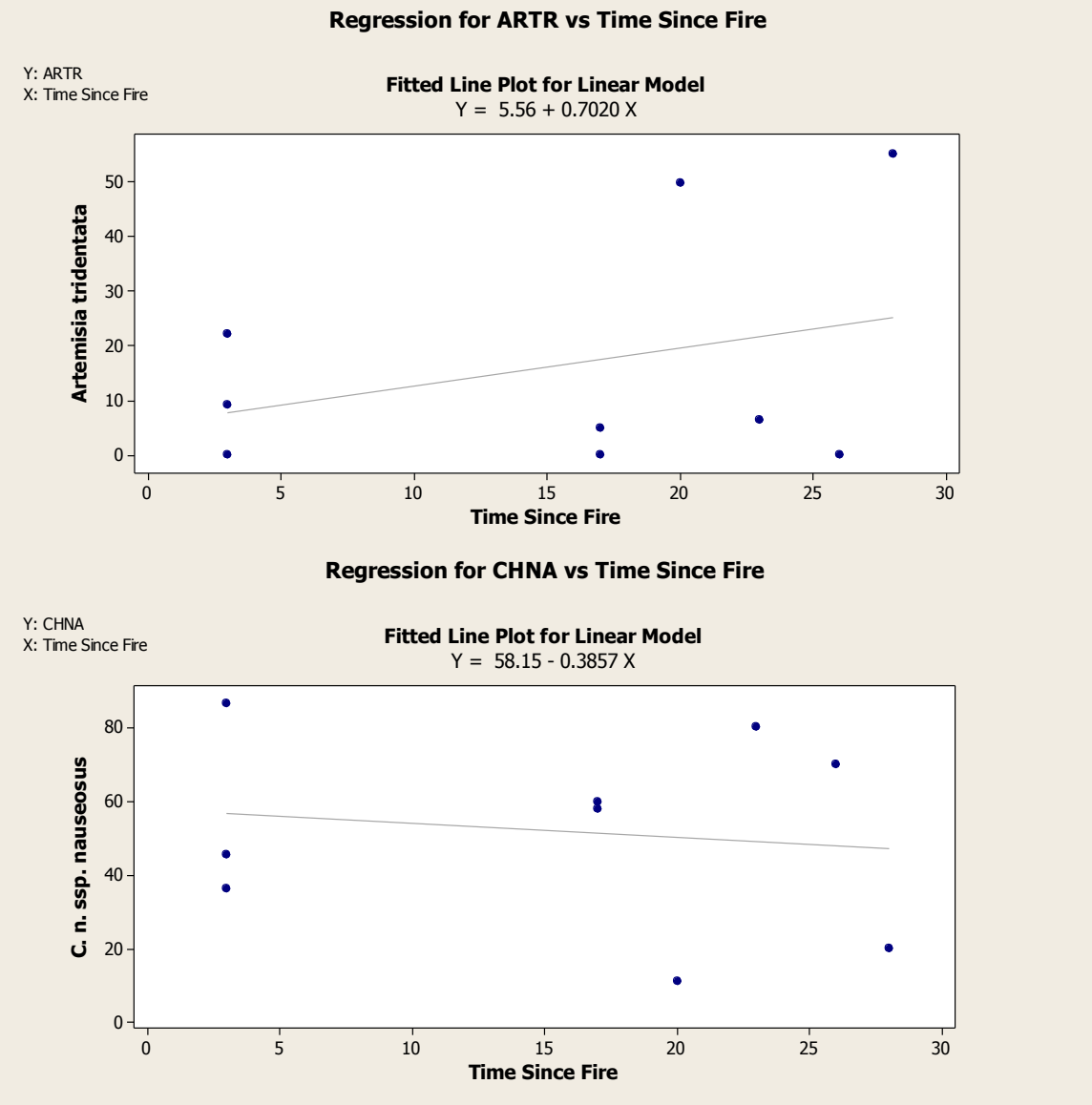


Figure 6. Regression for gray rubber rabbitbrush and big sagebrush as a percentage of the shrub community vs. time since fire.

As a percentage of the shrub community, big sagebrush density at a site was a good indicator of gray rubber rabbitbrush density (n=15, P<.001, R-sq=68.45) (Figure 7). Rabbitbrush decreases within the shrub community as sagebrush dominance increases.

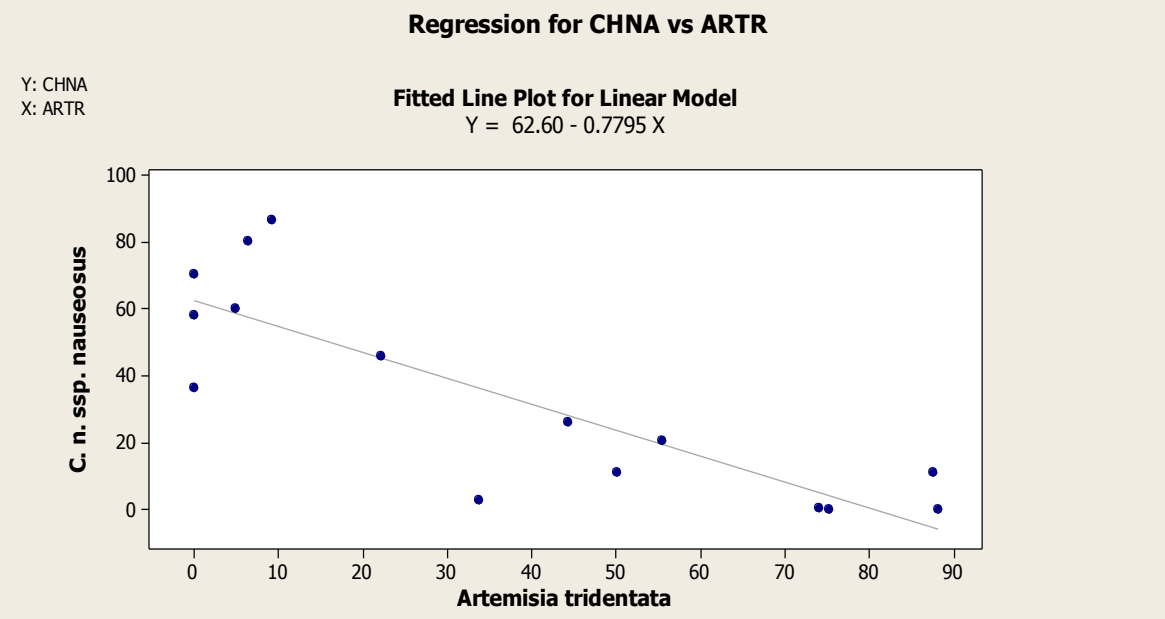


Figure 7. Regression for gray rubber rabbitbrush vs. big sagebrush density as a percentage of the shrub community. Gray rubber rabbitbrush decreases as a proportion of the shrub community as big sagebrush increases.

Analysis of Variance and Cluster Analysis

An analysis of variance based on the three fire age classes did not show significant differences among rabbitbrush density means (P=0.459). A cluster analysis did not indicate natural groupings with a high similarity index (Figure 8). Therefore, further ANOVA tests were not conducted.

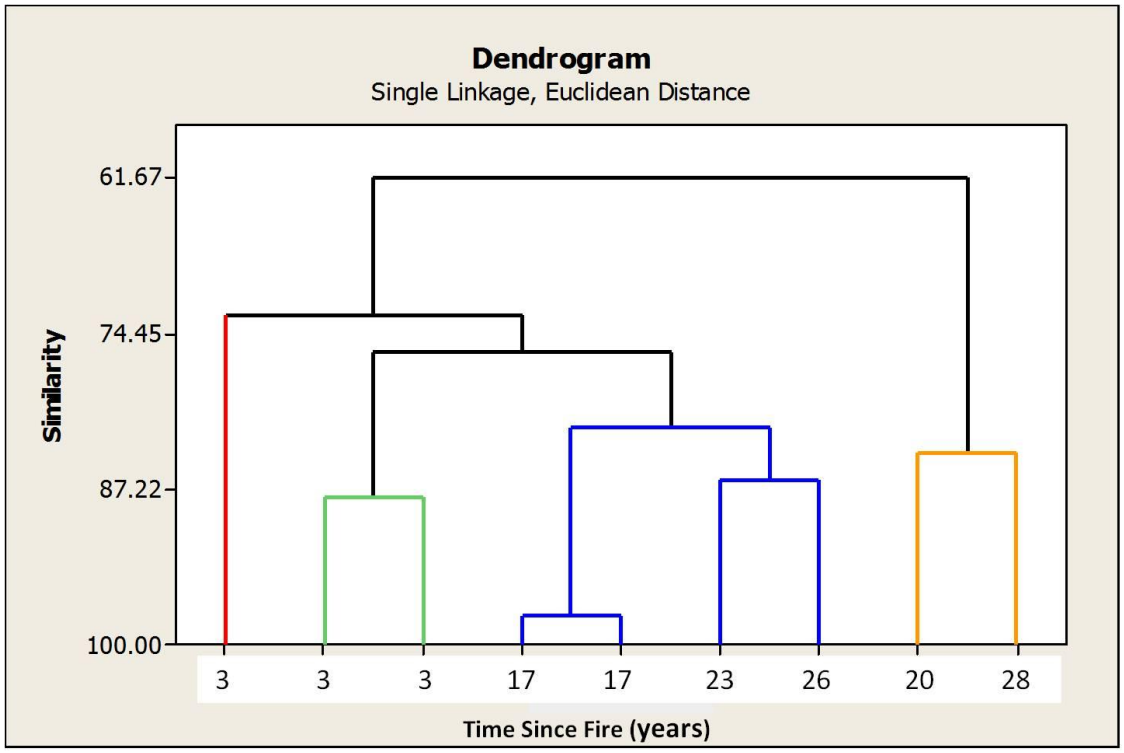


Figure 8. Dendrogram for cluster analysis of density and time since fire.

Burned and Non-Burned Comparison

Gray rubber rabbitbrush composed higher percentage of the shrub community in burned than non-burned sites (n=6, P=0.005) (Table 2).

Table 2. Means and standard deviations for gray rubber rabbitbrush as a proportion of the shrub community in burned and non-burned sites.

	Mean	Standard Deviation
Burned	57.198	28.813
Non-Burned	6.655	10.37

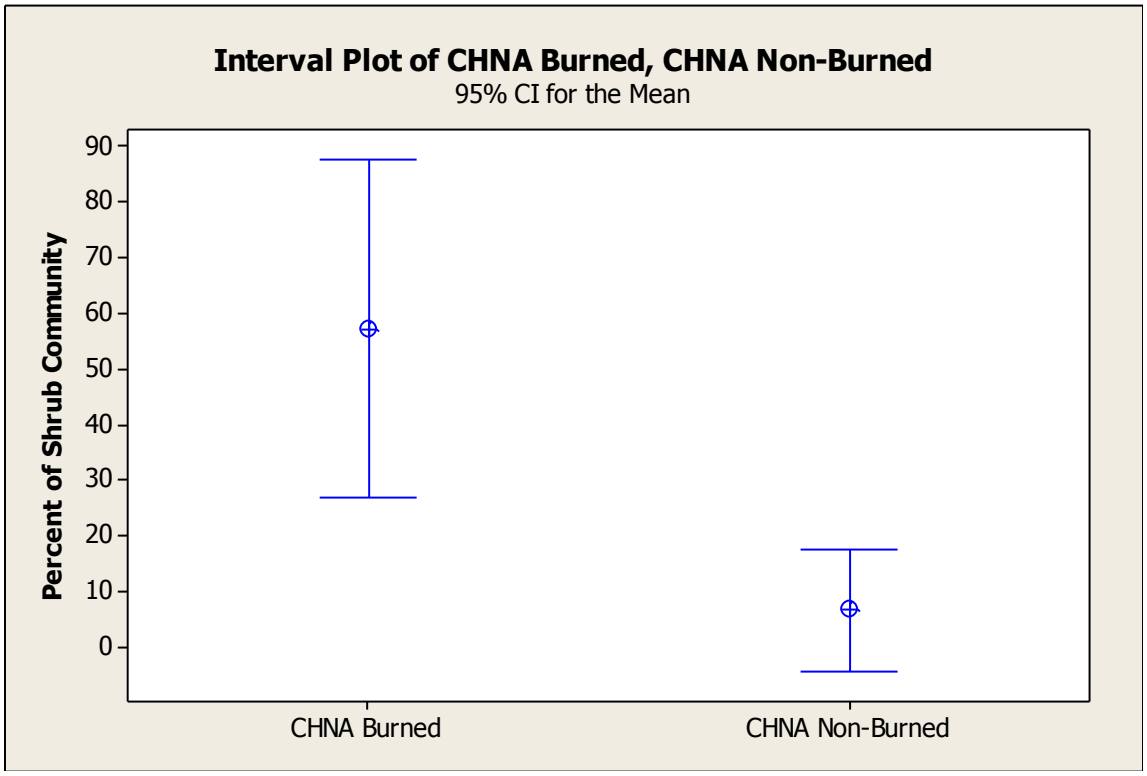


Figure 9. Interval plot for gray rubber rabbitbrush as a proportion of the shrub community in burned and non-burned sites.

Big sagebrush appears as a higher percentage of the shrub community in non-burned sites than burned sites (n=6, P=0.001) (Table 3) (Figure 10).

Table 3. Means and standard deviations for big sagebrush as a proportion of the shrub community in burned and non-burned sites.

	Mean	Standard Deviation
Burned	10.953	19.532
Non-Burned	67.135	22.805

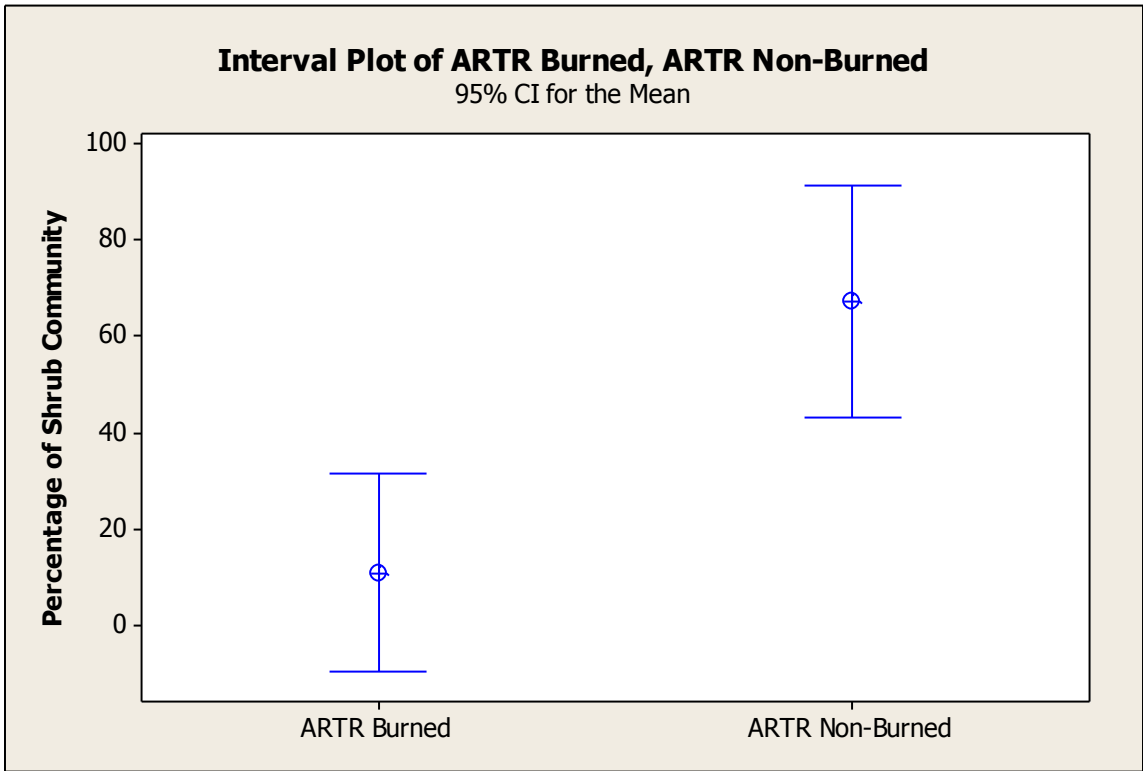


Figure 10. Interval plot for big sagebrush as a proportion of the shrub community in burned and non-burned sites.

Age and Browsing Relationships

Overall, there was not a significant relationship between a "high" browsing level assignment and "mature" age class for gray rubber rabbitbrush (n=13, P=0.261, R-sq=4.18) (Figure 11).

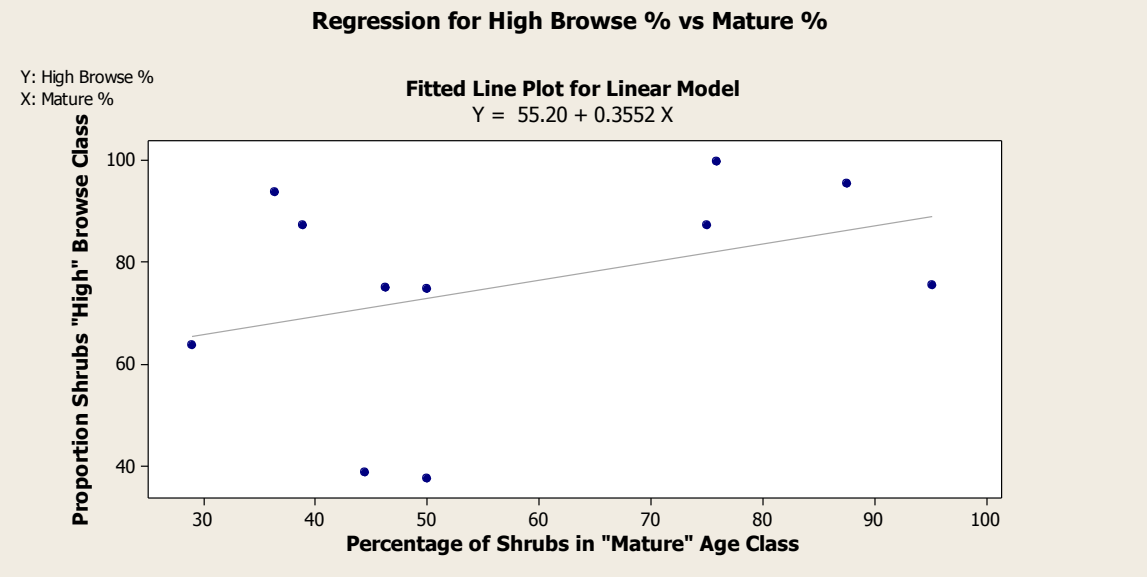


Figure 11. Regression for the proportion of rabbitbrush shrubs in the “high” browsing class vs. the percentage in “mature” age class.

The percentage of gray rubber rabbitbrush shrubs in the “high” browse class was not a statistically significant predictor of density as a proportion of the shrub community (n=13, P-value=0.161, R-sq=9.49%) (Figure 12).

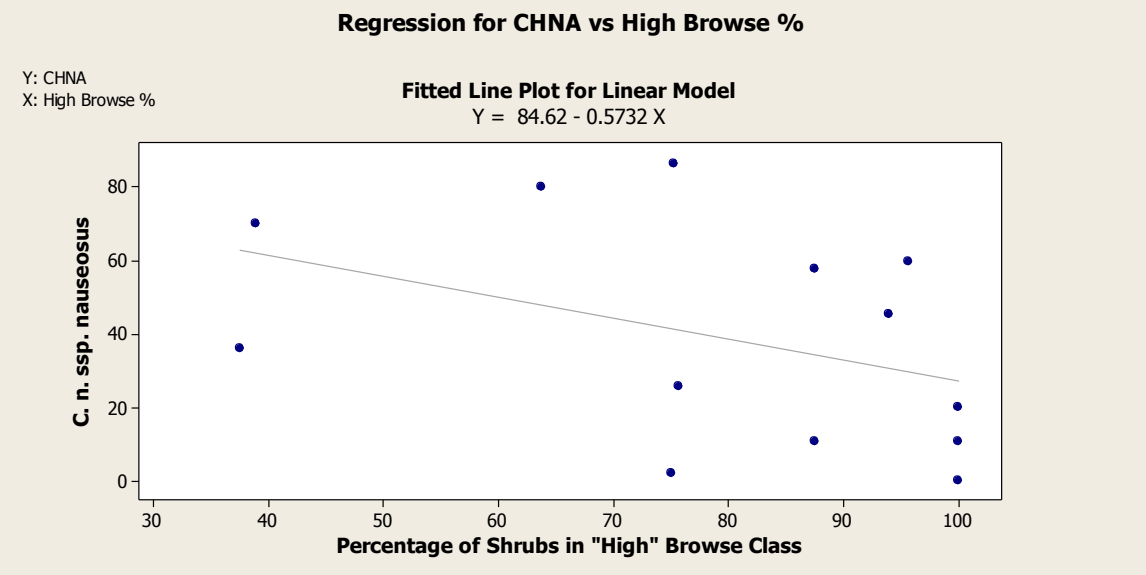


Figure 12. Regression for gray rubber rabbitbrush as a proportion of the shrub community vs. the percentage of shrubs in the "high" browse class.

A graph plotting community composition for the two dominant shrub species (gray rubber rabbitbrush and big sagebrush) shows no discernible pattern within a 30 year time frame after fire (Figure 13).

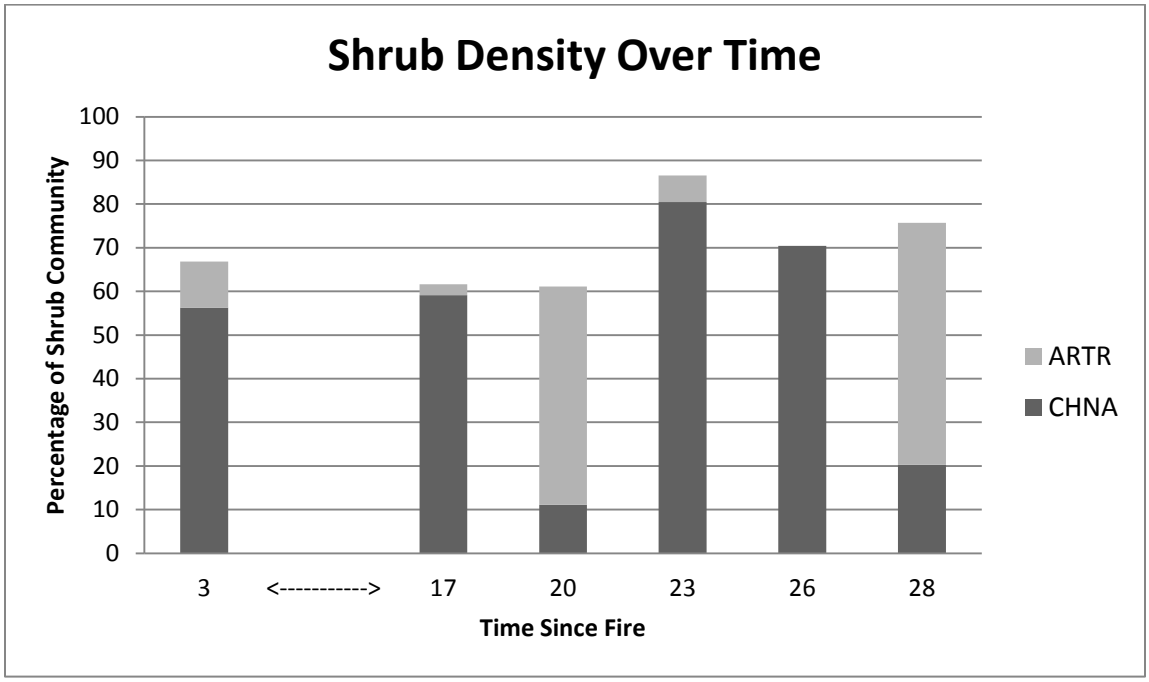


Figure 13. Big sagebrush (ARTR) and gray rubber rabbitbrush (CHNA) proportion within the shrub community as a function of time since fire. Site data for years 3 (n=3) and 17 (n=2) are averaged.

CHAPTER 5

DISCUSSION

Time since fire did not prove to be a valuable predictor of gray rubber rabbitbrush or big sagebrush density within the study area. This does not follow Wangler and Minnich (1996), who showed patterned increases and decreases in rubber rabbitbrush density followings fire, peaking between 33 and 35 years. They observed burns up to 160 years old, giving a broad chronological perspective on fire response (Wangler and Minnich 1996). Rabbitbrush subspecies was not considered.

There are several possible reasons that dominant shrubs at the sites in this study did not follow expected patterns within 30 years. More sample sites may have been necessary to capture successional trends. A sample size adequacy test based on sample standard devations and a 95% confidence interval was performed for rabbitbrush and sagebrush density. The results indicate that 107 and 75 sample sites, for rabbitbrush and sagebrush respectively, would be required to achieve a 5% margin of error for the means. Achieving such sample sizes for this study area would be unlikely because there were a limited number of sites that met all of the criteria for sampling, and re-sampling within the same burn would result in auto-correlation effects.

Additionally, we do not know how severely or frequently these sites burned. While none were burned since the recorded event date, frequency of previous fires before the recorded burns is not documented. Fire intensity affects the growth response of shrubs, and the response of subspecies *nauseosus* is not well defined (Wright et al. 1979,

Wright and Bailey 1982, Baker 2006). Thus, it may respond differently to fire than the rabbitbrush ecotype observed by Wangler and Minnich (1996). Also, fuel load differences between the pinyon-juniper zone that Wangler and Minnich (1996) observed and sagebrush-grasslands within the study area may account for different patterns of fire response.

Finally, the presence of bare, clay pan areas within burns (common in central and eastern MT) may influence how quickly sagebrush communities recover from fire. Sagebrush commonly grows in and around these areas, escaping mortality because of a lack of understory to carry fire into it. These sites serve as refuges for mature sagebrush and a seed source for rapid re-establishment in the surrounding area (Figure 13).

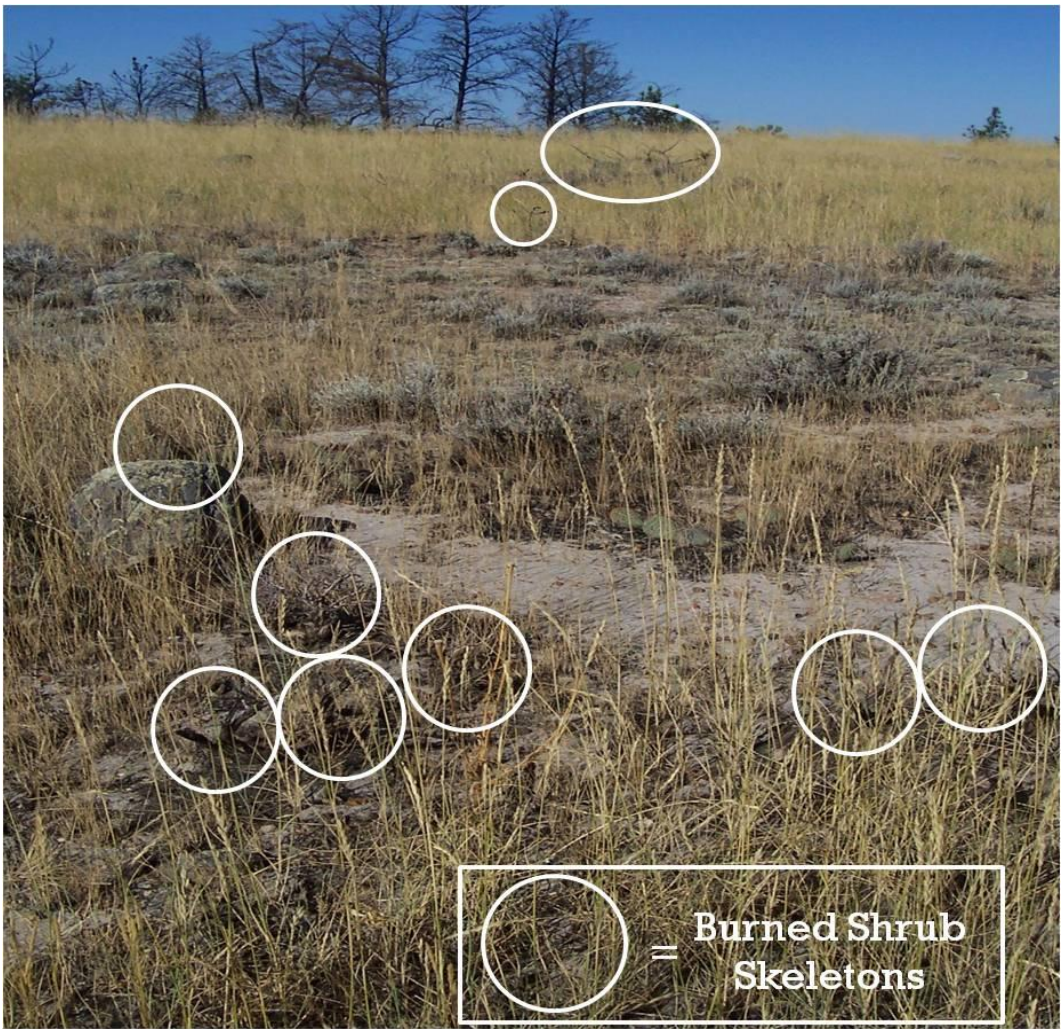


Figure 14. A microsite “refuge” for big sagebrush. Note unburned shrubs in the clay pan area and burned shrub skeletons on the perimeter.

Despite no linear relationship between shrub density and time since fire, the results indicate that gray rubber rabbitbrush was a larger community component than sagebrush in burned areas (57% compared to 11%). Sagebrush was a larger community component than rabbitbrush in non-burned areas (67% compared to 7%). Additionally, rabbitbrush density varied significantly according to sagebrush density. These data indicate that there is a possible threshold after fire where sagebrush begins to dominate and lesser shrubs such as gray rubber rabbitbrush decrease in abundance. This is

congruent with Wangler and Minnich (1996), who showed that rubber rabbitbrush increases immediately after fire and decreases as sagebrush begins to dominate over time.

It is intuitive that because gray rubber rabbitbrush receives most ungulate use in the late fall and early winter that larger, mature shrubs rising above the snow level would be subject to heavy browsing. Unexpectedly, the percentage of "mature" class shrubs at a site was not a significant predictor for the percentage of "high" browsing class individuals. However, for sites where greater than 40% of the gray rubber rabbitbrush was in the "mature" age class (n=8), percent of "mature" individuals was significantly correlated with the percent of "high" browsing class at $P<0.10$ (n=8, P=0.076, R-sq=33.76%). While not a strong relationship it may warrant further investigation. It is possible that ungulates prefer to browse sites where a high percentage of rabbitbrush individuals are available for use in snowy conditions.

Although this study did not find a significant relationship between heavy browsing and gray rubber rabbitbrush density, further investigation with more advanced methods of browse measurement would be useful. Browsing affects shrubs and their ability to cope with environmental stressors, and gray rubber rabbitbrush receives disproportionately intense use within the study area (Mackie 1970, Singer and Renkin 1995, Wood 2004). Therefore, specific measures of browsing use would be beneficial for resource planning and ungulate management. As an important browse species in this region, special care should be taken in understanding how gray rubber rabbitbrush interacts with both fire and browsing. The availability of gray rubber rabbitbrush on early successional sites may be important for meeting ungulate nutritional needs. Big

sagebrush is also a valuable winter forage for ungulates and late seral communities offer high nutritional value as well (Mackie 1970). The midwinter crude protein of Wyoming big sagebrush is 11.25%, exceeding the winter requirement for browsers (Wambolt 2004).

An analysis of variance confirmed the results of a cluster analysis showing no natural site groupings according to time since fire. This is reflective of the non-linear relationship observed for gray rubber rabbitbrush density in areas burned within the last 30 years.

A fire rotation between 100-240 years is commonly expected for Wyoming big sagebrush stands (Baker 2006). Because Wyoming big sagebrush was a high percentage of the shrub population in years 20 and 28 since fire, it is feasible that a shorter fire rotation such as that suggested by Reid and Fuhlendorf (2011) may not apply to specific shrub habitat types. Importantly, the 21-45 year estimation made by Reid and Fuhlendorf (2011) for the Missouri River Breaks is not specific to habitat types and encompasses a high degree of landscape variability.

Because site selection was randomized, a data gap occurred between 3 and 17 years following fire even though fires within that age range had been recorded. Future studies should aim to gather data across the entire age range; ignoring randomization if necessary. For shrub density as a function of time since fire a non-random approach to data collection may be preferrable.

CHAPTER 6

MANAGEMENT IMPLICATIONS

The results of this study indicate that the fire response of *Chrysothamnus nauseosus* ssp. *nauseosus* is similar to other *Chrysothamnus* species (Wangler and Minnich 1996, Tirmenstein 1999). It was the dominant shrub on three sites three years after fire, showing an ability to resprout following disturbance. On sites that had not burned in at least thirty years, it was outcompeted by sagebrush. Sagebrush is an excellent competitor for water and nutrients because of a strong lateral and vertical rooting system (Sturges 1977).

When considering prescribed fire or implications stemming from wildfire in sagebrush grasslands, we can expect gray rubber rabbitbrush to respond favorably to fire. At some time interval after disturbance big sagebrush will become the dominant shrub species. Despite clearly documented differences in the fire response of big sagebrush subspecies, this subspecies of rabbitbrush did not respond differently than the species as a whole.

The lack of a linear relationship between rabbitbrush density and time since fire suggests that managers should use caution when assuming community composition following fire. While rabbitbrush did resprout following disturbance, its persistence at a site will likely depend on burn severity and topo-edaphic conditions, which may give big sagebrush a colonization advantage.

Based on this research, land managers working in this study area can expect that locations with a high proportion of gray rubber rabbitbrush have recently burned. Also, areas where big sagebrush is a large proportion of the shrub population will have little gray rubber rabbitbrush. It will be available as an ephemeral forage base following fire, though sagebrush will serve as a longer term winter food source for ungulates.

REFERENCES CITED

Anderson, R.C., and A.J. Katz. Recovery of browse sensitive tree species following release from white-tailed deer *Odocoileus virginianus* zimmerman browsing pressure. *Biological Conservation* 63:203-208.

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

Bhat, R.B., B.L. Welch, D.J. Weber, and D.E. McArthur. 1990. Mid-winter protein, phosphorus, and digestibility of *Chrysothamnus nauseosus* subspecies. *Journal of Range Management* 43:177-179.

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River Plains. U.S. Department of Agriculture, Technical Bulletin 1075. 39p.

Bunting, S.C. 1985. Fire in sagebrush-grass ecosystems: Successional changes. In: Eds: Sanders, K. and J. Durham. Rangeland fire effects-A symposium. 1985. Idaho State Office, USDI-BLM, Boise, ID. p.7-11.

Canfield, R. H. 1941. Application of the line-intercept method in sampling range vegetation. *Journal of Forestry* 39:388–394.

Chadwick, H.W., and P.D. Dalke. 1965. Plant succession on dune sands in Fremont County, Idaho. *Ecology* 46:766-780.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing upon concepts of vegetation classification. *Ecological Monographs* 22:301-330.

Daubenmire, R. 1968a. Ecology of fire in grasslands. In: Ed: Cragg, J.B. Advances in ecological research. Academic Press Inc. New York, NY. p. 209-257.

Daubenmire, R. 1968b. Plant communities: A textbook of plant synecology. Harper and Row. New York, NY. 300p.

Davis, J. 1967. Some effects of deer browsing on chamise sprouts after fire. *American Midland Naturalist* 77:234-238.

Eichhorn, L.C., and C.R. Watts. 1984. Plant Succession on burns in the river breaks of central Montana. In: Ed: Tibbs, J.F. Proceedings of the Montana Academy of Sciences. 43:21-34.

Eustace, C.D. 1971. Mule deer food habits and browse use study. Montana Fish and Game. Federal Aid Final Report Project W-130-R-1 and 2, J-1-7.1.

Google Earth. 2005. Sand Creek. 47.606, -107.579. March 20, 2012.

Google Earth. 2011. Charles M. Russell National Wildlife Refuge. 47.722, -107.661. December 30, 2011.

Harniss, R.O., and R.B. Murray. 1973. 30 years of vegetal change following burning of sagebrush-grass range. *Journal of Range Management* 26:322-325.

Hobbs, N.T. 1996. Modification of ecosystems by ungulates. *Journal of Wildlife Management* 60:695-713.

Johnson, A.H., and R.M. Strang. 1983. Burning in a bunchgrass/sagebrush community: The southern interior of B.C. and northwestern.S. compared. *Journal of Range Management* 36:616-618.

Keigley, R.B., and M.R. Frisina. 1998. Browse evaluation by analysis of growth form. Volume I: methods for evaluating condition and trend. Helena, MT: Montana Fish, Wildlife and Parks. 153p.

Keilland, K., and J.P. Bryant. 1998. Moose herbivory in Taiga: Effects on biogeochemistry and vegetation dynamics in primary succession. *Oikos* 82:377-383.

Lesica, P., S.V. Cooper, and G. Kudray. 2007. Recovery of big sagebrush following fire in southwest Montana. *Rangeland Ecology and Management* 60:261-269.

Mackie, R.J. 1970. Range ecology and relations of mule deer, elk, and cattle in the Missouri River Breaks, Montana. *Wildlife Monographs* 79p.

McGinnies, W.G. 1972. North America. In: Eds: McKell, C.M., J.P. Blaisdell, and J.R. Goodin. Wildland shrubs-Their biology and utilization. USDA Forest Service GTR INT-1. Logan, Utah. 55-66.

McLendon, T., and E.F. Redente. 1991. Nitrogen and phosphorous effects on secondary succession dynamics on a semi-arid sagebrush site. *Ecology* 72:2016-2024.

Minitab Inc. 2012. Minitab 16. Minitab Incorporated. State College, PA, USA.

Montana NRIS. 2011. Digital elevation model-1km. Montana State Library. http://nris.mt.gov/nsdi/nris/EL11.gif.

Morgan, P., C.C. Hardy, T.W. Swetnam, M.G. Rollins, and D.G. Long. 2001. Mapping fire regimes across time and space: Understanding coarse and fine-scale fire patterns. *International Journal of Wildland Fire* 10:329-342.

Nesser, J.A., G.L. Ford, C.L. Maynard, and D.S. Page-Dumroese. 1997. Ecological units of the northern region: Subsections. USDA Forest Service GTR-INT-369. Ogden, UT.

NRCS. 2011. USDA, Natural Resource Conservation Service. Web Soil Survey. http://websoilsurvey.nrcs.usda.gov.

Patton, D.R., and J.M. Hall. 1966. Evaluating key areas by browse age and form class. *Journal of Wildlife Management* 30:476-480.

Perryman, B.L., and R.A. Olson. 2000. Age-stem diameter relationships of big sagebrush and their management implications. *Journal of Range Management* 53:342-346.

Raines, G.L., and B.R. Johnson. 1995. Digital representation of the Montana stage geologic map: A contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-691. http://pubs.usgs.gov/. 21p.

Reid, A.M., and S.D. Fuhlendorf. 2011. Fire management in the national wildlife refuge system: A case study of the Charles M. Russell National Wildlife Refuge, Montana. *Rangelands* 33:17-23.

Robertson, J.H., and H.P. Cords. 1957. Survival of rabbitbrush, Chrysothamnus spp., following chemical burning and mechanical treatments. *Journal of Range Management* 10:83-89.

Short, H.L., D.R. Dietz, and E. E. Remmenga. 1966. Selected nutrients in mule deer browse plants. *Ecology* 47:222-229.

Singer, F.J., and R.A. Renkin. 1995. Effects of browsing by native ungulates on the shrubs in big sagebrush communities in Yellowstone National Park. *Great Basin Naturalist* 55:201-12.

Sturges, D.L. 1977. Soil water withdrawal and root characteristics of big sagebrush. *American Midland Naturalist* 98:257-274.

Tirmenstein, D. 1999. Chrysothamnus nauseosus. In: Fire effects information system, (online). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/

Urness, P.J. 1966. Influence of range improvement practices on composition, production, and utilization of *Artemisia* deer winter range in central Oregon. Corvallis, OR: Oregon State University. 182 p. Dissertation.

VanDersal, W.R. 1972. Soil cover and stabilization. In: Eds: McKell, C.M., J.P. Blaisdell, and J.R. Goodin. Wildland shrubs-Their biology and utilization. USDA Forest Service GTR INT-1. Logan, UT. p. 82-87.

Wambolt, C.L., W.H. Creamer, and R.J. Rossi. 1994. Predicting big sagebrush winter forage by subspecies and browse form class. *Journal of Range Management* 47:231-234.

Wambolt, C.L., and H.W. Sherwood. 1999. Sagebrush response to ungulate browsing in Yellowstone. *Journal of Range Management* 52:363-369.

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

Wambolt. C.L. 2004. Browsing and plant age relationships to winter protein and fiber of big sagebrush subspecies. *Rangeland Ecology and Management* 57:620-623.

Wambolt, C.L., M.R. Frisina, S.J. Knapp, and R.M. Frisina. 2006. Effect of method, site, and taxon on line-intercept estimates of sagebrush cover. *Wildlife Society Bulletin* 34:440-445.

Wangler, M.J., and R.A. Minnich. 1996. Fire and succession in pinyon-juniper woodlands of the San Bernadino Mountains, California. *Madrono* 43:493-514.

Welch, B.L. 1989. Nutritive value of shrubs. In: Ed: C.M. McKell. Biology and utilitzation of shrubs. Academic Press, Inc. New York, New York. p. 405-424.

West, N. E. 2000. Synecology and disturbance regimes of sagebrush steppe ecosystems. In: Proceedings: Sagebrush steppe ecosystems symposium. Ed: P. G.. Entwistle. Publication No. BLM/ID/PT-001001+1150. Boise, ID: USDI Bureau of Land Management. p. 15-26.

White, P.S. 1979. Pattern, process, and natural disturbance in vegetation. *The Botanical Review* 45:229-299.

Willard, E.E., and C.M. McKell. 1978. Response of shrubs to simulated browsing. *Journal of Wildife Management* 42:514-519.

Winkler, G.L. 1987. Montana Chrysothamnus. Bozeman, MT: Montana State University. 94p. Thesis.

Winward, A.H. 1985. Fire in the sagebrush-grass ecosystem-The ecological setting. In: Eds: K.Sanders and J. Durham. Rangeland fire effects-A symposium. 1985. Idaho State Office, USDI-BLM, Boise, ID. p. 2-6.

Wood, C.K. 2004. The effects of prescribed burning on deer and elk habitat parameters in Montana's Missouri River breaks. Bozeman, MT: Montana State University. 79p. Thesis.

Wright, H.A., L.F. Neuenschwander, and C.M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: A state-of-the-art review. USDA Forest Service GTR INT-58. Ogden, UT.

Wright, H.A., and A.W. Bailey. 1982. Fire Ecology, United States and southern Canada. John Wiley & Sons. New York, NY. 501p.

Young, R.P. 1986. Fire ecology and management in plant communities of Malheur National Wildlife Refuge. Portland, OR: Oregon State University. 169 p. Thesis.

Young, J.A., and R.A. Evans. 1974. Population dynamics of green rabbitbrush in disturbed big sagebrush communities. *Journal of Range Management* 27:127-132.

Young, J.A., and R.A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. *Journal of Range Management* 31:283-289.

APPENDICES

APPENDIX A

SOIL DESCRIPTIONS

Site Number	Soil Unit Symbols	Dominant Soil Types	Dominant Soil Texture
1	1977F	Volborg-Pinebreaks-Rock outcrop association	Clay
2	64	Dilts-Julin-Rock outcrop complex	Clay
3	1977F	Volborg-Pinebreaks-Rock outcrop association	Clay
4	375D	Cambeth-Twilight-Cabbert complex	Silt Loam
5	64	Neldore-Bascovy-Rock outcrop complex	Silty Clay
6	64	Neldore-Bascovy-Rock outcrop complex	Clay
7	65, 234	Dilts-Thebo-Neldore clays; Thebo clay	Clay
8	521B, 973E	Elloam-Absher complex; Neldore, cool-Bascovy clays	Clay Loam, Clay
9	521B, 973E	Elloam-Absher complex; Neldore, cool-Bascovy clays	Clay Loam, Clay
10	1400F	Rock outcrop-Arsite association	Clay
11	251C, 1977F	Bascovy-Neldore clays; Volborg-Pinebreaks-Rock outcrop association	Clay
12	302B, 1977F	Marvan-Vanda clays; Volborg-Pinebreaks-Rock outcrop association	Clay
13	973E	Neldore, cool-Bascovy clays	Clay
14	973E	Neldore, cool-Bascovy clays	Clay
15	925C, 973E	Sunburst-Bascovy-Weingart complex; Neldore, cool-Bascovy clays	Clay

APPENDIX B

PERCENT COVER BY SITE

Shrub Species	**Site Number**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Chrysothamnus nauseosus* ssp. *nauseosus	1.3	1.8	--	0.9	--	--	--	1.4	--	--	0.3	--	1.2	--	1.6
Artemisia tridentata	--	0.2	4.7	--	--	4.4	6.4	--	1.1	2.9	0.8	5.1	--	1.4	--
Rhus trilobata	2.8	0.9	7.6	--	2.6	--	2.6	--	--	--	--	--	1.9	--	--
Sarcobatus vermiculatus	--	--	--	--	--	6.8	--	--	--	--	--	--	--	--	--
Artemisia cana	--	--	--	0.2	--	--	--	--	--	--	--	--	--	--	--
Eriogonum pauciflorum	--	--	--	0.3	--	--	--	--	1.1	0.2	--	--	--	--	--
Juniperus scopulorum	--	--	--	--	--	--	--	--	--	--	1.9	--	--	--	--
Gutierrezia sarothrae	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.3
Chrysothamnus nauseosus* ssp. *graveolens	0.4	--	4.5	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX C

NORMALITY TEST RESULTS AND

JOHNSON TRANSFORMATION VALUES

	AD Value	P-Value	Transformed AD Value	Transformed P-Value
Chrysothamnus nauseosus* ssp. *nauseosus				
Burned	0.255	0.574	--	--
Non-Burned	0.745	0.024	0.249	0.595
Artemisia tridentata				
Burned	1.010	<.005	0.500	0.121
Non-Burned	0.450	0.172	--	--

APPENDIX D

DENSITY (STEMS/HA)

Shrub Species	**Site Number**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Chrysothamnus nauseosus* ssp. *nauseosus	1984	9024	480	528	128	64	--	288	656	16	64	--	304	128	384
Artemisia tridentata	160	960	1312	256	--	848	2080	--	1120	3648	288	6736	--	1008	32
Rhus trilobata	176	208	96	--	176	16	32	208	48	--	128	--	96	16	16
Sarcobatus vermiculatus	--	48	64	--	--	1504	656	--	--	976	--	912	--	--	--
Artemisia cana	16	--	144	96	16	80	--	--	--	64	--	--	--	--	--
Eriogonum pauciflorum	--	--	--	160	16	--	--	--	704	208	--	--	32	--	64
Juniperus scopulorum	--	--	64	--	--	--	--	--	--	16	32	--	--	--	--
Gutierrezia sarothrae	16	144	--	--	16	--	--	--	--	--	64	--	--	--	144
Chrysothamnus nauseosus* ssp. *graveolens	112	--	208	--	--	--	--	--	--	--	--	--	--	--	--
Ribes cereum	16	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Atriplex confertifolia	--	--	--	48	--	--	--	--	--	--	--	--	--	--	--
Atriplex gardneri	--	--	--	64	--	--	--	--	--	--	--	--	--	--	--

APPENDIX E

GRAY RUBBER RABBITBRUSH BROWSING AND PLANT AGE CLASS DATA RAW COUNT

Site Number	Time Since Fire (years)	Plant Age Class			Browsing Class		
		Seedling	Juvenile	Mature	Low	Moderate	High
1	23	33	55	36	5	28	58
2	3	45	282	282	60	80	424
3	28	--	7	22	--	--	29
4	3	--	21	12	1	1	31
5	3	--	4	4	--	5	3
6	--	--	2	2	--	1	3
7	--	--	--	--	--	--	0
8	17	2	8	8	--	2	14
9	--	--	2	39	2	8	31
10	--	--	--	1	--	--	1
11	20	--	4	--	--	--	4
12	--	--	--	--	--	--	--
13	26	--	10	8	4	8	6
14	--	--	2	6	--	1	7
15	17	1	2	21	--	1	22